THE DISTRIBUTION OF EXCHANGEABLE CATIONS IN SOME SOILS IN THE VICINITY OF SOCORRO, NEW MEXICO.

A Dissertation
Presented to the Graduate Faculty of the
New Mexico Institute of Mining and Technology

In Partial Fulfillment
of the Requirements for the Degree of
Doctor of Philosophy in Earth Science

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ABSTRACT

Socorro soils are loamy calcisols formed under a warm semi-arid climate. They have developed from loamy calcareous alluvial deposits on terraces on both sides of the Rio Grande River. These terraces fall into three arbitrarily named levels: higher, intermediate, and lower. Soils vary from young, developed on lower terraces, to old alluvials, developed on intermediate and higher terraces, with paleosols found on high and intermediate terraces. The profiles of these soils are composed of thin A zones, with a high percentage of coarser rock fragments, resting on dense B zones of silty loam texture. The C horizon is present in most of the soils. Thickness of the soil profiles increases from the younger lower terraces to the older higher terraces.

Most of the soil profiles have a pronounced zone of lime accumulation, occurring relatively close to the surface in some soils and deep in others. The zone of lime accumulation is usually harder, more compact, and of lighter color than the surface soil.

Laboratory studies were made on five sets of model soil samples and on samples collected from seventy-four soil profiles from the Socorro area. The model soil samples were analyzed for soil reaction, particle size, soluble cations, exchangeable cations, electrical conductivity, and carbonate content. Additional samples

from the seventy-four soil profiles were analyzed for silt plus clay content, soil reaction, soluble cations, extractable cations, exchangeable cations, and clay minerals.

Exchangeable calcium and magnesium ions seem to follow parallel patterns in most of the soils. Their vertical distribution usually decreases to a certain level in the soil, then increases again at lower depths. In contrast, the sodium ion generally increases with depth then decreases at lower levels. The distribution of exchangeable potassium relative to the other cations is not consistent.

Movement of cations in the Socorro soils and their accumulation at certain depths in the subsoil are due to processes of chemical weathering. In the Socorro area there is not enough precipitation to provide a steady downward movement of the soil ions. As a result there is an accumulation of salts in the soil profile. In periods of rainfall these salts are transported downward in the soil to the point of maximum water penetration. This depth of maximum water penetration coincides with the depth of chemical weathering.

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INTRODUCTION

Purpose and Scope of This Investigation

This research was undertaken to determine the distribution of the exchangeable cations as a function of depth; the relations between distributions of exchangeable cations, lime accumulation, and depth of water penetration; and the depth of chemical weathering in soils of the Socorro area.

The most common exchangeable cations in semiarid regions are calcium, magnesium, sodium, and potassium. Therefore, they have been used as parameters for measuring changes in the chemical composition of the soils studied. The profiles of the individual exchangeable cations are the result of water movement accompanied by cation exchange reactions. The normal pattern of distribution is such that the most strongly adsorbed cations, such as calcium and magnesium, tend to accumulate in the surface horizon in greater amounts than do the other cations. The ions that are less strongly adsorbed, such as sodium ions, would increase with depth.

Due to the limited water infiltration in semiarid regions, the profiles of the exchangeable cations are quite different from ideal cases where water moves down through the whole soil profile. Preliminary studies revealed that soils in the vicinity of Socorro showed abrupt changes in the distribution of these exchangeable cations at certain depths within their profiles.

Location and General Features of the Area

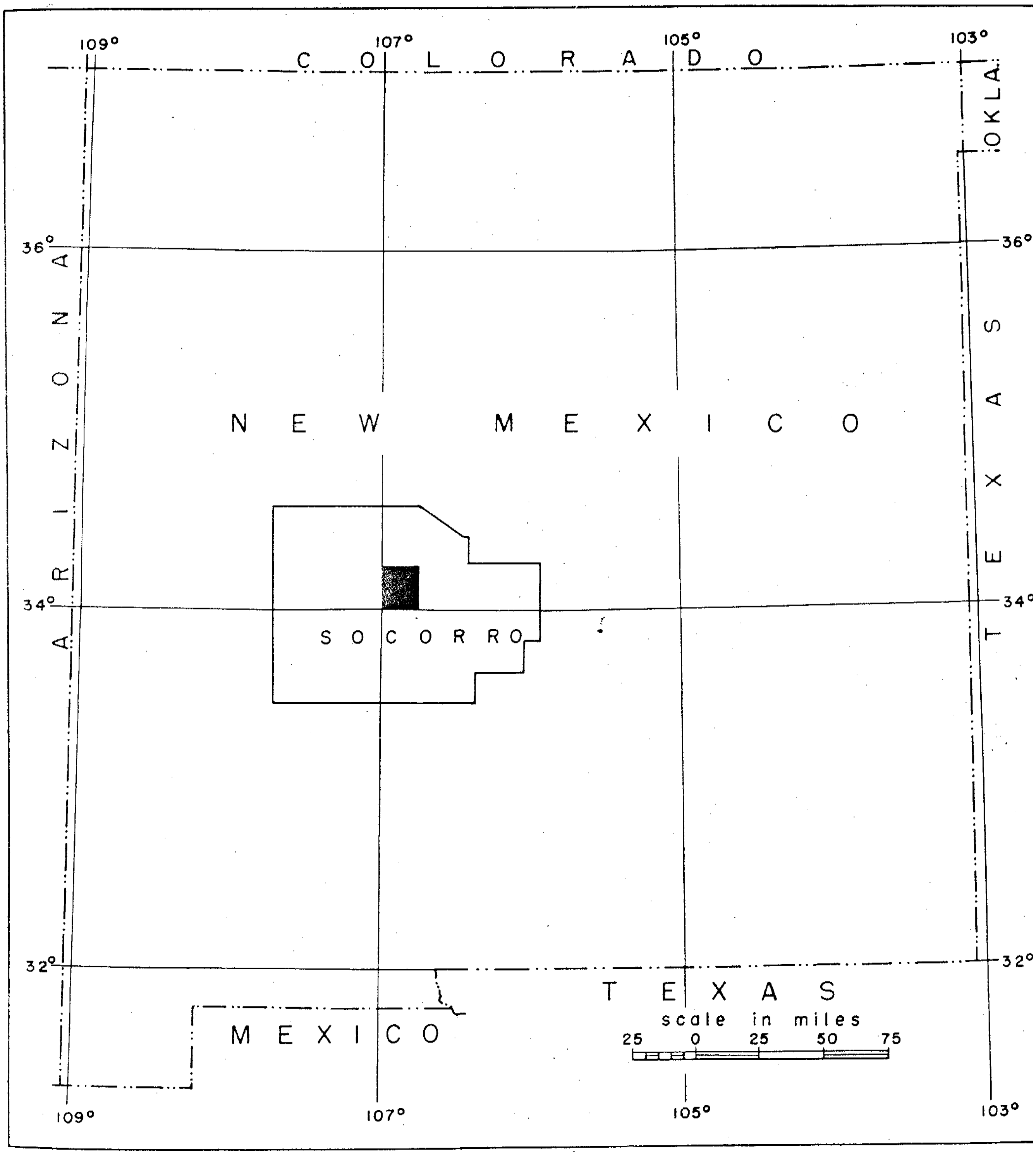
The area studied is situated in the U.S. Geological Survey fifteen minute Socorro quadrangle, Socorro County, New Mexico (Plates I and II). The quadrangle is bounded by parallels 34° 15' and 34° 00' north latitude and meridians 107° 00' and 107° 15' west longitude. The quadrangle is about 260 square miles in area and lies in the center of the County. The town of Socorro, the largest town and County Seat, is four miles north of the southern boundary of the Socorro quadrangle. Albuquerque is 75 miles north of Socorro, and El Paso, Texas is 195 miles to the south. U.S. Highways 60 and 85 run through the area east-west and north-south respectively. A few improved state roads and ranch roads are found within the area. These, along with some arroyos, constitute the means of access to

Plate I

Plate I

Index Map

Index map showing location of the area from which samples were obtained (shown in black).



Index map showing location of area studied.

Plate II

Plate II

Aerial photograph showing general
features of the area, (Waldron, 1956).


T1S
R1W
R1E
R2E

most of the sampled locations.

The Rio Grande River flows through the center of the area from the north to the south. It runs in a depression characterized by the presence of remnants of terraces on both sides.

Method of Sampling

Field work for this dissertation was started on June 6, 1961, and was continued through November 15, 1961. During this time four hundred and forty-eight soil samples were collected from seventy-four soil profiles. The locations of these soils are shown on the Socorro topographic map (Plate III). Five additional sets of soil profiles were later located, described, and sampled by horizon during the period of May 3, to May 25, 1962. The method used was that described in U.S.D.A. Soil Survey Staff, Handbook No. 18, (1951, p. 174-180). The original seventy-four soil profiles were sampled by arbitrary divisions. When a satisfactory soil section was found, a fresh vertical face was exposed by cutting back into the surface with a shovel or a geologic hammer. This surface was then smoothed and divided into genetic horizons, or into six equal layers. These layers were from six to twelve inches thick depending on the thickness of the soil profile. Samples were collected commencing with the lowest marked layer and working upward in order to avoid any contamination from the overlying soil. About two kilograms of soil were removed from each layer and placed into a cloth sack. The altitudes of the soils were determined by interpolation from topographic maps.

Previous Studies

There are no published records about the exchangeable cations present or the chemical composition of soils of the Socorro area. Though the importance of exchangeable cations is well recognized, information on their distribution in these soils is rather meager. Information on the concentration of cations in the different horizons may be useful in estimating the degree of leaching and weathering that have taken place in profile development. The author found in the literature, papers written by Hibbard (1940), Holmes (1943), Butler (1954), Swaine and Mitchell (1960), and Short (1960), dealing with the vertical distribution of trace elements in soils. These reports were helpful regarding methods of presentation of the data.

Climate

The Socorro area is considered to have a semiarid climate, based on an average annual precipitation of about ten inches, (Blair, 1942, p.295). The area is characterized by clear days, strong wind movement (particularly in the spring), summer rainfall, and some snow in the winter. The area has a wide seasonal range of temperature, rainfall, and evaporation. Climatic data on precipitation and temperature for the Socorro area and evaporation data for the Bosque del Apache area, which is just south of the Socorro area, were obtained from records of the U.S. Weather Bureau, (U.S. Department of Commerce, 1956-60).

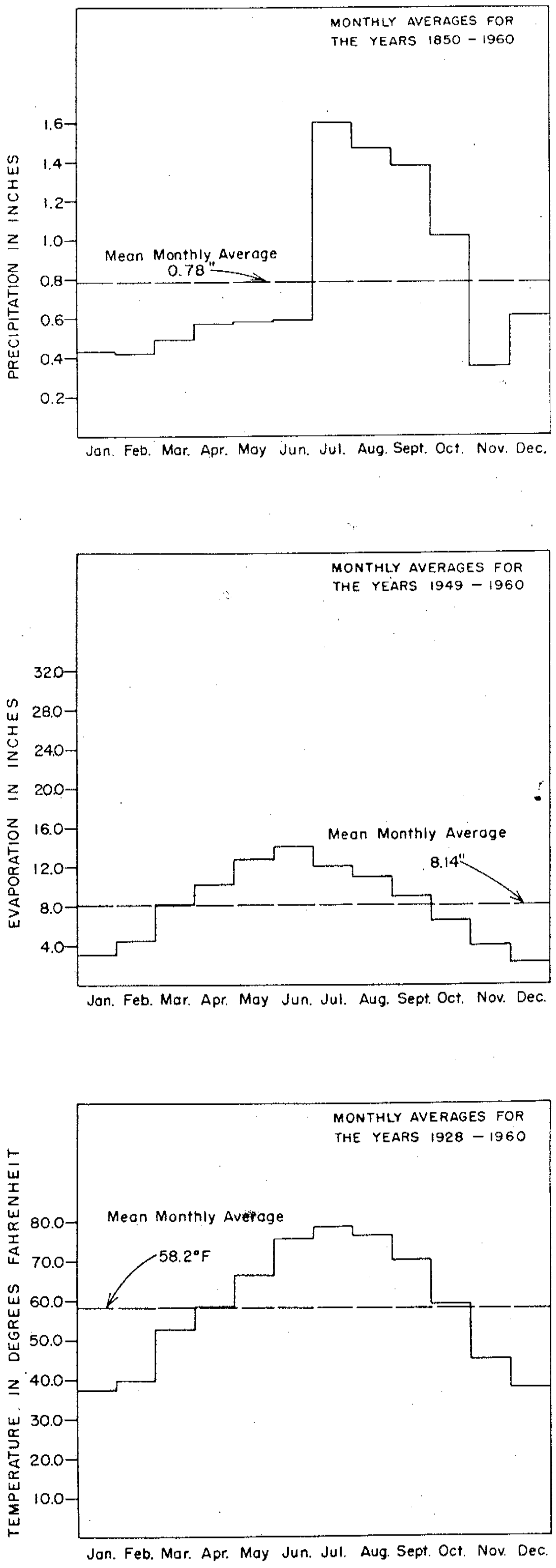
The average annual precipitation, based on data for the period 1850-1960, is 9.4 inches. The diagram in Plate IV shows that about 55% of the annual rainfall occurs in the four months, July, August, September, and October. Most of the summer rain occurs in heavy showers. The average annual snowfall does not exceed 3.0 inches, (Lasky, 1932, p.14). The average annual temperature, based on data for the period 1928-1960, is 58° F; the highest daily temperatures are in July, averaging 79° F, and the lowest are in January, averagin 37° F (Plate IV).

Pan evaporation data from the Bosque del Apache area near Socorro were used due to the lack of such data for the Socorro area. The evaporation rate is highest in the summer months. The average evaporation rates in May, June, and July are 12.8, 14.0, and 12.1 inches respectively. Average annual evaporation, based on data from 1949-1960, is 100 inches. The information on rainfall and precipitation shows that the evaporation/precipitation ratio is high in the Socorro area.

Plate IV

CLIMATIC DATA

AVERAGE MONTHLY PRECIPITATION, EVAPORATION & TEMPERATURE



FROM PUBLICATIONS OF
THE U.S. WEATHER BUREAU

Soil Location Numbers

The location numbering system used in this investigation is similar to one used by the U.S. Geological Survey. The locations of soil sections are determined according to the rectangular system for the subdivision of public land. The soil number 3S/1W-25Q, which was assigned to a soil section three miles south of Socorro, represents an example: 3S indicates Township 3 South (T.3S); 1W indicates Range 1 West (R.1W); 25Q means the southwestern quarter of the southeastern quarter of section 25. The letter Q shows the location within the section, according to the following diagram which represents divisions within the section.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Acknowledgments

The cooperation and financial assistance of the Ministry of Education of The United Arab Republic made this study possible. The writer owes his deep gratitude to the government of The United Arab Republic. Dr. J. A. Schufle deserves the author's greatest appreciation for his inspiration and encouragement regarding the particular problem chosen for this dissertation. The writer also wishes to express his gratitude to Drs. M. F. Stubbs, M. [illegible] Inabush, [illegible] Hall, and F. Kuellmer who gave advice to the author during the progress of the research and the preparation of the dissertation. Dr. H. Dregne of the New Mexico State University, Mr. B. Ahaskin, soil scientist, and Mr. A. L. Haigler of the New Mexico Institute of Mining and Technology, discussed several aspects of the research with the author. To them the author extends his gratitude. Many other members of the staff of New Mexico Institute of Mining and Technology and the Bureau of Mines and Mineral Resources have contributed to this study. The author expresses appreciation for the use of their time and equipment.

GENERAL GEOLOGY

The early geologic and physiographic development of the Socorro area has been controlled by structure, erosion, and deposition. The area can be divided physiographically into mountain highlands, terrace surfaces and the Rio Grande flood plain. The mountain ranges that lie to the west of the area: the Ladron, Lemitar, Socorro, and Magdalena mountains, and those to the east: the Manzano, Chupadero, and Oscura mountains, are remnants of the structural development of the Rio Grande graben. Uplifting resulted in elevation of these bordering highlands relative to the Rio Grande depression, (Spiegel, 1955, p.3-10). In the area there are several terrace remnants which slope toward the Rio Grande flood plain. These terrace surfaces indicate older, stable, Rio Grande base levels. They form one of the most outstanding physiographic features of the area.

The general trend of the Rio Grande Valley is in a north-south direction. The flood plain of the river is about three miles wide in the Socorro area and broadens to the north. The altitude of the river varies from 4,660 feet in the north to 4,570 feet in the south, indicating a very gentle gradient to the south. The river's flood plain being at an average elevation of 4,600 feet gives the area a maximum relief of 2,700 feet. The valley floor rises to the terrace plains through many arroyos. On the east side of the Rio Grande the drainage consists of more or less parallel streams which flow generally in a westerly direction to the Rio Grande. On the west side of the river the drainage consists of streams which flow generally in an easterly direction to the river. These arroyos and the Rio Grande constitute the main drainage of the area.

The soils studied in the Socorro area are developed on alluvial deposits which are found in a series of terraces on both sides of the Rio Grande. No detailed study has been made of the terraces in the Socorro area, although a study was made immediately north of the Socorro 15 minute quadrangle, (Denny, 1941), and in the Las Cruces area about 100 miles to the south, (Ruhe, 1962). For the purposes of this study the terraces have been placed in three general categories: lower, intermediate, and higher terraces. The lower terraces include the lowermost terraces above the recent flood plain of the Rio Grande and arroyos, and range up to the level on which the city of Socorro is situated. The intermediate terraces occur just above the lower terraces and range up to the high level just north of Escondida and Florida, New Mexico. The higher terraces include the terraces north of Escondida and all higher terraces.

The rock types found in the Socorro area include sedimentary, igneous, and metamorphic, and they range in age from Precambrian to Recent, (Wilpot and Wanek, 1951). The Pre-Cenozoic rocks and

Cenozoic volcanics are found mainly in mountains and hills on the margins of the Rio Grande Valley. The Cenozoic rocks cover broad areas on both sides of the valley and comprise the valley fill to a depth of at least 4,000 feet, (Anderson, 1953, p.29).

For descriptive purposes the rocks can be grouped into four categories: Precambrian, Paleozoic, Mesozoic, and Cenozoic (Plates V and VI); and into three geographical areas: the eastern border of the Rio Grande Valley, the western border of the Rio Grande Valley, and the Rio Grande Valley.

The Eastern Border of the Rio Grande Valley

Precambrian Rocks

Precambrian rocks make up the basement complex of the area. Granite, gneiss, and schist are the main rock types. Precambrian rocks are exposed in the southern part of the La Joyita Hills and in some areas east of Socorro (Plate V).

Paleozoic Rocks

Paleozoic sediments of the Socorro quadrangle are included in the Magdalena group and the Abo, Yeso, and San Andres formations. The Magdalena group is of Pennsylvanian age. Paleozoic sediments of this group predominate in the hills east of the river. The rocks are highly calcareous and consist predominantly of limestone, but also include sandstone and shale members. The Abo formation is of lower Permian (?) age, and consists of sandstone, shale, and arkose. The formation crops out in the hills east of the Rio Grande River. The Yeso formation is of Permian age and consists of limestone, gypsum, gypsiferous shale and sandstone; gypsum is mainly found in the Canas gypsum member. The San Andres formation of the upper Permian consists mainly of limestone, sandstone, and gypsum. It is exposed in a number of areas east of the river (Plate V).

Mesozoic Rocks

The Mesozoic rocks exposed in the area are of Cretaceous age. These are represented by Dakota sandstone, Mancos shale and the Mesa Verde group. Sediments of this period crop out only in the northeastern part of the area in Valle del Ojo de la Parida (Plate V).

Cenozoic Rocks

Tertiary--The Tertiary sediments outcropping in the area consist of the Baca, Popotosa (?), and Datil formations and the Santa Fe group. The Baca formation, which is composed of reddish sandstone and conglomerate, is exposed in the southern part of Valle del Ojo de la Parida. The presence of Popotosa formation in the area east of the Rio Grande is doubtful.* The Santa Fe group crops out in

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*Personal communication from Mr. Bruce DeBrine.

several areas east of the river. It includes sandstone, gravel, clay, and shale. It overlies earlier formations along the eastern border of the Rio Grande graben. The Datil formation is found in some areas in the northeastern side of the area. It consists of lava flows which are andesitic and rhyolitic in composition and interlayered sediments.

Quaternary--The Quaternary deposits are represented by pediment gravel, alluvium, alluvial fan deposits and sand dunes. These are all grouped under the term alluvial deposits for convenience. The alluvial materials, gravel, coarse and fine sand, silt, and clay, cover most of the early sediments present. The character of these materials indicates that they were derived from the erosion of the older formations present in the surrounding mountains.

The Western Border of the Rio Grande Valley

Precambrian Rocks

Granite, gneiss, schist, quartzite, and argillite (greenstone), are the main rock types in this group, (Lasky, 1932, p.17). They are exposed in the Socorro and the Lemitar Hills.

Paleozoic Rocks

Paleozoic rocks are represented by the Pennsylvanian Magdalena group consisting of limestone, conglomerates, shales and quartzite.

These sediments outcrop in the Socorro and the Lemitar Hills.

Cenozoic Rocks

Tertiary--Volcanic rocks and interbedded sediments of the Datil formation constitute most of the Socorro Peak district. These Tertiary sediments make up about one third of the exposed rocks of that area, (Lasky, 1932, p.119-20). This formation is also exposed in the Lemitar Hills. The Popotosa formation outcrops in the Socorro Peak area.* It is composed of sandstone, silt and clay. The Santa Fe group sediments are found exposed in many areas of the western border. These sediments rest on earlier rock units.

Quaternary--Quaternary sediments include pediment gravels, alluvium and alluvial fan deposits. Other rock units of Quaternary age are basalt flows. These sediments form a thin veneer over the older rock units.

The Rio Grande Valley

The valley fill deposits in the Rio Grande basin consist mostly of unconsolidated or partly consolidated sediments of the Cenozoic age. These sediments cover most of the area between the mountains. The Tertiary sediments in this area include the Baca and Popotosa

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*Personal communication from Dr. Zane Spiegel, 1962.

formations, and the Santa Fe group. The latter group, which is the most extensive deposit in the valley fill, is exposed along terrace escarpments, (Spiegel, 1955, p.40). The Quaternary sediments include pediment gravel, alluvium and alluvial fan deposits which are grouped here as alluvial deposits. The Quaternary deposits rest over the older sediments. The Rio Grande Valley is characterized by the presence of terrace remnants which represent a succession of terraces built by the Rio Grande by successive scouring consequent to lowering of its grade. Each of these terrace surfaces represent a period of Rio Grande stable base levels.

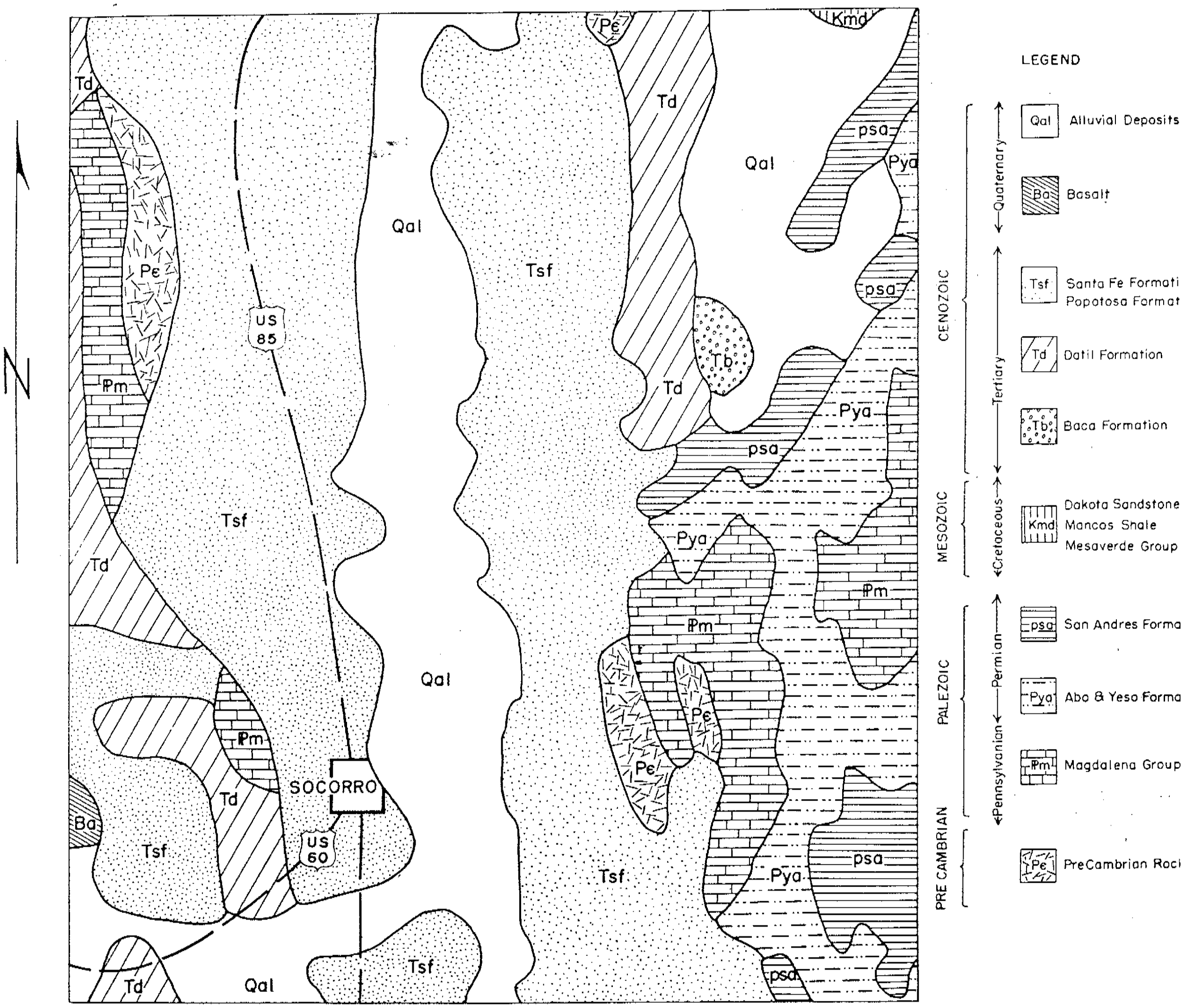
Since the sediments described were all formed as erosional products from the same general rock formations and deposited after mixing in a fluvial environment, they all have the same general characteristics of lithology, texture, cementation, and rock fragment types. These alluvial deposits contain cobbles, gravels, sand, and clay. Deposits on the eastern side of the river have more sedimentary rock fragments than those on the western side. The latter side has more volcanic and igneous debris.

For a summary of the geologic units in the three areas listed above, see Table I.

Plate V

Plate V

General geology of the Socorro quadrangle.



Modified from Geologic Highway Map
of New Mexico by The New Mexico Geological
Society 1961

0 1 2 3 4 5
SCALE IN MILES

GENERAL GEOLOGY OF THE SOCORRO QUADRANGLE

Plate VI

Plate VI

Generalized columnar sections
of the Socorro quadrangle.

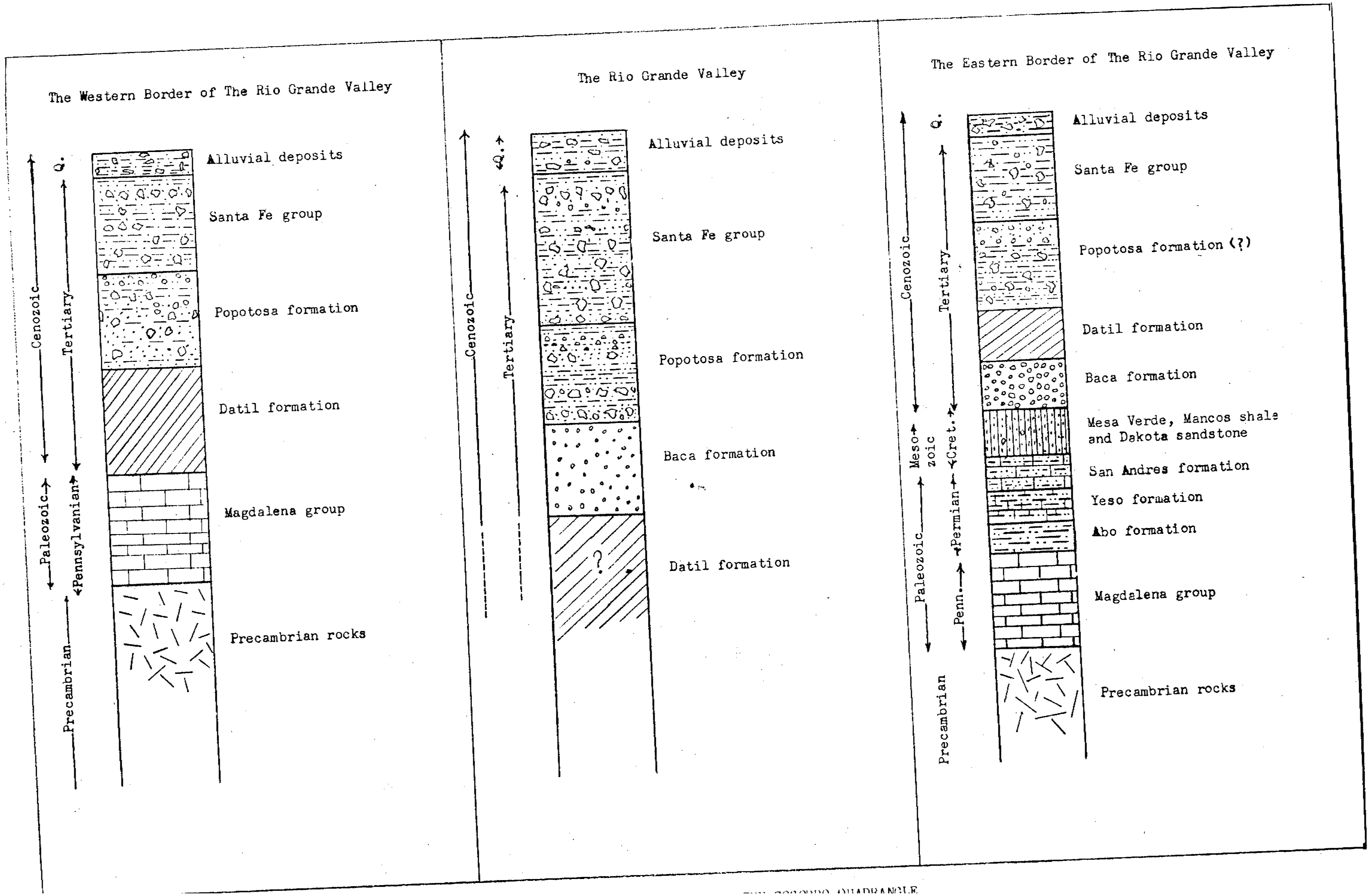

The Western Border of The Rio Grande Valley
Cenozoic
Tertiary
Q.
Paleozoic
Pennsylvanian
Precambrian
Alluvial deposits
Santa Fe group
Popotosa formation
Datil formation
Magdalena group
Precambrian rocks
The Rio Grande Valley
Cenozoic
Tertiary
Q.
Alluvial deposits
Santa Fe group
Popotosa formation
Baca formation
Datil formation
?
The Eastern Border of The Rio Grande Valley
Cenozoic
Tertiary
Q.
Mesozoic
Cret.
Paleozoic
Permian
Penn.
Precambrian
Alluvial deposits
Santa Fe group
Popotosa formation (?)
Datil formation
Baca formation
Mesa Verde, Mancos shale and Dakota sandstone
San Andres formation
Yeso formation
Abo formation
Magdalena group
Precambrian rocks

Table I

Table I

Summary of geologic units,
(Spiegel, 1955).

SUMMARY OF GEOLOGIC UNITS

Era	System		Geologic Unit	Thickness (ft.)	Description
CENOZOIC	Quaternary	Alluvial Deposits	Wind-blown sand		Fine to medium well-sorted sand.
			Alluvial fan deposits		Coarse debris at mountain fronts, merging into pediment gravels.
			Alluvium	0-200 ±	Fine sand, silt and some coarse channel gravels.
			Volcanic rocks		Basalt and basaltic flow.
	Upper Tertiary		Pediment gravel		Gravel and boulders in a silty or sandy matrix.
			Santa Fe group	500 to 5000 (est.)	Silt, clay, sand, and gravel beds having much horizontal and vertical variation.
			Popotosa formation	4000 to 5000 (est.)	Thick conglomeratic sandstone (upper part) and fine-grained sandstone, siltstone, and clay (lower part) containing much reworked volcanic debris.
	Lower Tertiary (?)		Datil formation	2000 (est.) ±	Thick flows of purple, red, and gray rhyolite and andesite with reworked tuffs and clays.
	Lower Tertiary		Baca formation	80 to 104	Sandstone and conglomerate, well cemented.
MESOZOIC	Cretaceous		Mesa Verde group	200 ±	Buff sandstone and shale.
			Mancos Shale	700 ±	Light brown sandstone, siltstone, and shale.
			Dakota sandstone	100 ±	Well cemented medium-grained sandstone mottled brown and black; some sandy black shale.
PALEOZOIC	Permian		San Andres formation:		
			Upper member	0 to 20	Siltstone and fine-grained sandstone.
			Limestone member	300 ±	Bedded limestone and gypsum with solutionally enlarged openings.
			Glorieta sandstone member	100 to 200	Massive light red-brown fine-medium-grained sandstone.
			Yeso formation: Joyita sandstone member	20 to 30	Mostly silstone and fine-grained sandstone.
			Canas gypsum member	0 to 30	Gypsum, limestone, and sandstone.
			Torres member	400 to 650	Gypsum, limestone, and sandstone.
			Meseta Blanca sandstone member	60 to 140	Massive light red-brown fine-medium-grained sandstone.
	Permian (?)		Abo formation	500 to 1100	Thick red shale beds, partially cemented sandstone and siltstone.
	Pennsylvanian	Magdalena Group	Bursum formation	80 to 120	Purple and maroon shale, fine-grained sandstone, and thin limestone layers.
			Madera limestone: Arkosic limestone member (east of the Rio Grande) possible equivalent of	0 to 520	Gray limestone with green-gray shale and well cemented sandstone, especially in lower half.
			Atrasado member (west of the Rio Grande)	550 to 800	Red to gray shale, conglomeratic sandstone and limestone.
			Lower limestone member (east of the Rio Grande) possible equivalent of	80 to 830	Cherty gray limestone, shale, and well cemented conglomeratic sandstone.
			Gray Mesa member (west of Rio Grande)	850 to 900	Mostly cherty gray limestone
			Sandia formation: Upper clastic member	400 ±	Well cemented conglomeratic sandstone, carbonaceous shale, and sandy limestone.
			Lower limestone member	0 to 15	Dark limestone and light colored sandstone.
	Precambrian			4000 to 5000	Schist, quartzite, rhyolite, and old intrusive granite.

ION EXCHANGE

Ionic exchange reactions are among the most important reactions occurring in soils. Ion exchange is that process by which cations and anions are exchanged between solid and liquid phases of the soil when in close contact with each other. Only cation exchange has been studied in the present investigation. Both the organic and inorganic constituents of a soil may play major roles in the exchange reactions. The soils studied in the Socorro area are low in organic content, so the role of organic constituents in the exchange process was not considered.

Ion Exchange Material of the Soil.

Ion exchange reactions are stoichiometric and reversible. They are true equilibrium reactions and can be represented as follows:

$$CR + D^{+} \rightleftharpoons DR + C^{+}$$

(R represents cation exchanger, C^{+} and D^{+} are cations)

The unit most used in dealing with exchange reactions is the milliequivalent, (m.e.), which is defined as the amount of any ion that will combine with or displace one milligram, (m.e.), of hydrogen. For example, one m.e. of calcium is 0.020 grams. Cation-exchange capacity can be defined quantitatively as the total exchangeable cations adsorbed by the soil in milliequivalents per 100 grams of solid (m.e./100 gms.).

Soil is a heterogeneous, disperse system of solid, liquid, and gaseous components in various proportions. The solid component of the soil is made up of primary minerals and hydrous oxides and secondary minerals which include some of the clay minerals. During the course of weathering, these minerals are broken down into finer and finer sized particles culminating in particles of colloidal size. The adsorptive power of particles increases with their fineness, reaching a maximum in the colloidal range owing to the high specific surface exposed.

Clay Minerals

The physical and chemical properties of soils are controlled to a considerable extent by clay minerals which act as centers of activity around which chemical reactions and base exchange occur. Clays are characterized by large surface areas per unit mass and the presence of surface charges to which ions become attached. The term clay carries with it several implications two of which are (a) "...an essential composition of particles of very fine size grades;" (b) "...an essential composition of crystalline fragments of minerals that are essentially hydrous aluminum silicates," (Grim, 1942; AGI, Glossary of Geology, 1960, p.52). Other definitions are, "Soil consisting of inorganic material, the grains of which have diameters smaller than 0.005mm."[U.S. Bureau of Soils Classification];

and "Fine grained soil that has a high plasticity index in relation to the liquid limit and consists mainly of particles less than 0.074 mm. (passing No. 200 sieve) in diameter." [Waterways Expt. Sta., 1953], (AGI, Glossary of Geology, 1960, p.52).

Formation of the various clay minerals hinges largely upon the hydrolysis of alumino-silicate minerals, most important of which are the feldspars and micas. A frequently occurring feldspar is orthoclase ($KAlSi_3O_8$). Hydrolysis of orthoclase goes slowly and can be represented by the following approximate equation, (Yaalon, 1959, p.74):

$$\underset{\text{orthoclase}}{2KAlSi_3O_8 + 11H_2O} \longrightarrow \underset{\text{intermediate products}}{\text{(cations and hydrous oxides)}} \longrightarrow$$

$$\underset{\text{kaolinite}}{Al_2Si_2O_5(OH)_4} + \underset{\text{soluble salts and ions}}{4H_2SiO_4 + 2K^+ + 2OH^-}$$

Clay minerals are aluminum silicates carrying in addition such cations as sodium, iron, or magnesium.

The layer lattice alumino-silicates can be divided into two categories on the basis of their silica:alumina ratio as follows:

1.) The 1:1 type includes those minerals in which a single layer is composed of silicon ions situated at the center of tetrahedra formed by four oxygen ions, alternating with a layer having an aluminum ion surrounded by six oxygen or hydroxyl ions arranged in the form of an octahedron.

Examples of this type are kaolinite, halloysite, nacrite, and dickite. Kaolinite, $Al_4Si_4O_{10}(OH)_8$, is the only one among the previously mentioned minerals, which is of importance in soils.

Silica and alumina layers are held together strongly by O-OH linkages, (Grim, 1953, p.47). Thus, the lattice is fixed and does not ordinarily expand when wetted with water. Cations and soil solution cannot enter between the structural units of the mineral. Ion exchange is thereby restricted to the outer surface. This is why kaolinite has a low exchange capacity. According to Grim, (1953, p.129), the exchange capacity of kaolinite ranges from 3 to 15 m.e./100 grams. The structural unit of kaolinite is neutral. Exchangeable cations are bound only by unsaturated bonds on the edges of the crystal particles.

2.) The 2:1 type includes a larger variety of clay minerals having unit structures consisting of two tetrahedral silica planes bonded together by one octahedral alumina plane. These planes are bound together by mutually shared oxygen atoms. The structural units are loosely held together by weak oxygen-alkali or -alkaline earth bonds. Examples of this type of clay mineral are montmorillonite, beidellite, illite, vermiculite, and chlorite. Of these, montmorillonite and illite are among the most important ion exchangers in soils.

Substitution and replacement within the octahedral aluminum layer are of great importance as they account for many of the exchange properties of montmorillonite. Common substitutions for Al^{+3} are Mg^{++} and Fe^{++}. Substitutions of Al^{+3} by cations of lower valence are accompanied by a resultant negative charge on the lattice. These negative charges are compensated for by cations located between the three layer units, such as Ca^{++}, Mg^{++}, K^{+}, and Na^{+}, and partly by substitution in the tetrahedral layer. These interlayer cations are actively or potentially exchangeable by other cations, depending on whether or not the interlayer distance is sufficient for the ions concerned to pass between the structural units. Similar substitution may occur for Si^{+4} within the tetrahedral layers. The extent of substitution determines such mineral properties as expansibility, cation exchange capacity, and potassium fixation, (Grim, 1953, p.58-59).

An outstanding feature of montmorillonite is an expandable structure. Water and other polar molecules, such as ethylene glycol, enter the unit layers causing the lattice to expand in the C-axis direction, (Warshaw and Roy, 1961, p.1476-7). Therefore, the C-axis dimension is not fixed but varies from about 9.6 to more than 17.0 angstroms. The C-axis dimension depends somowhat on the size of the interlayer cation; the larger the cation, the larger the C-axis. Cation exchange capacity of air dry montmorillonite ranges from 60 to 115 m.e./100 grams, (Kelley, 1948, p.30).

Cation Exchange Principles

Rate of Ion Exchange Reaction

As the exchange is a surface reaction, it proceeds just as fast as ions from the solution are supplied to the exchange material. The rate of exchange is generally more rapid for kaolinite minerals where the exchange takes place mainly on the edges of the particles. In the montmorillonite mineral most of the exchange occurs between the layers and the rate of exchange is therefore likely to be dependent on the interlayer spacing or degree of swelling. Exchange in other minerals of the exchange complex is slower than in the clay minerals.

Effect of Concentration

Kelley and Cummins, (1921, p.154-5), found that the replacement of Ca^{++} and Mg^{++} ions by Na^{+} ions increased as the concentration of the sodium in the soil solution increased. Gedroiz found the same results, however, he concluded that the replacement was not in direct proportion to the concentration, (Kelley, 1948, p.48). In general, with constant amounts of exchange material and exchange solution, the more concentrated the solution, the greater the amount of exchange.

Effect of Temperature

The temperature effect on cation exchange reaction is generally small. High temperature causes a slight increase in the rate of the rapid ion exchange, and a greater increase in the rate of the slow ion exchange (Kelley, 1948, p.53).

Influence of the Exchange Material

The following factors are of great influence on exchange reactions:

1.) The exchange capacity of the exchange material has an effect on the distribution of different ions adsorbed by it.

2.) The geometric fit of ions into the mineral structure influences the exchange reaction. Generally, the better a cation fits into its coordination, that is, the size of the cation relative to the size of the interstice in which it is present, the more strongly it is linked to the structure. For example, potassium has an ionic diameter of 2.66 A° which is the same as the diameter of the cavity in the oxygen layer of montmorillonite, so that the K^+ ion can just fit in one of these cavities, (Page and Baver, 1929, p.152). As a consequence, the K^+ ion becomes fixed.

3.) Clogging of exchange spots reduces the exchange capacity. Dion has pointed out that iron oxide may reduce the cation exchange capacity of clay minerals by a clogging action, (Dion, 1944, p.419-20).

Relative Replacing Power of Cations

In soils the relative replacing power of cations generally follows the order $M^+ < M^{++} < M^{+3}$ where the order of relative replacing power is related to the valency. The adsorption affinity increases with the valence. Ross, (1943, p.226), gave the following order of replacing power of ions: $Li^+ < Na^+ < H^+ < K^+ < Mg^{++} < Ca^{++}$. The relative replacing power of cations is influenced by many factors including the concentration of the solution, the exchange capacity of the exchange material, and the nature of the ions.

Source of the Negative Charge of the Exchange Material

The most well studied exchange materials are the clay minerals, thus, this discussion of the sources of the negative charges is restricted to clays. Grim, (1953, p.132-3), lists the following sources of negative charges:

1.) Exposed crystal edges, broken bonds, which are the unsatisfied valencies at the broken edges of the silica and alumina sheets, are sources of negative charges. The external surfaces of the minerals like kaolinite have some exposed hydroxyl groups which also act as exchange sites. The hydroxyl groups are attached to Al atoms within the alumina layer. The H of these OH groups dissociates leaving a negative charge carried by the O of the OH group. Broken bonds increase as the particle size decreases. This phenomenon apparently accounts for most of the exchange capacity of the 1:1 type clay minerals, and some of the exchange capacity of the 2:1 clay minerals.

2.) Ionic substitutions, another source of unsatisfied charge carried by clay minerals, is the substitution of one atom for another within the clay lattice. Mg may substitute for Al in the alumina layer, on the basis of one Mg atom for each Al atom replaced. Substitution within the silica layer may also take place. These replacements result in unsatisfied valency or negative charge which would be balanced by adsorption of cations. Ionic substitution is the most important factor of the 2:1 clay mineral adsorbing capacity.

SOILS OF THE SOCORRO AREA

Soils of the Socorro area have been developed on deposits that have passed through a cycle or cycles of weathering, transportation, and sedimentation. These deposits have been formed from material that was produced by weathering in past ages, removed by ordinary processes of denudation and deposited as alluvial deposits. Soil formation is due to a succession of continuous changes of these alluvial parent materials. In the process of soil development definite horizons are formed. The complete succession of horizons down to and including the upper part of the undifferentiated parent material constitutes the soil profile. Soil profiles which have attained full development are termed mature. Profiles which are not well developed or undeveloped are called immature.

The surface soil which has lost material to the lower strata is the A horizon; the lower soil stratum, subsoil, which has gained substances, is denoted as the B horizon. The zone underlying the B horizon is called the C horizon. This horizon may in some cases represent the undifferentiated parent material.

Weathering and Parent Material

Weathering of surface rocks gives soils as end products. The weathering processes are mainly due to the presence of water, oxygen, and carbon dioxide. Weathering reactions can be divided into two groups, physical and chemical. Physical weathering, or disintegration, is responsible for the gradual breaking down of rocks into smaller and smaller fragments without contributing chemical changes. Chemical weathering, or decomposition, involves chemical changes with formation of different products. Physical weathering renders rocks more susceptible to agents of chemical weathering and vice versa.

After being weathered, the products of disintegration and decomposition were removed mechanically and transported down to the valley. After the material was deposited, soil development started. The start of profile development in the partially weathered parent material does not halt the weathering process. The two processes can proceed simultaneously; and this is the case in the Socorro area. The weathering process ceases only when the soil material no longer contains unweathered minerals.

Physical Weathering

Rocks disintegrate slowly under the influence of many factors including temperature variations, rainfall, and wind movement. Rocks are aggregates of minerals which differ in their coefficients of expansion upon being heated. Thus, due to temperature changes, different stresses are set up which may eventually cause the rock to gradually crumble. Wetting, due to rainfall, and subsequent drying tends to weaken rock structure.

In semiarid regions like the Socorro area, where vegetation is sparse and winds of high velocity are more or less prevalent, much physical weathering is accomplished by the scouring action of windblown sand which erodes the rock masses. Other agencies of disintegration are moving waters in streams and freezing of water in rock fractures followed by its thawing.

Chemical Weathering

The presence of dissolved carbon dioxide aids the chemical action of water. In chemical weathering, some of the secondary products may originate by alteration in place of primary minerals while other products may originate by precipitation from solutions containing the soluble products of weathering.

The chemical weathering of rocks principally affects the silicate minerals such as feldspars, micas, ferromagnesian minerals, and corbonates. The disintegration and decomposition of these minerals depends on their stability in the presence of water and carbon dioxide. Certain minerals such as quartz remain practically unaltered by chemical weathering and persist in the soil. The most important chemical weathering reactions are simple solution, hydrolysis, hydration, oxidation, carbonation, and exchange reactions, (Reiche, 1950, p.19).

Simple Solution

Simple solution involving the removal of the weathered material is negligible except in cases where soluble salts are present in the disintegrated rock. Soluble salts are principally carbonates and bicarbonates of calcium, magnesium, sodium, and potassium which are produced during the decomposition of rocks and minerals. Other soluble salts that may be leached by simple solution are the sulfates and chlorides of alkali and alkaline earth metals.

Hydrolysis

Hydrolysis involves the reaction of an ion or a compound with water. The explanation of hydrolysis is that the water equilibrium, $H_2O \rightleftharpoons H^+ + OH^-$, is upset in the presence of certain compounds and ions. The actual amount of dissociation of water into hydrogen and hydroxyl ions is quite small, but the presence of carbon dioxide in solution increases the hydrogen ion concentration due to the formation of carbonic acid and thus the hydrolytic action of water is increased. Water containing carbon dioxide acts as a weak acid and affects carbonates and silicate minerals. The more finely divided the disintegrated rock mass, the greater the effect of water. Water reacts with minerals forming secondary products.

Hydration

In soils hydration involves the chemical combination of water with minerals. For example, oxides of iron hydrate to give limonite and geothite. Hydration preceeds hydrolysis of the alumino-silicate minerals, (Reiche, 1950, p.24). Hydration is accompanied by an increase in volume. Thus, it aids the physical weathering of rocks.

Oxidation

Oxidation takes place in the presence of an adequate amount of oxygen and affects mostly iron and manganese compounds. Certain ferromagnesian minerals contain ferrous iron which in the presence of oxygen and water becomes oxidized to the ferric state.

Carbonation

Carbonation, the formation of carbonates in the presence of carbonic acid, is an important process of chemical weathering in the Socorro area. When meteoric waters containing carbonic acid filter through rocks containing alkali and alkaline earth silicates, the first action consists in the partial reaction of these substances with the carbonic acid present and the resulting formation of alkaline carbonates and alkaline earth carbonates.

$$Na_2(\text{primary mineral anion}) + H_2CO_3 \rightleftharpoons H_2(\text{secondary mineral anion}) + Na_2CO_3$$

$$Ca(\text{primary mineral anion}) + H_2CO_3 \rightleftharpoons H_2(\text{secondary mineral anion}) + CaCO_3$$

This process is very slow when decomposition is affected by waters containing carbon dioxide at atmospheric pressure.

Exchange Reactions

Weathering is not simply the breakdown of primary minerals followed by leaching. "Far more commonly, chemical weathering is a matter of piece-meal ionic exchange, which alters, but does not destroy outright," (Reiche, 1950, p.37). Weathering processes involve the liberation of alkalies and alkaline earth ions which may or may not be retained by the secondary minerals, depending on exchange reactions. The nature of the weathered product depends to a great extent on whether or not the alkalies and alkaline earths are retained. Carbonic acid is one of the acids which facilitates exchange processes.

Soil Profile Development

The term soil has different meanings to workers in different fields. For example, the engineer refers to unconsolidated material at the earth's surface as soil, (Spangler, 1960, p.9), whereas the soil scientist defines soil as "The earth material which has been so modified and acted upon by physical, chemical, and biological agents that it will support rooted plants," (AGI, Glossary of Geology, 1960, p.271). The author prefers and follows the latter definition.

Soils of the Socorro area are found on lower, intermediate, and higher terraces.

The soils developed on the lower terraces may be subject to flooding. The parent materials of these soils are of recent deposition but they are older than those of the arroyo bottoms and have been modified to a certain extent by weathering. Soils of this category are found at different altitudes,(Plate III). Soils of the lower terraces are young; some lime accumulation is found in their subsoils. They have inherited their lime content from the older materials of the higher levels.

The soils found on intermediate terraces show more profile development than those developed on the lower terraces. They were developed from the same general parent materials under similar climatic conditions but they are of older age. Soils of this group are not subject to flooding since they lie well above the recent alluvial flood plain. The extent of leaching in these soils varies from one place to the other. The lime accumulation zone is harder than the lime accumulation zone of soils on lower terraces and it is closer to the surface.

Soils on the higher terraces are relatively mature. They are the oldest soils sampled from the area. These soils generally have a friable, loose, weathered surface, followed by a hard zone of lime accumulation. This zone of accumulation is usually hard to very hard, more compact, and of lighter color than the surface soil. Buried soils were found in places under more recently developed soils on the higher terraces.

Soils East of the Rio Grande.

Soils from the eastern side of the Rio Grande are of brown to dark brown and reddish brown colors. They are of sandy loam and loamy sand texture. Surface soils are mostly granular, loose, porous, and soft, with none to very few aggregates. The surface soil leads to the subsoil which commonly becomes lighter in color. The subsoil is usually of harder, crumbly to blocky, and prismatic structure. These soils contain calcium and magnesium carbonates as well as gypsum, and in some areas halite may be present. They effervesce with hydrochloric acid from the surface downward, the strength of effervescence increasing with depth, indicating a higher percentage of lime accumulation. Small lime concretions are usually visible at some depth in the profile. Calcium and magnesium carbonates can be found also as coatings around rock fragments and as cementing agents between sand and gravel. At depths ranging from 36 to 80 inches soils merge into their parent material. Parent materials range from unconsolidated alluvial sediments of the Quaternary or late Tertiary to reddish brown consolidated sediments of Tertiary and older periods.

Soils West of the Rio Grande.

Soils from the western side of the Rio Grande are of light brown to brown color. Surface soils are of sandy to sandy loam texture with a high degree of stoniness; they are loose, friable, and structureless. Subsoils are usually harder, firm, and of blocky or prismatic structure. Soils west of the river are less calcareous than those to the east. They contain less carbonate and gypsum in their profiles and they have developed from alluvial parent material dominated by volcanic and igneous rock fragments. These soils effervesce with hydrochloric acid from the surface downward, the strength of effervescence increasing with depth, indicating increasing lime accumulation. The lime accumulation zone is less pronounced than in soils east of the river.

Some soils in the vicinity of Socorro have been affected by sodium bicarbonate spring waters. This is indicated by chemical data (see Tables VIIB and VIIIB). In the area west of the Research Building of the New Mexico Institute of Mining and Technology, buried soils are found under much more recent sand and gravel on high terraces. These paleosols are comparable morphologically to modern soils. They have light textured A and heavier textured B horizons. In places, erosion has removed the recent deposits exposing the paleosols to a new cycle of weathering.

Five soil sections were studied and sampled in detail from the western side of the Rio Grande. These are described on the basis of field observations and laboratory analyses and hereafter are referred to as model soils. Profile descriptions will follow, whereas laboratory data are given in the Tables VIIA and VIIB. Horizon designations, symbols, color terms, texture, structure, and consistency descriptions used are those defined in the U.S.D.A., Soil Survey Staff, Handbook No. 18, (1951). One of these soils, 3S/1W-12N, is from the area affected by sodium bicarbonate springwater drainage (Plate VII). Another soil, 3S/1W-11B, is a buried paleosol (Plate VIII). Two soils, 3S/1W-25B and 1S/1W-3R, are relatively old alluvial soils (Plates IX and X); and the fifth soil, 2S/1W-25E, is a relatively recent soil (Plate XI). Soils 3S/1W-12N, 1S/1W-3R, 3S/1W-25B, and 2S/1W-25E are from intermediate terraces, while soil 3S/1W-11B is from a higher terrace.

Model Soil Profile Descriptions

<u>Soil 3S/1W-12N (A)</u>

Soil type: Old alluvial soil.

Parent material: Alluvial, contains volcanic rock fragments.

Physiography: Intermediate terrace.

Relief: Rolling, sloping.

Altitude: 4630 feet.

Drainage: Well drained.

Slope: 6% gradient.

Ground water: Deep.

Stoniness: 20 to 30% on the surface.

Erosion: Slight wind erosion and accumulation.

Root distribution: Few roots in the A layer.

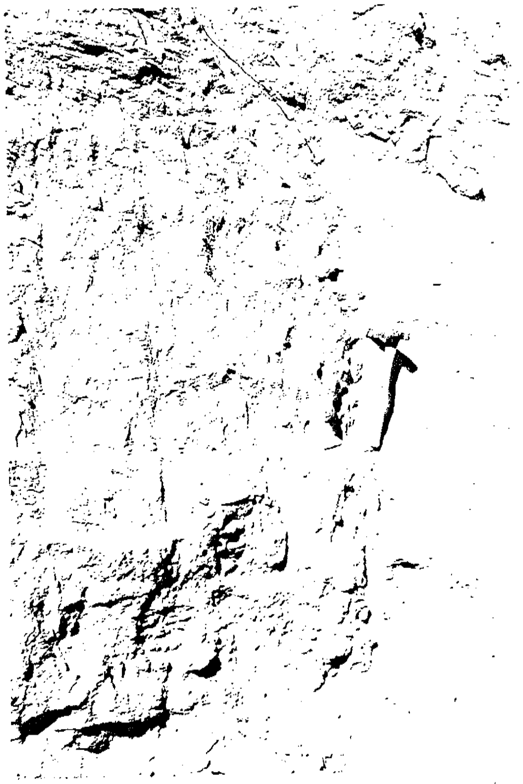
Soil morphology:

Zone	Depth (In.)	
A_o	0-2	Very light brown (10YR7/4,dry) and brown (7.5YR4/4,moist), coarse sandy loam, 30% gravel, structureless, loose, very friable, non-sticky when wet, very few roots, effervesces weakly, clear boundary.
A_1	2-12	Light brown (7.5YR6/4,dry) and brown (7.5 YR4/4,moist), loamy fine sand, moderate columnar structure, loose, very friable, slightly sticky when wet, few roots, effervesces strongly, clear boundary.
B	12-53	Light brown (7.5YR6/4,dry) and brown (7.5 YR4/4, moist), fine sandy loam, weak subangular blocky structure, slightly hard, firm, slightly sticky when wet, no roots, effervesces strongly, diffused boundary.
B_{bCa}	53-72	Brown (7.5YR4/4, dry) and brown (7.5YR 4/4, moist), silty clay loam, moderate columnar structure, hard, firm, and sticky when wet, no roots, effervesces strongly, abrupt boundary.
C_{Ca}	72-90	Light gray (10YR6/1, dry) and light yellowish brown (10YR6/4, moist), silt loam to silt, moderate columnar structure, hard, friable, slightly sticky when wet, effervesces strongly.
P	90 +	Medium yellowish brown (10YR5/5, dry) and medium yellowish brown (10YR5/4, moist), sand, structureless, loose, dry, very friable, non-sticky when wet, effervesces slightly, contains iron oxide staining.

Plate VII

Plate VII

Photograph of model soil 3S/1W-12N (A).



Soil 3S/1W-11B (B)

Soil type: Buried paleosol.

Parent material: Alluvial, contains volcanic rock fragments.

Physiography: High terrace.

Relief: Rolling.

Altitude: 4700 feet.

Drainage: Well drained.

Slope: 4% gradient.

Ground water: Deep.

Stoniness: More than 50% in top wash sediment (W).

Erosion: Slight wind erosion.

Root distribution: None.

Soil morphology:

Zone	Depth (In.)	
W		8 to 12 feet of very light gray (5YR7/1, dry), very stony, more than 50% cobbles and gravels, dominantly volcanic (rhyolite, reddish tuff, and breccia), few sedimentary rock fragments (sandstone, shale and limestone), shows no soil development, lower sides of pebbles coated with lime, abrupt boundary.
A_b	0-10	Light brown (7.5YR6/4, dry) and medium brown (5YR4/4, moist), sandy, soft, friable, non-sticky when wet, weak angular blocky structure, effervesces strongly.
B_{1b}	10-25	Brown (7.5YR5/2, dry) and dark brown (7.5YR4/2, moist), sandy loam, moderate blocky structure, slightly hard, firm, sticky, and slightly plastic when wet, clear boundary, effervesces strongly.

Plate VIII

Plate VIII

Photograph of model soil 3S/1W-11B (B).

B_{2b}	25-47	Light yellowish brown (10YR6/4, dry) and medium brown (5YR4/4, wet), loam, moderate angular blocky structure, slightly hard, firm, sticky, and slightly plastic when moist, effervesces strongly, diffuse boundary.
B_{3bCa}	47-62	Light yellowish brown (10YR6/4, dry) and medium brown (5YR5/4, moist), sandy loam, weak blocky structure, soft, friable, slightly sticky, non-plastic when moist, effervesces strongly, clear boundary.
C_b	62-80	Light brown (7.5YR6/4, dry) and brown 5YR3/4, moist), loam, weak blocky structure, soft, friable, slightly sticky, slightly plastic when moist, effervesces strongly, diffuse boundary.
P	80 +	Very light brown (5YR3/6, dry) and light brown (5YR4/6, moist), gravelly sand, structureless, loose, very sticky when wet, effervesces weakly.

Soil 3S/1W-25B (C)

Soil type: Old alluvial soil.

Parent material: Alluvial, contains volcanic rock fragments.

Physiography: Intermediate terrace.

Relief: Rolling and sloping.

Altitude: 4760 feet.

Drainage: Well drained.

Slope: 10% gradient.

Ground water: Deep.

Stoniness: 50% or more on the surface.

Erosion: Moderate wind erosion and accumulation.

Plate IX

Plate IX

Photograph of model soil 3S/1W-25B (C).

Root distribution: Very few roots in the A horizon.

Soil morphology:

Zone	Depth (In.)	
A_o	0-17	Pale brown (5YR6/2, dry) and light brown (5YR5/4, moist), very stony up to 50% cobbles and gravels, stony sandy texture, structureless, loose, non-sticky when wet, clear boundary, effervesces strongly.
A_1	17-27	Light brown (5YR6/4, dry) and brown (5YR 4/2, moist), sandy loam, weak blocky structure, slightly hard dry, friable moist, slightly sticky when wet, clear boundary, slight effervescence.
B	27-39	Light brown (5YR5/4, dry) and medium yellowish brown (10YR5/4, moist), loam, moderate angular blocky structure, hard, friable, slightly sticky when wet, clear boundary, slight effervescence.
B_{Ca}	39-84	Light brown (10YR5/3, dry) and yellowish brown (10YR5.5/4, moist), silty loam, moderate prismatic structure, very hard, firm moist, sticky when wet, clear to abrupt boundary, strong effervescence.
C	84-93	Light brown (5YR6/4, dry) and medium brown (5YR5/4, moist), sandy loam, weak blocky structure, slightly hard, friable moist, slightly sticky when wet, clear boundary, weak effervescence.
P	93 +	Very light brown (5YR4/6, dry) and light brown (5YR5/6, moist), sand, structureless, loose, non-sticky when wet, weak effervescence.

Soil 18/14-3R (D)

Soil type: Old alluvial soil.

Parent material: Alluvial, contains igneous rock fragments.

Physiography: Intermediate terrace.

Relief: Complex dessicated.

Altitude: 4700 feet.

Drainage: Well drained.

Slope: Complex.

Ground water: Deep.

Stoniness: None.

Erosion: Moderate wind erosion and accumulation.

Root distribution: Sparse in the surface A layer.

Soil morphology:

Zone	Depth (In.)	
A_0	0-14	Yellowish brown (10YR5/2, dry) and dark yellowish brown (10YR3/2, moist), sandy loam, granular weak structure, loose, very friable moist, non-sticky when wet, clear boundary, effervesces strongly.
A_1	14-24	Light brown (5YR5/4, dry) and brown (5YR 2.5/4, moist), silty loam, weak blocky structure, slightly hard, friable moist, sticky when wet, clear boundary, effervesces strongly.
B_{Ca}	24-57	Light brown (5YR5/4, dry) and brown (5YR 2.5/4, moist), silty loam, strong blocky structure, hard, friable moist, sticky when wet, clear boundary, effervesces strongly.
C_{Ca}	57-97	Light brown (5YR5/4, dry) and dark yellowish brown (10YR4/2, moist), sandy loam, strong blocky structure, hard, firm moist, very sticky when wet, clear boundary, effervesces strongly.

Plate X

Plate X

Photograph of model soil 1S/1W-3R (D).

P	97 +	Very light brown (5YR4/6, dry) and light brown (5YR5/4, moist), sandy, structureless, loose, non-sticky when wet, effervesces weakly.

Soil 2S/1W-25E (E)

Soil type: A relatively recent alluvial soil.

Parent material: Alluvial, contains volcanic and igneous rock fragments.

Physiography: Intermediate terrace.

Relief: Sloping.

Altitude: 4700 feet.

Drainage: Well drained.

Slope: 2% gradient.

Ground water: Deep.

Stoniness: Up to 50% in the surface A horizon and also between other genetic horizons.

Erosion: Moderate wind erosion and accumulation.

Root distribution: Very few roots in the A horizon.

Soil morphology:

Zone	Depth (In.)	
A_o	0-7	Light brown (5YR7/4, dry) and light brown (5YR5/5, moist), gravelly sand, structureless, soft, very friable moist, non-sticky when wet, 30 to 50% stoniness, clear boundary, effervesces weakly.
A_1	7-16	Light brown (5YR5/3, dry) and dark yellowish brown (10YR4/2, moist), gravelly sand,

Plate XI

Plate XI

Photograph of model soil 2S/1N-25E (E).

		structureless, soft, very friable moist, non-sticky when wet, clear boundary, effervesces strongly.
B_1	16-29	Light brown (5YR4/3, dry) and moderate brown (5YR3/4, moist), coarse sandy loam, medium blocky structure, slightly hard, friable moist, slightly sticky when wet, diffuse boundary, effervesces strongly.
B_{2Ca}	29-35	Light yellowish brown (10YR6/4, dry) and light brown (5YR5/5, moist), sandy loam, medium blocky structure, slightly hard friable moist, slightly sticky when wet, diffuse boundary, effervesces strongly.
C_{Ca}	35-52	Pale yellowish brown (10YR5/2, dry) and dark yellowish brown (10YR4/2, moist), fine sandy loam, weak blocky structure, soft, friable moist, non-sticky when wet, clear boundary, effervesces weakly.
P	52 +	Pale yellowish brown (10YR6/2, dry) and moderate yellowish brown (10YR5/3, moist), sandy, structureless, loose, non-sticky when wet, effervesces very weakly.

Soil Development

A generally accepted concept is that the development of soils is a function of five independent variables, (Jenny, 1941, p.12-13). These variables are parent material, climate, topography, organic activity, and time.

Parent Material

Parent rock weathers to give parent material. The following equation illustrates the difference between the parent rock and parent material, (Nikiforoff, 1949, p.219).

disintegration
parent rock → decomposition then → parent material → soils
transportation

The erosion products of the parent rocks were carried into the Socorro area mainly by the Rio Grande and its tributaries. Some material was carried in by the wind. The material was deposited as extensive alluvial fans and stream deposits. As observed from the geology of the area, parent rocks are mostly ash, granite, sandstone, limestone, and shale. The composition of these alluvial parent materials has a great influence on the soils formed.

Climate

Climatic factors include precipitation, temperature, wind, evaporation, and relative humidity. The soils of the Socorro area have been developed under a semiarid environment. As previously stated, the area is characterized by an average annual rainfall of about 10 inches, a mean annual temperature of 58° F, strong wind movement, and a high rate of evaporation. In the area, most of the rain comes during the summer and is lost by runoff and evaporation; so soil forming processes are probably slow. Salts formed from the weathering of soil minerals are not fully leached as infiltration from rainfall has been insufficient to remove these soil weathering products. Among these mineral salts present in the Socorro soils are carbonates of calcium, magnesium, and sodium, and sulfates of calcium. Under these climatic conditions the natural vegetation is sparse, the soil is not very thick, and erosion is considerable.

Topography

Topography is a less important soil forming factor than parent material or climate. In the Socorro area, most of the younger soils are at the lower elevations on the most recent terraces and the older soils are at the higher elevations on the higher terraces. The older soils have been subjected to weathering for a longer time than the younger soils. The extent of water penetration and active chemical weathering in these soils varies according to the topographic locations of the soils.

Organic Activity

In semiarid regions where vegetation is sparse, the organic content of the soil is low and thus organic activity is a less important factor in soil formation than in humid areas. The organic matter is usually added to the surface A layer in greater quantities than to deeper layers. Like soil clays, organic material is negatively charged and attracts positively charged ions to its surface. Therefore, organic material increases the soil's exchange capacity. Decay of organic matter in the soil produces carbon dioxide and also releases cations to the soil. Plant roots give off carbon dioxide and take up calcium, magnesium, potassium, and sodium ions as well as other nutrient elements from the soil exchange complex. The natural vegetation cover in the Socorro area, except that on the wet bottom lands near the Rio Grande River, is sparse and consists chiefly of scrubby mesquite (Prosopis fuliflora), rabbit-brush, "chamisa," (Chrysothamnus narseosus), greasewood (Sarcobatu vermiculatus), rattlesnake weed (Gutierrezia sarothrae), New Mexico thistle (Cirsium neomexicanum), Mexican-tea (Chenopodium ambrosioides), Mormon-tea (Ephedra), yellow daisy (Aploppus gracilis), salt cedar (Tamarin pentandra), locoweed (Astragalus artipes), screw bean (Prosopis pubescens), desert holly (Atriplex hymenelytra), desert willow (Chilopsis linearis), shadscale (Atriplex canescens), sagebrush (Artemisia tridentata), blazing-star (Mentzelia pumila), wild gourd (Marah gilensis), sedge (Cyperus difformis), challa (Opuntia acantho carpa), prickly pear (Opuntia compressa), and some species of wild grass and wild sunflowers.

Time

Soils change from young to mature with time. The relative ages of soils can be known from their degree of maturity, or horizon differentiation. In the Socorro area, soils developed on the higher terraces are more differentiated than those on the lower terraces.

Soil Analyses

The soil's coarse and medium materials are comparatively inactive, serving mainly as a supporting framework for the rest of the soil. A much more complicated function is served by the fine, or silt plus clay fraction. The finer soil fractions constitute the largest portion of the exchangeable material. They have large total surface areas which enhance their capacity for cation exchange. The experiment described in Appendix I shows that it is only necessary to study the reactions of the finer fractions instead of the whole soil in order to understand the cation exchange properties of the soils under investigation. All analyses were done on the silt plus clay fraction unless otherwise stated.

Mechanical Analysis

Complete mechanical size analysis down to and including the clay plus silt fraction (-200 mesh or -0.074 mm. grain diameter) was made on the five model profiles. Only the silt plus clay fraction of the other soils was measured. In several cases dilute hydrochloric acid was used to disperse soils before size analysis.

Soil Reaction (pH)

Soil acidity or alkalinity can be measured by the reaction of a soil-water system, expressed as its pH value, i.e., the negative logarithm of its hydrogen ion concentration. The terms used in this study to describe soil reactions are those set forth in the Proceedings of the Soil Science Society of America, (1956, p.436). Many different soil:water ratios are used by soil scientists. Those most used are 1:1, 1:2.5, 1:5, or 1:10, (Jackson, 1960, p.47). A 1:10 suspension of soil in water was used for pH measurements on all soils. The pH of the model soils was also measured on soil pastes.

Chemical Analysis

The exchangeable cation analysis of Socorro soils, which contain slightly soluble carbonates and soluble salts, is subject to difficulties which are not encountered with non-calcareous soils. The leachate of the replacing salt solution contains an appreciable amount of soluble salts and carbonates of calcium and magnesium. The cations brought in solution by the replacing salt solution are termed extractable cations in this research. To calculate the exchangeable cations, soluble cation content should be found independently and then subtracted from the extractable cations.

Soils east of the Rio Grande contain a high percentage of calcium and magnesium carbonates as well as gypsum. In such circumstances it is very difficult to differentiate the exchangeable from the soluble cations. Thus, only the extractable cations, which include both the exchangeable and the soluble cations, were determined on the majority of these soils. However, the amounts of exchangeable and soluble cations were measured for eleven representative soils for which the data may be considered approximate.

Extractable Cation Determination

Normal ammonium acetate solution of pH 7 is widely employed as the replacing agent for exchangeable cations. The ammonium acetate leachate contains the cations exchanged from the soil plus a certain amount entering by simple solution. The experiment described in Appendix II shows that a 1 N solution of ammonium acetate is capable of extracting all the available extractable cations from the soil. The method of cation extraction used was that suggested by the U.S. Salinity Laboratory Staff, Handbook No. 60, (1954, p.20), with some modifications.

1. Weigh 20.0 grams of ground, sieved, dry, soil of sizes less than 0.074 mm.
2. Transfer the sample to a 250 ml. flask.
3. Add 200.0 ml of 1 N ammonium acetate solution, shake and stir for one hour and let stand for twenty-four hours.
4. Filter the solution through a Buechner filter, applying moderate suction.
5. Cations in the extract solution were then detected by direct aspiration, using the flame spectrophotometer.

Soluble Cation Determination

Soluble cations were detected in soil-water leachates. Soil samples were soaked in water at a ratio of 1:10 for twenty-four hours. The same analytical procedure was then followed as was used in determining the extractable cations. Soluble calcium, magnesium, and sodium in m.e./100 gms. of silt plus clay were determined.

Cation Exchange Capacity

Cation exchange capacity of the virgin soil samples and that of the silt plus clay fractions were determined by means of 1 N sodium acetate solution of pH 8.2. A 1:10 soil:sodium acetate ratio was used, following the method described by the U.S. Salinity Laboratory Staff, Handbook No. 60, (1954, p.101). The soil acetate dispersion was allowed to stand twenty-four hours before leachate extraction.

Method of Flame Analysis

The cations potassium, sodium, calcium, and magnesium can be detected quantitatively using flame photometry. The Beckman Flame Spectrophotometer Model B was used for the chemical analyses. The older method for the analyses of these ions was by gravimetric means. This method is quite involved and would require considerable time if it was used to analyze samples from seventy-nine soils. The flame photometry method, which is easier and much faster, was preferred over all the other techniques.

It was found satisfactory to determine potassium with the 7665 A° lines and a red sensitive phototube; sodium, with the 5890 A° lines and a blue sensitive phototube. It is best to measure calcium at 5544 A° with the blue sensitive phototube, and magnesium at 3708 A° also with the blue sensitive phototube. According to Fields and others, (1951, p.219-32), the flame results they obtained for sodium and potassium were reproducible and agreed with the results of their chemical analyses. In the case of calcium, only the phosphate ion interfered with calcium transmittance. In soils of the Socorro area, the phosphate ion was not detected by the ammonium molybdate test; thus, it is not present, or is present in an amount too minor to cause any trouble. Calcium results were found to be reproducible. Magnesium proved more troublesome and less accurate. Tests for interference by Fields and others, (1951), showed that sodium ions if high, caused interference with the magnesium transmittance. For this analysis, interfering effects of calcium, sodium, potassium, and magnesium have been obviated by the addition of radiation buffers as suggested by West and others, (1950, p.558).

Conditions used for flame photometric analyses.

	Ca^{++}	Mg^{++}	K^{+}	Na^{+}
Concentration of standard solution for luminosity setting 100.0	1000.0 ppm.	1000.0 ppm.	1000.0 ppm.	1000.0 ppm.

Wave length setting	5544 A°	3708 A°	7665 A°	5890 A°
Phototube	Blue Sensitive.	Blue Sensitive.	Red Sensitive.	Blue Sensitive.
Sensitivity setting	3	4	3	3
Approximate slit width (mm)	0.8	1.1	0.3	0.3

The sodium, calcium, and potassium standard curves do not differ greatly from one series of determination to another. The magnesium standard curve does change from one series to the other, thus, it was frequently checked before each determination.

The precision of ten repeated soil analyses for calcium, magnesium, sodium and potassium was evaluated for standard deviation. The standard deviations for calcium, magnesium, sodium, and potassium were 0.46 m.e./100 gms. of soil, 0.40 m.e./100 gms. of soil, 0.30 m.e./100 gms. of soil, and 0.10 m.e./100 gms. of soil, respectively. From the above series of repeated analyses, the calculated percentages of error were: calcium, ±0.7%; magnesium, ±1.1%; sodium, ±2.6% and potassium, ±0.5%. However, since only two analyses were made of each sample in the routine analyses of the soils investigated, the above figures may not be exact. The chemical analyses results obtained by flame spectrophotometry are within ±5% of the values determined by gravimetric analyses methods, (Chapman and Pratt, 1961, p.201).

Electrical Conductivity

Electrical conductivity measurements were made on the extracts of saturated soil pastes according to the method set forth by the U.S. Salinity Laboratory Staff, Handbook No. 60, (1954, p.89-91). Soil pastes were allowed to stand twenty-four hours before measuring the electrical conductance of the supernatant liquid. The pipet type cell was used. The cell constant was checked and was found precisely equal to one. Conductivity results were expressed in terms of millimhos per centimeter (mmhos/cm) at 25° C.

Carbonate Analysis

Carbonate content and calcium carbonate equivalent were determined by acid neutralization according to the method described by the U.S. Salinity Laboratory Staff, Handbook No. 60, (1954, p.105).

A summary of the analytical data is given in Table II which follows. Complete analytical data are given in Tables VIIB, VIIIB, and IXB-C. The vertical distribution of extractable cations from soils east and west of the Rio Grande are presented in Plate XV (1-5).

X-ray Analysis of the Clay Fraction

X-ray diffraction furnishes an effective means of identifying and differentiating minerals in the clay fraction. X-ray patterns were obtained with a Philips spectrometer goniometer and an automatically recording Brown strip-chart potentiometer. Diffraction patterns were run with nickel-filtered copper radiation operating

Table II

Table II

Summary of analytical data.

Summary of Analytical Data

		Model Soils	Soils West of the Rio Grande	Soils East of the Rio Grande
pH		7.20 to 8.00	7.10 to 7.70	7.00 to 7.70
Silt plus Clay %		3.49 to 33.60	1.50 to 40.60	1.10 to 35.10
Extractable Cations (m.e./100 gms.)	Ca^{++}	10.00 to 26.00	7.60 to 50.00	8.00 to 50.00
	Mg^{++}	7.50 to 15.00	0.80 to 23.00	1.50 to 25.00
	Na^{+}	0.17 to 16.10	0.13 to 33.50	0.15 to 35.00
	K^{+}	0.26 to 1.90	0.17 to 7.70	0.18 to 13.50
Soluble Cations (m.e./100 gms.)	Ca^{++}	0.00 to 10.00	0.00 to 20.00	1.80 to 13.50
	Mg^{++}	0.00 to 8.84	0.00 to 9.00	0.00 to 5.48
	Na^{+}	0.00 to 6.50	0.00 to 15.80	0.00 to 11.40
Exchangeable Cations (m.e./100 gms.)	Ca^{++}	7.50 to 17.00	2.30 to 39.20	7.80 to 34.00
	Mg^{++}	3.33 to 13.84	0.00 to 19.60	3.85 to 17.43
	Na^{+}	0.17 to 9.60	0.00 to 29.40	0.00 to 17.20
	K^{+}	0.26 to 1.90	0.17 to 7.70	0.18 to 1.72
Total Exchangeable Cations (m.e./100 gms.)		17.85 to 35.27	6.29 to 62.30	11.14 to 50.63
Cation Exchange Capacity of Silt plus clay (m.e./100 gms.)		16.00 to 29.50		

Summary of Analytical Data (continued)

	Model Soils	Soils West of the Rio Grande	Soils East of the Rio Grande
Cation Exchange Capacity of soil (m.e./100 gms.)	1.70 to 10.00		
Electrical Conductivity x 10^3 (mhos/cm)	0.42 to 8.70		
CO_3%	1.56 to 2.09		3.60 to 5.73
$CaCO_3$%	2.60 to 3.48		6.00 to 9.55

at 40 kilovolts, 17 milliamperes, a scanning speed of 1° (2θ) per minute, 1° divergent and scatter slits, and .003 inch receiving slit. Instrument settings were 160 counts per second, full scale and time constant, 8 seconds. Scanning of the goniometer was limited to the range 2-60° (2θ) which was sufficient for the analysis of the minerals present. The instrument settings were maintained constant throughout the analyses of all samples so that intensity measurements might be compared for semi-quantitative analyses. Intensity measurements of the montmorillonite mineral in soil samples were compared with standard pure montmorillonite to determine its semi-quantitative concentration.

Preparation of the Sample

Clay particles were separated by means of sedimentation of the coarser materials, following Stokes theorem of settling rates, (Twenhofel, 1939, p.196-97). Clay samples were dried on low heat and then ground lightly in an agate mortar. From each clay sample two slides were prepared, one air dry and the other saturated with ethylene glycol, (Warshaw and Roy, 1961, p.1467). Ethylene glycol causes an expansion of the montmorillonite lattice which is necessary to distinguish it from illite.

Minerals detected in the clay fractions of Socorro soils can be divided into major and minor constituents (Table III).

Major Constituents

Minerals present in this group showed high, easily recognized intense reflections. They were detected in all the samples.

Quartz: Quartz is present in high amounts. It gives a strong, sharp pattern. The strongest reflection is from a lattice spacing of 3.35 Å and can be detected even when quartz is present in less than one per cent, (MacEwan, 1951, p.307).

Potash-feldspar: Potash-feldspars gave two prominant peaks, one less strong than the other in the region corresponding to 3.06-3.35 Å, (MacEwan, 1951, Plate XII,6, p.312).

Montmorillonite: The strongest peaks of montmorillonite reflections ranged in spacing from 12 to 15 Å, depending on the degree of hydration of the mineral, (Warshaw and Roy, 1961, p.1432). Ethylene glycol treatment caused an increase of the spacing values to 15-19 Å. There are other recognized peaks which occur at the equivalent of 4.5 Å and 2.5 Å, (Brindley and MacEwan, 1951, Table XIV,1, p.320). By comparing intensities of montmorillonite reflections of the unknown samples with intensities of a standard montmorillonite sample, approximate quantitative values were estimated. Results showed that montmorillonite values were between 7 and 43%.

Minor Constituents

Minerals present in this group had less intense reflections.

Calcite: Calcite was detected in most of the samples. Its most recognized spacings are at 3.01, 2.00, and 1.87 A°, (MacEwan, 1951, Table XII,7, p.312). Calcium carbonate could be contaminated with magnesium carbonate.

Hydrated Iron Oxides: Geothite and hematite were found in minor amounts in many of the samples. The most recognized spacings are at 4.90, 2.70, 2.23, 1.48, and 1.44 A°, (Rooksby, 1951, Table X,2, p.264).

Biotite: Biotite was found in some of the samples studied. Identified spacings are at 2.65, and 2.45 A, (Grim and others, 1951, Table V,7, p.171).

Kaolinite: Kaolinite was detected in small amounts. Identified spacings are at 7.00, 7.30, 4.32, 2.27, and 1.59 A°, (Brindley, 1951, Table II,3, p.71).

The x-ray analytical data are given in Table III which follows.

Discussion of Analytical Results

1. The amount of exchangeable calcium and magnesium ions in the model soils, as shown in Table VIIB, tends generally to decrease

Table III

Table III

X-ray analytical data

Abbreviations:

K-feld. = Potash feldspar
Cal. = Calcite   Bi. = Biotite
Mont. = Montmorillonite   Qz. = Quartz
Kaol. = Kaolinite   Feo. = Iron oxides

Soil No.	Location No.	Depth In.	Date of Analysis	X-ray Analysis	
				Major Constituents	Minor Constituents
62	1S/1E-23P	0-9	1/6/62	K-feld.,Qz.,Mont.(8.2%)	Cal.,Kaol.,Bi.,Feo.
		9-18		Qz.,K-feld.,Mont.(7.2%)	Cal.,Kaol.
		18-27		Qz.,K-feld.,Mont.(7.2%)	Cal.,Kaol.,Bi.,Feo.
		27-36		Qz.,K-feld.,Mont.(10.0%)	Cal.,Kaol.,Bi.,Feo.
		36-45		Qz.,K-feld.,Mont.(9.1%)	Cal.,Kaol.,Bi.
		45-54		Qz.,K-feld.,Mont.(8.5%)	Cal.,Kaol.,Bi.
7	2S/1W-25M	0-6	1/7/62	K-feld.,Qz.,Mont.(15.3%)	Kaol.,Cal.,Bi.,Feo.
		6-12		K-feld.,Qz.,Mont.(11.8%)	Cal.,Bi.,Kaol.
		12-18		Qz.,K-feld.,Mont.(10.2%)	Cal.,Bi.,Feo.
		18-24		Qz.,K-feld.,Mont.(11.8%)	Cal.
		24-30		Qz.,K-feld.,Mont.(11.8%)	Cal.
		30-36		Qz.,K-feld.,Mont.(15.0%)	Cal.,Kaol.
3	2S/1W-36N	0-12	1/8/62	K-feld.,Qz.,Mont.(11.6%)	Cal.,Kaol.
		12-24		Qz.,K-feld.,Mont.(11.6%)	Cal.
		24-36		Qz.,K-feld.,Mont.(9.4%)	Cal.
		36-48		Qz.,K-feld.,Mont.(17.6%)	Kaol.,Cal.,Feo.
		48-60		K-feld.,Qz.,Mont.(21.2%)	Cal.,Feo.
		60-72		Qz.,Mont.(27.0%),K-feld.	Cal.,Kaol.
15	3S/1W-12N	0-12	1/9/62	Qz.,K-feld.,Mont.(11.8%)	Cal.,Bi.,Kaol.
		12-24		Qz.,K-feld.,Mont.(22.3%)	Cal.,Bi.,Kaol.,Feo.
		24-36		Qz.,K-feld.,Mont.(21.0%)	Cal.,Kaol.,Bi.
		36-48		Qz.,K-feld.,Mont.(15.2%)	Cal.,Kaol.,Bi.
		48-60		Qz.,K-feld.,Mont.(23.5%)	Cal.,Bi.,Kaol.(?)
		60-72		Qz.,K-feld.,Mont.(19.4%)	Bi.,Cal.,Kaol.(?)
21	3S/1W-27J	0-6	1/10/62	Qz.,Mont.(13.0%),K-feld.	Cal.,Bi.,Feo.
		6-12		Qz.,Mont.(24.1%),K-feld.	Bi.
		12-18		Qz.,Mont.(22.3%),K-feld.	Bi.,Cal.
		18-24		Mont.(33.0%),Qz.,K-feld.	Cal.,Kaol.
		24-30		Mont.(37.5%),Qz.,K-feld.	Bi.,Cal.
		30-36		Mont.(38.7%),Qz.,K-feld.	Bi.,Cal.,Feo.
33	1S/1W-15E	0-8	1/12/62	K-feld.,Qz.,Mont.(17.0%)	Cal.,Bi.
		8-16		K-feld.,Qz.,Mont.(21.6%)	Cal.,Feo.,Kaol.
		16-24		K-feld.,Qz.,Mont.(20.5%)	Cal.
		24-32		K-feld.,Mont.(37.5%),Qz.	Cal.
		32-40		Qz.,K-feld.,Mont.(32.9%)	Cal.,Kaol.
		40-48		Qz.,K-feld.,Mont.(16.5%)	Cal.,Kaol.
52	2S/1W-11P	0-6	1/13/62	K-feld.,Qz.,Mont.(29.5%)	Cal.
		6-12		K-feld.,Qz.,Mont.(16.5%)	Cal.,Kaol.
		12-18		K-feld.,Qz.,Mont.(15.1%)	Cal.
		18-24		Qz.,K-feld.,Mont.(37.0%)	Cal.,Kaol.,Feo.
		24-30		Qz.,Mont.(41.0%),K-feld.	Cal.
		30-36		Qz.,Mont.(25.1%),K-feld.	Cal.,Feo.
56	1S/1W-28D	0-6	1/15/62	Qz.,K-feld.,Mont.(19.5%)	Kaol.,Cal.,Feo.
		6-12		Qz.,K-feld.,Mont.(17.6%)	Cal.,Kaol.
		12-18		Qz.,K-feld.,Mont.(14.8%)	Cal.
		18-24		Qz.,K-feld.,Mont.(19.5%)	Cal.,Bi.,Kaol.
		24-30		Qz.,Mont.(25.2%),K-feld.	Cal.,Feo.
		30-36		Qz.,Mont.(21.0%),K-feld.	Cal.,Kaol.
64	2S/1E-28C	0-6	1/17/62	Qz.,K-feld.,Mont.(19.4%)	Cal.,Feo.,Kaol.
		6-12		Qz.,Mont.(27.0%),K-feld.	Feo.,Cal.,Kaol.
		12-18		Qz.,K-feld.,Mont.(20.0%)	Feo.,Cal.
		18-24		Qz.,Mont.(43.5%),K-feld.	Feo.,Cal.,Kaol.
		24-30		Qz.,Mont.(36.0%),K-feld.	Cal.,Feo.
		30-36		Qz.,K-feld.,Mont.(21.0%)	Cal.,Feo.,Kaol.
67	2S/1E-33P	0-6	1/18/62	Qz.,K-feld.,Mont.(24.3%)	Feo.,Cal.,Bi.
		6-12		Qz.,K-feld.,Mont.(27.0%)	Feo.,Cal.
		12-18		Qz.,Mont.(31.5%),K-feld.	Feo.,Cal.
		18-24		Qz.,K-feld.,Mont.(20.0%)	Feo.,Cal.,Bi.
		24-30		Qz.,Mont.(33.0%),K-feld.	Cal.,Kaol.,Feo.
		30-36		Qz.,Mont.(23.0%),K-feld.	Cal.,Kaol.,Feo.
77	3S/1E-28P	0-8	1/18/62	Qz.,K-feld.,Mont.(16.0%)	Feo.,Cal.,Kaol.
		8-16		Qz.,K-feld.,Mont.(17.6%)	Feo.,Cal.,Kaol.
		16-24		Qz.,K-feld.,Mont.(16.5%)	Feo.,Cal.,Kaol.
		24-32		Qz.,K-feld.,Mont.(22.5%)	Feo.,Cal.,Kaol.
		32-40		Qz.,K-feld.,Mont.(16.5%)	Feo.,Cal.,Kaol.
		40-48		Qz.,K-feld.,Mont.(13.0%)	Feo.,Cal.,Kaol.

until the lower B or C horizons are reached; then there is usually an increase in the amount of these ions. Exchangeable calcium predominates over the other cations in more than 70% of the soil horizons. However, it should be noted that the concentration of magnesium in the same horizons is also high.

In model soils A and B, soluble calcium is highest at the surface. On the other hand, soluble magnesium and sodium increase with depth to certain levels and then decrease. Exchangeable calcium:magnesium ratios in the model soils A, B, and D, increase down to a certain depth, then decrease. In soils C and E there is a decrease and then an increase, (Table IV).

2. The chemical data show the distribution of the exchangeable cations and the relation between them. In general, exchangeable calcium decreases with depth, then increases in the lime accumulation zone. Magnesium has the same distribution pattern in most of the soils. Sodium usually increases with depth, then decreases in the lime accumulation zone. The increase in exchangeable calcium and magnesium at some depth within the soil profile and the decrease in sodium mark the top of the lime accumulation zone.

3. All the surfaces of the model soils contain carbonates; strong effervescence is usually encountered upon application of dilute hydrochloric acid. In each of the soils analyzed there has been a significant concentration of calcium carbonate at the lower

B or C horizons in contrast to the surface soil.

4. The distribution of sodium ions in the water extracts of all soils shows a direct relationship to the distribution of exchangeable sodium. However, in the case of magnesium, there is an inverse relationship.

5. Generally the pH values increase with depth. This increase may be associated with the accumulation of calcium carbonate. Measurements of the 1:10 soil-water pH are usually higher than those determined for soil pastes.

6. The distribution of exchangeable potassium in the soil profiles and its relation to the other cation distributions showed no consistent relationship. Potassium has a random distribution in most of the profiles investigated.

7. The cation exchange capacity determined for model profiles show that the soils' exchange complexes are saturated. Cation exchange capacity increases with the increase of the clay plus silt content of the soil.

8. The model profiles show no regular pattern as to clay plus silt distribution with depth. However, the following distributional trends may be recognized in all the remainder of the soils: (a) the percentage of clay plus silt decreases with depth in 27% of the soils; (b) the percentage of clay plus silt shows no maxima or minima in 36% of the soils; and (c) the percentage of clay plus

silt shows a maximum value at some depth in 37% of the soils. These results all indicate random distributions.

9. X-ray analyses of some profiles both east and west of the river show that the clay minerals are predominantly montmorillonite. Quartz and potash-feldspar are among the main constituents of the clay size minerals; calcite, kaolinite, biotite, and iron oxides are among the minor constituents (Table III).

10. Electrical conductivity values for the model profiles increase with depth until the parent material is reached and then they decrease. Conductivity values reflect the high salinity of the soils. An approximate linear relation is obtained by plotting conductivity values against total solubles.

Old alluvial model soil A and buried model soil B contain a greater amount of soluble cations than do the other model soils C, D, and E.

11. Exchange distribution indices for the model profiles show that much of the calcium, sodium, and magnesium, moving downward through the soil, was retained by the B and/or the C horizon (Table V).

It is assumed that the soil profile has been developed from a relatively uniform material. Complete uniformity of the parent material would be an ideal condition which probably does not exist. However, use of an assumption of uniformity is the best way under which a comparison of the modified and unmodified materials is possible.

12. The data of the buried soil B, a model profile, showed no differences from those of the other modern soils. Consequently, it is believed that environmental conditions under which the buried soils were developed were much like those under which the modern soils have been formed or else are in equilibrium with present day conditions.

13. All other soils collected west of the Rio Grande and all of those collected east of the river show the same general results as those listed above for the model soils. However, there are some specific differences.

In soils studied from east of the river, soluble calcium shows varying trends. In some soils it is highest in the surface; in other soils it is highest in the lime accumulation zone; in others it is constant with depth. Soluble magnesium has no systematic distribution pattern, but soluble sodium increases with depth. The total exchangeable cations of soils west and east of the river show that the soils' exchange complexes are saturated.

Soils west of the river near the town of Socorro are affected by sodium bicarbonate springs and thus are high in exchangeable sodium; most of the other soils are low in exchangeable sodium.

Soils east of the river are problematic since they contain soluble cations, carbonates of calcium and magnesium, and gypsum in higher amounts than in those west of the river (Table VI). Therefore, exchangeable cations determined by deducting soluble cations from extractable cations are probably higher than the actual value.

Interpretations of Analytical Results

1. A study of the exchange distribution index given in Table V for the model soils shows that the various profiles usually contain more exchangeable calcium, sodium, and magnesium than the parent material. The largest gains in exchangeable cations occur in the B and/or C horizons. The amounts of exchangeable calcium and magnesium are especially high in the surface soil and in the lime accumulation zone. The exchangeable sodium is generally low, except in areas affected by sodium bicarbonate springs. The exchangeable potassium is generally low, probably due to its fixation. The distribution of potassium relative to the other cations is not consistent.

2. Mechanical analyses show the soils studied have sandy, sandy loam, and loamy sand textures.

3. Rain water runs off quickly and these soils do not absorb much of it, therefore there is little penetration of water into the lower layers of the soil. A negligible penetration of water into the soil, followed by evaporation of the moisture back into the atmosphere, prevents the possibility of thorough leaching of the

surface soil.

4. Results of the chemical analyses and study of the profile morphologies show there is reason to believe that any loss of calcium and magnesium ions through leaching or cation exchange can be gradually replenished from the supply of calcium and magnesium carbonates in the soil.

5. It is safe to conclude that the base exchange complex is saturated. Exchangeable calcium and magnesium ions seem to follow, in most cases, parallel patterns in the soils. Their vertical distribution usually decreases to certain depths then increases again at lower levels. Sodium generally increases with depth, then decreases at lower levels of the soil.

The data given in Plate XIV shows that in every profile there is a definite zone of carbonate accumulation occurring at some depth down from the surface as well as at the surface. In some of the profiles it is very difficult to determine at what exact depth the carbonate accumulation commences. This is particularly true of the young profiles on the lower terraces.

6. The development of a lime accumulation zone may be considered one of the most important pedogenic processes of these soils. These carbonates may have been present originally in the parent material of the soils. Because of low rainfall, percolation of water through the profile is not sufficient to remove the car-

bonates that existed in the parent material or those produced by reaction of carbon dioxide and water with the mineral material of the soil.

7. Soils in the Socorro area have developed from calcareous alluvial deposits. Soils east of the Rio Grande contain visible amounts of gypsum. Horizons well below the surface contain gypsum crystals. Gypsum originates from Tertiary and Paleozoic sediments and also from the direct evaporation of solutions carrying calcium and sulfate ions.

8. In Socorro soils, rain water dissolves carbonates and sulfates of calcium and magnesium in the upper layers of the soil. Sodium salts which are easily leached out from the upper soil layers as soluble salts, accumulate in the lower soil levels. This leads to a saturation of the exchange complex of the upper soil horizons by calcium and magnesium. On the other hand, the increasing quantity of sodium in the solution of the lower levels influences the enrichment of the exchange complex by sodium in this area. As most of the sodium ions gain exchangeable positions, the sodium decreases relative to calcium and magnesium in the soil solution. As a result, the concentration of calcium and magnesium becomes higher and thus these elements saturate lower soil exchange levels. This zone of exchangeable calcium and magnesium enrichment coincides with the zone of lime accumulation.

Table IV

Table IV

Exchangeable calcium:magnesium ratio in model soils.

Exchangeable Calcium:Magnesium Ratio

Soil	Zone	Ratio
A	A_o	1.52
	A_1	1.75
	B	2.36
	B_{bca}	1.21
	C_{ca}	1.50
	P	1.47
B	W	1.78
	A_b	1.87
	B_{1b}	2.62
	B_{2b}	3.60
	B_{3b}	2.00
	C_b	1.93
	P	2.15
C	A_o	0.99
	A_1	0.96
	B	0.86
	B_{ca}	0.78
	C	0.95
	P	0.85
D	A_o	1.60
	A_1	1.64
	B_{ca}	1.62
	C_{ca}	1.21
	P	1.11
E	A_o	1.06
	A_1	0.98
	B_1	0.95
	B_{2ca}	0.87
	C_{ca}	1.17
	P	1.60

Table V

Table V

Exchange distribution index of model soils.

Exchange Distribution Index[*]

The ratio of an exchangeable cation concentration in a soil horizon to the concentration of that cation in the parent material (P). Exchangeable cation concentrations are given in table VII-B.

Soil	Zone	Ca^{++}	Na^{+}	Mg^{++}	K^{+}
A	A_o	1.23	0.30	1.19	1.28
	A_1	1.08	0.77	0.90	0.60
	B	1.15	1.42	0.72	0.82
	B_{bca}	0.98	1.65	1.19	0.93
	C_{ca}	1.31	1.12	1.28	0.60
	P	1.00	1.00	1.00	1.00
B	A_b	1.02	0.61	1.17	1.11
	B_{1b}	1.02	1.63	0.84	1.61
	B_{2b}	1.12	1.21	0.67	1.57
	B_{3b}	1.09	1.02	1.17	1.33
	C_b	1.05	1.31	1.17	1.06
	P	1.00	1.00	1.00	1.00
C	A_o	1.25	0.13	1.08	0.50
	A_1	1.12	0.72	1.00	0.36
	B	1.00	1.61	1.00	0.64
	B_{ca}	1.07	2.36	1.19	0.66
	C	1.03	5.10	0.93	0.75
	P	1.00	1.00	1.00	1.00
D	A_o	1.60	0.25	1.12	2.71
	A_1	1.46	0.76	1.00	1.48
	B_{ca}	1.53	2.53	1.06	1.31
	C_{ca}	1.26	1.24	1.19	0.79
	P	1.00	1.00	1.00	1.00
E	A_o	1.12	0.26	1.69	1.85
	A_1	0.98	0.51	1.61	1.16
	B_1	0.81	0.89	1.37	0.89
	B_{2ca}	1.03	1.28	1.87	0.68
	C_{ca}	1.20	0.61	1.63	0.53
	P	1.00	1.00	1.00	1.00

[*] Short, 1961, p.550.

Table VI

Table VI

Carbonate and calcium carbonate percentages
in five soils east of the Rio Grande River.

Carbonate and Calcium-Carbonate Percentage in Five Soils East of the Rio Grande.

Soil	Depth (In.)	CO_3%	$CaCO_3$%
23	0-6	5.28	8.80
	6-12	4.80	8.00
	12-18	4.37	7.28
	18-24	5.10	8.50
	24-30	5.52	9.20
	30-36	5.13	8.55
44	0-7	4.95	8.25
	7-14	4.45	7.40
	14-21	5.28	8.80
	21-28	5.45	9.09
	28-35	5.73	9.55
	35-42	5.34	8.90
66	0-6	3.60	6.00
	6-12	4.85	8.08
	12-18	3.89	6.48
	18-24	4.84	8.04
	24-30	5.37	8.95
	30-36	4.97	8.28
62	0-9	5.19	8.65
	9-18	5.13	8.55
	18-27	4.92	8.20
	27-36	5.22	8.70
	36-45	5.19	8.65
	45-54	4.14	7.70
73	0-6	4.89	8.15
	6-12	5.13	8.55
	12-18	5.79	9.65
	18-24	5.31	8.85
	24-30	4.94	8.24
	30-36	5.19	8.65

Water Movement

Downward water movement is an important process in soil profile differentiation for it carries both the dissolved and the colloidal material through the soil. In humid areas where the infiltration rate is high these substances may be moved down to the water table. However, in semiarid regions, water infiltration is more limited; thus, these materials may be carried only to shallow depths in the soil. As rain falls on the surface of the ground, a portion runs off, a portion evaporates, and a portion infiltrates the soil. The amount of water that moves down through soil depends on structure and texture of the soil and the amount and duration of rainfall. In the model soils studied, infiltrating waters carry carbonates and other salts down to certain depths in the B or the C horizons.

When water enters the soil it tends to migrate downward to a zone of saturation where the soil pores become completely filled with water. Movement of water through soil pores is brought about by the action of gravitation forces alone or in combination with the capillary forces. Soil pores may be divided into two sizes, large macropores and small capillary pores. Water moves in the larger pores mainly under the influence of gravity and in the finer pores under the influence of capillary forces. Water moves quickly between the larger connected pores and slowly between the fine connected pores.

Forms of Soil Moisture.

The main forms of soil moisture are gravitational, capillary, and pellicular. Water vapor may be also present in the soil, (Buckman and Brady, 1960, p.171). Forms of soil moisture can be defined as follows: (1) gravitational water: water that moves freely under the influence of gravitational forces; (2) capillary water: water which is held between soil grains and moves under the influence of capillary forces; (3) pellicular water: "Water adhering as films to the surfaces of openings and occurring as wedge shaped bodies at junctures of interstices in the zone of aeration," (Tolman, 1937, p.561).

Soil water infiltration will occur as long as there are potential differences between different areas in the soil. Water will move from a higher to a lower potential area, (Gardner, 1960, p.5).

Water Movement Under Gravitational Force

The earth's gravitational force provides the principal potential which influences water infiltration down through soils.

Capillary Water Movement

In sandy and loamy soils many of the pores are non-capillary or only weakly so. Thus, capillary height cannot be great. Terzaghi, (1942, p.340), reported the following capillary heights in different fractions of a sand at a temperature of 17°C.

Grain size (mm.)	5.0-2.0	2.0-1.0	1.0-0.5	0.5-0.2	0.2-0.1	0.1-0.05
Capillary rise (mm.)	2.5	6.5	13.1	24.6	42.8	105.5

The porosity of the sands tested ranged between the narrow limits of 40.1 and 41.3% and averaged 41%.

Capillary attraction of soil for water is in all directions. When runoff water soaks into the soil, capillarity will aid gravity in pulling moisture down. If the surface layer of the soil dries up, capillarity might oppose gravity, thus, tending to pull water upward.

Water Vapor Movement

A slow movement of moisture may occur in the vapor phase by normal vapor pressure phenomena. Vapor will tend to move from regions of high vapor pressure to those of lower vapor pressure, (Buckman and Brady, 1960, p.190). Water vapor movement tends to equalize moisture content throughout the soil column.

Rate of Water Movement Through Soils

In discussing infiltration of water through soil, reference should be made to Darcy's law which describes saturated water flow.

Darcy's equation: $V = -PI$

V = water velocity
P = hydraulic conductivity
I = hydraulic gradient

The hydraulic gradient determines the direction of water flow. Hydraulic conductivity depends on pore sizes and their interconnections; thus, clays have lower conductivity than sands, (Takagi, 1960, p.95).

Water Movement in Socorro Soil Profiles

Flow of water in soils of the Socorro area tends to be of the unsaturated type. Unsaturated flow takes place in soils where some of the pores do not become completely filled with water. As water from rainfall and runoff penetrates through the dry soil, it flows first through the larger pores then through the finer ones, down through the soil under the influence of gravity and capillary forces. Water moves down through the soil leaving behind a film of moisture adsorbed to soil particles. This pellicular water will either remain in place or move very slowly.

Due to high temperatures, low humidity, and wind movement, evaporation will dry out the upper few inches of the soil near the surface. Under such conditions of a dry surface soil and a wet subsoil, capillarity will tend to pull water upward. However, upward water movement to replace the moisture lost by surface evaporation, opposing the gravitational pull downward, is probably small and the zone affected by such movement is probably limited. Finally, some water loss from soil depths may take place by upward movement of vapor from the higher vapor pressure areas to lower vapor pressure areas near the surface.

Lime Accumulation As An Indicator of the Depth of Water Penetration

In the Socorro area soils have been subjected to an average annual rainfall of about ten inches since their deposition. Rainfall has been insufficient to remove carbonates present in the soils when they were deposited or those carbonates which have developed through the normal chemical processes of weathering. A well-to-poorly-developed lime accumulation zone lies between average depths from 18 to 72 inches from the surface. This lime zone is characterized by a high percentage of carbonate which occurs as minute specks or as a fine precipitate throughout that zone.

The most abundant carbonate of soils is calcium carbonate which is relatively insoluble. Sodium carbonate is the most common soluble carbonate found in these calcareous soils. Qualitative analyses of samples from the lime accumulation zone showed the existence of Ca^{++}, Mg^{++}, Na^{+}, CO_3^{--}, and SO_4^{--} ions in considerable amounts and Cl^{-} ions in minor amounts. From the chemical analyses it is logical to assume the presence of these salts: calcium carbonate, calcium sulfate, magnesium carbonate, magnesium sulfate, sodium carbonate and sodium chloride. Removal of lime from the surface soil and its accumulation at lower depths plays a very important role in the profile formation of calcisols. The process is called calcification, (Reiche, 1950, p.32).

Origin of Calcium and Magnesium Carbonates

Calcium and magnesium carbonates are produced from the following sources:

1. Calcium and magnesium bicarbonates are formed in the weathering of silicates.
2. Limestone and gypsum are present in the area.
3. Sodium carbonate acts as a precipitant for calcium and magnesium carbonates. When solutions of $CaSO_4$ and $Na_2CO_3$are mingled, $CaCO_3$ will precipitate according to the following: $CaSO_4 + CO_3^{--} \rightleftharpoons SO_4^{--} + CaCO_3$.

The formation of lime accumulation zones involves solution, transportation, and precipitation.

Solution and Precipitation Processes

The relatively insoluble carbonates of calcium and magnesium are dissolved by carbon dioxide which is present in water. Therefore, they are regarded as present in the bicarbonate form, as shown by the reverse of the following equation:

$$Ca^{++} + 2HCO_3^- \rightleftharpoons CaCO_3 + H_2O + CO_2$$

Calcium bicarbonate, however, is somewhat unstable in solution and can be broken down to normal calcium carbonate rather easily.

From the chemical equation given above, one can predict the following factors will affect the solubility and precipitation of calcium carbonate:

1. Water: An increased infiltration of rain water containing CO_2 will directly increase the solution of carbonates. Evaporation, controlled by the humidity of the air, the temperature, and the amount of rainfall penetrating the soil, is an important factor which will cause precipitation of calcium and magnesium carbonates. Rain water dissolves carbonates and the resulting solution moves downward through the dry soil. Hydration of the soil particles removes water from the solution; thus, calcium and magnesium carbonates precipitate.

2. Carbon dioxide pressure: The atmosphere contains about 0.03%-0.04% CO_2. Carbon dioxide pressure increases in the soil due to organic activity. Soil air may contain up to 0.3% CO_2. As the CO_2 pressure increases, more calcium ions will be in solution. Evaporation, rise in temperature, and mechanical agitation of the bicarbonate solution will release some CO_2. A decrease in CO_2

pressure will cause precipitation of calcium and magnesium carbonates.

3. Calcium carbonate addition: As the soil solution moves down through the soil, it gains more carbonates from the soil profile. This addition of carbonates will bring about precipitation if the saturation limit is exceeded.

4. pH: Since calcium carbonate is more soluble in acidic media, some may precipitate if the pH increases.

5. Common ion effect: The presence of calcium sulfate may aid in the precipitation of calcium carbonate. Calcium sulfate as gypsum, $CaSO_4 \cdot 2H_2O$, is soluble to the extent of 0.223 grams in 100 grams of cold water. A solution of this salt will diffuse downward and calcium carbonate will precipitate when $[Ca^{++}][CO_3^{--}] > K_{sp}$ owing to the common ion effect.

Transportation Process

As rain water runs off it will dissolve carbonates of calcium and magnesium from sediments and from surface soils. Some of this solution moves downward and passes into dry soil. More carbonates are added to the solution from the soil. The water will keep moving down until it reaches a certain depth where its salts will be precipitated.

Theories of Lime Accumulation in Soils

Some of the theories explaining the formation of caliche (lime accumulation) assume an upward capillary movement of ground water followed by evaporation. For such a process to occur, a shallow water table is essential. Barshad, (1955, p.38), says, "Little water moves upward unless the water table is present within about five feet of the surface and at the same time the surface is subjected to desiccation. Such movement may bring about accumulation of salts in the surface horizon and on the surface and result in the formation of alkali and alkaline soils."

Other hypotheses emphasize the role of evaporation in causing accumulation. Marbut, (1927, p.17-19), designated the process by which the upper horizons of soil become depleted of calcium and the lower horizons develop a zone of carbonate accumulation as "calcification." He assumed that the zone of carbonate accumulation marked the average depth of moisture penetration. He maintained that the accumulation was brought about by the transference of carbonates which were present in the upper horizons after they were changed to bicarbonates. This solution percolated downward to the point where water ceased its penetration and there deposited its load.

Schantz, (1923, p.81-3), maintained that carbonates are dissolved out of the surface by periodic rains and are precipitated at lower levels only as these levels are desiccated by plant roots.

He concluded that in eastern Colorado, where the "caliche" zone has developed at a depth of 14 to 18 inches, no carbonate accumulation layer would have developed if short grass vegetation had not adsorbed the soil moisture. He stated that, "The depth of soil to the layer of carbonate accumulation is a measure of the depth of moisture under the natural vegetation during all but exceptional years."

Hawker, (1927), has shown that progressive leaching of the upper soil zone results in the concentration of calcium carbonate at gradually increasing depths in the soil, first invisible, then as grains, then as nodules, then as definite layers of clay high in calcium carbonate, finally as a solid bed of caliche. These gradations as shown by Hawker may occur in soils whose stage of development progressively increases with the stage of development of caliche.

Lime Accumulation in Socorro Soils

Some of the controlling factors in lime accumulation in Socorro soils include the permeability of the soil, parent material, and position of the water table.

The average depths to the lime accumulation zones are 35 inches in lower terrace soils, 28 inches in intermediate terrace soils, and 23 inches in higher terrace soils. Above the lime accumulation zones, these soils generally are loamy sand, granular, loose, and porous. In such soils, solutions will move downward easily. Parent materials in the area studied are calcareous in nature. Runoff carries down and dissolves calcium and magnesium carbonates from these calcareous materials and also from the surface soils. Beneath the area studied the water table lies at depths ranging from 30 to 200 feet. Accumulation of calcium and magnesium carbonates in these soils must be regarded as due to descending waters since capillarity cannot be assumed to lift ground water up 30 to 200 feet.

Keeping in mind the conditions controlling the preferred direction of the reaction represented by the general equation,

$$M^{++} + 2HCO_3^{-} \rightleftharpoons MCO_3 + CO_2 + H_2O.$$

$$(M = Ca^{++} \text{ or } Mg^{++} \text{ ions})$$

the author suggests the following mechanism as a possible means of lime accumulation in Socorro soils.

Rain water in equilibrium with atmospheric carbon dioxide, dissolves the carbonates of calcium and magnesium more completely in the upper surface layers of the soil. As the soil solution moves downward through the soil, it passes into a dry environment. Some water will be removed by hydration of soil particles. Due to surface evaporation, water will diffuse upward as vapor through the soil pores more rapidly than it could by capillarity from the moist soil zone. This means the evaporating surface is below the ground surface. The presence of calcium sulfate and magnesium sulfates in the soil may also aid in carbonate precipitation from solution. Calcium and magnesium sulfate solutions, being more soluble than the respective carbonates, will leach downward first. Calcium and magnesium then follow in solution as hydrogen carbonates and finally precipitate as insoluble carbonates at the level where sulfate ion concentration is high because of the common ion effect. Other factors involved in the deposition of calcium and magnesium carbonates are the slight increase in soil pH with depth and the decrease of carbon dioxide pressure due to low biologic activity and evaporation. Evaporation will eventually dry the entire soil leaving a zone of lime accumulation at the depth of maximum water penetration.

Depth of Chemical Weathering

The depth of chemical weathering may be defined as the depth in the soil that is reached by the chemical weathering action. As water is a necessary element for chemical weathering reactions, then the depth of chemical weathering coincides with the depth of water penetration.

Movement of metal cations downward from the top layers of the soil and their accumulation in the subsoil are due to processes of chemical weathering. In the Socorro area there is not enough water to provide a steady movement of solutions through the soils, which results in accumulation of salts in the soil profile. These salts are predominantly calcium and magnesium carbonates and sulfates. They are transported downward in periods of heavy rainfall to the point of maximum water penetration, and there precipitated. Thus, products of weathering are not removed from the profile and the soils remain alkaline.

During the process of chemical weathering there is a constant breaking down of silicates of calcium, magnesium, and the alkalies, with the resultant formation of alkali and alkaline earth carbonates and sulfates, together with other salts. Whatever the agents of chemical weathering are, they work from the surface of the soil downward. These decomposing agents lose their activity and become quite inert at some depth in the soil, at the depth of maximum water penetration.

Chemical weathering is a slow process. It depends on many factors such as composition of the soil, its texture, and temperature. In the presence of insoluble carbonates, the influence of weathering is retarded. The depth to which chemical weathering has penetrated varies greatly in the soils studied. In cases where the surface soil material is removed by erosion, chemical weathering may go on indefinitely.

Factors in determining the depth of the weathering profile are:

Composition

The inorganic portion of the soil consists of minerals which come from the parent material or are weathered from the primary minerals in it. The wide differences in the resistance of minerals to chemical weathering depends upon their chemical properties and stability. Among the least stable minerals are plagioclase and hornblende. Orthoclase and biotite are moderately stable; quartz is one of the most stable minerals, (Goldich, 1938, p.17-58).

Texture

Water runs through coarse textured soils too rapidly to allow profound chemical weathering and depth of water penetration is probably great. Water percolation is slowed up in loamy soils. Thus, chemical weathering may be more active.

Water Infiltration

The chief conditions favoring chemical weathering are those of continual percolation by water carrying carbon dioxide. Hence, decomposition will keep on at an increasing rate to a depth corresponding to the depth of water penetration.

Temperature

Chemical weathering is more rapid in a warm climate than in a cold one.

Time

Since weathering is a slow process, time is a very important factor. The depth of chemical weathering increases with time.

SUMMARY AND CONCLUSIONS

In analyzing the experimental data obtained in this study, one finds a number of inconsistencies, some of which may be explained as errors in field or laboratory procedure, while others remain as yet unexplainable. However, the author feels justified in drawing the following conclusions, based on the experimental results obtained from: soil morphological data and descriptions; analytical data, including the vertical distribution of the soluble and exchangeable cations of calcium, magnesium, sodium, and potassium; the vertical distribution of the clay plus silt fraction; the x-ray analysis of the clay fraction; soil reaction (pH); and insoluble carbonate content.

Important conclusions from this study are:

1. In general, the amounts of exchangeable calcium and magnesium are relatively high near the surface and again in the deeper horizons of the soil. Usually exchangeable sodium is low near the surface and then increases with depth until the undifferentiated parent material is reached; here sodium generally decreases. The distribution of exchangeable potassium relative to the other cations is not consistent. The change in the distribution patterns of these replaceable ions is correlated with the depth of water penetration.

2. The development of a lime accumulation zone at some depth

below the surface may be considered one of the most important pedogenic processes of these soils. The depth of lime accumulation may be indicative of the depth of water penetration. The depth of chemical weathering generally corresponds to the depth of water penetration.

3. The soils of the Socorro area are soils of accumulation, not in the sense of clay accumulation as in mature profile development, but the accumulation of salts in the B or C horizons. Thus, the weathering effects have been largely limited to the replacement of ions through exchange reactions and the accumulation of salts.

Other conclusions from this study are:

1. Soils of the Socorro area are neutral to moderately alkaline. Alkalinity usually increases slightly with depth, probably due to the increase in the amounts of insoluble carbonates.

2. Soils of the Socorro area may be described as loamy, zonal, saline, alkaline, calcareous (calcisols), alluvial soils.

3. The base exchange complex of the Socorro soils is saturated.

4. The only clay mineral found in a significant amount is montmorillonite which has a high exchange capacity.

Recommendations for further studies:

1. The effect of carbonate and sulfate accumulations in soils upon the accurate determination of exchangeable cation content.

2. Caliche development in reference to water penetration.

Symbols and Abbreviations for the Following Tables

A_o: Surface gravelly layer.
A : Surface soil.
B : Subsoil horizon, divided in some soils into subhorizons, B_1, B_2, ...etc.
B_{Ca}: Calcareous B horizon.
b : Subletter b indicates a buried soil horizon.
C : Soil horizon above the parent material.
C_{Ca}: Calcareous C horizon.
P : Parent material.
W : Calcareous wash.
m.e. : Milliequivalents.
C.E.C. : Cation exchange capacity.
E.C. : Electrical conductivity.
R.F. : Rock fragments.
Agg. : Aggregates.

Table VIIA

Table VIIA

Physical data for model soils.

Soil No.	Location No.	Date of Collection	Alt. Ft.	Horizon	Depth In.	C.Sand %	M.Sand %	F.Sand %	V.F.Sand %	Clay & Silt %	pH Paste	pH 1:10
A	3S/1W-12N	5/8/62	4630	A_o	0-2	35.40	17.50	30.62	2.92	13.00	7.70	7.85
				A_1	2-12	18.10	16.78	57.40	0.15	7.75	8.00	8.30
				B	12-58	28.72	29.10	33.41	0.37	8.20	7.80	7.92
				B_{bca}	58-72	17.45	25.05	48.00	0.27	9.30	7.85	7.90
				C_{ca}	72-90	20.37	20.24	48.84	0.33	10.02	7.85	7.95
				P	90-	20.28	15.75	52.66	2.73	8.46	7.70	7.85
B	3S/1W-11B	5/13/62	4700	W		56.23	23.95	16.02	0.33	3.49	7.70	7.87
				A_b	0-10	34.35	36.80	16.78	3.90	8.10	7.65	7.80
				B_{1b}	10-25	33.83	16.05	31.37	3.46	15.63	7.35	7.52
				B_{2b}	25-47	41.60	19.30	26.83	3.40	9.15	7.70	7.83
				B_{3b}	47-62	40.05	18.45	28.01	3.37	10.20	7.73	7.90
				C_b	62-80	24.98	18.35	41.51	2.52	12.46	7.90	7.95
				P	80-	35.95	31.85	18.01	5.23	9.00	7.65	7.75
C	3S/1W-25B	5/18/62	4760	A_o	0-17	47.02	11.00	23.82	5.62	12.50	7.70	7.85
				A_1	17-27	31.70	10.60	32.32	7.97	17.46	7.65	7.85
				B	27-39	16.65	14.60	43.36	9.90	15.60	7.80	7.95
				B_{ca}	39-84	30.10	18.02	33.86	4.83	13.03	7.75	7.85
				C	84-98	17.20	32.85	36.74	1.93	11.23	7.65	7.80
				P	98-	47.70	15.45	25.17	3.87	7.74	7.60	7.75
D	1S/1W-3R	5/21/62	4700	A_o	0-14	2.87	8.30	64.40	9.33	14.83	7.20	7.40
				A_1	14-24	6.20	7.78	41.62	11.76	33.60	7.70	7.85
				B_{ca}	24-57	23.72	19.00	33.03	7.45	16.20	7.65	7.85
				C_{ca}	57-97	31.30	16.90	29.57	5.35	16.90	7.45	7.62
				P	97-	19.64	28.50	38.62	1.58	11.80	7.45	7.50
E	2S/1W-25E	5/22/62	4700	A_o	0-7	41.41	17.80	31.02	3.45	6.27	7.45	7.60
				A_1	7-16	47.35	12.80	30.60	3.47	5.66	7.55	7.65
				B_1	16-29	39.12	17.22	29.87	5.00	8.68	7.60	7.70
				B_{2ca}	29-35	30.30	12.42	35.40	6.83	13.80	7.65	7.85
				C_{ca}	35-52	15.00	14.13	53.65	5.32	11.40	7.50	7.62
				P	52-	27.15	24.00	44.55	0.52	3.75	7.50	7.57

Table VIIB

Table VIIB

Chemical data for model soils.

Soil No.	Location No.	Date of Analysis	Horizon	Depth In.	Extractable Cations m.e./100 gms.				Soluble Cations m.e./100 gms.			Exchangeable Cations m.e./100 gms.				Total Exchange-able Cations m.e./100 gms.	C.E.C. Silt & Clay m.e./100 gms.	C.E.C. Soil	E.C.x10^3 mmhos/cm	CO_3%	$CaCO_3$%
					Ca^{++}	Na^+	Mg^{++}	K^+	Ca^{++}	Na^+	Mg^{++}	Ca^{++}	Na^+	Mg^{++}	K^+						
A	3S/1W-12N	5/11/62	A_o	0-2	26.00	2.43	12.50	0.92	10.00	0.69	2.00	16.00	1.74	10.50	0.92	29.16	25.00	3.70	6.58	1.86	3.11
			A_1	2-12	20.00	6.50	10.83	0.43	6.00	2.05	2.83	14.00	4.45	8.00	0.43	26.88	23.20	2.40	3.10	1.79	2.98
			B	12-58	18.00	13.00	9.17	0.59	3.00	5.20	2.83	15.00	8.30	6.34	0.59	30.23	27.20	3.00	5.00	1.75	2.91
			B_{bca}	58-72	14.00	16.10	14.17	0.67	1.25	6.50	3.66	12.75	9.60	10.51	0.67	33.53	28.30	4.00	5.77	2.04	3.41
			C_{ca}	72-90	19.50	13.00	15.00	0.43	2.50	6.50	3.66	17.00	6.50	11.34	0.43	35.27	29.50	3.90	8.50	2.02	3.36
			P	90-	16.00	6.50	10.83	0.72	3.00	0.69	2.00	13.00	5.81	8.83	0.72	28.36	24.40	2.20	1.76	1.56	2.60
B	3S/1W-11B	5/15/62	W		17.75	0.62	8.30	0.26	6.00	0.28	1.67	11.75	0.34	6.63	0.26	18.98	17.60	0.80	2.12	2.00	3.34
			A_b	0-10	16.90	2.60	14.00	0.51	6.00	1.22	8.27	10.90	1.38	5.83	0.51	18.62	17.80	1.78	7.70	1.86	3.11
			B_{1b}	10-25	13.00	5.85	12.50	0.74	2.10	2.16	8.33	10.90	3.69	4.17	0.74	19.50	22.10	4.00	6.13	1.72	2.87
			B_{2b}	25-47	16.00	4.90	14.67	0.72	4.00	2.16	11.24	12.00	2.74	3.33	0.72	18.79	20.00	2.20	8.70	1.99	3.32
			B_{3b}	47-62	15.50	4.00	14.67	0.61	3.75	1.70	8.84	11.75	2.30	5.83	0.61	20.49	19.10	2.43	5.43	2.04	3.41
			C_b	62-80	14.50	4.35	12.50	0.49	3.25	1.39	6.67	11.25	2.96	5.83	0.49	20.53	22.10	3.10	4.56	1.98	3.31
			P	80-	12.00	3.30	11.56	0.46	1.25	1.04	6.67	10.75	2.26	4.99	0.46	18.46	19.10	2.20	3.15	1.83	3.05
C	3S/1W-25B	5/20/62	A_o	0-17	12.50	0.17	13.50	0.46	0.00	0.00	0.83	12.50	0.17	12.67	0.46	25.80	24.40	3.80	0.87	1.98	3.30
			A_1	17-27	11.25	1.95	12.50	0.33	0.00	1.04	0.83	11.25	0.91	11.67	0.33	24.16	22.10	4.50	1.72	1.82	3.04
			B	27-39	10.00	3.30	11.66	0.59	0.00	1.26	0.00	10.00	2.04	11.66	0.59	24.29	25.10	4.30	1.18	1.75	2.91
			B_{ca}	39-84	12.00	5.85	14.67	0.61	1.25	2.87	0.83	10.75	2.98	13.84	0.61	28.18	23.20	3.50	3.40	2.08	3.47
			C	84-98	10.90	10.40	12.50	0.69	0.60	4.00	1.67	10.30	6.40	10.83	0.69	28.22	21.70	3.25	4.43	1.99	3.32
			P	98-	10.00	1.26	11.66	0.92	0.00	0.00	0.00	10.00	1.26	11.66	0.92	23.84	20.00	2.43	0.42	1.65	2.75
D	1S/1W-3R	5/24/62	A_o	0-14	12.00	1.26	8.30	1.90	0.00	0.50	0.83	12.00	0.76	7.47	1.90	22.13	20.00	4.00	1.26	1.89	3.15
			A_1	14-24	10.90	4.00	7.50	1.03	0.00	1.74	0.83	10.90	2.26	6.67	1.03	20.86	24.40	10.00	1.88	1.92	3.20
			B_{ca}	24-57	15.50	11.55	11.23	0.92	4.00	4.00	4.15	11.50	7.55	7.08	0.92	27.05	19.10	4.00	5.90	2.02	3.36
			C_{ca}	57-97	14.00	8.05	12.07	0.55	4.40	4.35	4.15	9.60	3.70	7.92	0.55	21.77	20.85	5.00	6.80	2.04	3.41
			P	97-	11.50	5.85	7.50	0.70	4.00	2.87	0.83	7.50	2.98	6.67	0.70	17.85	16.00	2.20	5.05	1.86	3.11
E	2S/1W-25E	5/25/62	A_o	0-7	15.00	3.50	12.07	1.90	3.00	1.74	0.83	12.00	1.76	11.24	1.90	26.90	24.40	3.25	3.90	1.98	3.30
			A_1	7-16	13.50	6.30	11.55	1.20	3.00	2.87	0.83	10.50	3.43	10.72	1.20	25.85	22.10	2.30	4.15	1.86	3.11
			B_1	16-29	12.70	10.00	10.80	0.92	4.00	4.00	1.67	8.70	6.00	9.13	0.92	24.75	21.70	3.10	6.30	1.98	3.31
			B_{2ca}	29-35	11.50	13.00	15.00	0.70	0.60	4.35	2.50	10.90	8.65	12.50	0.70	32.75	27.90	5.00	5.25	2.09	3.48
			C_{ca}	35-52	14.00	5.85	12.50	0.55	1.25	1.74	1.67	12.75	4.11	10.83	0.55	28.24	25.10	4.00	3.20	2.06	3.43
			P	52-	15.50	8.05	9.17	1.03	4.85	1.26	2.50	10.65	6.79	6.67	1.03	25.14	24.70	2.20	4.00	1.95	3.26

Table VIIIA

Table VIIIA

Physical data for soils collected west of the Rio Grande River.

Soil No.	Location No.	Date of Collection	Alt. Ft.	Depth In.	Silt & Clay %	pH 1:10	Description of Soil
3	2S/1W-36N	6/12/61	4640	0-12	12.2	7.40	Light brown-gray,loose,soft,structureless,few R.F. (gneissic and volcanic).
				12-24	10.5	7.50	
				24-36	29.0	7.50	Lighter in color than above,more clayey,weak gran loose,few R.F.
				36-48	12.2	7.60	
				48-60	19.0	7.60	Dull gray-brown,firm structure,lime mottling,slig sticky,no R.F.
				60-72	11.8	7.60	
5	2S/1W-23N	6/11/61	4800	0-10	11.0	7.60	Light gray,loose,soft,weak granular,few R.F.,non-sticky.
				10-20	8.0	7.40	
				20-30	10.8	7.50	Brown-gray,few R.F.,more clayey than above,moderat blocky structure,lime mottling,slightly sticky.
				30-40	16.5	7.50	
				40-50	16.3	7.60	Light red-brown,hard,blocky structure,few R.F., slightly sticky.
				50-60	19.0	7.60	
6	3S/1W-2R	8/19/61	4620	0-6	25.4	7.65	Light brown,clayey,soft,loose,weak granular, very few R.F.,non-sticky.
				6-12	18.7	7.70	
				12-18	20.0	7.60	Light brown,less clayey,hard,compact,no R.F., firm,slightly sticky.
				18-24	18.0	7.60	
				24-36	19.0	7.65	Same color as above,no R.F.,calcareous agg.
				36-48	14.0	7.65	Brown color,hard,stoney,limey,weak structure.
				48-60	5.2	7.70	Light brown color,hard,structureless,calcareous.
7	2S/1W-25M	7/14/61	4720	0-6	12.7	7.30	Light brown,loose,weak granular,few R.F.,soft, non-sticky.
				6-12	10.0	7.50	
				12-18	7.3	7.55	Lighter brown color,harder structure than above, specks of lime,slightly sticky.
				18-24	8.1	7.50	
				24-30	4.8	7.50	Same as above,contains more lime.
				30-36	2.0	7.50	Same color as above,sandy,few R.F.,structureless.
8	3S/1W-11B	7/17/61	4680	0-10	7.2	7.50	Same as 2S/1W-25M
				10-20	4.3	7.60	
				20-30	6.8	7.55	
				30-40	5.4	7.60	
				40-50	6.4	7.60	
				50-60	6.3	7.60	
9	3S/1W-14F	7/15/61	4720	0-10	10.4	7.00	Dark gray-brown,soft,loose,structureless, few granitic R.F.
				10-20	12.0	7.00	
				20-30	12.0	7.10	Medium gray-brown,weak blocky structure,lime specks,slightly sticky,few R.F.
				30-40	14.0	7.10	
				40-50	11.4	7.10	Same color as above,moderate blocky structure, calcareous cementing,slightly sticky.
				50-60	8.0	7.15	
10	3S/1W-15L	7/17/61	4860	0-10	13.0	7.15	Ashey gray-brown,loose crumb structure,few graniti R.F.
				10-20	12.6	7.10	
				20-30	8.0	7.10	Same color as above,moderate crumb structure.
				30-40	13.3	7.15	Lighter gray-brown than above,soft,loose crumb structure,very few R.F.
				40-50	18.2	7.20	
				50-60	12.8	7.22	Same color as above,limey agg.
11	3S/1W-23H	7/17/61	4790	0-10	9.4	7.50	Light brown,granular,soft,loose,structureless, few R.F.,lime specks.
				10-20	8.3	7.50	
				20-30	5.6	7.45	Brown,sandy,structureless,few granitic R.F.
				30-40	7.2	7.46	Same as above, less R.F.
				40-50	6.9	7.40	Brown,calcareous cementing.
				50-60	2.6	7.40	More sandy than above,few R.F.,lime specks.
12	3S/1W-24J	7/17/61	4700	0-10	9.4	7.20	Brown,sandy,loose,soft,structureless, no R.F.
				10-20	8.1	7.15	
				20-30	7.3	7.15	Brown,sandy,loose,structureless.
				30-40	6.9	7.20	Brown,few R.F.,lime specks.
				40-50	5.2	7.20	Same as above,more lime specks.
				50-60	5.5	7.25	Sandy,brown,loose,structureless.
13	3S/1W-36Q	7/17/61	4680	0-10	14.0	7.60	Brown,loose,friable,structureless,non-sticky, few R.F.
				10-20	13.0	7.55	
				20-30	11.4	7.55	Same as above layer.
				30-40	8.4	7.50	Light brown,sandy,weak blocky,lime specks, lime cementing.
				40-50	5.9	7.60	
				50-60	6.9	7.60	Light brown,hard,limey.
14	3S/1W-25Q	7/17/61	4720	0-10	9.7	7.45	Same as 3S/1W-36Q
				10-20	10.6	7.45	
				20-30	11.6	7.50	
				30-40	9.8	7.55	
				40-50	9.5	7.60	
				50-60	7.4	7.60	

Soil No.	Location No.	Date of Collection	Alt. Ft.	Depth In.	Silt & Clay %	pH 1:10	Description of Soil
15	3S/1W-12N	11/3/60	4640	0-12	10.6	7.50	Gray,loose,friable,structureless,fe F.,
				12-24	11.1	7.65	non-sticky.
				24-36	10.1	7.60	Gray-brown,hard,weak blocky structure,
				36-48	9.8	7.60	slightly sticky.
				48-60	10.7	7.65	Sandy,gray-brown,limey R.F.
				60-72	8.6	7.65	Same as above.
16	3S/1W-25J	6/17/61	4730	0-6	7.5	7.55	
				6-12	9.1	7.55	
				12-18	8.0	7.50	Same as 3S/1W-36Q
				18-24	7.3	7.55	
				24-30	8.1	7.60	
				30-36	8.5	7.60	
17	3S/1E-31E	6/17/61	4660	0-8	9.3	7.65	Light gray,hard,stoney,specks of lime,
				8-16	10.9	7.60	many R.F.
				16-24	10.4	7.60	Brown-gray,few gypsum crystals,weak
				24-32	11.2	7.65	blocky structure,limey agg.
				32-40	5.3	7.65	Light brown,few R.F.,weak blocky structure,
				40-48	4.6	7.65	few lime specks.
21	3S/1W-27J	7/22/61	4940	0-6	7.8	7.30	Brown,soft,loose,weak granular structure,
				6-12	8.4	7.20	few plant remnants,few R.F.
				12-18	7.1	7.10	Gray-brown,hard,moderate blocky structure,
				18-24	8.4	7.10	R.F. coated with lime.
				24-30	7.7	7.10	Brown,hard,moderate blocky structure,
				30-36	8.8	7.05	fewer R.F.,few specks of lime.
22	3S/1W-33C	7/22/61	5200	0-6	11.7	7.50	
				6-12	9.2	7.45	
				12-18	7.6	7.45	Same as 3S/1W-27J
				18-24	7.3	7.45	
				24-30	7.2	7.55	
				30-36	8.5	7.55	
38	3S/1W-31G	7/26/61	5355	0-5	14.1	7.30	Gray,soft,loose,structureless,slightly
				5-10	11.1	7.27	sticky,many granitic R.F.
				10-15	9.4	7.25	More R.F. than above.
				15-20	8.3	7.25	
				20-25	8.7	7.30	Dark gray color,more R.F.
				25-30	10.3	7.30	
39	3S/2W-36A	7/27/61	5480	0-6	26.6	7.30	Dark gray-brown,hard,weak blocky structure,
				6-12	25.3	7.20	few R.F.
				12-18	14.6	7.15	Same as above.
				18-24	14.4	7.20	Dark gray-brown,hard,moderate blocky
				24-30	10.9	7.25	structure,lime specks.
				30-36	9.8	7.50	Same as above.
76	3S/1W-21Q	8/26/61	5350	0-6	10.6	7.40	Gray,sandy,soft,loose,structureless,
				6-12	14.2	7.40	non-sticky,few R.F.
				12-18	11.8	7.40	Gray,hard,moderate blocky structure,
				18-24	14.6	7.42	slightly sticky.
				24-30	9.6	7.44	Same as above,more R.F. than in
				30-36	10.5	7.48	surface layers,lime specks.
75	3S/1W-22J	8/26/61	4850	0-6	5.3	7.37	
				6-12	9.3	7.38	
				12-18	6.7	7.40	Same as 3S.1W-21Q
				18-24	8.9	7.35	
				24-30	5.9	7.40	
				30-36	5.5	7.45	
50	3S/1W-3Q	7/31/61	4765	0-8	10.8	7.40	Light gray,sandy soil,few plant remnants,
				8-16	13.3	7.42	lime specks.
				16-24	10.0	7.42	Gray,sandy,weak granular structure,few
				24-32	8.0	7.45	lime specks.
				32-40	7.8	7.48	Same as above,more lime specks.
				40-48	9.0	7.50	More R.F. than above.
63	3S/1W-35C	8/5/61	4700	0-6	9.4	7.43	
				6-12	7.2	7.40	
				12-18	7.4	7.48	Same as 3S/1W-3Q
				18-24	7.2	7.52	
				24-30	7.3	7.56	
				30-36	1.5	7.60	

Soil No.	Location No.	Date of Collection	Alt. Ft.	Depth In.	Silt & Clay %	pH 1:10	Description of Soil
40	2S/1W-21J	7/28/61	4880	0-6	14.2	7.41	Reddish-brown, soft, loose, weak blocky structure, few R.F.
				6-12	14.5	7.40	
				12-18	10.0	7.40	Reddish-brown, hard, moderate blocky structure, lime cemented agg.
				18-24	8.4	7.48	
				24-30	9.3	7.49	Same as above.
				30-36	8.4	7.50	Gray, more R.F., few lime specks.
41	2S/1W-28D	7/28/61	4975	0-6	9.3	7.34	
				6-12	7.4	7.33	
				12-18	8.5	7.29	Same as 2S/1W-21J
				18-24	9.2	7.40	
				24-30	8.5	7.40	
				30-36	8.0	7.45	
42	2S/1W-29F	7/28/61	5060	0-9	4.4	7.30	Light gray, loose, soft, sandy, structureless, few R.F.
				9-18	3.3	7.35	
				18-27	3.8	7.42	More sandy, more R.F.
				27-36	3.3	7.41	Light gray, specks of lime, weak blocky structure.
				36-45	3.6	7.38	
				45-54	3.9	7.40	High lime content.
20	2S/1W-25L	5/18/60	4640	0-6	29.0	7.50	Light brownish-yellow, loose, soft, clayey, friable, no R.F.
				6-12	40.6	7.50	
				12-18	22.3	7.55	Yellowish-brown, weak blocky structure.
				18-24	17.5	7.60	Same as above, lime specks.
				24-36	17.3	7.65	Light brown, lime cemented R.F.
				36-48	14.2	7.65	Same as above, no R.F.
				48-60	7.6	7.70	Sandy, very soft, structureless, no R.F.
28	2S/1W-13L	7/23/61	4640	0-6	3.5	7.35	Light gray-brown, sandy, soft, loose, structureless, few R.F.
				6-12	3.8	7.35	
				12-18	4.1	7.30	Very light brown, specks of lime.
				18-24	4.7	7.30	Same as above.
				24-30	3.4	7.40	Light brown, sandy, higher in lime content.
				30-36	5.6	7.40	Same as above.
4	2S/1W-14R	6/11/61	4700	0-12	14.8	7.50	
				12-24	11.6	7.40	
				24-36	7.1	7.30	Same as 2S/1W-13L
				36-48	12.0	7.50	
				48-60	9.8	7.50	
				60-72	8.1	7.60	
				72-84	7.5	7.60	
29	2S/1W-14N	7/23/61	4735	0-6	2.9	7.32	
				6-12	3.1	7.30	
				12-18	3.9	7.30	Same as 2S/1W-13L
				18-24	3.8	7.35	
				24-30	3.7	7.40	
				30-36	3.2	7.40	
53	2S/1W-20A	8/4/61	5020	0-6	6.4	7.41	Gray, soft, loose, structureless, many R.F. (granitic).
				6-12	6.9	7.43	
				12-18	7.7	7.40	Same as above.
				18-24	10.5	7.40	Light gray-brown, slightly hard, weak blocky structure, few lime specks.
				24-30	9.7	7.45	
				30-36	8.8	7.50	Same as above.
52	2S/1W-11P	8/2/61	4735	0-6	13.7	7.48	
				6-12	15.0	7.46	
				12-18	13.3	7.45	Same as 2S/1W-20A
				18-24	12.2	7.50	
				24-30	12.7	7.52	
				30-36	17.7	7.50	
31	2S/1W-9J	7/25/61	4960	0-6	15.1	7.39	Light gray-brown, loose, soft, structureless, few R.F.
				6-12	10.9	7.40	
				12-18	7.3	7.42	Light gray-brown, slightly hard, weak blocky structure, lime mottling.
				18-24	4.2	7.45	
				24-30	6.8	7.47	Same as above.
				30-36	6.1	7.46	Light brown, slightly hard, weak blocky.
32	2S/1W-9N	7/15/61	5120	0-6	9.9	7.38	
				6-12	6.7	7.40	
				12-18	6.1	7.44	Same as 2S/1W-9J
				18-24	6.4	7.48	
				24-30	6.1	7.48	
				30-36	7.3	7.42	

Soil No.	Location No.	Date of Collection	Alt. Ft.	Depth In.	Silt & Clay %	pH 1:10	Description of Soil
30	2S/1W-3P	7/25/61	4800	0-6	4.9	7.40	Same as 2S/1W-9J
				6-12	6.0	7.45	
				12-18	11.3	7.42	
				18-24	10.7	7.40	
				24-30	11.9	7.41	
				30-36	5.9	7.45	
37	2S/1W-2L	7/26/61	4650	0-8	22.0	7.40	Dark gray-brown, soft, loose, granular, few R.F., clayey agg.
				8-16	21.0	7.37	
				16-24	24.2	7.33	Dark gray-brown, slightly hard, weak blocky structure.
				24-32	18.6	7.37	
				32-40	18.8	7.39	Same as above, lime specks and lime coated R.F.
				40-48	18.5	7.41	
56	1S/1W-28D	8/4/61	5200	0-6	17.7	7.32	Yellowish-gray, soft, loose, structureless, granitic R.F.
				6-12	38.0	7.38	
				12-18	36.9	7.33	Brownish-gray, more clayey, slightly hard, sticky, moderate blocky structure.
				18-24	37.1	7.36	
				24-30	39.5	7.32	Same as above, few lime specks.
				30-36	34.1	7.38	Grayish-brown, weak blocky structure.
55	1S/1W-16D	8/4/61	4925	0-6	5.7	7.28	Gray-brown, soft, granular, sandy, few R.F.
				6-12	5.8	7.31	
				12-18	5.1	7.30	Same as above, less R.F.
				18-24	5.5	7.30	Same as above.
				24-30	2.8	7.30	Light gray-brown, coarse, sandy, few lime specks and gypsum crystals.
				30-36	3.8	7.35	
51	1S/1W-33G	8/2/61	4960	0-6	14.6	7.48	Same as 2S/1W-2L
				6-12	12.8	7.42	
				12-18	13.2	7.42	
				18-24	16.0	7.48	
				24-30	16.1	7.45	
				30-36	23.4	7.43	
54	2S/1W-7R	8/4/61	5360	0-6	14.5	7.31	Same as 2S/1W-2L
				6-12	12.5	7.29	
				12-18	12.5	7.32	
				18-24	13.0	7.30	
				24-30	11.4	7.34	
				30-36	12.5	7.36	
34	1S/1W-11M	7/26/61	4680	0-8	13.0	7.28	Light gray, soft, sandy, structureless, no R.F.
				8-16	5.6	7.20	
				16-24	7.0	7.25	Light gray, sandy, few R.F.
				24-32	3.1	7.24	Same as above.
				32-40	3.0	7.22	Light gray, more sandy than above, few lime cemented agg.
				40-48	3.9	7.30	
33	1S/1W-15E	7/26/61	4810	0-8	13.0	7.40	Same as 1S/1W-11M
				8-16	12.8	7.42	
				16-24	12.3	7.50	
				24-32	8.4	7.47	
				32-40	11.6	7.38	
				40-48	10.0	7.39	
43	1S/1W-14L	7/29/61	4680	0-10	2.9	7.38	Gray, loose, sandy, structureless, few R.F.
				10-20	3.6	7.42	
				20-30	2.7	7.41	Same as above.
				30-40	4.3	7.42	Gray, loose, structureless, few R.F.
				40-50	9.6	7.45	Gray, slightly hard, more clayey than above, lime cemented agg.
				50-60	13.7	7.40	
35	1S/1W-22R	7/26/61	4660	0-8	11.4	7.39	Same as 1S/1W-11M
				8-16	13.7	7.35	
				16-24	19.1	7.39	
				24-32	16.3	7.35	
				32-40	17.0	7.32	
				40-48	12.2	7.30	
36	1S/1W-35D	7/26/61	4655	0-8	14.9	7.40	Same as 1S/1W-11M
				8-16	16.9	7.37	
				16-24	16.5	7.30	
				24-32	16.2	7.30	
				32-40	14.4	7.35	
				40-48	18.6	7.35	

Table VIIIB

Table VIIIB

Chemical data for soils collected west of the Rio Grande River.

Soil No.	Location No.	Date of Analysis	Depth In.	Extractable Cations m.e./100 gms.				Soluble Cations m.e./100 gms.			Exchangeable Cations m.e./100 gms.				Total Exchangeable Cations
				Ca^{++}	Na^{+}	Mg^{++}	K^{+}	Ca^{++}	Na^{+}	Mg^{++}	Ca^{++}	Na^{+}	Mg^{++}	K^{+}	
3	3S/1W-36N	9/19/61	0-12	15.50	1.00	13.30	1.90	2.30	0.00	2.00	13.20	1.00	11.30	1.90	27.40
			12-24	14.00	5.60	15.00	1.80	1.80	1.80	3.90	12.20	3.80	11.10	1.80	28.90
			24-36	14.00	18.00	19.00	1.60	2.00	10.90	6.50	12.00	7.10	12.50	1.60	33.20
			36-48	13.50	22.50	19.00	1.30	2.50	13.80	5.80	11.00	8.70	13.20	1.30	34.20
			48-60	15.00	17.50	17.50	0.70	1.50	7.60	1.70	13.50	9.90	15.80	0.70	39.90
			60-72	13.50	21.00	15.00	0.60	1.30	15.80	2.40	12.20	5.20	12.60	0.60	30.60
5	2S/1W-23N	9/19/61	0-10	17.50	1.70	16.60	0.90	4.50	0.13	5.60	13.00	1.57	11.00	0.90	26.47
			10-20	16.50	3.20	13.30	0.67	3.50	0.13	3.75	13.00	3.07	9.55	0.67	26.29
			20-30	16.00	6.30	13.00	0.69	2.90	0.13	3.75	13.10	6.17	9.25	0.69	29.21
			30-40	15.50	8.00	10.80	0.95	3.60	0.13	1.80	11.90	7.87	9.00	0.95	29.72
			40-50	17.50	1.43	13.30	0.60	2.00	0.13	1.40	15.50	1.30	11.90	0.60	29.30
			50-60	17.00	0.65	13.30	0.82	2.50	0.13	1.80	14.50	0.52	11.50	0.82	27.34
6	3S/1W-2R	9/18/61	0-6	13.70	16.00	17.50	0.56	1.35	1.92	0.00	12.35	14.08	17.50	0.56	44.49
			6-12	13.50	28.50	17.00	0.61	1.50	4.30	1.40	12.00	24.20	15.60	0.61	51.80
			12-18	13.00	30.50	15.80	0.67	2.00	4.30	0.00	11.00	26.20	15.80	0.67	53.67
			18-24	13.00	32.50	15.00	0.82	2.50	4.30	1.70	10.50	28.20	13.30	0.82	52.82
			24-36	12.00	33.50	13.30	0.80	2.00	4.10	1.70	10.00	29.40	11.60	0.80	51.80
			36-48	13.70	18.20	21.00	0.48	1.80	3.80	1.40	11.90	14.40	19.60	0.48	46.38
			48-60	12.00	14.80	18.70	1.30	0.48	3.80	1.40	10.70	11.00	17.30	0.48	39.48
7	2S/1W-25M	9/19/61	0-6	20.70	0.39	12.50	1.40	6.00	0.13	3.75	14.70	0.26	8.80	1.40	25.16
			6-12	20.50	0.48	10.80	0.69	7.30	0.13	3.56	13.20	0.35	7.24	0.69	21.48
			12-18	20.30	0.56	9.20	0.62	8.00	0.13	1.40	12.30	0.43	7.80	0.62	21.15
			18-24	19.00	1.10	7.50	0.69	6.70	0.13	1.40	12.30	0.97	6.10	0.69	20.06
			24-30	20.20	0.65	12.50	0.93	4.05	0.13	3.75	16.15	0.52	8.75	0.93	26.35
			30-36	19.00	0.83	15.00	0.80	5.00	0.15	2.15	14.00	0.70	12.35	0.80	27.85
8	3S/1W-11B	9/19/61	0-10	16.00	3.00	15.00	1.20	3.50	0.78	1.40	12.50	2.22	13.60	1.20	29.52
			10-20	14.50	6.30	13.30	0.98	3.50	1.92	2.15	11.00	4.38	11.15	0.98	27.51
			20-30	13.70	10.00	12.50	0.85	3.00	3.50	2.15	10.70	6.50	10.35	0.85	26.40
			30-40	12.50	11.80	10.80	0.78	2.50	3.70	1.40	10.00	8.10	9.40	0.78	28.28
			40-50	15.00	6.60	17.50	0.92	1.80	1.73	1.40	13.20	4.87	16.10	0.92	35.09
			50-60	16.50	9.10	19.00	1.00	3.00	2.60	2.15	13.50	6.50	16.85	1.00	37.85
9	3S/1W-14F	9/14/61	0-10	16.00	2.50	13.30	2.45	2.30	1.00	1.70	13.70	1.50	11.60	2.45	29.25
			10-20	13.70	2.70	12.50	1.90	0.90	1.00	1.70	12.80	1.70	10.80	1.90	27.20
			20-30	12.20	4.60	10.80	1.48	0.60	1.70	2.15	11.60	2.90	8.65	1.48	24.63
			30-40	13.70	5.60	13.30	1.26	0.70	2.60	2.00	13.00	3.00	11.30	1.26	28.56
			40-50	12.50	4.20	15.00	1.40	0.90	2.30	1.70	11.60	1.90	13.30	1.40	28.20
			50-60	13.20	4.60	15.00	1.40	1.30	2.80	1.40	11.90	1.80	13.60	1.40	28.70
10	3S/1W-15L	9/19/61	0-10	15.50	3.50	19.00	0.98	2.30	1.30	1.70	13.20	2.20	17.30	0.98	33.68
			10-20	12.50	3.90	13.30	0.82	0.90	1.60	1.70	11.60	2.30	11.60	0.82	26.32
			20-30	11.50	7.10	11.70	0.69	0.50	2.60	2.15	11.00	4.50	9.55	0.69	25.74
			30-40	10.00	32.50	11.70	0.67	0.35	15.80	2.80	9.65	16.70	8.90	0.67	35.92
			40-50	13.70	5.40	16.60	0.80	0.50	2.30	2.15	13.20	3.10	14.45	0.80	31.55
			50-60	11.50	6.85	15.00	0.77	0.60	2.10	2.15	10.90	4.75	12.85	0.77	29.27
11	3S/1W-23H	9/19/61	0-10	18.50	1.90	16.20	0.45	3.50	0.90	4.75	15.00	1.00	11.45	0.45	27.90
			10-20	16.50	4.40	17.50	0.47	3.00	1.80	5.80	13.50	2.60	11.70	0.47	25.27
			20-30	15.50	6.70	20.70	0.58	2.90	3.00	7.60	12.60	3.70	13.10	0.58	29.98
			30-40	14.70	8.00	21.60	0.60	2.00	2.50	9.00	12.70	5.50	12.60	0.60	31.40
			40-50	13.70	9.10	23.00	0.62	2.10	2.80	8.70	11.60	6.30	14.30	0.62	32.82
			50-60	16.50	6.30	12.10	0.51	2.00	1.40	1.40	14.50	4.90	10.70	0.51	30.61
12	3S/1W-24J	9/26/61	0-10	14.20	2.74	17.50	0.45	3.00	0.87	0.00	11.20	1.87	17.50	0.45	31.02
			10-20	13.20	3.10	16.30	0.50	2.50	0.70	1.40	10.70	2.40	14.90	0.50	28.50
			20-30	11.50	4.60	15.00	0.56	2.50	0.20	1.40	9.00	4.40	13.60	0.56	27.56
			30-40	11.50	5.90	13.40	0.58	2.50	0.20	1.70	9.00	5.70	11.70	0.58	26.98
			40-50	13.70	2.40	17.50	0.45	2.50	0.20	1.40	11.20	2.20	16.10	0.45	29.95
			50-60	14.20	2.70	15.00	0.50	3.00	0.30	1.40	11.20	2.40	13.60	0.50	27.70
13	3S/1W-36Q	9/26/61	0-10	20.00	10.80	20.70	0.82	4.00	3.50	1.40	16.00	7.30	19.30	0.82	43.42
			10-20	15.70	12.40	19.50	0.87	4.00	4.10	1.70	11.70	8.30	17.80	0.87	38.67
			20-30	14.70	13.80	13.30	1.03	4.40	3.50	2.15	11.30	10.30	11.15	1.03	33.78
			30-40	13.70	13.60	9.30	1.00	4.00	3.50	2.15	9.70	10.10	7.15	1.00	27.95
			40-50	17.00	11.30	15.00	0.90	3.50	3.05	2.15	13.50	8.25	12.85	0.90	35.50
			50-60	15.50	9.30	12.10	0.84	3.50	3.80	2.80	12.00	5.40	9.30	0.84	27.54
14	3S/1W-25Q	9/26/61	0-10	16.40	1.95	12.00	0.73	1.30	1.00	2.15	15.10	0.95	9.85	0.73	26.63
			10-20	14.70	4.55	17.50	0.84	2.00	1.70	2.80	12.70	2.85	14.70	0.84	31.09
			20-30	13.20	25.60	17.30	1.20	2.40	9.60	2.80	10.80	16.00	14.50	1.20	42.50
			30-40	12.20	27.90	20.40	1.72	2.20	10.90	2.80	10.00	17.00	17.60	1.72	46.32
			40-50	17.50	17.40	12.00	1.15	1.80	4.90	2.80	15.70	12.50	9.20	1.15	38.55
			50-60	15.50	10.00	9.20	1.10	2.00	2.20	2.15	13.50	13.30	7.05	1.10	34.95

Soil No.	Location No.	Date of Analysis	Depth In.	Extractable Cations m.e./100 gms.				Soluble Cations m.e./100 gms.			Exchangeable Cations m.e./100 gms.				Total Exchangeable Cations
				Ca^{++}	Na^{+}	Mg^{++}	K^{+}	Ca^{++}	Na^{+}	Mg^{++}	Ca^{++}	Na^{+}	Mg^{++}	K^{+}	
15	3S/1W-12N	9/28/61	0-12	28.50	10.00	13.20	0.58	12.00	0.43	1.70	16.50	9.57	11.50	0.58	38.15
			12-24	17.00	15.40	12.00	0.67	3.50	1.74	2.15	13.50	13.66	9.85	0.67	37.68
			24-36	15.70	20.90	10.00	0.95	4.40	3.05	2.15	11.30	17.85	7.85	0.95	37.95
			36-48	13.20	23.50	9.40	1.10	6.60	4.30	2.80	6.60	19.20	6.60	1.10	33.50
			48-60	16.70	19.50	13.20	0.82	6.10	4.10	2.80	10.60	15.40	10.40	0.82	37.22
			60-72	14.20	15.40	12.00	0.73	4.00	2.85	1.70	10.20	12.55	10.30	0.73	33.78
16	3S/1W-25J	9/28/61	0-6	17.50	0.92	10.00	1.90	3.00	0.20	1.70	14.50	0.72	8.30	1.90	25.42
			6-12	16.20	1.10	9.40	1.90	3.20	0.20	1.70	13.00	0.90	7.70	1.90	23.50
			12-18	14.20	1.30	6.20	2.20	2.60	0.13	1.40	11.60	1.17	4.80	2.20	19.77
			18-24	16.20	0.80	12.00	1.30	3.50	0.17	1.70	12.70	0.63	10.30	1.30	24.93
			24-30	16.00	1.00	13.20	1.70	1.50	0.25	1.40	14.50	0.75	11.80	1.70	28.75
			30-36	18.70	1.10	12.00	1.50	4.20	0.13	1.40	14.50	0.97	10.60	1.50	27.57
17	2S/1E-31E	9/28/61	0-8	18.50	2.90	17.50	0.37	1.30	1.00	2.80	17.20	1.90	14.50	0.37	33.97
			8-16	15.70	11.30	15.20	0.43	2.00	4.90	2.15	13.70	6.40	13.05	0.43	33.68
			16-24	14.50	13.70	13.20	0.50	2.40	5.30	1.70	12.10	8.40	11.50	0.50	32.50
			24-32	17.00	10.40	12.00	0.56	2.80	4.10	2.00	14.20	6.30	10.00	0.56	31.06
			32-40	15.20	7.30	15.00	0.33	0.90	2.20	1.40	14.30	5.10	13.60	0.33	33.33
			40-48	17.50	9.20	17.50	0.63	4.00	3.05	2.80	13.50	6.15	14.50	0.63	34.78
21	3S/1W-27J	10/1/61	0-6	15.70	0.48	9.30	1.50	1.70	0.00	0.00	14.00	0.48	9.30	1.50	25.28
			6-12	14.20	0.56	10.60	1.60	1.10	0.00	1.60	13.10	0.56	9.00	1.60	24.25
			12-18	13.20	0.65	13.20	1.70	0.90	0.00	4.10	12.30	0.65	9.10	1.70	23.75
			18-24	13.20	0.73	15.00	2.20	1.70	0.00	5.60	11.50	0.73	9.40	2.20	23.83
			24-30	15.00	0.48	10.60	1.40	1.30	0.00	0.00	13.70	0.48	10.60	1.40	26.18
			30-36	13.70	0.56	9.30	2.10	1.20	0.00	0.00	12.50	0.56	9.30	2.10	24.46
22	3S/1W-33C	10/1/61	0-6	17.50	0.48	15.00	0.80	2.50	0.10	4.75	15.00	0.38	10.25	0.80	26.43
			6-12	15.20	0.63	9.10	0.92	2.20	0.20	1.80	13.00	0.43	7.30	0.92	21.65
			12-18	11.00	0.80	7.90	2.10	1.30	0.25	1.40	9.70	0.55	6.50	2.10	18.85
			18-24	10.00	0.80	4.60	3.90	0.90	0.17	0.00	9.10	0.63	4.60	3.90	18.23
			24-30	18.50	0.54	10.80	1.10	4.40	0.20	1.40	14.10	0.34	9.40	1.10	24.94
			30-36	17.00	0.63	9.10	1.20	3.00	0.30	1.70	14.00	0.33	7.40	1.20	22.93
38	3S/1W-31G	10/13/61	0-5	18.50	0.30	7.70	2.10	2.50	0.10	0.00	16.00	0.20	7.70	2.10	26.00
			5-10	17.50	0.61	7.70	2.10	2.50	0.13	0.00	15.00	0.48	7.70	2.10	25.28
			10-15	16.20	0.78	6.80	1.60	3.00	0.17	1.40	13.20	0.61	5.40	1.60	20.81
			15-20	15.20	1.00	6.80	1.30	4.40	0.30	1.40	10.80	0.70	5.40	1.30	18.20
			20-25	20.70	0.52	9.20	2.40	4.00	0.30	1.70	16.70	0.22	7.50	2.40	26.82
			25-30	23.00	0.43	10.80	2.30	4.00	0.20	1.70	19.00	0.23	9.10	2.30	30.63
39	2S/2W-36A	10/15/61	0-6	10.00	0.13	8.30	5.10	0.00	0.00	0.56	10.00	0.13	7.74	5.10	22.97
			6-12	9.70	0.13	6.80	4.90	0.50	0.00	0.56	9.20	0.13	6.24	4.90	20.47
			12-18	8.90	0.13	5.20	2.10	0.35	0.00	0.56	8.55	0.13	4.64	2.10	15.42
			18-24	7.60	0.13	3.21	1.20	0.00	0.00	0.56	7.60	0.13	2.65	1.20	17.60
			24-30	10.00	0.13	10.80	1.40	0.00	0.00	0.56	10.00	0.13	10.24	1.40	21.77
			30-36	11.00	0.13	9.20	1.10	0.90	0.00	0.56	10.10	0.13	8.64	1.10	19.97
76	3S/1W-21Q	10/31/61	0-6	16.50	0.30	6.70	2.50	2.60	0.00	0.83	13.90	0.30	5.87	2.50	22.57
			6-12	15.80	1.40	6.00	2.60	2.80	0.25	0.83	13.00	1.15	5.17	2.60	21.92
			12-18	15.80	1.90	5.00	1.50	3.10	0.60	0.00	12.70	1.30	5.00	1.50	20.50
			18-24	15.00	2.20	5.00	1.20	4.00	0.75	0.42	11.00	1.45	4.58	1.20	18.23
			24-30	17.00	1.00	7.80	1.10	2.25	0.45	1.40	14.75	0.55	6.40	1.10	22.80
			30-36	16.30	0.70	6.70	1.40	3.65	0.13	1.70	12.65	0.57	5.00	1.40	19.62
75	3S/1W-22J	10/31/61	0-6	15.30	0.30	6.00	2.40	0.00	0.00	0.83	15.30	0.30	5.17	2.40	23.17
			6-12	17.00	0.30	4.20	1.90	2.50	0.00	0.00	14.50	0.30	4.20	1.90	20.90
			12-18	18.30	0.43	0.80	2.20	4.30	0.00	0.00	14.00	0.43	0.80	2.20	17.43
			18-24	19.00	0.79	6.00	2.30	2.00	0.00	0.00	17.00	0.79	6.00	2.30	26.09
			24-30	17.50	0.52	6.70	1.40	2.00	0.00	1.40	15.50	0.52	5.30	1.40	22.72
			30-36	18.30	0.25	6.00	1.30	3.80	0.00	1.70	14.50	0.25	4.30	1.30	20.35
50	3S/1W-3Q	10/21/61	0-8	15.00	3.30	16.70	4.50	3.00	1.40	1.70	12.00	1.90	15.00	4.50	33.40
			8-16	13.50	4.10	13.40	1.40	3.50	2.10	2.15	10.00	2.00	11.25	1.40	24.65
			16-24	11.40	5.60	12.50	1.30	3.50	4.30	2.15	7.90	1.30	10.35	1.30	20.85
			24-32	21.50	4.10	16.70	1.20	6.60	2.85	1.70	14.90	1.25	15.00	1.20	32.35
			32-40	17.00	2.60	18.00	1.30	4.00	1.60	2.15	13.00	1.00	15.85	1.30	31.15
			40-48	16.50	1.70	15.80	1.40	3.00	0.87	2.80	13.50	0.83	13.00	1.40	28.73
63	2S/1W-35C	10/26/61	0-6	13.50	0.30	10.60	1.00	0.00	0.00	0.00	13.50	0.30	10.60	1.00	25.40
			6-12	12.50	0.37	8.80	0.60	0.90	0.00	0.00	11.60	0.37	8.80	0.60	21.37
			12-18	12.30	0.30	7.80	0.60	0.50	0.00	0.00	11.80	0.30	7.80	0.60	20.50
			18-24	15.30	0.43	11.70	0.70	0.90	0.00	0.00	14.40	0.43	11.70	0.70	27.23
			24-30	13.00	0.37	8.80	0.60	0.60	0.00	0.00	12.40	0.37	8.80	0.60	22.17
			30-36	14.50	0.30	9.60	0.70	1.30	0.00	0.00	13.20	0.30	9.60	0.70	23.80

Soil No.	Location No.	Date of Analysis	Depth In.	Extractable Cations m.e./100 gms.				Soluble Cations m.e./100 gms.			Exchangeable Cations m.e./100 gms.				Total Exchangeable Cations
				Ca^{++}	Na^{+}	Mg^{++}	K^{+}	Ca^{++}	Na^{+}	Mg^{++}	Ca^{++}	Na^{+}	Mg^{++}	K^{+}	
40	2S/1W-21J	10/15/61	0-6	17.00	2.00	12.10	1.40	3.00	1.26	1.40	14.00	0.74	10.70	1.40	26.84
			6-12	16.50	2.10	11.70	1.50	3.50	0.70	2.00	13.00	1.40	9.70	1.50	25.60
			12-18	16.20	2.20	10.80	1.60	3.50	0.35	2.15	12.70	1.85	8.65	1.60	24.80
			18-24	15.20	2.40	10.00	1.20	2.70	0.00	1.80	12.50	2.40	8.20	1.70	24.80
			24-30	16.50	1.80	12.90	1.20	2.50	0.00	0.90	14.00	1.80	12.00	1.20	29.00
			30-36	15.70	1.60	13.80	1.00	3.00	0.00	2.00	12.70	1.60	11.80	1.00	27.10
41	2S/1W-28D	10/15/61	0-6	21.50	1.10	9.20	1.60	1.80	0.58	1.40	19.70	0.52	7.80	1.60	29.62
			6-12	21.00	1.70	10.00	2.00	4.90	1.10	1.70	16.10	0.60	8.30	2.00	27.00
			12-18	20.20	2.40	9.20	2.10	1.80	0.70	1.70	18.40	1.70	7.50	2.10	29.70
			18-24	19.50	2.40	8.30	2.30	1.80	0.70	1.40	17.70	1.70	6.90	2.30	28.60
			24-30	18.20	5.30	6.80	3.60	2.50	0.70	1.70	15.70	4.60	5.10	3.60	29.00
			30-36	22.00	1.40	10.80	1.60	4.00	1.00	1.40	18.00	0.40	9.40	1.60	29.40
42	2S/1W-29F	10/16/61	0-9	20.20	1.30	9.20	1.10	6.00	0.00	1.40	14.20	1.30	7.80	1.10	24.40
			9-18	19.50	3.60	8.30	1.10	7.30	0.00	1.40	12.20	3.60	6.90	1.10	23.80
			18-27	18.50	4.70	7.70	1.20	8.00	0.00	1.40	10.50	4.70	6.30	1.20	22.70
			27-36	17.00	5.70	5.20	1.30	9.00	0.00	1.40	12.00	5.70	3.80	1.30	22.80
			36-45	16.20	7.80	10.80	1.20	7.30	0.00	1.40	8.90	7.80	9.40	1.20	27.30
			45-54	22.00	1.30	10.00	1.20	8.00	0.00	1.40	14.00	1.30	8.60	1.20	25.10
20	2S/1W-25L	9/30/61	0-6	20.50	10.80	17.50	0.30	7.50	3.50	4.75	13.00	7.30	12.75	0.30	33.35
			6-12	19.00	13.70	13.20	0.37	8.30	4.10	3.00	10.70	9.60	10.20	0.37	30.87
			12-18	17.00	20.50	12.10	0.50	6.50	5.60	1.90	10.50	14.90	10.20	0.50	36.10
			18-24	21.50	11.70	10.80	0.43	3.80	2.20	2.15	17.70	9.50	8.65	0.43	36.28
			24-36	22.00	11.30	21.60	0.40	4.60	3.50	4.75	17.40	7.80	16.85	0.40	42.45
			36-48	21.00	12.60	19.10	0.35	3.90	3.00	1.40	17.10	9.60	17.70	0.35	44.75
			48-60	15.20	6.90	12.10	0.30	2.20	2.60	0.56	13.00	4.30	11.54	0.30	29.14
28	2S/1W-13L	10/7/61	0-6	35.50	0.60	10.00	0.47	20.00	0.00	1.80	15.50	0.60	8.20	0.47	24.77
			6-12	31.00	1.60	9.20	0.57	19.10	0.00	1.80	11.90	1.60	7.40	0.57	21.47
			12-18	24.00	2.90	8.30	0.59	10.80	0.00	1.40	13.20	2.90	6.90	0.59	23.59
			18-24	23.00	4.70	8.00	0.62	9.00	0.00	1.40	14.00	4.70	6.60	0.62	25.92
			24-30	19.50	9.10	6.80	7.70	11.50	0.00	1.40	8.00	9.10	5.40	7.70	30.20
			30-36	30.00	1.00	8.30	0.53	15.30	0.00	1.40	14.70	1.00	6.90	0.53	23.13
4	2S/1W-14R	9/19/61	0-12	18.50	2.10	15.00	1.60	2.50	0.28	0.00	16.00	1.82	15.00	1.60	34.42
			12-24	16.20	2.30	13.30	0.73	1.80	0.22	1.40	14.40	2.08	11.90	0.73	29.11
			24-36	16.20	2.50	12.00	0.64	2.50	0.58	0.00	13.70	1.92	12.00	0.64	28.26
			36-48	15.50	7.00	10.80	0.60	2.50	1.10	1.40	13.00	5.90	9.40	0.60	28.90
			48-60	19.50	3.70	17.50	0.60	2.50	1.56	1.40	17.00	2.14	16.10	0.60	35.84
			60-72	50.00	5.60	21.00	1.10	10.80	3.20	1.40	39.20	2.40	19.60	1.10	62.30
			72-84	21.50	6.80	19.00	1.10	6.10	2.60	1.70	15.40	4.20	17.30	1.10	38.00
29	2S/1W-14N	10/7/61	0-6	15.70	0.30	8.00	0.71	3.50	0.00	0.00	12.20	0.30	8.00	0.71	21.21
			6-12	15.20	0.40	6.80	0.85	3.50	0.00	0.00	11.70	0.40	6.80	0.85	19.75
			12-18	15.00	0.80	5.60	0.99	3.00	0.00	0.00	12.00	0.80	5.60	0.99	19.39
			18-24	14.50	1.70	4.20	1.10	2.60	0.00	0.00	11.90	1.70	4.20	1.10	18.90
			24-30	16.50	0.70	10.80	0.82	1.80	0.00	1.40	14.70	0.70	9.40	0.82	25.62
			30-36	17.50	0.80	12.10	0.87	3.70	0.00	1.70	13.80	0.80	10.40	0.87	25.87
53	2S/1W-20A	10/21/61	0-6	15.70	0.15	13.40	0.87	3.00	0.00	2.75	12.70	0.15	10.65	0.87	24.37
			6-12	15.00	0.24	11.70	0.77	3.50	0.00	3.00	11.50	0.24	8.70	0.77	21.21
			12-18	14.00	0.24	10.60	0.73	3.50	0.00	2.80	10.50	0.24	7.80	0.73	19.27
			18-24	13.00	0.24	7.50	0.60	2.50	0.00	1.40	10.50	0.24	6.10	0.60	17.44
			24-30	17.00	0.24	16.70	0.52	2.50	0.00	2.75	14.50	0.24	13.95	0.52	29.21
			30-36	18.20	0.24	15.80	0.70	3.80	0.00	3.75	14.40	0.24	12.05	0.70	27.39
52	2S/1W-11P	10/21/61	0-6	14.00	0.52	18.00	1.10	3.50	0.00	7.75	10.50	0.52	10.25	1.10	22.37
			6-12	13.50	1.00	15.80	0.87	3.40	0.00	6.90	10.10	1.00	8.90	0.87	20.87
			12-18	12.50	1.50	13.40	0.82	3.50	0.00	5.30	9.00	1.50	8.10	0.82	19.42
			18-24	14.00	0.61	19.20	0.61	2.00	0.00	6.00	12.00	0.61	13.20	0.61	26.42
			24-30	12.50	0.44	20.00	0.55	2.00	0.00	8.30	10.50	0.44	11.70	0.55	23.19
			30-36	13.00	0.70	18.00	0.47	3.00	0.00	6.70	10.00	0.70	11.30	0.47	22.47
31	2S/1W-9J	10/8/61	0-6	17.50	0.24	13.80	0.33	5.00	0.00	3.56	12.50	0.24	10.24	0.33	23.31
			6-12	16.20	0.37	12.90	0.31	4.60	0.00	2.75	11.60	0.37	10.15	0.31	22.43
			12-18	17.20	1.30	11.70	0.35	5.90	0.00	2.15	11.30	1.30	9.55	0.35	22.50
			18-24	10.50	2.00	10.00	0.38	0.90	0.00	1.40	9.60	2.00	8.60	0.38	20.58
			24-30	15.20	0.69	12.90	0.27	2.00	0.00	1.40	13.20	0.69	11.50	0.27	25.66
			30-36	15.70	1.60	15.80	0.24	3.40	0.00	2.75	12.30	1.60	13.05	0.24	27.19
32	2S/1W-9N	10/8/61	0-6	14.00	0.15	8.30	0.65	3.00	0.00	0.56	11.00	0.15	7.74	0.65	19.54
			6-12	13.00	0.19	7.70	0.71	3.50	0.00	1.40	9.50	0.19	6.30	0.71	18.04
			12-18	11.70	0.24	6.80	0.94	4.90	0.00	0.56	6.80	0.24	6.24	0.94	14.22
			18-24	10.50	0.30	5.20	0.97	2.50	0.00	0.56	8.00	0.30	4.64	0.97	13.91
			24-30	17.00	0.15	7.70	0.64	4.90	0.00	0.56	12.10	0.15	7.14	0.64	20.03
			30-36	18.20	0.10	9.20	0.71	6.10	0.00	1.40	13.10	0.10	7.80	0.71	21.71

Soil No.	Location No.	Date of Analysis	Depth In.	Extractable Cations m.e./100 gms.				Soluble Cations m.e./100 gms.			Exchangeable Cations m.e./100 gms.				Total Exchangeable Cations
				Ca^{++}	Na^{+}	Mg^{++}	K^{+}	Ca^{++}	Na^{+}	Mg^{++}	Ca^{++}	Na^{+}	Mg^{++}	K^{+}	
30	2S/1W-3P	10/8/61	0-6	14.50	0.19	7.70	0.65	0.00	0.00	0.00	14.50	0.19	7.70	0.65	23.04
			6-12	14.00	0.25	6.80	0.68	0.60	0.10	0.00	13.40	0.15	6.80	0.68	21.03
			12-18	13.50	0.61	5.20	0.82	2.75	0.20	0.00	10.75	0.41	5.20	0.82	17.18
			18-24	13.00	0.78	5.20	0.94	3.50	0.40	0.66	9.50	0.38	4.54	0.94	15.36
			24-30	12.50	0.89	3.20	1.20	3.15	0.50	0.66	9.35	0.39	2.54	1.20	13.48
			30-36	15.70	0.19	6.80	0.76	2.75	0.60	0.66	12.95	0.00	6.14	0.76	19.85
37	2S/1W-2L	10/13/61	0-8	16.50	0.13	7.70	1.30	3.00	0.00	0.00	13.50	0.13	7.70	1.30	22.63
			8-16	16.20	0.13	6.80	0.89	3.50	0.00	0.00	12.70	0.13	6.80	0.89	20.52
			16-24	15.20	0.24	6.80	0.77	3.50	0.00	0.00	11.70	0.24	6.80	0.77	19.51
			24-32	13.00	0.30	5.20	0.61	1.80	0.00	0.00	11.20	0.30	5.20	0.61	17.31
			32-40	20.00	0.13	7.70	1.10	6.00	0.00	0.00	14.00	0.13	7.70	1.10	22.93
			40-48	18.50	0.13	8.30	0.98	5.30	0.00	0.00	13.20	0.13	8.30	0.98	22.61
56	1S/1W-28D	10/22/61	0-6	15.25	0.30	11.70	1.10	0.30	0.00	1.40	14.95	0.30	10.30	1.10	26.65
			6-12	15.00	0.30	10.60	1.20	1.80	0.00	1.70	13.20	0.30	8.90	1.20	23.60
			12-18	12.50	1.40	7.80	1.30	2.60	0.00	0.50	9.90	1.40	7.30	1.30	19.90
			18-24	12.30	2.60	6.00	1.30	2.90	0.00	0.00	9.40	2.60	6.00	1.30	19.30
			24-30	11.80	6.30	5.00	1.10	1.80	0.00	0.00	10.00	6.30	5.00	1.10	22.40
			30-36	14.50	4.30	9.60	0.90	1.00	0.00	1.40	13.50	4.30	8.20	0.90	26.90
55	1S/1W-16D	10/22/61	0-6	15.00	0.52	7.84	0.65	2.50	0.00	0.00	12.50	0.52	7.84	0.65	21.51
			6-12	14.50	0.60	6.67	0.58	2.80	0.00	0.00	11.70	0.60	6.67	0.58	19.55
			12-18	14.00	0.79	6.00	0.33	2.80	0.00	0.00	11.20	0.79	6.00	0.33	18.32
			18-24	13.50	1.00	5.00	0.31	3.00	0.00	0.00	10.50	1.00	5.00	0.31	16.81
			24-30	11.70	0.52	4.17	0.17	2.50	0.00	0.00	9.20	0.52	4.17	0.17	14.06
			30-36	17.50	1.26	9.60	0.68	3.50	0.00	0.00	14.00	1.26	9.60	0.68	25.54
51	1S/1W-33G	10/21/61	0-6	14.00	0.15	11.70	0.92	1.40	0.00	2.00	12.60	0.15	9.70	0.92	23.37
			6-12	13.00	0.15	10.60	0.77	2.00	0.00	1.40	11.00	0.15	9.20	0.77	21.12
			12-18	13.00	0.24	8.80	0.76	3.10	0.00	1.80	9.90	0.24	7.00	0.76	17.90
			18-24	11.70	0.37	6.60	0.61	2.40	0.00	0.00	9.30	0.37	6.60	0.61	16.88
			24-30	14.50	0.78	13.40	0.52	1.00	0.00	2.00	13.50	0.78	11.40	0.52	26.20
			30-36	15.70	0.30	14.60	0.64	2.60	0.00	3.56	13.10	0.30	11.04	0.64	25.08
54	2S/1W-7R	10/22/61	0-6	14.00	0.15	6.70	1.00	1.80	0.00	0.00	12.20	0.15	6.70	1.00	20.05
			6-12	13.50	0.15	7.30	0.90	2.50	0.00	0.00	11.00	0.15	7.30	0.90	19.35
			12-18	12.50	0.19	7.80	0.75	2.50	0.00	1.40	10.00	0.19	6.40	0.75	17.34
			18-24	11.70	0.30	8.80	0.72	1.80	0.00	2.80	9.90	0.30	6.00	0.72	16.92
			24-30	11.40	1.40	10.60	0.68	1.20	0.00	1.80	10.20	1.40	8.80	0.68	21.08
			30-36	10.50	1.60	11.70	0.60	2.20	0.00	3.56	8.30	1.60	8.14	0.60	18.64
34	1S/1W-11M	10/11/61	0-8	15.20	2.00	8.30	0.55	3.00	1.26	1.40	12.20	0.73	6.90	0.55	20.38
			8-16	12.20	2.10	7.70	0.58	3.50	0.78	1.70	8.70	1.32	6.00	0.58	16.60
			16-24	10.50	2.30	5.20	0.62	8.20	1.10	2.15	2.30	1.25	3.05	0.62	7.22
			24-32	9.20	2.60	1.50	0.65	4.90	1.26	1.70	4.30	1.34	0.00	0.65	6.29
			32-40	14.50	1.90	9.20	0.49	5.75	1.40	2.15	8.75	0.50	7.05	0.49	16.79
			40-48	13.00	1.70	12.10	0.52	7.00	1.40	2.15	6.00	0.30	9.95	0.52	16.77
33	1S/1W-15E	10/11/61	0-8	14.00	0.19	7.70	0.43	1.80	0.00	0.00	12.20	0.19	7.70	0.43	20.52
			8-16	11.70	1.00	6.80	0.53	0.00	0.00	0.00	11.70	1.00	6.80	0.53	20.03
			16-24	10.50	3.60	5.20	0.58	0.00	0.00	0.00	10.50	3.60	5.20	0.58	19.88
			24-32	9.70	7.60	4.20	0.62	0.00	1.50	0.00	9.70	6.10	4.20	0.62	20.62
			32-40	12.50	4.10	11.70	0.47	0.00	2.00	0.00	12.50	2.10	11.70	0.47	26.77
			40-48	11.00	1.90	9.20	0.49	0.00	0.65	0.00	11.00	1.25	9.20	0.49	21.94
43	1S/1W-14L	10/16/61	0-10	17.00	3.10	10.80	0.79	3.00	1.26	0.00	14.00	1.84	10.80	0.79	27.43
			10-20	15.70	6.80	9.20	0.82	3.50	2.85	1.40	12.20	3.95	7.80	0.82	24.77
			20-30	15.00	7.40	7.70	0.92	3.50	1.92	0.00	11.50	5.48	7.70	0.92	25.60
			30-40	13.50	9.10	6.00	1.30	2.50	2.60	0.00	11.00	6.50	6.00	1.30	24.80
			40-50	17.00	6.00	9.20	0.94	3.00	0.70	1.40	14.00	5.30	6.80	0.94	28.04
			50-60	21.00	4.10	12.00	1.20	3.50	1.00	1.70	17.50	3.10	10.30	1.20	32.10
35	1S/1W-22R	10/11/61	0-8	12.50	0.24	6.00	0.38	0.00	0.00	0.00	12.50	0.24	6.00	0.38	19.12
			8-16	11.70	0.78	6.80	0.97	0.00	0.00	1.80	11.70	0.78	5.00	0.97	18.45
			16-24	8.90	1.90	7.70	1.40	0.00	0.00	3.10	8.90	1.90	4.60	1.40	16.80
			24-32	7.60	3.10	8.30	1.70	0.00	0.00	4.60	7.60	3.10	3.70	1.70	16.10
			32-40	13.00	1.70	6.00	0.26	1.50	0.00	0.50	11.50	1.70	5.50	0.26	18.96
			40-48	17.00	2.90	5.20	0.45	2.60	0.00	1.40	14.40	2.90	3.80	0.45	21.55
36	1S/1W-35D	10/13/61	0-8	15.20	0.24	7.70	1.20	1.80	0.00	0.00	13.40	0.24	7.70	1.20	22.54
			8-16	15.70	0.52	6.80	0.94	3.40	0.00	0.00	12.30	0.52	6.80	0.94	20.56
			16-24	14.50	0.78	5.20	0.52	4.00	0.00	0.00	10.50	0.78	5.20	0.52	17.00
			24-32	13.00	1.10	4.20	0.35	3.50	0.00	0.00	9.50	1.10	4.20	0.35	15.15
			32-40	13.00	1.60	3.20	0.31	3.90	0.00	0.00	9.10	1.60	3.20	0.31	14.21
			40-48	17.00	0.30	6.80	0.26	3.50	0.00	0.00	13.50	0.30	6.80	0.26	20.86

Table IXA

Table IXA

Physical data for soils collected east of the Rio Grande River.

Soil No.	Location No.	Date of Collection	Alt. Ft.	Depth In.	Silt & Clay %	pH 1:10	Description of Soil
71	3S/1E-32C	8/20/61	4600	0-8	6.1	7.60	Light brown,loose,soft,friable,structureless,non-sticky,very few R.F.
				8-16	7.9	7.55	
				16-24	3.2	7.60	Reddish brown,sandy,very weak granular structure,very few R.F.
				24-32	4.3	7.50	
				32-40	4.4	7.60	Same as above,lime coated R.F.
				40-48	1.2	7.60	Same as above.
72	3S/1E-28P	8/20/61	4660	0-8	5.9	7.60	Same as 3S/1E-32C
				8-16	7.9	7.55	
				16-24	5.8	7.50	
				24-32	7.6	7.60	
				32-40	5.6	7.60	
				40-48	4.0	7.60	
73	3S/1E-27P	8/20/61	4740	0-6	4.5	7.60	Same as 3S/1E-32C
				6-12	5.0	7.50	
				12-18	4.6	7.65	
				18-24	6.2	7.55	
				24-30	11.2	7.60	
				30-36	3.1	7.60	
74	3S/1E-26L	8/20/61	4880	0-7	10.7	7.55	Same as 3S/1E-32C
				7-14	7.8	7.50	
				14-21	5.2	7.54	
				21-28	5.5	7.53	
				28-35	4.7	7.55	
				35-42	4.4	7.60	
70	3S/1E-5G	8/6/61	4600	0-6	12.2	7.50	Brown,loose,soft,structureless,non-sticky,no R.F.
				6-12	8.8	7.46	
				12-18	7.6	7.37	Reddish brown,very hard,firm,strong blocky structure.
				18-24	7.8	7.30	
				24-30	8.9	7.37	Reddish brown,hard,strong blocky structure, lime mottling,few gypsum crystals.
				30-36	10.3	7.40	
67	2S/1E-33P	8/6/61	4780	0-6	10.0	7.28	Gray-yellow,sandy,loose,structureless,non-sticky,few R.F.
				6-12	6.5	7.20	
				12-18	6.0	7.26	Light yellowish gray,weak blocky structure, hard,few R.F.
				18-24	1.6	7.35	
				24-30	1.4	7.32	Light gray,loose,soft,structureless,lime coated R.F.
				30-36	1.1	7.34	
68	2S/1E-34Q	8/6/61	4920	0-6	5.8	7.35	Same as 2S/1E-33P
				6-12	7.0	7.32	
				12-18	7.5	7.40	
				18-24	8.4	7.41	
				24-30	6.5	7.36	
				30-36	11.4	7.44	
69	3S/1E-2P	8/6/61	4960	0-10	7.0	7.62	Light brown-gray,slightly hard,slightly firm, weak granular structure,few R.F.
				10-20	6.1	7.57	
				20-30	5.8	7.60	Same as above,fewer R.F.
				30-40	5.6	7.62	Light brown,hard,firm,weak blocky structure, lime cementing.
				40-50	7.6	7.60	
				50-60	9.7	7.70	Same as above.
27	2S/1E-32D	7/23/61	4635	0-6	3.2	7.42	Same as 3S/1E-5G
				6-12	4.2	7.40	
				12-18	3.9	7.35	
				18-24	7.9	7.35	
				24-30	5.4	7.40	
				30-36	3.3	7.43	
26	2S/1E-29D	7/23/61	4660	0-6	7.1	7.44	Same as 3S/1E-5G
				6-12	5.3	7.45	
				12-18	6.1	7.48	
				18-24	4.8	7.49	
				24-30	4.2	7.50	
				30-36	5.0	7.50	

Soil No.	Location No.	Date of Collection	Alt. Ft.	Depth In.	Silt & Clay %	pH 1:10	Description of Soil
64	2S/1E-28C	8/6/61	4770	0-6	10.3	7.53	Reddish brown,loose,friable,structureless, non-sticky,few granitic R.F.
				6-12	8.4	7.50	
				12-18	8.4	7.53	Reddish brown,slightly hard,firm,weak granular structure.
				18-24	11.5	7.52	
				24-30	10.0	7.55	Same as above,few lime concretions.
				30-36	9.2	7.58	Brown,loose,structureless sand.
65	2S/1E-26D	8/6/61	5000	0-8	13.1	7.60	Same as 2S/1E-28C
				8-16	15.6	7.62	
				16-24	19.6	7.59	
				24-32	20.0	7.57	
				32-40	21.3	7.65	
				40-48	21.2	7.64	
66	2S/1E-36B	8/6/61	5130	0-6	15.1	7.20	Brown,loose,soft,weak crumbly structure, few plant remnants,few R.F.
				6-12	13.3	7.30	
				12-18	29.8	7.19	Brown,slightly hard,moderate blocky structure,calcareous agg.
				18-24	24.3	7.10	
				24-30	22.4	7.28	Same as above,contains gypsum crystals.
				30-36	16.3	7.30	Same as above.
18	2S/1E-19L	7/17/61	4640	0-10	20.5	7.55	Reddish brown,soft,loose,friable,structureless,non-sticky,few plant remnants,few R.F.
				10-20	10.4	7.55	
				20-30	7.5	7.60	Reddish brown,slightly hard,firm,weak blocky structure,no plant remnants,lime specks.
				30-40	8.0	7.60	
				40-50	9.4	7.65	Reddish brown,hard,moderate blocky structure.
				50-60	12.1	7.65	Dark reddish brown,loose,weak blocky structure.
19	2S/1E-17N	7/17/61	4700	0-8	9.4	7.45	Same as 2S/1E-19L
				8-16	9.7	7.50	
				16-24	8.3	7.50	
				24-32	9.1	7.53	
				32-40	12.7	7.50	
				40-48	18.5	7.60	
23	2S/1E-17K	7/22/61	4800	0-6	10.3	7.55	Reddish brown,slightly firm,slightly hard, weak granular structure, few R.F.
				6-12	10.4	7.55	
				12-18	17.7	7.60	Reddish brown,slightly hard,firm,moderate blocky structure,few R.F.
				18-24	14.1	7.60	
				24-30	21.6	7.60	Same as above,lime specks.
				30-36	23.4	7.60	Reddish brown,loose,structureless sand.
24	2S/1E-9Q	7/22/61	5000	0-6	13.0	7.55	Same as 2S/1E-17K
				6-12	13.5	7.55	
				12-18	13.5	7.50	
				18-24	11.1	7.50	
				24-30	13.5	7.48	
				30-36	18.4	7.50	
44	2S/1E-12D	7/30/61	5150	0-7	16.3	7.50	Brick-red,loose,crumb structure,few R.F.
				7-14	15.3	7.46	
				14-21	18.1	7.42	Reddish brown,hard,firm,strong blocky structure,sticky.
				21-28	8.3	7.50	
				28-35	10.1	7.46	Reddish brown,slightly hard,moderate blocky structure,lime specks.
				35-42	11.5	7.45	
45	2S/2E-6K	7/30/61	5200	0-12	13.1	7.00	
				12-24	30.0	7.12	
				24-36	32.5	7.25	Same as 2S/1E-12D,more clayey,minute gypsum crystals in bottom two layers.
				36-48	27.5	7.28	
				48-60	30.0	7.32	
				60-72	25.0	7.35	
46	2S/2E-5M	7/30/61	5250	0-8	18.9	7.15	Reddish brown,loose,structureless, slightly sticky,few plant remnants,few R.F.
				8-16	14.0	7.25	
				16-24	13.3	7.30	Reddish brown,slightly hard,firm,weak blocky structure,no plant remnants.
				24-32	11.0	7.38	
				32-40	9.4	7.35	Same as above,lime concretions,gypsum crystals,few R.F.
				40-48	17.7	7.39	

Soil No.	Location No.	Date of Collection	Alt. Ft.	Depth In.	Silt & Clay %	pH 1:10	Description of Soil
47	1S/2E-32M	7/30/61	5160	0-10	17.4	7.39	Light gray,slightly hard,weak granular structure,slightly sticky,many R.F.
				10-20	31.5	7.47	
				20-30	35.1	7.46	Hard,firm,strong blocky structure,very sticky.
				30-40	23.0	7.48	Slightly hard,firm,moderate blocky structure.
				40-50	14.6	7.47	Same as above,lime specks and gypsum crystals.
				50-60	27.9	7.42	Same as above,less lime accumulation.
48	1S/2E-29R	7/30/61	5225	0-6	20.3	7.52	Reddish brown,soft,loose,friable,structureless,few R.F.,lime agg.,plant remnants.
				6-12	14.5	7.56	
				12-18	13.4	7.48	Reddish brown,hard,firm,weak blocky structure, lime concretions and gypsum crystals.
				18-24	17.0	7.46	
				24-30	17.1	7.46	Same as above.
				30-36	18.6	7.35	Less lime,few R.F.
29	1S/1E-36Q	7/30/61	5110	0-6	9.0	7.48	Same as 1S/2E-29R
				6-12	9.1	7.49	
				12-18	8.8	7.49	
				18-24	15.9	7.49	
				24-30	20.5	7.50	
				30-36	20.0	7.52	
25	1S/1E-35J	7/23/61	5100	0-6	13.9	7.30	Light yellowish-gray,loose,soft,stoney, structureless,many volcanic R.F.
				6-12	20.4	7.32	
				12-18	13.8	7.42	Lighter color than above,slightly hard,firm, weak blocky structure,fewer R.F.
				18-24	12.5	7.44	
				24-30	16.6	7.44	Light gray,slightly hard,firm,lime cemented agg.,few volcanic R.F.
				30-36	12.7	7.42	
57	1S/1E-22K	8/5/61	4940	0-6	20.4	7.50	Same as 1S/1E-35J
				6-12	22.0	7.48	
				12-18	17.8	7.48	
				18-24	14.6	7.60	
				24-30	12.0	7.50	
				30-36	14.5	7.47	
58	1S/1E-35A	8/5/61	5080	0-6	12.9	7.55	Same as 1S/1E-35J
				6-12	14.0	7.60	
				12-18	11.5	7.58	
				18-24	11.0	7.55	
				24-30	8.8	7.55	
				30-36	8.4	7.60	
59	1S/1E-25B	8/5/61	5055	0-9	17.5	7.43	Dark brown,slightly hard,firm,weak blocky structure,overlain by calcareous playa deposit.
				9-18	7.3	7.36	
				18-27	8.7	7.30	Dark brown,very hard,very firm,strong blocky structure,lime cementing.
				27-36	12.2	7.28	
				36-45	13.8	7.20	Same as above.
				45-54	5.8	7.30	Dark brown,fewer lime concretions than above.
62	1S/1E-23P	8/5/61	4960	0-9	7.1	7.23	Brown,loose,soft,structureless, no R.F.
				9-18	8.9	7.15	
				18-27	10.8	7.13	Slightly hard, firm, moderate blocky structure, slightly sticky,few R.F.
				27-36	9.3	7.24	
				36-45	14.0	7.30	Brown,weak blocky structure,lime concretions, few R.F.
				45-54	12.6	7.35	
60	1S/2E-18A	8/5/61	5195	0-6	10.0	7.44	Light brown,loose,soft,structureless,lime coated R.F.
				6-12	9.7	7.42	
				12-18	11.8	7.48	Very light brown,slightly hard,firm,weak blocky structure,limey agg. and lime coated R.F.,gypsum crystals.
				18-24	19.3	7.23	
				24-30	22.0	7.20	
				30-36	15.5	7.10	Same as above.
61	1S/2E-8G	8/5/61	5280	0-10	12.0	7.23	Same as 1S/1E-23P
				10-20	11.8	7.35	
				20-30	11.2	7.38	
				30-40	10.8	7.38	
				40-50	12.8	7.40	
				50-60	13.3	7.46	

Table IXB

Table IXB

Complete chemical data for soils
collected east of the Rio Grande River.

Soil No.	Location No.	Date of Analysis	Depth In.	Extractable Cations m.e./100 gms.				Soluble Cations m.e./100 gms.			Exchangeable Cations m.e./100 gms.				Total Exchangeable Cations
				Ca^{++}	Na^{+}	Mg^{++}	K^{+}	Ca^{++}	Na^{+}	Mg^{++}	Ca^{++}	Na^{+}	Mg^{++}	K^{+}	
73	2S/1E-27P	10/31/61	0-6	13.00	0.19	6.70	0.33	1.80	0.13	0.00	11.20	0.06	6.70	0.33	18.29
			6-12	12.50	0.19	7.80	0.31	1.80	0.13	1.40	10.70	0.06	6.40	0.31	17.47
			12-18	12.30	0.19	6.00	0.29	1.80	0.13	1.40	10.50	0.06	4.60	0.29	15.45
			18-24	11.80	0.19	5.00	0.24	1.80	0.13	1.40	10.00	0.06	3.60	0.24	13.90
			24-30	11.00	0.10	3.08	0.20	1.80	0.13	1.40	9.20	0.06	1.68	0.20	11.14
			30-36	24.00	0.19	7.80	0.27	8.25	0.17	1.40	15.75	0.02	6.40	0.27	22.44
69	3S/1E-2P	10/28/61	0-10	15.00	0.52	6.00	0.55	3.50	0.17	0.00	11.50	0.35	6.00	0.55	18.40
			10-20	14.50	2.50	11.70	0.64	4.05	0.78	3.56	10.45	1.72	8.14	0.64	20.95
			20-30	13.00	4.10	12.50	0.62	2.70	1.26	4.75	10.30	2.84	7.75	0.62	21.51
			30-40	11.00	19.70	11.70	0.51	3.20	11.40	1.80	7.80	8.30	9.90	0.51	26.51
			40-50	15.00	6.80	13.40	0.71	2.50	1.40	2.15	12.50	5.40	11.25	0.71	29.86
			50-60	11.75	1.30	14.60	1.10	1.80	0.35	3.75	9.95	0.95	10.85	1.10	22.85
27	2S/1E-32D	10/7/61	0-6	12.50	0.19	9.60	0.35	1.80	0.13	1.40	10.70	0.06	8.20	0.35	19.31
			6-12	11.30	0.30	8.80	0.38	1.80	0.13	1.70	9.50	0.17	7.10	0.38	17.15
			12-18	10.00	1.57	7.70	0.45	1.80	0.13	1.70	8.20	1.44	6.00	0.45	16.09
			18-24	8.80	3.57	7.30	0.45	1.80	0.20	1.70	7.00	3.37	5.60	0.45	16.42
			24-30	13.50	0.43	11.70	0.31	1.80	0.35	1.70	11.70	0.08	10.00	0.31	22.09
			30-36	12.50	0.30	9.20	0.26	3.00	0.60	1.70	9.50	0.00	7.50	0.26	17.26
64	2S/1E-28C	10/26/61	0-6	11.40	0.15	10.60	0.98	1.80	0.17	0.00	9.60	0.00	10.60	0.98	21.18
			6-12	11.30	0.25	9.60	0.69	1.80	0.20	1.40	9.45	0.05	8.20	0.69	18.39
			12-18	11.00	0.89	7.84	0.43	1.80	0.20	0.00	9.20	0.69	7.84	0.43	18.16
			18-24	12.50	0.43	11.70	0.52	2.50	0.43	0.00	10.00	0.00	11.70	0.52	22.22
			24-30	13.00	0.70	12.50	0.48	3.00	0.86	0.00	10.00	0.00	12.50	0.48	22.98
			30-36	11.75	0.79	10.60	0.41	2.50	1.00	0.00	9.25	0.00	10.60	0.41	20.26
66	2S/1E-36B	10/27/61	0-6	36.00	15.80	17.90	4.80	13.50	5.90	2.80	22.50	9.90	15.10	4.80	52.30
			6-12	35.50	22.00	8.70	1.30	12.50	10.80	2.15	23.00	11.20	6.55	1.30	42.05
			12-18	33.00	24.00	15.80	1.28	11.25	10.80	1.70	21.75	13.20	14.10	1.28	50.33
			18-24	41.00	9.40	19.20	0.75	13.50	5.20	1.70	27.50	4.20	17.50	0.75	49.95
			24-30	42.50	14.30	13.40	0.69	12.50	7.80	2.15	30.00	6.50	11.25	0.69	48.44
			30-36	37.00	18.40	16.70	0.64	11.24	10.00	2.15	25.75	8.40	14.55	0.64	49.34
18	2S/1E-19L	9/30/61	0-10	32.50	0.48	17.50	0.60	0.30	0.08	0.07	32.20	0.40	17.43	0.60	50.63
			10-20	31.50	1.44	15.00	1.18	4.05	0.50	0.56	27.45	0.94	14.44	1.18	44.04
			20-30	24.50	10.80	10.80	1.72	7.30	4.30	3.75	17.20	6.50	7.05	1.72	32.47
			30-40	19.50	15.20	9.30	2.10	6.00	4.35	3.56	13.50	10.85	5.74	2.10	32.19
			40-50	25.00	13.20	16.20	0.96	8.00	4.80	5.48	17.00	8.40	10.72	0.96	37.08
			50-60	20.80	12.60	16.20	1.15	6.70	5.60	3.75	14.10	7.00	12.45	1.15	33.55
23	2S/1E-17K	10/1/61	0-6	15.50	1.25	12.10	0.29	1.80	0.20	0.00	13.70	1.05	12.10	0.29	27.14
			6-12	14.20	5.45	12.10	0.31	1.80	0.78	1.40	12.40	4.67	10.70	0.31	28.08
			12-18	11.50	8.05	10.80	0.36	1.80	1.40	0.00	9.70	6.55	10.80	0.36	27.41
			18-24	11.00	10.84	7.90	0.45	3.00	2.18	1.40	8.00	8.66	6.50	0.45	23.61
			24-30	16.00	8.05	13.20	0.29	4.90	2.60	1.40	11.10	5.45	11.80	0.29	28.64
			30-36	12.50	8.70	10.80	0.33	2.50	2.18	1.40	10.00	6.52	9.40	0.33	26.25
44	2S/1E-12D	10/16/61	0-7	20.00	0.37	12.00	0.26	5.50	0.00	1.70	14.50	0.37	11.30	0.26	26.43
			7-14	17.00	0.44	11.65	0.29	4.50	0.00	1.40	12.50	0.44	10.25	0.29	23.48
			14-21	16.20	0.61	12.10	0.33	5.00	0.00	1.40	11.20	0.61	10.70	0.33	22.84
			21-28	15.20	0.89	10.80	0.35	2.30	0.00	1.40	12.90	0.89	9.40	0.35	23.54
			28-35	17.00	0.36	12.90	0.49	2.75	0.00	1.40	14.25	0.36	11.50	0.49	26.60
			35-42	14.50	0.69	11.70	0.18	1.50	0.00	1.40	13.00	0.69	10.30	0.18	24.17
45	2S/2E-6K	10/16/61	0-12	47.50	0.37	12.90	0.33	13.50	0.35	2.15	34.00	0.02	10.75	0.33	45.10
			12-24	32.50	6.35	11.20	0.31	11.25	1.92	2.80	21.25	4.43	8.40	0.31	34.39
			24-36	30.50	9.60	10.00	0.27	11.75	4.50	2.15	18.75	5.10	7.85	0.27	31.97
			36-48	25.00	20.50	9.20	0.24	11.75	3.30	2.15	13.25	17.20	7.05	0.24	37.74
			48-60	28.50	7.60	8.33	0.35	7.50	3.70	2.15	21.00	3.90	6.18	0.35	31.43
			60-72	32.00	9.10	12.00	0.30	5.75	5.20	2.15	26.25	3.90	9.85	0.30	40.30
25	1S/1E-35J	10/3/61	0-6	14.20	0.47	10.83	1.31	1.80	0.13	1.40	12.40	0.34	9.43	1.31	23.48
			6-12	13.70	0.72	9.16	1.18	1.80	0.17	1.40	11.90	0.55	7.76	1.18	21.39
			12-18	13.20	2.56	6.25	0.79	1.80	0.35	1.40	11.40	2.21	4.85	0.79	19.25
			18-24	11.50	9.56	6.25	0.67	1.80	1.00	1.40	9.70	8.56	4.85	0.67	23.78
			24-30	14.20	1.43	13.30	0.51	1.80	0.78	1.40	12.40	0.65	11.90	0.51	25.46
			30-36	16.00	7.17	15.00	0.47	1.80	1.73	1.40	14.20	5.44	13.60	0.47	33.71
62	1S/1E-23P	10/25/61	0-9	41.00	0.43	10.60	1.14	8.25	0.30	2.15	32.75	0.13	8.45	1.14	41.72
			9-18	37.00	0.52	8.75	0.80	8.00	0.20	1.70	29.00	0.32	7.05	0.80	37.17
			18-27	29.50	0.79	7.84	0.87	8.75	0.35	2.15	20.75	0.44	5.69	0.87	27.75
			27-36	28.50	1.39	6.00	0.92	9.20	0.60	2.15	19.30	0.79	3.85	0.92	24.86
			36-45	38.00	1.08	9.60	0.69	8.25	0.70	2.15	29.75	0.38	7.45	0.69	38.27
			45-54	40.50	2.45	11.70	0.90	9.20	0.87	2.15	31.30	1.56	9.55	0.90	43.31

Table IXC

Table IXC

Partial chemical data for soils
collected east of the Rio Grande River.

Soil No.	Location No.	Date of Analysis	Depth In.	Extractable Cations m.e./100 gms.				Total Extractable Cations
				Ca^{++}	Na^{+}	Mg^{++}	K^{+}	
71	3S/1E-32C	10/28/61	0-8	14.00	0.25	6.70	1.02	21.97
			8-16	13.00	0.30	6.00	0.34	19.60
			16-24	12.50	0.43	4.20	4.31	17.40
			24-32	12.30	1.00	8.80	0.45	22.60
			32-40	14.00	0.25	7.80	0.38	22.40
			40-48	10.50	0.30	5.50	0.31	16.10
72	3S/1E-28P	10/31/61	0-8	14.00	1.00	7.80	0.38	23.20
			8-16	13.50	0.52	6.70	0.31	21.00
			16-24	13.00	1.00	5.00	0.26	19.30
			24-32	14.50	0.60	7.80	0.24	23.10
			32-40	14.00	2.20	8.80	0.22	25.22
			40-48	13.00	2.60	6.70	0.20	22.50
74	3S/1E-26L	10/31/61	0-7	13.50	0.19	7.80	0.44	21.90
			7-14	15.80	0.25	8.80	0.64	25.50
			14-21	15.30	0.30	6.70	0.82	23.10
			21-28	15.00	0.52	5.00	0.89	21.40
			28-35	33.50	1.00	4.20	0.66	39.40
			35-42	32.50	2.10	10.60	0.55	45.80
70	3S/1E-5G	10/28/61	0-6	43.00	31.60	23.40	1.20	99.20
			6-12	30.00	33.00	22.10	1.30	86.40
			12-18	20.90	34.00	16.70	1.40	73.00
			18-24	30.50	27.00	25.00	1.40	83.90
			24-30	39.50	35.00	23.40	1.30	99.20
			30-36	14.80	21.70	15.60	0.60	52.70
67	2S/1E-33P	10/27/61	0-6	17.00	0.52	13.40	0.69	31.60
			6-12	16.50	3.60	10.60	0.44	31.10
			12-18	16.25	5.00	9.60	0.41	31.30
			18-24	14.00	10.40	8.80	0.34	33.50
			24-30	18.50	6.00	12.50	0.62	37.60
			30-36	22.50	2.20	10.60	0.69	36.00
68	2S/1E-34Q	10/27/61	0-6	14.50	3.30	12.50	0.48	30.80
			6-12	13.00	3.80	9.60	0.55	27.00
			12-18	14.00	2.10	10.60	0.50	27.20
			18-24	13.00	1.56	9.60	0.47	24.00
			24-30	13.00	3.56	12.50	0.43	29.50
			30-36	13.50	4.34	11.70	0.50	30.00
26	2S/1E-29D	10/3/61	0-6	13.70	0.47	10.80	0.76	25.70
			6-12	13.20	0.55	10.80	0.83	25.40
			12-18	12.20	0.55	9.20	0.79	22.70
			18-24	11.00	0.63	7.90	0.89	20.40
			24-30	14.70	0.47	4.50	0.95	20.60
			30-36	10.50	0.47	10.80	0.69	22.50
65	2S/1E-26D	10/26/61	0-8	11.35	2.45	13.40	0.62	27.90
			8-16	14.00	5.00	15.80	0.58	35.60
			16-24	12.50	6.37	13.40	0.54	32.80
			24-32	11.35	4.70	12.50	0.52	29.10
			32-40	12.50	4.34	15.80	0.62	33.20
			40-48	11.70	5.00	14.60	0.69	32.00
19	2S/1E-17N	9/30/61	0-8	17.00	0.34	12.10	0.36	29.80
			8-16	15.50	0.56	11.80	0.45	28.30
			16-24	15.00	0.91	9.30	0.45	25.70
			24-32	13.70	1.43	7.90	0.49	23.50
			32-40	18.00	0.83	15.00	0.24	34.10
			40-48	25.70	0.65	10.80	0.26	37.40
24	2S/1E-9Q	10/3/61	0-6	12.50	1.00	20.80	0.33	34.60
			6-12	11.00	8.05	17.50	0.35	37.00
			12-18	10.00	8.55	15.80	0.44	34.80
			18-24	9.00	20.90	13.20	0.56	43.70
			24-30	12.50	9.60	19.60	0.41	42.10
			30-36	10.50	14.80	24.20	0.51	50.00

Soil No.	Location No.	Date of Analysis	Depth In.	Extractable Cations m.e./100 gms.				Total Extractable Cations
				Ca^{++}	Na^{+}	Mg^{++}	K^{+}	
46	2S/2E-5M	10/16/61	0-8	31.50	1.08	11.70	0.30	44.60
			8-16	22.00	8.70	9.20	0.33	40.20
			16-24	16.50	12.80	8.33	0.34	38.00
			24-32	15.00	15.85	8.33	0.37	39.60
			32-40	17.00	11.80	10.80	0.27	39.90
			40-48	18.20	12.80	11.70	0.24	42.90
47	1S/2E-32M	10/16/61	0-10	14.50	0.24	13.70	0.59	29.00
			10-20	12.50	0.70	12.90	0.45	26.60
			20-30	11.70	2.86	11.70	0.34	26.60
			30-40	11.00	4.08	10.00	0.33	25.40
			40-50	12.50	1.87	12.00	0.48	26.90
			50-60	11.70	1.08	13.70	0.53	27.00
48	1S/2E-29R	10/21/61	0-6	13.50	1.00	18.00	1.43	33.90
			6-12	12.20	8.50	14.60	1.48	36.80
			12-18	9.20	10.40	13.40	1.56	34.60
			18-24	8.50	13.70	11.70	1.69	35.60
			24-30	8.00	12.20	23.40	1.61	45.20
			30-36	16.20	10.40	20.80	1.28	48.70
49	1S/1E-36Q	10/21/61	0-6	16.20	0.15	16.70	0.58	33.60
			6-12	15.00	0.15	15.80	0.55	31.50
			12-18	14.00	0.15	13.40	0.49	28.00
			18-24	13.00	0.15	11.70	0.38	25.20
			24-30	14.00	0.15	18.00	0.35	32.50
			30-36	17.00	0.15	16.70	0.33	34.20
57	1S/1E-22K	10/24/61	0-6	13.00	0.15	15.80	0.58	29.50
			6-12	13.50	0.19	20.80	0.51	35.00
			12-18	13.00	0.19	14.60	0.50	28.30
			18-24	12.50	0.25	4.17	0.50	17.50
			24-30	14.50	0.25	12.50	0.60	27.90
			30-36	12.20	0.19	9.60	0.51	22.50
58	1S/1E-35A	10/24/61	0-6	13.00	1.26	6.67	1.10	22.10
			6-12	11.75	4.34	6.00	0.77	22.90
			12-18	11.35	9.40	5.00	0.68	26.50
			18-24	11.00	10.60	9.60	0.50	31.70
			24-30	12.25	5.30	10.60	0.29	28.40
			30-36	11.35	5.95	7.84	0.27	25.50
59	1S/1E-25B	10/24/61	0-9	32.00	0.15	6.00	0.72	38.90
			9-18	28.50	0.19	5.00	0.43	34.10
			18-27	25.50	0.19	2.10	0.41	28.20
			27-36	29.50	0.19	6.70	0.37	36.80
			36-45	33.00	0.19	7.80	0.43	41.40
			45-54	50.00	0.19	4.20	0.48	54.90
60	1S/2E-18A	10/25/61	0-6	18.25	0.19	7.84	0.41	23.70
			6-12	16.50	0.89	10.60	0.24	28.20
			12-18	32.50	7.75	15.80	0.22	56.30
			18-24	50.00	0.52	11.70	0.28	62.50
			24-30	49.00	0.43	9.60	0.20	59.20
			30-36	50.00	0.60	8.75	0.24	59.60
61	1S/2E-8G	10/25/61	0-10	15.75	0.37	13.40	0.90	30.50
			10-20	15.00	0.52	11.70	0.87	28.10
			20-30	14.50	1.08	10.60	0.76	27.00
			30-40	14.00	1.39	8.75	0.59	24.90
			40-50	15.25	1.00	11.70	0.82	28.80
			50-60	13.00	1.70	9.60	0.87	25.20

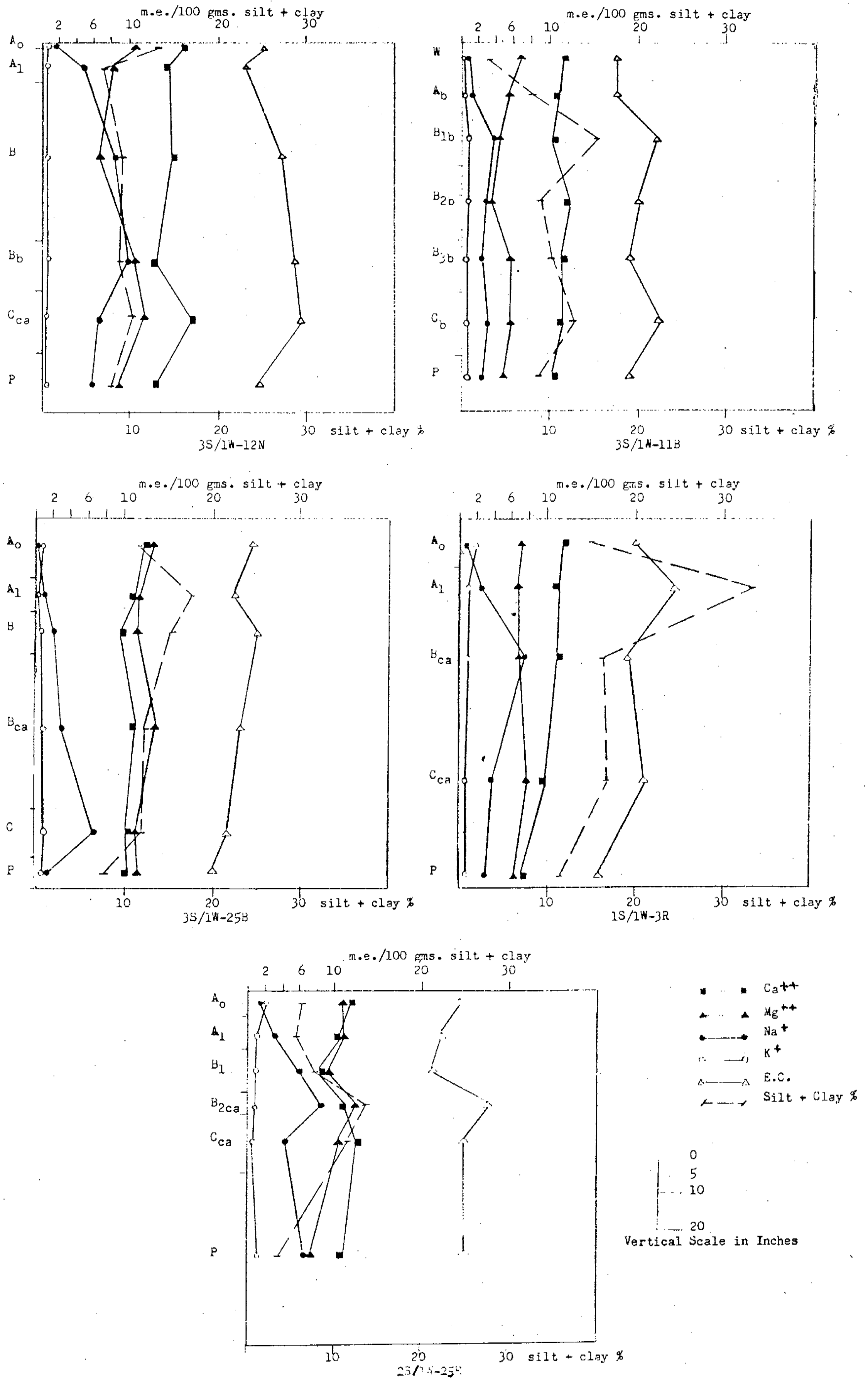
Plate XII

Plate XII

Distribution of exchangeable cations, clay plus silt, and cation exchange capacity of model soils.

Note: W is not to scale.

DISTRIBUTION OF EXCHANGEABLE CATIONS, CLAY + SILT AND CATION EXCHANGE CAPACITY



3S/1W-12N

3S/1W-11B

3S/1W-25B

1S/1W-3R

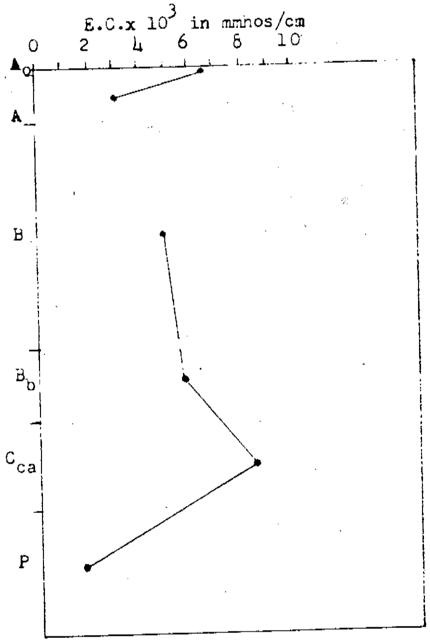
2S/1W-25R

Plate XIII

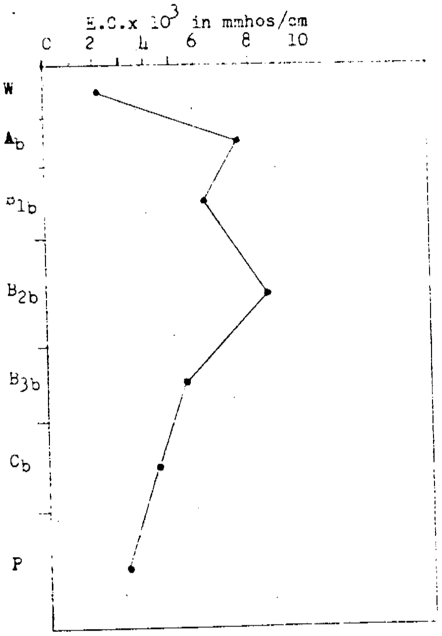
Plate XIII

Electrical conductivity of model soils.

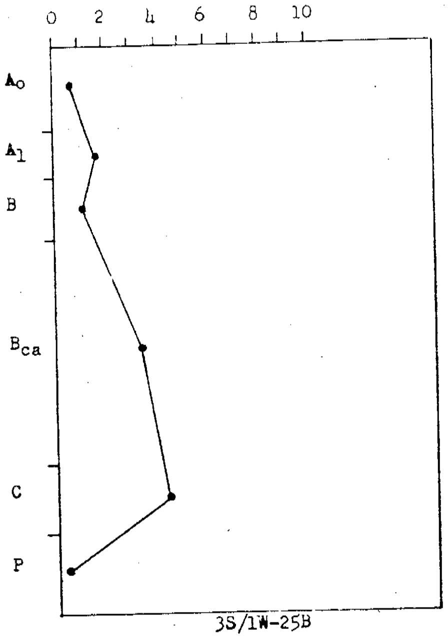
Note: W is not to scale.



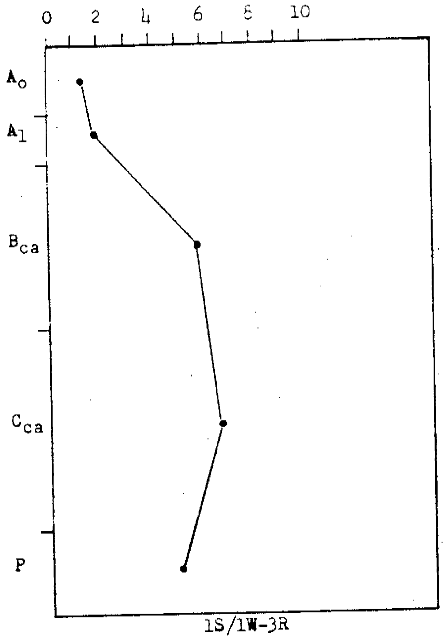
3S/1W-12N



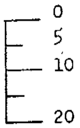
3S/1W-11B



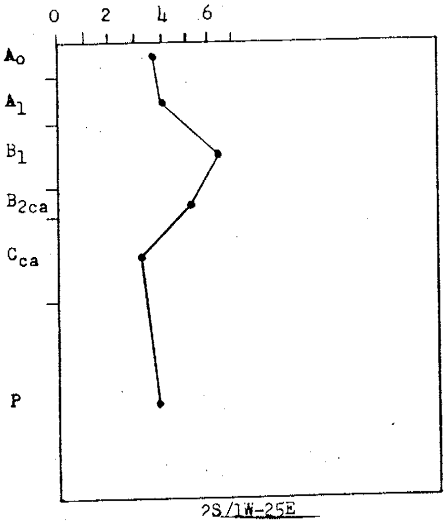
3S/1W-25B



1S/1W-3R



Vertical Scale in Inches



2S/1W-25E

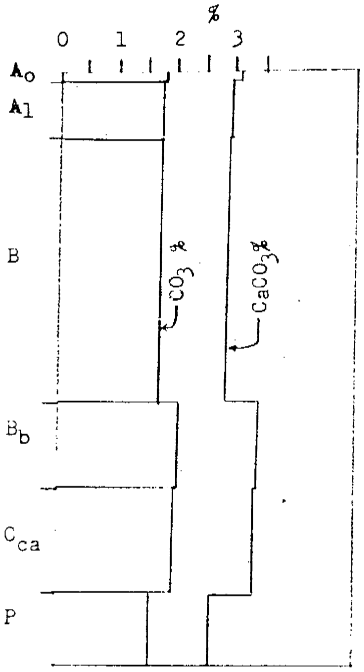
Plate XIV

Plate XIV

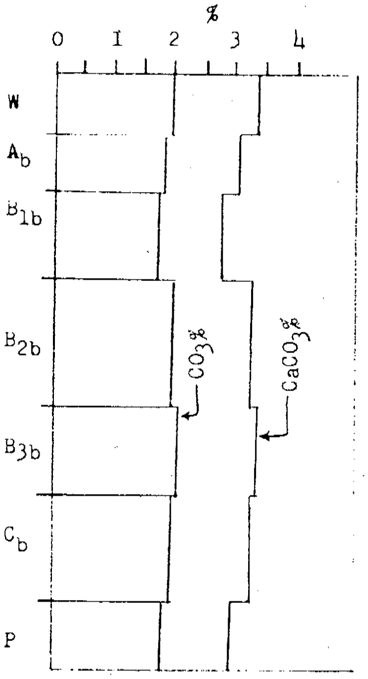
Distribution of carbonate and calcium carbonate equivalent in model soils.

Note: W is not to scale.

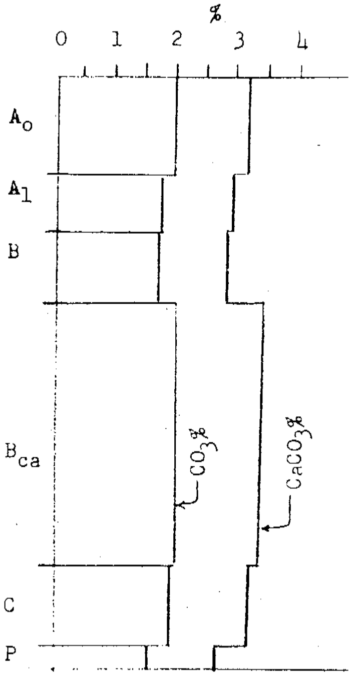
CARBONATE AND CALCIUM CARBONATE EQUIVALENT DISTRIBUTION CHART



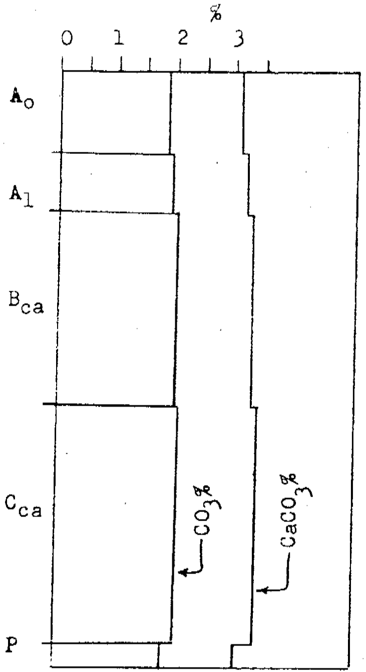
3S/1W-12N



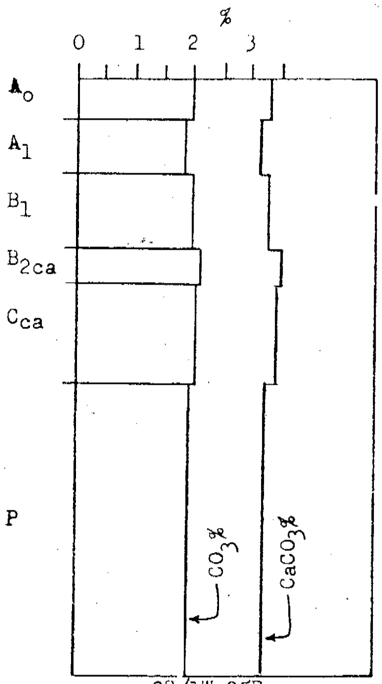
3S/1W-11B



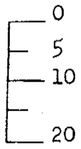
3S/1W-25B



1S/1W-3R



2S/1W-25E

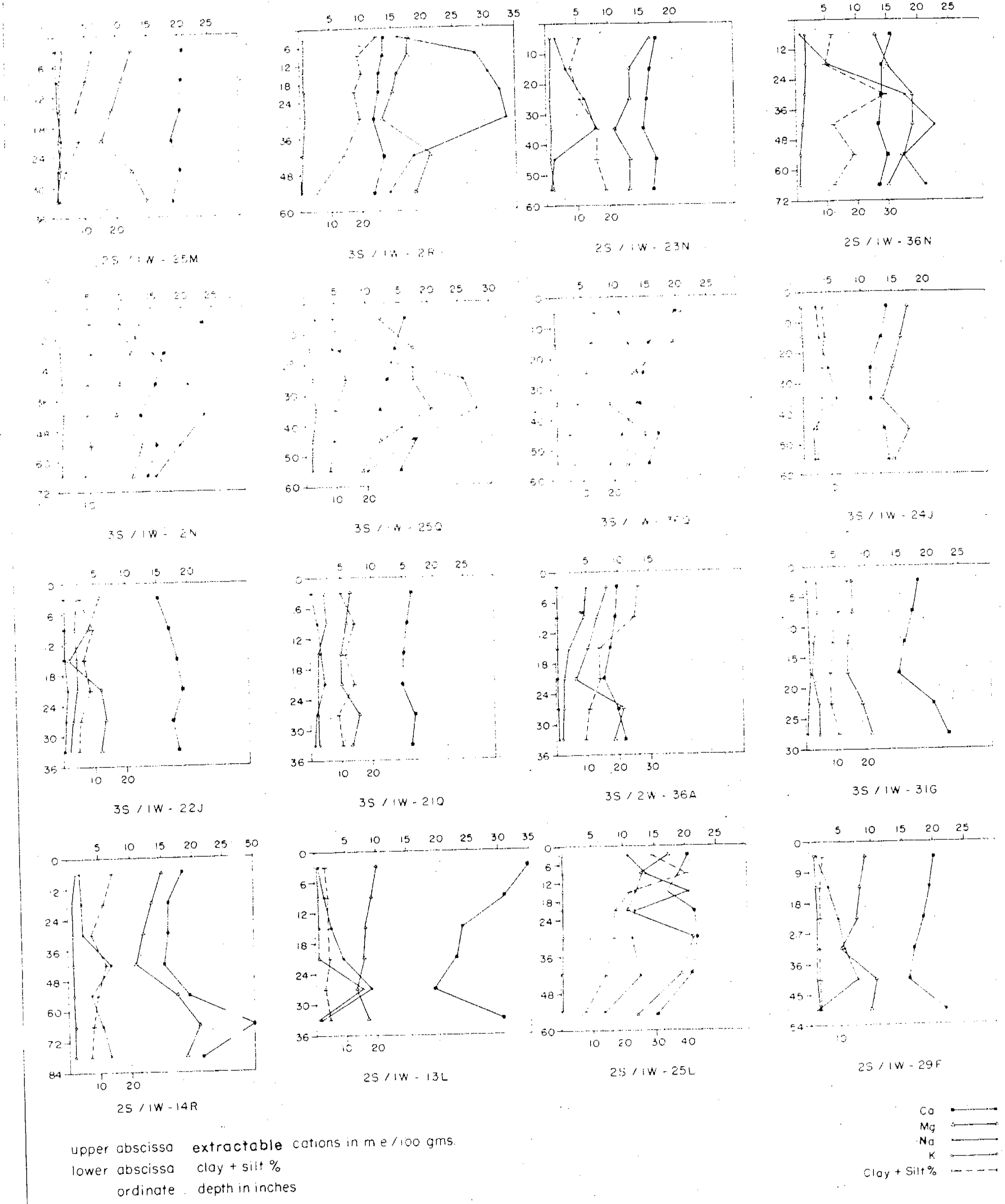


Vertical Scale in Inches

Plates XV (1-5)

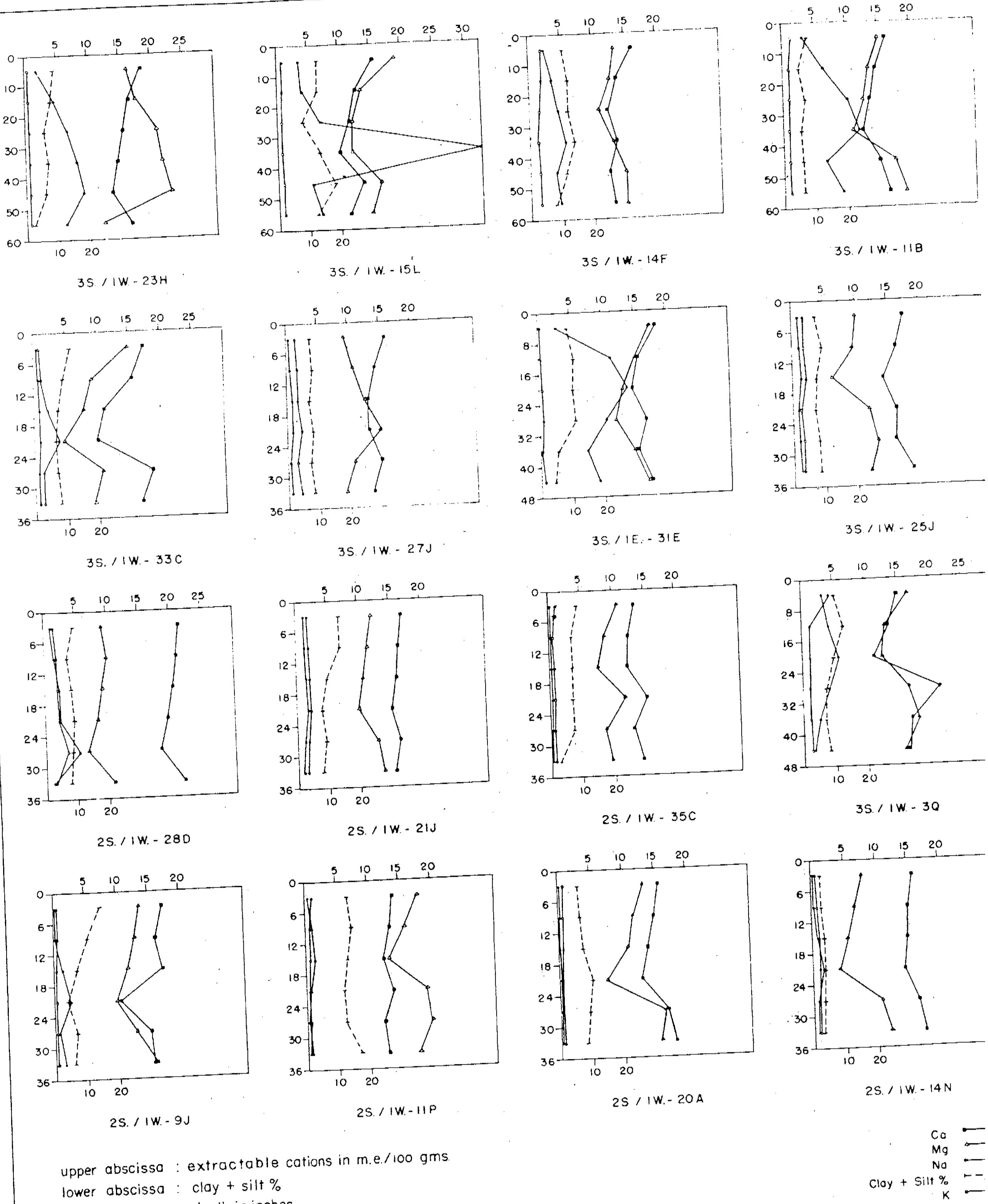
Plates XV (1-5)

Distribution of extractable cations and clay plus silt fraction in soils collected east and west of the Rio Grande River.



upper abscissa extractable cations in m e / 100 gms.
lower abscissa clay + silt %
ordinate depth in inches

DISTRIBUTION OF EXTRACTABLE IONS (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) AND CLAY + SILT 1



3S. / 1W. - 23H

3S. / 1W. - 15L

3S / 1W. - 14F

3S. / 1W. - 11B

3S. / 1W. - 33C

3S. / 1W. - 27J

3S. / 1E. - 31E

3S / 1W. - 25J

2S. / 1W. - 28D

2S. / 1W. - 21J

2S. / 1W. - 35C

3S. / 1W. - 3Q

2S. / 1W. - 9J

2S. / 1W. - 11P

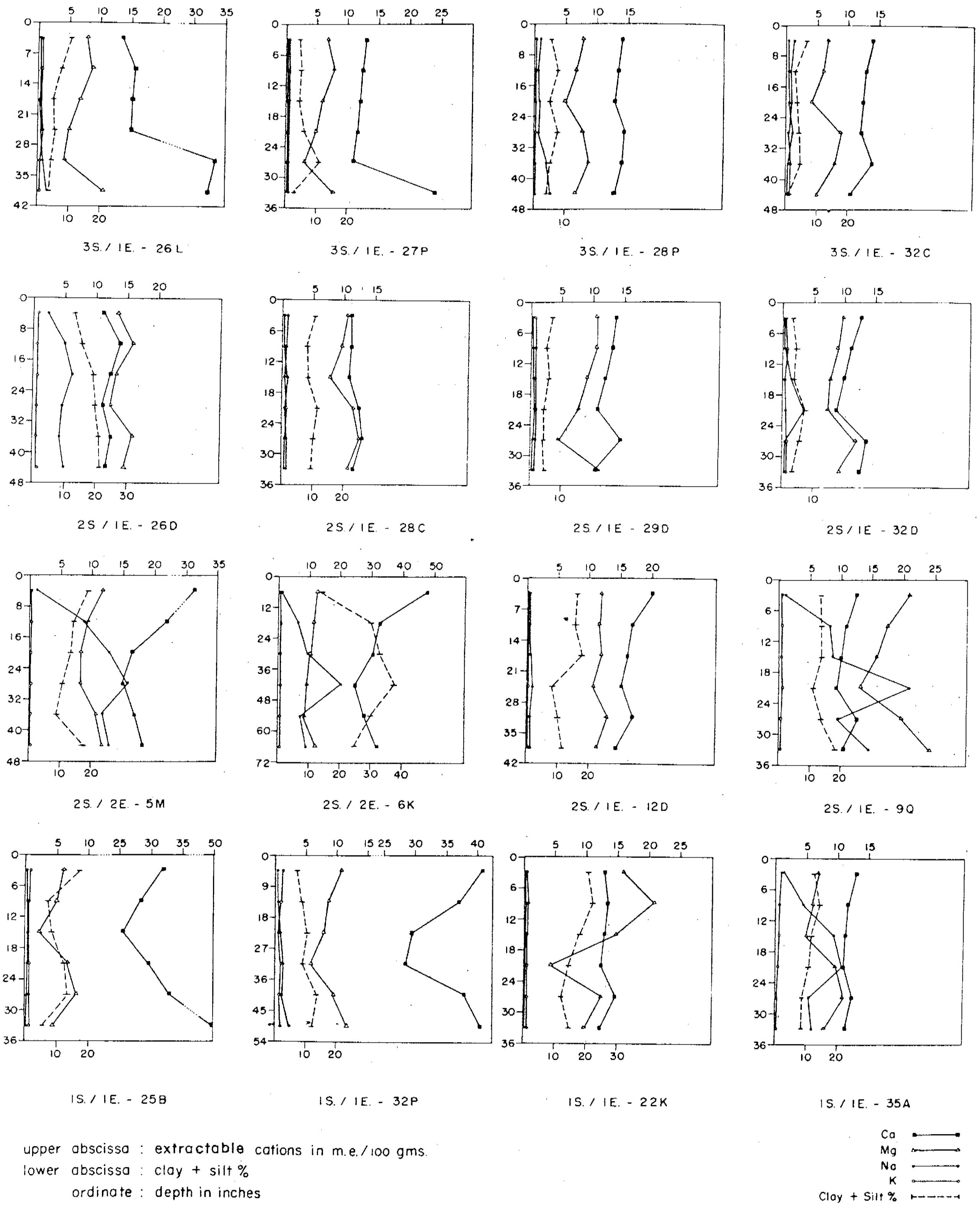
2S / 1W. - 20A

2S. / 1W. - 14N

upper abscissa : extractable cations in m.e./100 gms.
lower abscissa : clay + silt %
ordinate : depth in inches

DISTRIBUTION OF EXTRACTABLE IONS (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) AND CLAY + SILT

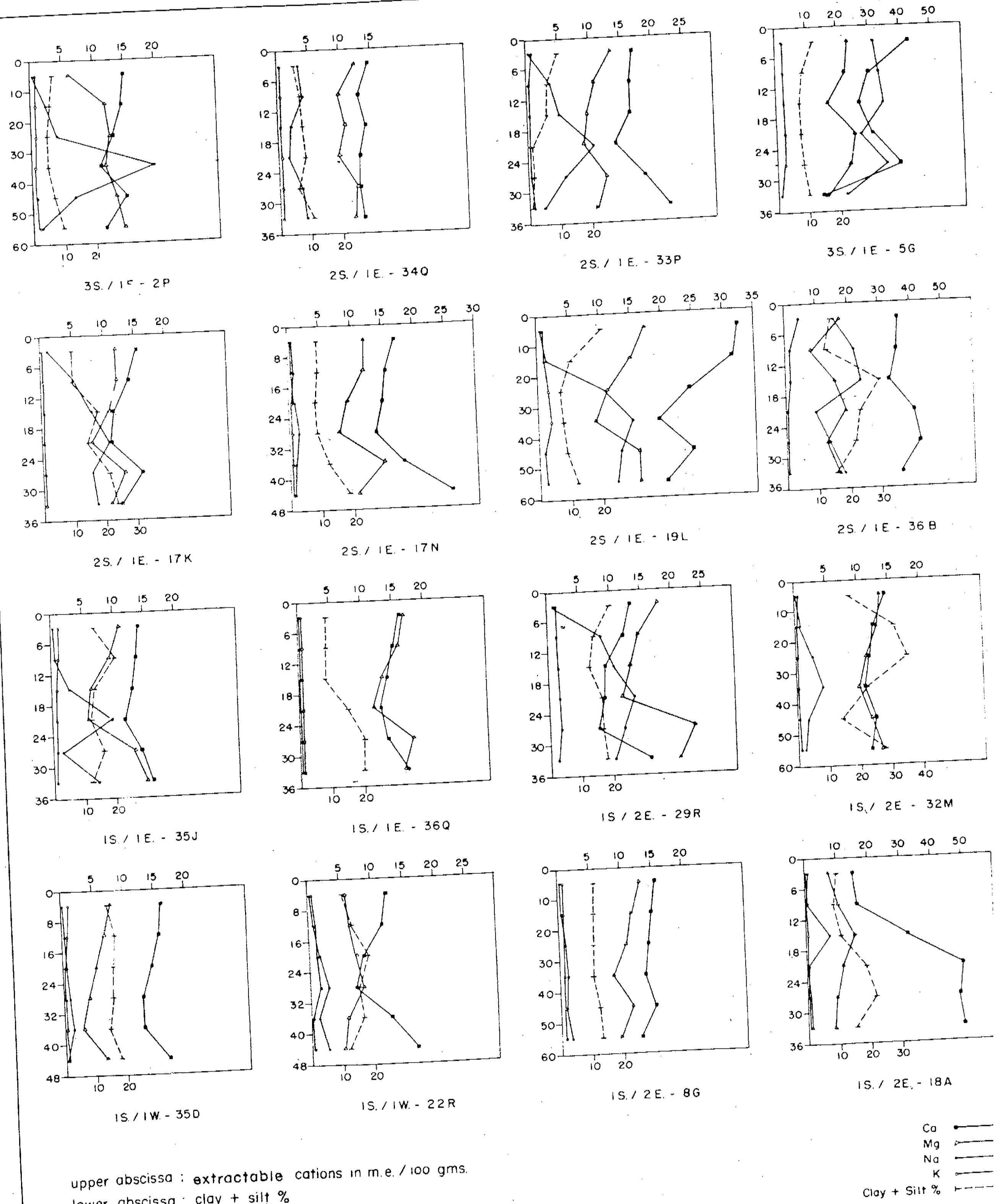
2



3S. / 1E. - 26L
3S. / 1E. - 27P
3S. / 1E. - 28P
3S. / 1E. - 32C
2S / 1E. - 26D
2S / 1E. - 28C
2S / 1E - 29D
2S / 1E - 32D
2S. / 2E. - 5M
2S. / 2E. - 6K
2S. / 1E. - 12D
2S. / 1E. - 9Q
1S. / 1E. - 25B
1S. / 1E. - 32P
1S. / 1E. - 22K
1S. / 1E. - 35A

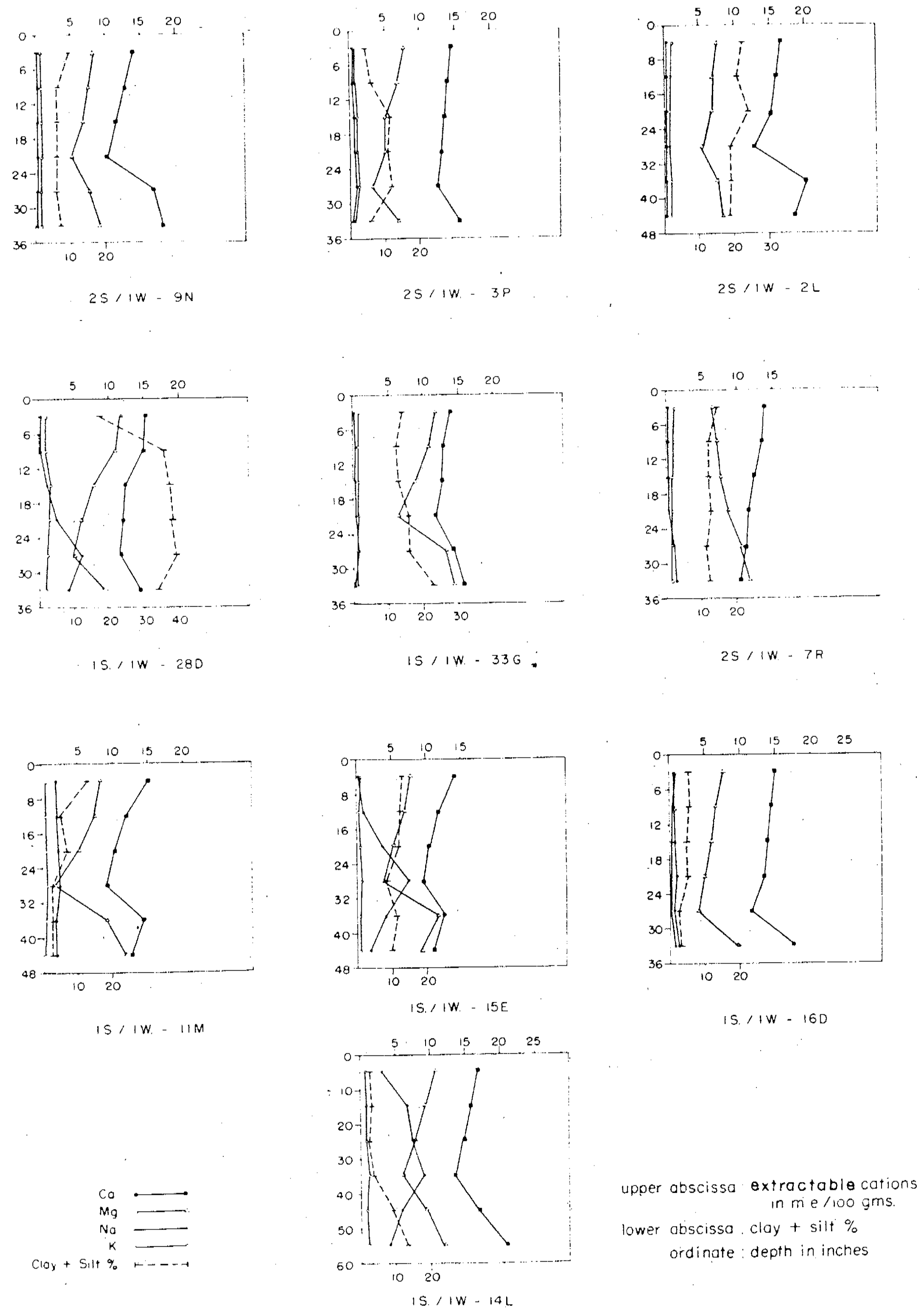
upper abscissa : extractable cations in m.e./100 gms.
lower abscissa : clay + silt %
ordinate : depth in inches

DISTRIBUTION OF EXTRACTABLE IONS (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) AND CLAY + SILT $\boxed{3}$



upper abscissa : extractable cations in m.e. / 100 gms.
lower abscissa : clay + silt %
ordinate : depth in inches

DISTRIBUTION OF EXTRACTABLE IONS (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) AND CLAY + SILT ④



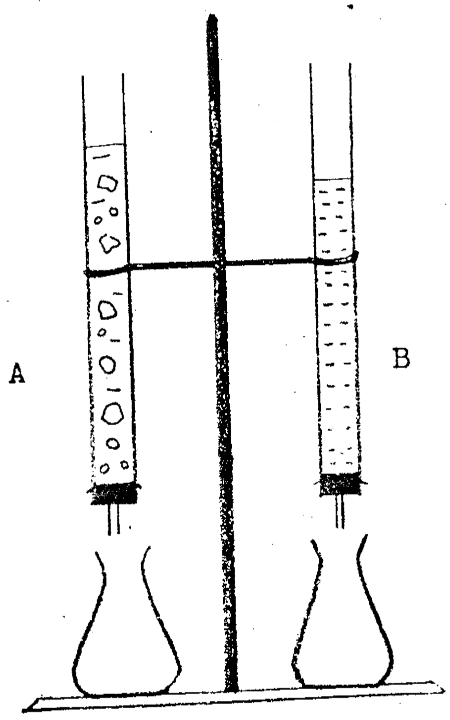
DISTRIBUTION OF EXTRACTABLE IONS (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) AND CLAY + SILT 5

APPENDIX I

Cation Exchange of Clay Plus Silt Versus That of the Total Soil.

The cation exchange material of soils is composed mainly of the finer size fractions which provide a great surface area of adsorption. The following experiment was performed to demonstrate this.

Two glass columns, 16 inches long and 1½ inches in diameter, were set up in the laboratory as shown in the diagram.



Three hundred grams of soil from locality 3S/1W-12P were lightly ground and poured into column A. Three hundred grams of clay plus silt, from the same soil, were put in column B. The soil material used was collected from the top ten inches of the sampled profile. The following table shows the mechanical size analysis of the soil used.

Mesh (Tyler)	Size (In.)	Weight (gms.)	%
+20	+0.0328	41.0	13.7
65	0.0082	124.0	41.5
100	0.0058	14.0	4.7
150	0.0041	11.5	3.8
200	0.0029	26.7	9.3
-200	-0.0029	79.6	26.5
		299.0	99.[illegible]

The clay plus silt fraction constitutes 26.5% of the soil.

One liter of normal ammonium acetate solution was added to each column. Filtrates were received in flasks. Solution seeped through column B in 95 minutes and through column A in 75 minutes. Filtrates of A and B were completed to one liter with distilled water and analyzed for calcium, magnesium, sodium, and potassium by flame photometry. The following is the result of analysis:

Sample	Na^+ ppm.	Ca^{++} ppm.	Mg^{++} ppm.	K^+ ppm.
A	23.2	83.0	25.0	13.0
B	67.0	280.0	73.0	40.0

A has 26.5% clay plus silt, and B has 100.0%.

The results show the ratio of A:B is 1:2.9 for Na^+, 1:3.4 for Ca^{++}, 1:3.1 for Mg^{++}, and 1:3.1 for K^+. The ratio of clay plus silt content is 1:3.8. The results also show that the most important reactive fraction in cation exchange is the clay plus silt rather than the larger soil particles. Thus, it is satisfactory to study the behavior and chemical reactions of the finer fractions of the soil rather than the whole soil in order to understand the exchangeable cation distribution.

APPENDIX II

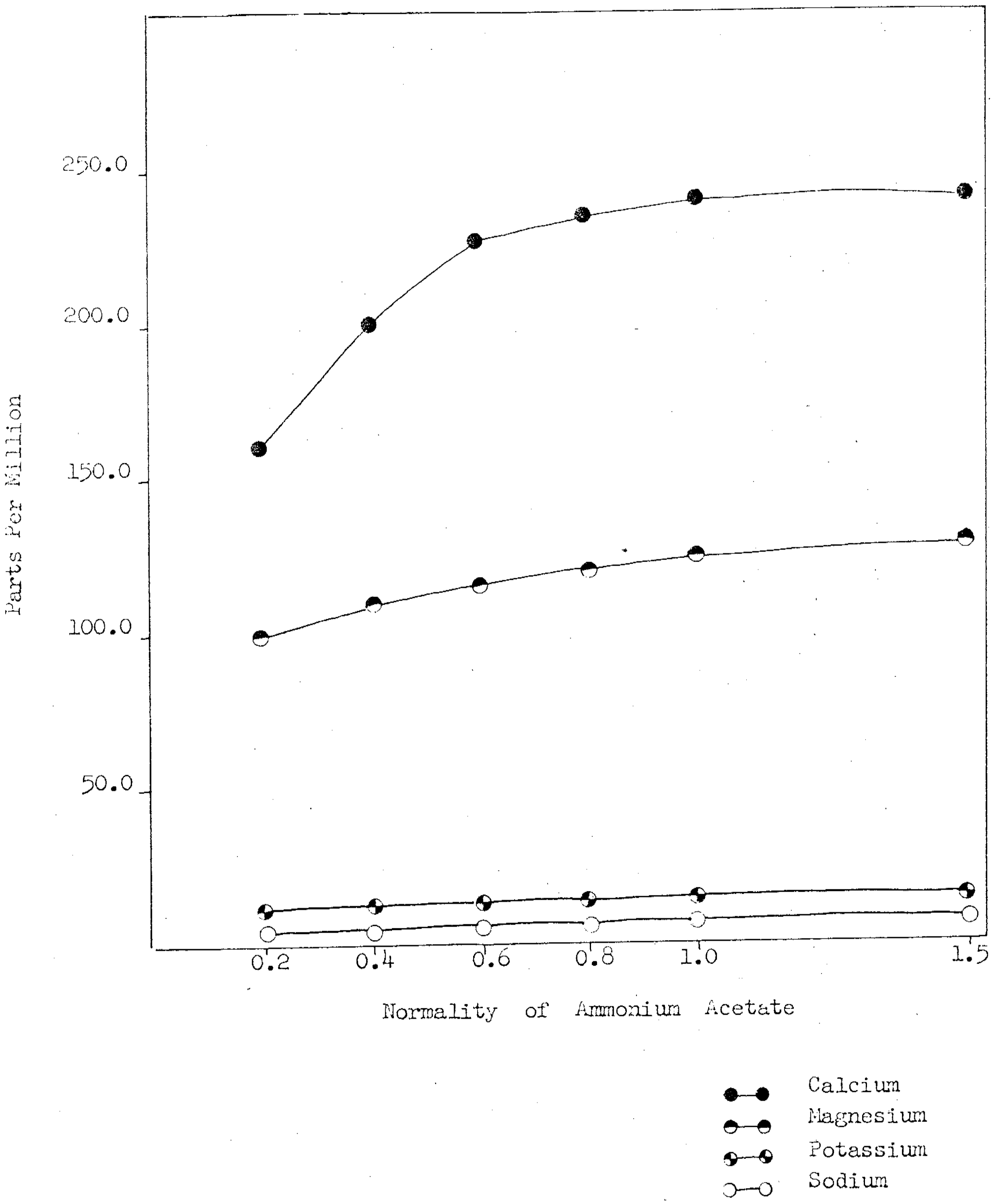
Ammonium Acetate Test

This experiment was done to show that 1 N ammonium acetate solution can extract all the available extractable cations from the soil. Twenty grams of clay plus silt from soil locality 2S/1W-9J were soaked twenty-four hours in 200.0 ml. 1.5 N ammonium acetate solution. Other samples of the same weights were soaked in 1.0, 0.8, 0.6, 0.4, and 0.2 N ammonium acetate solutions for the same length of time. The filtrates were analyzed for calcium, sodium, magnesium, and potassium. The following are the results:

Extract of ammonium acetate	Na^+ ppm.	Ca^{++} ppm.	Mg^{++} ppm..	K^+ ppm.
1.5 N	8.5	240.0	130.0	15.5
1.0 N	8.5	240.0	125.0	15.0
0.8 N	6.5	235.0	120.0	14.5
0.6 N	5.7	227.0	115.0	14.5
0.4 N	5.0	200.0	110.0	13.5
0.2 N	4.6	160.0	100.0	12.0

The above results show that 1.0 N ammonium acetate solution is satisfactory for this research.

Appendix II


Parts Per Million
250.0
200.0
150.0
100.0
50.0
0.2
0.4
0.6
0.8
1.0
1.5
Normality of Ammonium Acetate
Calcium
Magnesium
Potassium
Sodium

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