CHARACTERIZATION, GENESIS AND NUMERICAL TAXONOMY OF SODIC SOILS IN NORTH CENTRAL OKLAHOMA

By

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TABLE OF CONTENTS

LIST OF TABLES

Table | Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The research reported in this dissertation is divided into three chapters, each is a manuscript prepared for publication in Professional Journals. These manuscripts appear just as they will be submitted for publication, except for a few minor modifications.

Slickspots occur in irregular sized and shaped spots in central and western Oklahoma. In this region they occur on Permian as well as Pennsylvanian aged material. Slickspots occur extensively in semi-arid and subhumid regions and occasionally in humid regions. They are found on varying topographies but usually in flats or depressions.

Slickspots present very important problems in crop production and range management as well as in uses of soil for engineering purposes. If Mollisols contain large amounts of sodium salts, sodium replaces the other cations and saturates colloidal particles of the organic matter, forming sodium humate, which is mobile enough to be moved downward. Downward movement of sodium humate reduces the amount of organic matter in the surface horizons. In this situation the rate of addition would be less than the rate of removal of organic matter and the slickspots formed through this process would have a lighter color and less organic matter in the surface horizons than the surrounding, normal, soils. The overall role of sodium in plant growth has not yet been well defined or definitely established. It may have desirable effects in some species and undesirable effects in others. Its effect may be favorable at low concentrations and unfavorable at higher levels. Bower and Wadleigh (1949) recognized that as the relative concentration of Na in soils increases, its uptake by plants usually increases, with consequent reduction in the uptake of Ca^{++}, Mg^{++}, and K^{+}. In the subsurface horizons clay particles sorb sodium ions. If more than 6% of the exchange complex is occupied by sodium ions, clay particles start to disperse. If exchangeable sodium saturates 15% or more of the cation exchange capacity, almost all the clay particles disperse and their stability decreases. Engineers use the term "dispersive" for soils with the latter quality.

Sodic soils can be classified according to their sodium content. Their sodium salts may be derived from parent material or they may be brought in, by external agents such as wind and water. The knowledge of their origin and their taxonomy is necessary for effective reclamation and the prevention of pollution of the surrounding soils.

A large number of slickspots, which usually support short grasses in a tall grass area, are found in north central Oklahoma. A detailed study was undertaken in order to gain a better understanding of their genesis and taxonomy. A typical toposequence of slickspots and normal Mollisols was selected for this study in NW¼ of Section 17T. 25N., R5E., 30 miles west of Pawhuska, Osage County. The variation between and within such pedons is the result of the processes of horizon differentiation which is the result of the interaction of soil forming factors.

Bakhtar and Gray (1971) collected information about the possible soil forming factors and presented it in a preliminary report. The area displays a surface of maturely dissected relief. The highest point of NW¼, Section 17, is in the northeast part which has an elevation of 318 meters. The lowest is in the southwest sector with an elevation of 300 meters. Harlan (1958) presents a map of natural vegetative covers. Our study area is located in the tall grasses area of the map where field observations support the information gathered by Harlan. The predominate vegetative cover is tall grasses with blue grama, a short grass, dominating the slickspots. Vegetation is a very important observable phenomenon of sodic soils and can be used for analysis of aerial photos and for a preliminary mapping of slickspots in an area of normal Mollisols. Soils in Osage County are developed under a warm temperate, subhumid, continental climate which influences morphological losses, gains, transfers and transformations. The mean annual temperature for this county is approximately 16^{o}C. The annual evapotranspiration is about 86 centimeters. Hartronft (1965) states that; geologic material that crop out and underlie soils of the study site are early Permian and belong to the Wellington-Admire unit, which consists of interbedded shales, sandstone, and siltstone. Most of the unit is reddish colored shale or silty shale. The clayey material contains lenses of beds of sandstone and also thin siltstone beds. Fay (1972) indicates that the rocks that crop out and underlie soils of the toposequence are Pennsylvanian and belong to the Oscar formation with Herington limestone at the top.

In a preliminary study chemical and physical analyses were made on soil samples taken from the cut along the road on the west side of section 17. Resulting data, together with observations on vegetation, were used to locate seven sampling pedons. Ground water levels were noted within 142 and 254 cm of the surface in July 1970. A total of

79 samples from soils and parent material, as well as 5 samples from ground water, were taken. Mineralogy of the selected horizons and total weatherable minerals in the soil and underlaying geologic formations will lead the investigator to study the similarity between solum, the true soil, and the soil parent material. Statistical analysis of laboratory data together with the morphology of pedons will aid in grouping the horizons and hence the pedons.

The objectives of this research and this project are divided into three parts:

1. Characterization of a typical toposequence of Mollisols and Slick-spot soils, a statistical analysis.

2. Genesis of sodic soils and the origin of Sodium in their profiles.

3. A Statistical Procedure in taxonomy of sodic soils.

CHAPTER II

CHARACTERIZATION OF A TYPICAL TOPOSEQUENCE OF MOLLISOLS AND SLICKSPOT SOILS A STATISTICAL ANALYSIS[1/]

Abstract

Characterization of the selected pedons occuring in a toposequence of slickspots and Mollisols was the objective of this report. The vegetative cover of the sampling site was studied using a point method of pasture analysis. The slickspots represent a light tone on the aerial photos due to the abundance of short grasses.

A total of 79 pedogenic horizons from the solum and underlying strata were sampled. Characterization processes were carried out on the samples, using a slipped block design. This design was used so that the effect of the day to day variation in the laboratory could be removed.

The toposequence displayed mollic epipedons, argillic, and natric horizons. The total thickness of the mollic epipedons varied in the toposequence. The thickness of the solum decreased as elevation increased.

[1/]Article co-authored with Fenton Gray and Robert D. Morrison and to be submitted for publication in Soil Science Society of America Proceeding.

The laboratory results indicated no evidence of salinity. The soil reaction and exchangeable sodium percentage have been used in distinguishing the salt affected soils from the other, normal, soils. Salinity, alkalinity and sodicity classes were established based upon the quantitative values which have bearing on the performance of many, although not all, agricultural crops. According to this classification Pedons 1, 2, 4 and 7 belonged to the alkaline - strongly sodic class.

Additional Key Words for Indexing: Pedogenic horizons, selected pedons, North Central Oklahoma, Mollisols.

Introduction and Review of Literature

Kellogg (1959) states that soil scientists need to know what characteristics are important, what degrees of differences in each are significant, how they react to one another, and finally, what combination of characteristics are significantly unlike other combinations. Arnold (1965) states that soils have certain morphological features and associated properties which can be expressed qualitatively and in most instances quantitatively.

Simonson (1959) views the horizon differentiation to be due to the processes of addition, removal, transfer and transformation. These proceed in Aridisols as well as in Alfisols and Mollisols with a difference only in the intensity of the processes, strongly affected by the soil forming factors. For example there is a small loss of soluble salts and a small gain of organic matter in Aridisols, there is a significant amount of gain in organic matter and recycling of bases in Mollisols. Formation of calcium carbonates from the combination of CO_2 and Ca^{++} is one of the important features in the genesis of

Mollisols. In a process of intense leaching, calcium carbonate leaches out. If leaching is not pronounced this compound accumulates in the profile in the form of powder or concretion and may form a calcic horizon. Quantitative measurement of "calcium carbonate equivalent" is thus the indirect determination of a soil moisture regime.

Smith (1963) states that the soils in a given taxon will have many common properties and that from those we should select the ones which serve our purposes best. In his study of salt affected soils the author of this paper examines those characteristics which are related to the genesis of the soils, and which can be used to construct the framework of their genesis and taxonomy. The amount, type and distribution of soluble salts, exchangeable bases, and pH, together with the other chemical and physical properties of the soil, are the most important measurements required in order to determine the genesis and taxonomy of salt affected soils.

Several limits have been suggested for distinguishing the salt affected soils from normal soils. The United States Salinity Laboratory (1954) used terms which closely agree with the Russian classification of salt affected soils. The term "saline" refers to those soils for which the conductivity of the saturation extract is more than 4 mmhos/cm at 25^{o}C and the ESP is less than 15. Ordinarily, the pH is less than 8.5. These soils correspond to the "white alkali" soils of Hilgard (1906) and to the "solonchaks" of the Russian soil scientists. The term "saline alkali" is applied to soils for which the conductivity of the saturation extract is greater than 4 mmhos/cm at 25^{o}C and the ESP is greater than 15. Under these conditions of excessive salts, the pH readings are seldom higher than 8.5 and the particles remain flocculated. This description is similar to that for soils which the Russian scientists call "Solodized-solonetz." The term "non-saline alkali" is applied to soils for which the ESP is greater than 15 and the conductivity of the saturation extract is less than 4 mmhos/cm at 25°C. The pH reading usually ranges between 8.5 and 10. These soils correspond to Hilgard's "black alkali" soils and to "solonetz" soils described by the Russian scientists. These salt affected soils frequently occur in different types of climatic regions and in irregular sized and shaped spots refered to as "slickspots".

According to Northcote and Skene (1972) the term "salt affected" soil in its broadest sense may be taken to include (i) soils in which the growth of plants is subnormal or where only halophytic species persist, (ii) soil profiles with particular morphologies, and (iii) soils merely containing greater amounts of soluble salts than are found in "normal" soils. As used in their publication the term simply means soils with certain defined saline, sodic, and alkaline properties. The criteria used by these Australian Scientists for soil salinity, sodicity and alkalinity respectively are; chloride ions expressed as the percent sodium chloride equivalent, exchangeable sodium as a percentage of the total cation exchange capacity, and pH of a 1:5 soil:water suspension. Choice of these bases of expression was dictated to some extent by past analytical practices.

All the different morphological, chemical and physical criteria which are used in the various systems of classification reflect genetic influences as well as agricultural interests. It is important for soil scientists to have adequate soil samples with sufficient characterization data in order for them to reflect concepts of genesis in their taxonomy.

Characterization of a typical toposequence of Mollisols and slickspots is the objective of this research paper. The report only introduces the characteristics of the pedogenic horizons, it does not reach any conclusions about their genesis.

Timon (1962) developed a statistical design named "slipped block design". The basic model for this design is the same as for a general two-way classification without interaction. The model is

$$Y_{ijk} = \mu + \rho_i + \beta_j + \tau_k + \varepsilon_{ijk}$$

μ = overall mean effect

ρ_i = effect due to i^{th} replicate $\quad i = 1,2,\ldots\rho.$

β_j = effect due to j^{th} block $\quad j = 1,2,\ldots\beta.$

τ_k = effect due to k^{th} treatment $\quad k = 1,2,\ldots\tau.$

ε_{ijk} = random error associate with Y_{ijk}.

Y_{ijk} = respond due to i^{th} replicate, j^{th} block and k^{th} treatment.

The use of this design should remove the effect of time-to-time laboratory variations and lowers the variance of a treatment mean.

Procedures Applied

The selection of the study site was based on a brief study of aerial photos of Osage County, Oklahoma. Recognizable light tone spots were then examined in the field and it was found that these light spots corresponded to areas dominated by blue grama grasses within a predominantly little bluestem area. Bakhtar and Gray (1971) explained the sampling procedures. Seven deep pits were dug with a back hoe for detailed study (Figure 2.1). Five of the pits reached

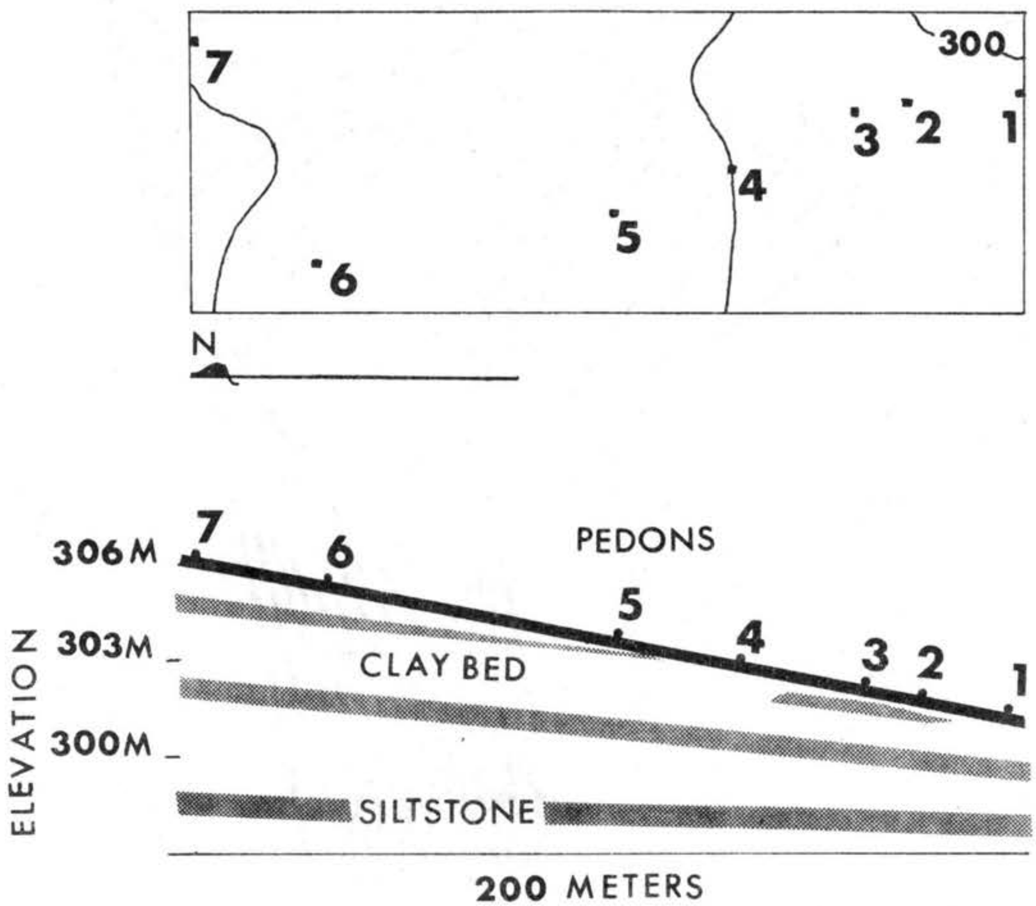


Figure 2.1. A Cross Section of the Toposequence Located in NW¼ of Section 17. T. 25 N., R. 5 E. Osage County Oklahoma

below the ground water level. The authors analyzed the water samples and the data were published in their manuscript.

This study is concerned with the field and laboratory investigations. Field analyses included the study of vegetative covers and morphology of the pedons. Laboratory investigations involve the chemistry, mechanics and mineralogy of the selected pedons.

Vegetation

The vegetative cover of the sampling site was studied using the point method of pasture analysis as explained by Levy (1933). Dr. Wilfred McMurphy of Oklahoma State University who conducted the measurements, used a ten point frame. A total of 400 points were read at each pedon site.

Morphology

In describing the pedons, the nomenclature of horizon designation was the same as that in the Soil Survey Manual (1951) with ammendments from Soil Classification, A Comprehensive System 7th Approximation (1961). All of the pedogenic horizons were described and sampled accurately.

Statistical design

Seven arbitrary soil samples were added to the 79 research samples, and the total was then randomly numbered from 01 through 86. A slipped block design with 86 treatments, 17 basic blocks and two replicates was constructed with the following model:

$$Y_{ijk} = \mu + \rho_i + \beta_j + \tau_k + \varepsilon_{ijk}$$

$i = 1,2$

$j = 1,2,\ldots, 17$

$k = 1,2,\ldots, 86$

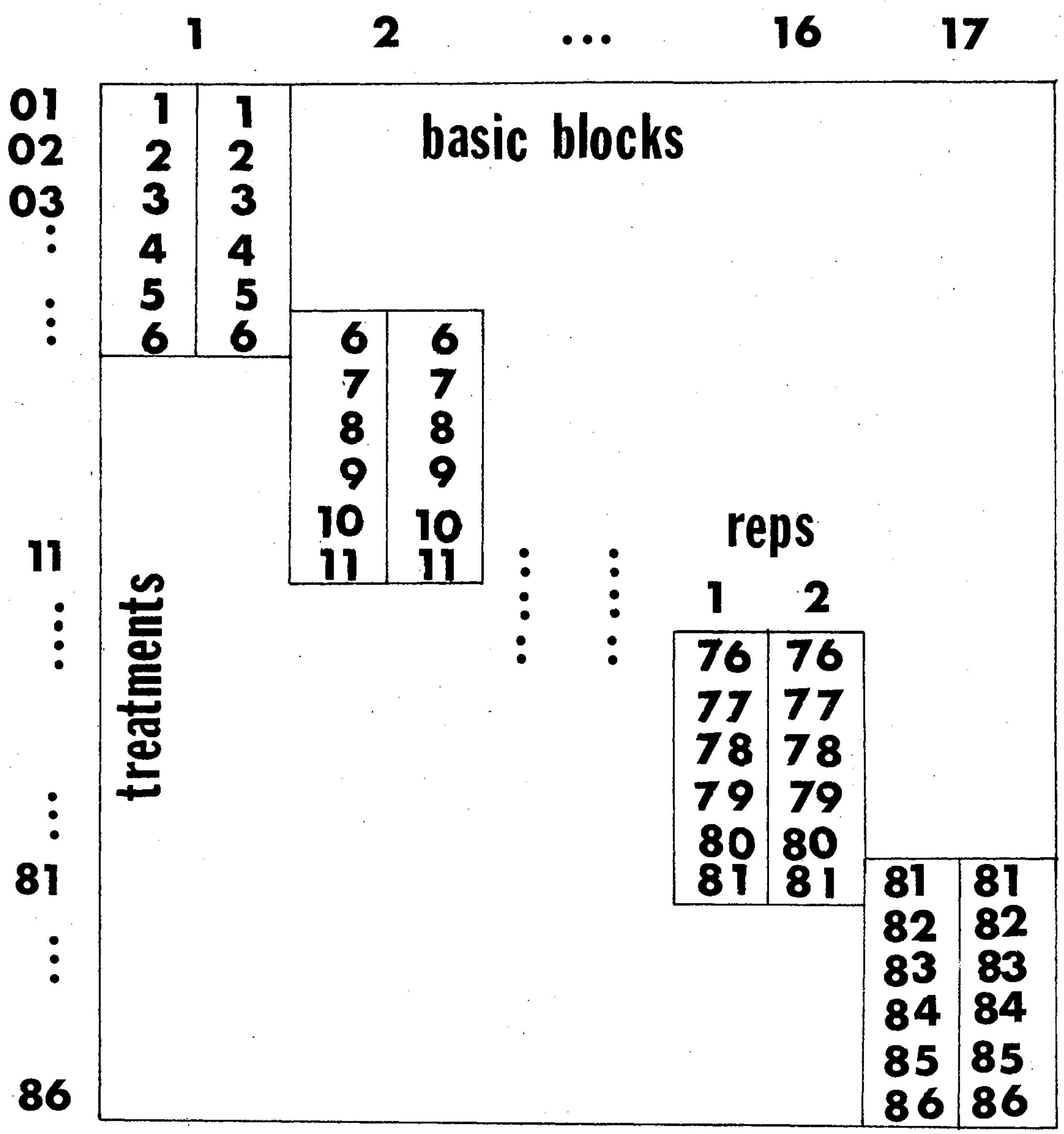
All the laboratory analyses of the samples were carried out using the design (Table 2.1). A multiple regression method was used to adjust the treatment effects according to the block effects, assuming that $\Sigma\rho_i = \Sigma\beta_j = \Sigma\tau_k = 0$. The SAS Program (1972) available in the computer center at Oklahoma State University was used to process the statistical analysis. In order to obtain an adjusted treatment mean, a constant equal to the unadjusted overall mean was added to each treatment effect. For this purpose the treatment effects, which could be either positive or negative, were punched on I.B.M. cards. A FORTRAN Program which was developed for this research was used to compute the adjusted values of physical and chemical properties. This program also produced the histograms related to some properties of the pedons (Appendix A).

Mechanical Analyses

Natural Peds were used for particle size analysis. Since the subsurface horizons contained carbonates as a cementing agent which could prevent the complete dispersion of the soil, a procedure was developed by the author to remove this cementing agent and obtain the complete dispersion of the soil particles. This procedure was the result of combining two procedures earlier developed by the Soil Survey Staff (1967) and Kittrick and Hope (1963). The procedure is explained in the following pages in detail.

TABLE 2.1

SLIPPED BLOCK DESIGN AS USED FOR LABORATORY ANALYSES



A. Materials

1. Cellulose Tubes, 5½ inches wide
2. Buckets, 8-10 liters
3. Paper clips, and rubber bands
4. Plastic or glass tubes ¼ inch in diameter, 5 inches long.
5. Plastic thread
6. Centrifuge tubes 250-ml.

B. Chemicals

1. Sodium Acetate .5 to 1.0 N solution, pH adjusted to 5 using Acetic Acid. (Use technical grade NaAc).
2. Hydrogen Peroxide 35%.

C. Removing carbonates

1. Cut an 8 in. piece of the cellulose tube (5¼ in); make a ½ in. fold. Fold three times on one end, use paper clips to seal it. The tube is now a 6½" x 5½" dialysis membrane sack.
2. Weigh 40 grams of the air dried soil (natural peds or disturbed soil, depending on the purpose of experiment).
3. Add 200 ml of NaAc (B.1.) solution and install a plastic or glass tube in the mouth of the sack. Use a rubber band to shut the mouth of the sack. Move the tube outward so that the end of the plastic or glass tube is not in the soil solution in the sack. Use the plastic thread to suspend the sack in a bucket containing 5 liters of the B.1. solution with the plastic tube above the solution.
4. Leave it for one week. The CO_2 bubbles from the reaction of the carbonates and acid pH solution will fill the sacks, knead the membranes to release bubbles of CO_2. Keep the contents

in the bucket until no more bubbles form. For soils of Oklahoma two weeks should be enough.

5. Siphon the solution into another container, from the bucket, and fill the bucket with city water. Keep the samples in this solution for one week.
6. Siphon off the water, fill the bucket with fresh city water and keep it for 24 hours.
7. Remove the water, and transfer the soil solutions from the sacks into 250 ml centrifuge tubes. Centrifuge at 6000 R.P.M. for 10 minutes, discard the clear solution. Break down the soil in the tube, using 25 ml of distilled water, and a mechanical vibrator, stirring rod, or a malt mixer with a rubber tip.
8. For best results add 25 ml of 0.5 N. NaAc, to the Centrifuge tubes, place in a water bath, and raise the temperature to 75^o - 80^oC. Use glass stirring rods and mix the samples continuously for 30 minutes.
9. Cool the bottles, and centrifuge at 6000 R.P.M. for 10 minutes. Discard the clear solution, add 25 ml of distilled water, and break down the soil again. The sample is now ready for step D.

D. Removing Organic Matter

1. Place the centrifuge tubes in a water bath and add 2 ml of 35% H_2O_2. While stirring the samples raise the temperatures to 75-80^oC. Maintain this temperature, continue stirring the samples, and gradually add 2 ml portions of H_2O_2. When OM is removed the color of the soil tends to be light. For a soil

with 2.5% OM, 10-12 ml of H_2O_2 is usually sufficient for removal.

2. Cool the bottles, centrifuge, and discard the clear solution.
3. Add 50 ml of distilled water, break down the soil in the bottom of the tubes, shake 5 minutes and then centrifuge again. If the solution is clear it means the sample is not dispersed, repeat step D - 3 until the soil goes into dispersion.

E. Complimentary Mechanical Dispersion of Soil

1. Wash the soil suspension in a 10-mesh sieve, (do not use more than 300 ml of water), and collect the material retained by sieve, in a 30 ml beaker, and the material which passed through the sieve is a 400 ml beaker.
2. Use a sonic vibrator, with the large needle, set the dial on 80, and vibrate the sample in the 400 ml beaker for 5 minutes. For best results turn the beaker around the needle continuously to complete the break down of coagulums.
3. Transfer into a 1000 ml hydrometer jar, place in a constant temperature room or water bath, and use either pipette or hydrometer for analysis.

F. Pipette method of analysis

1. Apply the pipette method of analysis as outlined by Day (1965). Use a 25 ml sampling pipette in the constant temperature room. The settling time for 20, 5, and 2-micron particles are 4.68, 75.00, and 469.00 minutes respectively at 21°C. The same author explains all the details for the pipette method of analysis.

2. Pipette 25 ml of the suspension from exactly 10 cm below the existing surface of the solution. Transfer the pipetted material into 100 ml beakers which already have been weighed to a tenth of a milligram with an analytical balance. Wash the pipette with 25 ml of distilled water in the same beaker. Place the beakers in an oven at 100°C for 24 hours. Cool them in a desicator, and weigh the beakers and contents to a tenth of a milligram. The same procedure should be followed after each of the three chosen time intervals.

3. Pass the soil suspension through sieves no. 18, 35, 60, 140, and 270, and wash throughly with distilled water using a rubber hose. Dry the retained material and weigh. Save the suspension which contains silt and clay for clay mineralogy if desired.

G. Calculation

S = original weight of soil

g = weight of material retained on sieve No. 10

om = percent organic matter content of the soil

tss = percent total soluble solids content of the soil

cc = percent calcium carbonate content of the soil

CF = calculation factor which is the function of the removed material.

$$CF = \frac{100.0}{(s-g) - \frac{(S-g)\ (om + tss + cc)}{100}}$$

vcs = dry weight of the particles retained on sieve No. 18

cs = dry weight of the particles retained on sieve No. 35

ms = dry weight of the particles retained on sieve No. 60

fs = dry weight of the particles retained on sieve No. 140

vfs = dry weight of the particles retained on sieve No. 270

msi = dry weight of the particles from the first pipetting

fsi = dry weight of the particles from the second pipetting

c = dry weight of the particles from the third pipetting

Particles coarser than 2 mm	$\% \text{ GRA} = \frac{g. (100)}{S}$
Very coarse sand	% VCS = vcs . CF
Coarse sand	% CS = cs . CF
Medium sand	% MS = ms . CF
Fine sand	% FS = fs . CF
Total sand	% Sand = %VCS+%CS+%MS+%FS+%VFS
Fine silt	% FSI = (fsi - c). CF
Medium silt	% MSI = (msi - fsi). CF
Coarse Silt	% CSI = 100.0 - (% Sand + % Clay + % MSI + % FSI)
Total Silt	% Silt = % CSI + % MSI + % FSI

Chemical Analyses

Chemical analyses were conducted using the methods employed by the soil characterization laboratory at Oklahoma State University. If other procedures were used, necessary modifications were made in order to adapt them to the laboratory facilities and soil conditions.

Unless other sources are named, the constituents of the exchange complex and the soluble components of the soils were measured applying the procedures introduced by the United States Salinity Laboratory

(1954). The amount of extractable bases were measured in a NH_4 - acetate soil extract. The amounts of total soluble salts, soluble cations and anions, were determined in a water soil extract. A 1:5 soil:water mixture was shaken for six hours, then centrifuged at 5000 R.P.M. and the supernatant was filtered through Whatman 42 filter paper using a buchner funnel. Pre-washed celite was used as the filtering aid. Na^+ and K^+ were quantified using a Coleman model 21 flame photometer. The regression of Y (concentration) on the X(scale reading) for the standard solutions were determined and regression equations were used for computing the unknowns. Ca^{++} and Mg^{++} were measured by titrating with 0.01 N EDTA Solution as the titrant. Cl^- was titrated with 0.005 N $AgNO_3$. CO_3^{--} was determined when an aliquet was titrated with 0.01 N HCl using phenolphthalein, to a colorless end point, then titration continued using methyl orange indicator for the HCO_3^- determination. SO_4^{--} was measured applying an adsorption indicator method. The titration was carried out in a mixture of methanol and water. The indicator for titration was Alizarin Red S (sodium alizarin sulfonate), as explained by Fritz and Schenk, Jr. (1969). Total soluble solids and resistivity of the soil water extract were measured applying gravimetric and Weatstone bridge techniques respectively. Conductivity was calculated in micro mhos/cm at 25°C from resistivity figures using a standard solution of 0.01 N KCl.

Extractable Al^{+++} was determined from a leachate of soil with 1.0 N KCl. McLean (1965) gives all the details in Agronomy Monograph No. 9. Extractable acidity was measured using the $Bacl_2$ - triethanolamine method as described by Soil Survey Staff (1967). Soil reaction was determined in a 1:1 mixture of soil and water and also in 1:1 mixture of soil and 1.0 N KCl.

A Perchloric acid - digestion method was used to measure total phosphorus. The molybdovanadophosphoric acid colorimetry method was applied using a model 6D Coleman spectrophotomer, Soil Survey Staff (1967), presents full details on this procedure.

Determination of organic matter was accomplished by grinding the soils to a 60-mesh fineness. The $K_2Cr_2O_7$ oxidation method was applied as explained by United States Salinity Laboratory Staff (1954). Ferrous ammonium sulfate was used as a titrant.

An acetic acid dissolution method was used to measure calcium carbpnate equivalent as introduced by Gedroits (1963). A 5-g soil sample was treated with 50 ml of .5 N acetic acid and the temperature was raised to 60°C on a hot plate. After the reaction was completed and the released Co_2 was removed the sample was cooled and a 25 ml aliquot was titrated with a .25 N NaOH solution.

Mineralogical Analyses

The final step in particle size separation was to separate the sand fractions by passing the suspension through a 270 mesh sieve. The solution containing silt and clay was transferred to an acid jar. The water level was brought to a height of 10 cm, and after three and one-half hours, the upper five cm of the suspension was syphoned off into a 20-liter container. The syphoning was repeated until all the clay particles were separated from the silt size material. The fine clay (<0.2μ), and coarse clay (0.2 to 2.0 μ), was separated by means of a Sharples super centrifuge. The clay subfractions were then flocculated, using $SrCl_2$. The excess water was removed by syphoning and then clay samples were transfered into 250 ml centrifuge tubes and excess salts were throughly washed.

A portion of each clay suspension was placed in a 50-ml centrifuge tube, saturated with $MgCl_2$, and washed throughly with distilled water up to a complete dispersion. The samples were mounted on ceramic slides by the use of a suction plate. A General Electric X-ray (XRD-6) diffractometer was used and 2θ angles for the clay minerals were obtained for Mg - saturated samples. The 2θ angles were again determined after glycerol-solvation, K-saturation, and heating the K-saturated specimen at $500^{o}C$ for four hours. The 2θ angles were then converted into a diffraction spacing and clay minerals were identified qualitatively.

Results

Vegetation

The results of the point method of pasture analysis are presented in Table 2.2. Little Bluestem is the predominant grass in the area of all of the pedons except pedons 1 and 7, where buffalo and blue grama grasses predominate. A direct relationship does not exist between the density or type of vegetative population and sodium content. The total vegetation population is larger in slickspots than in the surrounding normal soils. Slickspots give a light tone to aerial photos due to the abundance of short grasses, not because of the total population of vegetative cover. The predominance of tall grasses within an area such as the study site does not necessarily indicate the absence of sodium in the profile.

TABLE 2.2

ANALYSIS OF VEGETATION COVERING THE RESEARCH AREA

Name	Pedon 1 Count/400	%	Pedon 2 Count/400	%	Pedon 3 Count/400	%	Pedon 4 Count/400	%	Pedon 5 Count/400	%	Pedon 6 Count/400	%	Pedon 7 Count/400	%
Bare ground	272	68	288	72	295	73.7	310	77.5	297	74.2	302	75.5	300	75.0
1. Andropogon scoparius little Bluestem			49	43.7	61	58.0	50	55.5	56	54.3	64	65.3	7	7.0
2. Andropogon gerardi big bluestem			12	10.7	20	19.0	7	7.7	14	13.5	13	13.2	3	3.0
3. Sorghastrum nutans indiangrass			1	.8	4	3.8	12	13.3	13	12.6	7	7.1	1	1.0
4. Panicum virgatum switchgrass			1	.8			3	3.3	2	1.9	3	3.0		
TOTAL DECREASERS	0		63	56.3	85	80.[illegible]	72	80.0	85	82.5	87	88.7	11	11.0
5. Bouteloua curtipendula sideoats grama					5	4.7	1	1.1	1	.9	2	2.0		
6. Eragrostic spectabilis purple lovegrass					1	.9			1	.9				
7. Sporobolus asper tall dropseed			3	2.7	1	.9	3	3.3			2	2.0		
8. Andropogon saccharoides silver bluestem					1	.9	4	4.4			1	1.0	1	1.0
9. Bouteloua gracilis blue grama	94	13.4	7	6.3			-		6	5.8	2	2.0	42	42.0
10. Buchloe dactyloides buffalograss	32	25.0	17	15.2					1	.9			5	5.0
11. Leptoloma cognatum fall witchgrass			2	1.8										
12. Chloris verticillata windmillgrass	1	.8	2	1.8	1	.9			4	3.8			1	1.0
13. Paspalum stramineum sand paspalum			1	.8										
14. Panicum scribnerianum scribner panicum											1	1.0		
15. Bouteloua hirsuta hairy grama									1	.9				
TOTAL INCREASERS	127	39.2	32	28.6	9	8.3	8	8.8	14	13.2	8	8.0	49	49.0
16. Bromus japonicus Japanese brome			3	2.7	1	.9	2	2.2					4	4.0
17. Aristida oligantha prairie threeawn			6	5.4	1	.9	5	5.5	3	2.9	1	1.0	34	34.0
TOTAL ANNUAL GRASSES			9	8.1	2	1.8	7	7.7	3	2.9	1	1.0	38	38.0
18. Ambrosia psilostachya western ragweed	1	.8	3	2.7	1	.9	1	1.1			1	1.0	2	2.0
19. Aster ericoides heath aster			2	1.8	1	.9	1	1.1						
20. vernonia baldwini baldwin ironweed			1	.8			1	1.1			1	1.0		
21. Lespedeza virginica slender lespedeza					2	1.9								
22. Linum sulcatum flax									1	.9				
TOTAL FORBS	1	.8	6	5.3	4	3.7	10	3.3	4	3.8	2	1.0	2	2.0
23. Symphoricarpos orbiculatus buckbrush					4	3.8								
24. Carex spp. sedge			2	1.8	1	.9								
TOTAL VEGETATION	128	32	112	28	105	26.3	90	22.5	103	25.8	98	24.5	100	25.0

Morphology and Laboratory Findings

The toposequence selected for this study is located within the reddish prairie zone. The selected pedons are significantly influenced by the additions, removals, transfers and transformations of the organic and inorganic material during the aging of the system. These processes have enhanced the horizon differentiation and formation of the pedons having individual properties. Study of the genesis and taxonomy of the soils is possible if their characteristics are identified precisely. The following pages present the morphology, mechanics and chemistry of the seven selected pedons. Profile descriptions are abreviated and submitted with the laboratory data. The individual profile descriptions are included in Appendix B of this manuscript.

Pedon 1 (Table 2.3). This is a dark colored soil, developed on a slightly concave relief. The soil is poorly drained and the level of the ground water noted to be at 165 cm below the surface in July. The A horizon is 17 cm thick and presents a platy structure. The value and chroma of the B21t horizon are smaller than AP, due to accumulation of dispersed organic matter in this horizon. Prismatic structure of the subsurface horizons is the important feature of this soil. Prisms are capped with silt loam material which is lighter in color than the prisms. Continuous clay films, segregated calcium carbonates in thread-like form, and fine and medium distinct strong brown mottles are noticable below the B23t horizon. The B3 horizon was noted to be below the surface of the ground water.

The laboratory analyses of the soil samples indicate that clay increases and silt decreases abruptly from the A to the B horizon.

TABLE 2.3

FIELD AND LABORATORY FINDINGS
PEDON 1

PROFILE DESCRIPTION:

SAMPLE NUMBER	LAB NO.	HORIZON	DEPTH	THICKNESS	COLOR(M)	TEXTURE	STRUCTURE	CONSISTENCE
70-CK-57-1-01	77	AP	0- 10CM	10CM	10.0YR 3/2	VFSL	1M&CPL	MVFR
70-CK-57-1-02	30	A1	10- 17CM	7CM	10.0YR 3/1	SIL	1MPL	MVFR,DVH
70-CK-57-1-03	67	B21T	17- 35CM	18CM	10.0YR 2/1	SIC	3MPR-3FABK	MVFI,DEH
70-CK-57-1-04	31	B22TCA	35- 55CM	20CM	10.0YR 3/2	SIC	1CPR-2FABK	MVFI,DEH
70-CK-57-1-05	16	B23T	55- 83CM	28CM	10.0YR 4/2	SICL	1CPR-2MFMABK	MVFI,DEH
70-CK-57-1-06	3	B24T	83-119CM	36CM	10.0YR 4/2	SICL	1MABK	MVFI,DEH
70-CK-57-1-07	42	B25T	119-144CM	25CM	7.5YR 4/2	SICL	1MABK	MVFI,DEH
70-CK-57-1-08	24	B26T	144-165CM	21CM	7.5YR 4/2	SICL	1F&MABK	MVFI,DEH
70-CK-57-1-09	34	B3	165-231CM	66CM	7.5YR 4/2	SIC	1MABK	MVFI,DEH
70-CK-57-1-10	6	C	231-253CM	22CM				

PHYSICAL ANALYSIS:

SAMPLE NUMBER	LAB NO.	PER CENT GRA	VCS	CS	MS	FS	VFS	SAND	CSI	MSI	FSI	SILT	CLAY	CLASS
70-CK-57-1- 1	77	0.00	0.37	0.04	0.13	1.66	5.95	8.15	43.28	31.62	4.62	79.52	12.33	SIL
70-CK-57-1- 2	30	0.89	0.37	0.11	0.24	2.40	7.21	10.34	48.71	23.45	1.25	73.41	16.25	SIL
70-CK-57-1- 3	67	0.00	0.41	0.03	0.11	0.78	1.68	3.00	24.07	30.24	5.00	59.32	37.69	SICL
70-CK-57-1- 4	31	0.87	0.28	0.01	0.10	1.80	5.49	7.77	32.03	20.65	3.05	55.73	36.50	SICL
70-CK-57-1- 5	16	0.87	0.00	0.00	0.09	1.01	4.52	5.58	30.73	20.28	4.11	55.12	40.21	SIC
70-CK-57-1- 6	3	0.00	0.00	0.05	0.16	3.42	5.42	9.05	27.52	16.57	5.34	49.44	42.58	SIC
70-CK-57-1- 7	42	1.35	0.46	0.11	0.26	3.05	5.61	9.49	32.88	16.85	4.42	54.16	36.35	SICL
70-CK-57-1- 8	24	0.99	0.00	0.06	0.09	0.77	5.46	6.38	33.34	16.91	3.83	54.08	40.42	SIC
70-CK-57-1- 9	34	1.06	0.44	0.14	0.15	3.64	8.25	12.62	29.82	14.91	3.47	48.20	39.18	SICL
70-CK-57-1-10	6	9.25	0.00	0.07	0.15	1.78	1.43	3.42	30.58	15.49	8.77	54.84	42.60	SIC

CHEMICAL ANALYSIS:

SAMPLE NUMBER	LAB NO.	EXTRACTABLE CATIONS MEQ/100 GMS CA	MG	K	NA	H	AL	EXCHANGEABLE CATIONS MEQ/100 GMS CA	MG	K	NA	SUM
70-CK-57-1- 1	77	4.47	0.18	0.23	0.95	2.63	0.00	4.47	0.14	0.22	0.47	5.29
70-CK-57-1- 2	30	7.15	3.43	0.10	1.22	1.50	0.00	7.13	3.39	0.08	0.78	11.38
70-CK-57-1- 3	67	17.45	4.97	0.42	6.51	0.02	0.00	17.35	4.84	0.41	4.20	26.80
70-CK-57-1- 4	31	19.97	7.75	0.36	7.15	0.11	0.00	19.95	7.50	0.34	4.76	32.55
70-CK-57-1- 5	16	12.66	7.86	0.40	7.63	0.73	0.00	12.61	7.73	0.38	6.34	27.05
70-CK-57-1- 6	3	16.62	7.44	0.39	6.64	0.00	0.00	16.57	7.40	0.37	5.03	29.37
70-CK-57-1- 7	42	11.83	8.17	0.42	7.35	0.32	0.00	11.83	8.06	0.41	5.74	26.04
70-CK-57-1- 8	24	15.75	9.14	0.34	7.44	0.16	0.00	15.73	9.09	0.33	5.87	31.01
70-CK-57-1- 9	34	16.00	8.58	0.39	6.83	1.09	0.00	16.00	8.47	0.39	5.25	30.11
70-CK-57-1-10	6	36.14	6.31	0.10	3.79	0.00	0.00	36.09	6.23	0.08	2.67	45.08

SAMPLE NUMBER	LAB NO.	SOLUBLE CATIONS MEQ/100 GMS CA	MG	K	NA	SUM	SOLUBLE ANIONS MEQ/100 GMS CL	SO4	CO3	HCO3	SUM
70-CK-57-1- 1	77	0.00	0.05	0.01	0.48	0.54	0.03	0.00	0.03	0.37	0.44
70-CK-57-1- 2	30	0.02	0.04	0.01	0.44	0.51	0.55	0.00	0.06	0.46	1.08
70-CK-57-1- 3	67	0.09	0.13	0.02	2.31	2.55	1.88	0.00	0.03	1.76	3.68
70-CK-57-1- 4	31	0.02	0.25	0.02	2.39	2.68	2.13	0.00	0.06	1.75	3.95
70-CK-57-1- 5	16	0.05	0.13	0.02	1.29	1.50	0.97	0.00	0.07	0.65	1.69
70-CK-57-1- 6	3	0.05	0.05	0.02	1.60	1.72	1.97	0.00	0.00	1.46	3.43
70-CK-57-1- 7	42	0.00	0.10	0.01	1.61	1.73	1.25	0.00	0.03	1.42	2.70
70-CK-57-1- 8	24	0.02	0.06	0.02	1.58	1.67	1.49	0.00	0.19	1.47	3.15
70-CK-57-1- 9	34	0.00	0.11	0.01	1.58	1.69	1.55	0.00	0.11	1.53	3.18
70-CK-57-1-10	6	0.05	0.08	0.02	1.12	1.27	1.32	0.00	0.00	1.26	2.58

SAMPLE NUMBER	LAB NO.	PER CENT OM	PPM TOTAL P	PER CENT CACO3	PER CENT TSS	MIC MHS 1:5 EC	1:1 PH KCL	H2O	MEQ/100 GMS CEC
70-CK-57-1- 1	77	2.36	161.56	0.53	0.02	93.14	5.48	6.72	8.62
70-CK-57-1- 2	30	2.11	158.56	0.67	0.07	99.21	6.03	7.67	12.95
70-CK-57-1- 3	67	2.27	172.56	1.19	0.21	418.01	7.13	8.47	28.36
70-CK-57-1- 4	31	1.84	184.56	1.50	0.31	518.86	7.28	8.62	27.19
70-CK-57-1- 5	16	1.36	190.56	0.91	0.23	282.34	7.03	8.52	28.27
70-CK-57-1- 6	3	0.65	129.56	1.00	0.19	273.25	7.18	8.52	26.51
70-CK-57-1- 7	42	0.62	115.56	1.01	0.13	278.77	7.13	8.42	28.47
70-CK-57-1- 8	24	0.38	121.56	1.36	0.16	270.16	7.08	8.62	28.05
70-CK-57-1- 9	34	0.24	146.56	1.46	0.14	311.50	7.23	8.52	28.22
70-CK-57-1-10	6	0.24	196.56	17.27	0.15	203.47	7.39	8.87	21.44

INTERPRETIVE CALCULATIONS:

SAMPLE NUMBER	LAB NO.	% CA/MG	% CEC/CLAY	ESP	SSP	SAR	% SOLUBLE/EXTRACTABLE CA	MG	% BASE SATURATION NAAC	SUM CAT
70-CK-57-1- 1	77	2435.90	69.94	5.40	91.94	4.44	0.00	34.40	61.37	66.82
70-CK-57-1- 2	30	208.49	79.70	5.99	88.60	3.77	0.26	1.10	87.85	88.33
70-CK-57-1- 3	67	350.84	75.26	14.81	92.85	9.72	0.54	2.73	94.51	99.94
70-CK-57-1- 4	31	257.55	74.51	17.49	92.80	9.22	0.09	3.33	119.70	99.65
70-CK-57-1- 5	16	161.10	70.30	22.43	89.39	6.10	0.40	1.67	95.70	97.37
70-CK-57-1- 6	3	223.28	62.26	18.99	93.93	10.24	0.31	0.63	110.79	100.00
70-CK-57-1- 7	42	144.91	78.32	20.16	95.75	10.08	0.00	1.27	91.48	98.79
70-CK-57-1- 8	24	172.21	69.39	20.92	95.47	11.51	0.12	0.62	110.57	99.48
70-CK-57-1- 9	34	186.58	72.02	18.61	96.00	9.70	0.00	1.25	106.70	96.50
70-CK-57-1-10	6	572.59	50.33	12.47	90.70	6.11	0.14	1.33	210.22	100.00

The clay distribution curve is similar to those of argillic horizons, except that clay content remains nearly constant through the B and C horizons. The particle size distribution of the control section indicates that this pedon fits into the fine textural family. The profile contains more than 1% organic matter to a depth of 55 cm (Figure 3.2). The soil reaction is neutral to basic for the A horizon and strongly basic for the subsurface horizons. The electrical conductivity of the soil water extract shows an insignificant amount of soluble salts. Exchangeable bases occupy more than 60% of the exchange complex of this profile and exchangeable Na^+ saturates 14 to 22% of the cation exchange capacity of the subsurface horizons.

Pedon 2 (Table 2.4). This soil presents a dark colored profile developed on a smooth relief. The soil is poorly drained and the level of the ground water was noted to be at 170 cm below the surface in July. The A horizon is 30 cm thick, with a coarse platy parting to weak medium granular structure. An abrupt smooth boundary exists between the A and B horizons. The upper part of the B horizon presents a strong medium prismatic parting to moderate medium angular blocky structure. The upper part of the B horizon presents a strong medium prismatic parting to moderate medium angular blocky structure. The upper 2.5 cm of prisms are capped and sides are coated with a silt loam material which presents a lighter color than the prisms. Continuous clay films are observable in subsurface horizons. About 50% of the peds are coated with dark gray organic stains while fine distinct strong brown mottles are observable within the B horizon above the level of the ground water. Calcium carbonate concretions are present more than 100 cm from the surface.

TABLE 2.4

FIELD AND LABORATORY FINDINGS
PEDON 2

PROFILE DESCRIPTION:

SAMPLE NUMBER	LAB NO.	HORIZON	DEPTH	THICKNESS	COLOR(M)	TEXTURE	STRUCTURE	CONSISTENCE
70-CK-57-2-01	25	AP	0- 20CM	20CM	10.0YR 3/1	VFSL	1MCPL-1MGR	MVFR,DH
70-CK-57-2-02	4	A1	20- 30CM	10CM	10.0YR 3/1	SIL	M	MVFR,DH
70-CK-57-2-03	48	B21T	30- 48CM	18CM	10.0YR 2/2	SICL	3MPR-2MABK	MFI,DVH
70-CK-57-2-04	43	B22T	48- 71CM	23CM	10.0YR 3/2	SICL	2MPR-2F&MAB	MVFI,DEH
70-CK-57-2-05	23	B23T	71- 99CM	28CM	10.0YR 4/2	SIC	1CPR-1MABK	MVFI,DEH
70-CK-57-2-06	20	B24TCA	99-119CM	20CM	10.0YR 4/2	SIC	1MABK	MVFI,DEH
70-CK-57-2-07	36	B25TCA	119-154CM	35CM	10.0YR 4/2	SIC	1F&MABK	MVFI,DEH
70-CK-57-2-08	81	B26T	154-170CM	16CM	10.0YR 4/2	SIC	1MABK	MVFI,DEH
70-CK-57-2-09	58	B3	170-223CM	53CM	10.0YR 4/3	SIC	1M&CABK	MVFI,DEH
70-CK-57-2-10	53	C	223-259CM	36CM				

PHYSICAL ANALYSIS:

SAMPLE NUMBER	LAB NO.	PER CENT GRA	VCS	CS	MS	FS	VFS	SAND	CSI	MSI	FSI	SILT	CLAY	CLASS
70-CK-57-2- 1	25	0.89	0.00	0.04	0.11	0.81	5.57	6.52	53.06	17.30	1.73	72.14	22.22	SIL
70-CK-57-2- 2	4	0.00	0.00	0.05	0.20	4.01	7.94	12.20	49.35	14.67	3.36	67.38	21.52	SIL
70-CK-57-2- 3	48	1.30	0.50	0.11	0.30	2.34	4.46	7.70	47.55	14.35	3.24	65.14	27.16	SICL
70-CK-57-2- 4	43	1.24	0.52	0.12	0.26	2.88	6.25	10.03	36.13	14.64	3.02	53.78	36.19	SICL
70-CK-57-2- 5	23	0.94	0.00	0.00	0.00	0.08	4.45	4.54	35.94	15.55	3.18	54.57	41.82	SIC
70-CK-57-2- 6	20	0.94	0.00	0.00	0.00	1.39	5.50	6.89	34.60	16.07	3.30	53.96	40.10	SIC
70-CK-57-2- 7	36	1.22	0.46	0.07	0.19	3.31	8.82	12.86	33.30	13.75	3.05	50.11	37.04	SICL
70-CK-57-2- 8	81	0.00	0.39	0.03	0.07	2.73	7.87	11.09	23.88	24.58	4.83	53.29	35.62	SICL
70-CK-57-2- 9	58	0.75	0.49	0.06	0.15	2.60	5.75	9.05	32.50	22.79	3.73	59.02	31.93	SICL
70-CK-57-2-10	53	1.54	0.55	0.16	0.33	4.75	8.41	14.21	46.37	8.60	3.25	58.22	27.57	SICL

CHEMICAL ANALYSIS:

SAMPLE NUMBER	LAB NO.	EXTRACTABLE CATIONS MEQ/100 GMS CA	MG	K	NA	H	AL	EXCHANGEABLE CATIONS MEQ/100 GMS CA	MG	K	NA	SUM
70-CK-57-2- 1	25	9.88	5.02	0.15	1.44	2.79	0.00	9.80	4.92	0.13	1.08	15.94
70-CK-57-2- 2	4	11.42	3.22	0.09	0.67	1.75	0.00	11.37	3.19	0.08	0.49	15.14
70-CK-57-2- 3	48	10.08	6.11	0.28	3.34	2.18	0.00	10.06	5.99	0.27	2.92	19.25
70-CK-57-2- 4	43	12.40	2.81	0.30	5.94	0.65	0.00	12.40	2.72	0.30	5.23	20.65
70-CK-57-2- 5	23	17.45	10.69	0.30	7.41	0.00	0.00	17.40	10.61	0.29	5.78	34.08
70-CK-57-2- 6	20	9.26	15.79	0.33	7.13	0.00	0.00	9.21	15.68	0.31	5.53	30.73
70-CK-57-2- 7	36	16.67	10.28	0.32	6.19	0.00	0.00	16.67	10.16	0.32	4.65	31.80
70-CK-57-2- 8	81	12.81	7.55	0.37	5.42	0.00	0.00	12.81	7.46	0.36	4.05	24.68
70-CK-57-2- 9	58	23.32	8.27	0.37	4.35	0.00	0.00	23.32	8.13	0.36	3.16	34.98
70-CK-57-2-10	53	13.84	6.98	0.36	1.94	0.00	0.00	13.83	6.78	0.35	1.52	22.48

SAMPLE NUMBER	LAB NO.	SOLUBLE CATIONS MEQ/100 GMS CA	MG	K	NA	SUM	SOLUBLE ANIONS MEQ/100 GMS CL	SO4	CO3	HCO3	SUM
70-CK-57-2- 1	25	0.08	0.10	0.02	0.36	0.56	0.53	0.00	0.07	0.56	1.16
70-CK-57-2- 2	4	0.05	0.03	0.01	0.17	0.27	0.32	0.00	0.00	0.36	0.68
70-CK-57-2- 3	48	0.02	0.11	0.01	0.42	0.56	0.56	0.00	0.03	0.48	1.08
70-CK-57-2- 4	43	0.00	0.09	0.00	0.71	0.80	0.35	0.00	0.03	0.72	1.60
70-CK-57-2- 5	23	0.04	0.08	0.02	1.62	1.77	1.40	0.00	0.17	1.45	3.02
70-CK-57-2- 6	20	0.05	0.11	0.02	1.60	1.78	2.01	0.00	0.07	1.76	3.85
70-CK-57-2- 7	36	0.00	0.12	0.01	1.54	1.67	1.63	0.00	0.09	1.49	3.20
70-CK-57-2- 8	81	0.00	0.08	0.01	1.38	1.47	1.10	0.00	0.03	1.18	2.31
70-CK-57-2- 9	58	0.00	0.14	0.01	1.19	1.33	1.01	0.00	0.03	1.17	2.21
70-CK-57-2-10	53	0.01	0.20	0.01	0.42	0.64	0.70	0.00	0.03	0.53	1.26

SAMPLE NUMBER	LAB NO.	PER CENT OC	PPM TOTAL P	PER CENT CACO3	PER CENT TSS	MIC MHS 1:5 EC	1:1 PH KCL	H2O	MEQ/100 GMS CEC
70-CK-57-2- 1	25	3.09	228.56	0.72	0.13	45.54	5.73	7.02	18.04
70-CK-57-2- 2	4	2.43	174.56	0.44	0.09	29.23	5.73	7.02	13.95
70-CK-57-2- 3	48	2.15	153.56	0.71	0.06	109.33	5.98	6.97	22.16
70-CK-57-2- 4	43	1.29	139.56	0.83	0.07	172.31	6.58	7.77	31.53
70-CK-57-2- 5	23	0.63	124.56	1.79	0.21	297.61	7.08	8.62	31.14
70-CK-57-2- 6	20	0.62	122.56	1.34	0.18	327.05	7.18	8.62	29.33
70-CK-57-2- 7	36	0.32	125.56	1.44	0.13	311.50	7.28	8.52	23.74
70-CK-57-2- 8	81	0.24	153.56	1.10	0.07	283.70	6.88	8.37	23.14
70-CK-57-2- 9	59	0.08	165.56	1.74	0.06	249.00	7.13	8.42	30.96
70-CK-57-2-10	53	0.04	182.56	0.63	0.02	97.08	6.68	7.72	26.01

INTERPRETIVE CALCULATIONS:

SAMPLE NUMBER	LAB NO.	% CA/MG	% CEC/CLAY	ESP	SSP	SAR	% SOLUBLE/EXTRACTABLE CA	MG	% BASE SATURATION NAAC	SUM CAT
70-CK-57-2- 1	25	196.57	81.16	6.02	69.64	1.67	0.82	2.09	88.36	85.12
70-CK-57-2- 2	4	354.49	64.81	3.54	68.45	1.25	0.45	0.85	109.54	89.66
70-CK-57-2- 3	48	165.12	81.61	13.19	82.11	2.32	0.18	1.88	86.37	89.82
70-CK-57-2- 4	43	441.28	87.14	16.58	93.57	4.86	0.00	3.17	65.50	96.97
70-CK-57-2- 5	23	163.22	74.45	18.58	93.74	9.10	0.26	0.78	109.46	100.00
70-CK-57-2- 6	20	58.64	73.15	18.84	92.25	8.08	0.55	0.68	104.77	100.00
70-CK-57-2- 7	36	162.24	77.61	16.19	95.41	8.79	0.00	1.20	110.63	100.00
70-CK-57-2- 8	81	169.74	64.97	17.48	95.80	9.57	0.00	1.11	106.63	100.00
70-CK-57-2- 9	58	281.99	96.98	10.22	93.40	6.48	0.00	1.66	112.96	100.00
70-CK-57-2-10	53	198.27	94.33	5.83	76.95	1.63	0.08	2.96	86.43	100.00

The results of the laboratory examinations indicate more than a 25% increase in clay content from A to B, which increases to B23t and reduces gradually to the bottom of the profile. The particle size distribution of the upper 100 cm indicates that this soil belongs to the fine family in textural classification. Organic matter decreases gradually from the surface to the bottom of the profile, staying above 1% in the top 77 cm (Figure 3.4). The A and B21t horizons are neutral in reaction and the lower horizons have a basic reaction. The electrical conductivity of the soil water extract indicates no evidence of salinity. Exchangeable bases have saturated more than 60% of the exchange complex in the descending order of; Ca^{++}, Mg^{++}, Na^{+} and K^{+}. Exchangeable sodium also saturates from 13 to 18% of the cation exchange capacity of the subsurface horizons.

Pedon 3 (Table 2.5). This profile consists of dark-colored horizons developed on a smooth relief. The soil is moderately well drained and the level of the ground water was noted to be at a depth of 190 cm from the surface in July. The A horizon is 40 cm thick with a mainly granular structure. The B horizon displays some prismatic parting to granular structure. Continuous clay films, a few non intersecting slickensides, and strong brown mottles are noticeable in the subsurface horizons. The B3 horizon was noted to be below the level of the ground water.

The laboratory analyses of the soil samples indicate a high amount of silt which decreases with depth. Clay content increases about 20% from A1 to A3 horizon. The particle size distribution of the control section indicates that this soil belongs to the fine silty family in textural classification. This soil contains more

TABLE 2.5

FIELD AND LABORATORY FINDINGS
PEDON 3

PROFILE DESCRIPTION:

SAMPLE NUMBER	LAB NO.	HORIZON	DEPTH	THICKNESS	COLOR(M)	TEXTURE	STRUCTURE	CONSISTENCE
70-CK-57-3-01	44	AP	0- 15CM	15CM	10.0YR 2/1	SIL	1MSBK-2MGR	MVFR,DH
70-CK-57-3-02	13	A1	15- 22CM	7CM	10.0YR 2/1	SIL	2MGR	MVFR,DH
70-CK-57-3-03	5	A3	22- 40CM	18CM	10.0YR 2/2	SIL	1CPR-2MGR	MFR,DH
70-CK-57-3-04	76	B1	40- 53CM	13CM	10.0YR 3/2	SICL	1M&CPR-2MGR	MFR,DVH
70-CK-57-3-05	64	B21T	53- 66CM	13CM	7.5YR 3/2	SICL	2MPR-2MGR	MFI-DVH
70-CK-57-3-06	80	B22T	66- 99CM	33CM	7.5YR 4/2	SICL	2MPR-2F&MABK	MVFI,DEH
70-CK-57-3-07	2	B23T	99-126CM	27CM	7.5YR 4/2	SIC	1MPR-2MABK	MVFI,DEH
70-CK-57-3-08	10	B24T	126-149CM	23CM	7.5YR 4/2	SIC	1M&CABK	MVFI,DEH
70-CK-57-3-09	73	B25TCA	149-170CM	21CM	7.5YR 4/2	SIC	1M&CABK	MVFI,DEH
70-CK-57-3-10	17	B26T	170-190CM	20CM	7.5YR 4/4	SIC	1M&CABK	MVFI,DEH
70-CK-57-3-11	33	B31	190-226CM	36CM	7.5YR 5/4	SIC	1CABK	MVFI,DEH
70-CK-57-3-12	11	C	226-256CM	30CM	5.0YR 5/6	SICL	M	MVFI,DEH

PHYSICAL ANALYSIS:

SAMPLE NUMBER	LAB NO.	PER CENT GRA	VCS	CS	MS	FS	VFS	SAND	CSI	MSI	FSI	SILT	CLAY	CLASS
70-CK-57-3- 1	44	1.21	0.44	0.07	0.19	3.49	7.97	12.17	49.14	13.55	2.33	65.02	22.81	SIL
70-CK-57-3- 2	13	0.77	0.00	0.00	0.07	1.08	8.02	9.17	46.43	13.35	3.65	63.43	28.32	SICL
70-CK-57-3- 3	5	0.00	0.00	0.04	0.13	3.94	7.58	11.69	40.85	11.27	3.24	55.36	34.03	SICL
70-CK-57-3- 4	76	0.00	0.38	0.01	0.05	2.31	6.76	9.51	30.61	25.20	4.01	59.81	30.67	SICL
70-CK-57-3- 5	64	0.00	0.41	0.00	0.08	1.76	4.04	6.30	34.61	24.29	3.86	62.75	30.96	SICL
70-CK-57-3- 6	80	0.00	0.43	0.04	0.09	2.26	6.46	9.29	25.54	26.94	2.79	55.27	35.45	SICL
70-CK-57-3- 7	2	0.00	0.00	0.09	0.21	3.84	6.54	10.68	28.17	12.66	4.85	45.68	44.67	SIC
70-CK-57-3- 8	10	0.40	0.00	0.10	0.25	3.98	6.91	11.25	32.45	12.75	4.99	50.18	39.52	SICL
70-CK-57-3- 9	73	0.47	0.49	0.13	0.11	2.98	6.76	10.47	22.13	22.47	5.12	49.72	39.81	SICL
70-CK-57-3-10	17	1.84	0.00	0.08	0.05	3.06	8.71	11.90	31.66	10.84	2.78	45.28	43.62	SIC
70-CK-57-3-11	33	0.96	0.45	0.07	0.11	4.23	10.44	15.31	35.04	9.50	1.97	46.51	39.18	SICL
70-CK-57-3-12	11	1.61	0.00	0.42	0.48	4.92	11.36	17.18	36.36	6.97	3.66	48.98	34.50	SICL

CHEMICAL ANALYSIS:

SAMPLE NUMBER	LAB NO.	EXTRACTABLE CATIONS MEQ/100 GMS CA	MG	K	NA	H	AL	EXCHANGEABLE CATIONS MEQ/100 GMS CA	MG	K	NA	SUM
70-CK-57-3- 1	44	11.06	10.43	0.55	0.37	6.07	0.00	11.00	10.13	0.49	0.32	21.94
70-CK-57-3- 2	13	12.45	5.03	0.34	0.07	5.82	0.00	12.30	4.88	0.30	0.07	17.55
70-CK-57-3- 3	5	13.53	5.49	0.27	0.05	6.28	0.00	13.41	5.37	0.25	0.05	19.08
70-CK-57-3- 4	76	10.44	2.91	0.38	0.62	5.41	0.00	10.42	2.79	0.37	0.25	13.83
70-CK-57-3- 5	64	10.80	3.74	0.37	0.45	6.05	0.00	10.40	3.60	0.36	0.31	15.07
70-CK-57-3- 6	80	12.66	4.77	0.45	0.87	4.99	0.00	12.66	4.67	0.44	0.52	18.29
70-CK-57-3- 7	2	17.96	9.37	0.38	0.55	2.91	0.00	17.91	8.31	0.37	0.44	27.02
70-CK-57-3- 8	10	16.67	8.06	0.35	0.64	2.28	0.00	16.62	7.95	0.33	0.50	25.40
70-CK-57-3- 9	73	22.65	4.56	0.43	1.29	0.88	0.00	22.36	4.26	0.41	0.62	27.65
70-CK-57-3-10	17	28.83	8.32	0.33	1.55	0.08	0.00	28.51	8.00	0.32	1.28	38.11
70-CK-57-3-11	33	17.19	7.55	0.36	1.21	1.35	0.00	17.16	7.20	0.35	0.80	25.52
70-CK-57-3-12	11	14.82	6.62	0.30	0.59	2.64	0.00	14.77	6.54	0.29	0.48	22.08

SAMPLE NUMBER	LAB NO.	SOLUBLE CATIONS MEQ/100 GMS CA	MG	K	NA	SUM	SOLUBLE ANIONS MEQ/100 GMS CL	SO4	CO3	HCO3	SUM
70-CK-57-3- 1	44	0.06	0.30	0.06	0.05	0.47	0.39	0.00	0.03	0.42	0.84
70-CK-57-3- 2	13	0.15	0.20	0.03	0.00	0.38	0.18	0.00	0.00	0.28	0.46
70-CK-57-3- 3	5	0.12	0.12	0.02	0.00	0.26	0.14	0.00	0.00	0.20	0.34
70-CK-57-3- 4	76	0.02	0.13	0.02	0.36	0.53	0.10	0.00	0.03	0.32	0.45
70-CK-57-3- 5	64	0.00	0.14	0.01	0.14	0.28	0.20	0.00	0.03	0.29	0.52
70-CK-57-3- 6	80	0.00	0.10	0.01	0.35	0.45	0.09	0.00	0.03	0.23	0.35
70-CK-57-3- 7	2	0.05	0.07	0.01	0.11	0.24	0.19	0.00	0.00	0.15	0.35
70-CK-57-3- 8	10	0.05	0.11	0.02	0.15	0.33	0.25	0.00	0.00	0.30	0.55
70-CK-57-3- 9	73	0.29	0.30	0.02	0.67	1.27	0.85	0.00	0.03	0.93	1.82
70-CK-57-3-10	17	0.32	0.33	0.02	0.36	1.02	0.97	0.00	0.07	0.84	1.88
70-CK-57-3-11	33	0.03	0.34	0.01	0.40	0.78	0.70	0.00	0.03	0.64	1.38
70-CK-57-3-12	11	0.05	0.08	0.01	0.11	0.25	0.26	0.00	0.00	0.30	0.56

SAMPLE NUMBER	LAB NO.	PER CENT OM	PPM TOTAL P	PER CENT CACO3	PER CENT TSS	MIC MHS 1:5 EC	1:1 PH KCL	H2O	MEQ/100 GMS CEC
70-CK-57-3- 1	44	4.48	275.56	0.53	0.07	78.27	5.48	6.17	22.88
70-CK-57-3- 2	13	3.73	248.56	0.48	0.11	20.58	5.53	6.52	20.83
70-CK-57-3- 3	5	3.03	219.56	0.61	0.09	11.55	5.28	6.37	22.16
70-CK-57-3- 4	76	2.61	196.56	0.64	0.01	86.98	5.33	6.47	19.56
70-CK-57-3- 5	64	2.07	180.56	0.73	0.00	204.40	5.48	6.57	24.33
70-CK-57-3- 6	80	1.20	143.56	0.65	0.02	79.06	5.48	6.77	23.61
70-CK-57-3- 7	2	0.87	128.56	0.95	0.09	30.06	6.23	7.42	29.06
70-CK-57-3- 8	10	0.63	121.56	0.66	0.08	37.37	6.58	7.62	29.19
70-CK-57-3- 9	73	0.58	93.56	1.43	0.04	210.05	6.98	8.07	25.32
70-CK-57-3-10	17	0.52	105.56	2.61	0.15	156.47	7.18	8.17	30.16
70-CK-57-3-11	33	0.42	98.56	1.10	0.07	130.86	6.88	8.12	27.34
70-CK-57-3-12	11	0.30	142.56	0.75	0.07	22.48	6.53	7.67	23.47

INTERPRETIVE CALCULATIONS:

SAMPLE NUMBER	LAB NO.	% CA/MG	% CEC/CLAY	ESP	SSP	SAR	% SOLUBLE/EXTRACTABLE CA	MG	% BASE SATURATION NAAC	SUM CAT
70-CK-57-3- 1	44	106.03	100.29	1.38	14.30	0.18	0.52	2.99	95.90	78.32
70-CK-57-3- 2	13	245.30	73.56	0.36	0.00	0.00	1.24	4.05	84.27	75.10
70-CK-57-3- 3	5	246.59	65.10	0.23	0.00	0.00	0.89	2.28	86.11	75.23
70-CK-57-3- 4	76	358.50	63.77	1.30	75.93	1.88	0.24	4.50	70.69	71.88
70-CK-57-3- 5	64	289.10	78.59	1.26	62.14	0.76	0.00	3.76	61.94	71.35
70-CK-57-3- 6	80	265.52	66.61	2.20	84.02	2.24	0.00	2.06	77.47	78.58
70-CK-57-3- 7	2	214.55	65.05	1.52	51.09	0.63	0.28	0.80	93.00	90.29
70-CK-57-3- 8	10	206.80	73.86	1.70	52.65	0.73	0.31	1.41	87.03	91.77
70-CK-57-3- 9	73	496.57	63.60	2.43	60.72	1.76	1.28	7.02	109.21	96.93
70-CK-57-3-10	17	346.48	69.15	4.25	43.14	0.91	1.11	4.07	126.32	99.80
70-CK-57-3-11	33	227.74	71.61	2.94	64.82	1.32	0.16	4.79	93.33	94.99
70-CK-57-3-12	11	223.84	68.01	2.05	50.85	0.63	0.35	1.17	94.11	89.32

than 1% organic matter from the surface to the depth of 100 cm (Figure 3.6). Soil reaction varies from acid to neutral, basic and strongly basic within the profile. Base saturation is more than 60% of the total cation exchange capacity. Exchangeable sodium saturates a negligible percentage of the exchange complex.

Pedon 4 (Table 2.6). This profile is a dark colored soil developed on a smooth relief with 2% slope. The soil is somewhat poorly drained, and the level of ground water was not found within 320 cm of the surface at the time of sampling. The A horizon is 33 cm thick with a platy structure. An abrupt wavy boundary separates the A and B horizons. The B horizon presents a moderate coarse prismatic, parting to moderate medium angular blocky structure. Prisms are coated and have 2 cm caps of silty loam material which are very dark grayish brown in color. Continuous clay films, fine black concretions, and very dark brown organic stains are observable below the B1 horizon. Calcium concretions are also occurring in B23tca and lower horizons.

Laboratory data denote an increase of about 50% in clay content from the A to the B horizons. Clay content increases with depth, and the C2 horizon contains 82% total clay. The particle size analysis of the control section places this pedon in the fine textural family. Organic matter decreases within the profile, but the top 100 cm contains more than 1% organic matter (Figure 3.9). The soil reaction is neutral in the first 80 cm and changes to strongly basic in the lower parts of the profile. Exchangeable bases are in the order of: Ca^{++}, Mg^{++}, Na^{+}, and K^{+} and saturate more than 60% of the total cation exchange capacity. Exchangeable sodium saturates 14 to 19% of the

TABLE 2.6

FIELD AND LABORATORY FINDINGS
PEDON 4

PROFILE DESCRIPTION:

SAMPLE NUMBER	LAB NO.	HORIZON	DEPTH	THICKNESS	COLOR(M)	TEXTURE	STRUCTURE	CONSISTENCE
70-CK-57-4-01	40	AP	0- 22CM	22CM	10.0YR 2/2	SIL	1M&CPL	MVFR,DH
70-CK-57-4-02	75	A1	22- 33CM	11CM	10.0YR 3/2	SIL	1CPL	MVFR,DH
70-CK-57-4-03	83	B1	33- 53CM	20CM	10.0YR 4/3	SICL	2CPR-2MABK	MFI,DEH
70-CK-57-4-04	63	B21T	53- 81CM	28CM	7.5YR 3/2	SICL	2MPR-3F&MABK	MVFI,DEH
70-CK-57-4-05	66	B22T	81-104CM	23CM	7.5YR 4/2	SICL	1CPR-2F&MABK	MVFI,DEH
70-CK-57-4-06	49	B22TCA	104-124CM	20CM	7.5YR 4/4	SICL	2MABK	MVFI,DEH
70-CK-57-4-07	35	B23TCA	124-152CM	28CM	5.0YR 4/4	SICL	1MABK	MFI,DEH
70-CK-57-4-08	74	B24T	152-180CM	28CM	5.0YR 4/6	SICL	1MABK	MFI,DEH
70-CK-57-4-09	15	B31	180-200CM	20CM	2.5YR 4/4	SIC	1M&CABK	MFI,DEH
70-CK-57-4-10	61	B32CA	200-228CM	28CM	5.0YR 4/6	SICL	1MABK	MFI,DVH
70-CK-57-4-11	59	C1	228-259CM	31CM	5.0YR 4/4	C		MVFI,DEH
70-CK-57-4-12	45	C2	259-289CM	30CM	5.0YR 4/4	C		
70-CK-57-4-13	27	C3	289-320CM	31CM	5.0YR 4/4	C		

PHYSICAL ANALYSIS:

SAMPLE NUMBER	LAB NO.	PER CENT GRA	VCS	CS	MS	FS	VFS	SAND	CSI	MSI	FSI	SILT	CLAY	CLASS
70-CK-57-4- 1	40	1.17	0.40	0.06	0.27	6.22	9.88	16.84	55.77	6.24	1.68	63.70	19.46	SIL
70-CK-57-4- 2	75	0.00	0.38	0.08	0.19	3.73	13.17	17.55	33.51	26.17	3.89	63.57	18.87	SIL
70-CK-57-4- 3	83	0.00	0.42	0.03	0.10	2.84	7.64	11.01	27.31	24.24	6.63	58.18	30.80	SICL
70-CK-57-4- 4	63	0.00	0.41	0.00	0.08	1.74	2.33	4.55	28.32	25.25	5.14	58.71	36.78	SICL
70-CK-57-4- 5	66	0.00	0.42	0.01	0.07	1.77	3.85	6.12	25.21	25.59	5.53	56.33	37.55	SICL
70-CK-57-4- 6	49	1.47	0.52	0.11	0.23	2.63	4.85	8.34	36.60	13.47	4.88	54.95	36.71	SICL
70-CK-57-4- 7	35	3.85	0.42	0.06	0.04	3.39	8.54	12.45	28.24	11.77	3.95	43.96	43.59	SIC
70-CK-57-4- 8	74	0.00	0.50	0.09	0.11	3.31	6.36	10.36	15.66	22.65	6.98	45.68	43.95	SIC
70-CK-57-4- 9	15	1.09	0.00	0.05	0.04	0.45	3.43	3.98	17.03	14.73	13.67	45.43	51.43	SIC
70-CK-57-4-10	61	0.76	0.57	0.09	0.10	0.00	0.00	0.76	9.05	20.92	17.35	47.32	53.18	SIC
70-CK-57-4-11	59	16.97	2.39	1.29	1.27	1.46	2.90	9.30	16.73	12.87	9.56	39.16	51.54	C
70-CK-57-4-12	45	2.50	0.67	0.43	0.59	1.25	1.68	4.62	11.48	0.00	4.28	15.76	82.28	C
70-CK-57-4-13	27	3.25	0.70	0.67	0.68	1.12	2.16	5.34	7.16	2.53	13.32	23.01	71.66	C

CHEMICAL ANALYSIS:

SAMPLE NUMBER	LAB NO.	EXTRACTABLE CATIONS MEQ/100 GMS CA	MG	K	NA	H	AL	EXCHANGEABLE CATIONS MEQ/100 GMS CA	MG	K	NA	SUM
70-CK-57-4- 1	40	8.90	3.69	0.20	0.62	4.19	0.00	8.89	3.46	0.18	0.41	12.93
70-CK-57-4- 2	75	5.24	0.80	0.22	1.24	3.81	0.00	5.24	0.77	0.21	0.75	6.97
70-CK-57-4- 3	83	5.45	1.99	0.29	2.65	3.28	0.00	5.45	1.97	0.28	2.20	9.90
70-CK-57-4- 4	63	9.67	5.59	0.33	4.56	2.51	0.00	9.67	5.53	0.33	3.98	19.50
70-CK-57-4- 5	66	10.24	5.64	0.34	5.68	0.40	0.00	10.24	5.58	0.33	4.95	21.10
70-CK-57-4- 6	49	11.88	7.44	0.30	5.89	0.09	0.00	11.88	7.34	0.29	4.69	24.19
70-CK-57-4- 7	35	13.58	7.85	0.25	5.85	0.73	0.00	13.58	7.75	0.24	4.54	26.12
70-CK-57-4- 8	74	11.37	5.80	0.31	5.79	0.42	0.00	11.37	5.76	0.31	4.98	22.41
70-CK-57-4- 9	15	15.75	8.84	0.14	4.72	0.66	0.00	15.70	8.77	0.12	4.08	28.67
70-CK-57-4-10	61	37.74	7.75	0.22	5.33	0.00	0.00	37.74	7.60	0.21	3.88	49.42
70-CK-57-4-11	59	38.15	7.29	0.32	4.04	0.00	0.00	38.15	7.16	0.31	3.04	48.66
70-CK-57-4-12	45	40.26	6.67	0.20	3.80	0.00	0.00	40.26	6.50	0.19	2.84	49.80
70-CK-57-4-13	27	28.16	9.81	0.19	2.75	0.00	0.00	28.08	9.70	0.18	2.01	39.96

SAMPLE NUMBER	LAB NO.	SOLUBLE CATIONS MEQ/100 GMS CA	MG	K	NA	SUM	SOLUBLE ANIONS MEQ/100 GMS CL	SO4	CO3	HCO3	SUM
70-CK-57-4- 1	40	0.01	0.23	0.02	0.21	0.47	0.53	0.00	0.03	0.46	1.03
70-CK-57-4- 2	75	0.00	0.03	0.01	0.49	0.53	0.04	0.00	0.03	0.33	0.41
70-CK-57-4- 3	83	0.00	0.02	0.01	0.44	0.47	0.00	0.00	0.03	0.40	0.44
70-CK-57-4- 4	63	0.00	0.06	0.01	0.58	0.65	0.45	0.00	0.03	0.40	0.88
70-CK-57-4- 5	66	0.00	0.06	0.01	0.72	0.79	0.50	0.00	0.03	0.45	0.98
70-CK-57-4- 6	49	0.00	0.11	0.01	1.21	1.33	1.16	0.00	0.03	1.04	2.23
70-CK-57-4- 7	35	0.00	0.10	0.01	1.32	1.44	1.29	0.00	0.09	1.26	2.64
70-CK-57-4- 8	74	0.00	0.03	0.01	0.82	0.86	0.11	0.00	0.03	0.57	0.71
70-CK-57-4- 9	15	0.05	0.06	0.01	0.65	0.77	0.25	0.00	0.00	0.35	0.60
70-CK-57-4-10	61	0.00	0.15	0.01	1.46	1.62	1.24	0.00	0.03	1.32	2.60
70-CK-57-4-11	59	0.00	0.13	0.01	1.00	1.14	0.90	0.00	0.03	1.10	2.04
70-CK-57-4-12	45	0.00	0.17	0.01	0.96	1.13	0.64	0.00	0.03	1.11	1.78
70-CK-57-4-13	27	0.08	0.12	0.01	0.74	0.96	0.84	0.00	0.12	0.92	1.87

SAMPLE NUMBER	LAB NO.	PER CENT OM	PPM TOTAL P	PER CENT CACO3	PER CENT TSS	MIC MHS 1:5 EC	1:1 PH KCL	H2O	MEQ/100 GMS CEC
70-CK-57-4- 1	40	3.76	225.56	0.41	0.08	92.76	5.78	6.62	17.47
70-CK-57-4- 2	75	2.25	172.56	0.29	0.02	87.68	5.33	6.82	11.27
70-CK-57-4- 3	83	1.81	156.56	0.56	0.01	111.24	5.28	7.02	13.90
70-CK-57-4- 4	63	1.72	130.56	0.93	0.04	117.91	6.18	7.37	28.21
70-CK-57-4- 5	66	1.03	109.56	0.92	0.03	138.50	6.88	8.22	26.65
70-CK-57-4- 6	49	0.60	115.56	0.71	0.10	239.46	6.98	8.22	25.93
70-CK-57-4- 7	35	0.38	107.56	1.10	0.13	228.24	7.18	8.47	26.51
70-CK-57-4- 8	74	0.41	115.56	0.77	0.03	154.65	6.73	8.27	24.92
70-CK-57-4- 9	15	0.35	163.56	0.86	0.11	114.71	6.73	8.12	28.08
70-CK-57-4-10	61	0.39	184.56	6.08	0.08	257.37	7.03	8.42	33.88
70-CK-57-4-11	59	0.37	310.56	7.46	0.04	212.54	7.08	8.52	31.82
70-CK-57-4-12	45	0.37	270.56	4.26	0.06	220.22	6.93	8.02	36.81
70-CK-57-4-13	27	0.28	366.56	1.74	0.07	138.56	6.83	8.17	34.73

INTERPRETIVE CALCULATIONS:

SAMPLE NUMBER	LAB NO.	% CA/MG	% CEC/CLAY	ESP	SSP	SAR	% SOLUBLE/EXTRACTABLE CA	MG	% BASE SATURATION NAAC	SUM CAT
70-CK-57-4- 1	40	241.43	89.77	2.34	55.59	0.85	0.09	6.67	74.04	75.54
70-CK-57-4- 2	75	653.98	59.72	6.57	94.24	5.64	0.00	3.97	61.87	64.65
70-CK-57-4- 3	83	274.30	45.14	15.86	95.40	6.69	0.00	0.89	71.21	75.11
70-CK-57-4- 4	63	172.97	76.71	14.09	92.92	4.61	0.00	1.15	69.12	88.61
70-CK-57-4- 5	66	181.43	70.98	18.59	94.18	5.88	0.00	1.08	79.18	98.12
70-CK-57-4- 6	49	159.64	70.65	18.03	94.20	7.33	0.00	1.49	93.26	99.63
70-CK-57-4- 7	35	172.90	60.82	17.13	94.79	8.26	0.00	1.32	98.54	97.28
70-CK-57-4- 8	74	196.14	56.70	19.97	96.17	8.89	0.00	0.59	89.94	98.18
70-CK-57-4- 9	15	178.23	54.60	14.52	86.41	3.82	0.32	0.72	102.10	97.76
70-CK-57-4-10	61	486.69	63.71	11.44	93.70	7.48	0.00	2.00	145.87	100.00
70-CK-57-4-11	59	523.29	61.75	9.56	92.17	5.50	0.00	1.85	152.93	100.00
70-CK-57-4-12	45	603.40	44.73	7.73	90.36	4.66	0.00	2.58	135.31	100.00
70-CK-57-4-13	27	286.93	48.46	5.77	82.58	3.33	0.30	1.19	115.06	100.00

total exchange complex of the horizons below the A1 horizon.

Pedon 5 (Table 2.7). This profile is a dark colored soil which is redder in subsurface horizons. The soil is developed on a slightly convex relief and is moderately well drained. Ground water level did not occur within 236 cm of the surface at the time of sampling. The A horizon is 50 cm thick with moderate fine and medium granular structure which continues to the B1 horizon. The B21t horizon displays a moderate medium prismatic parting to moderate fine granular blocky structure. Common distinct yellowish red mottles and continuous or patchy clay films are present within the B horizon.

The laboratory analyses of the soil samples indicate an increase of about 20% in clay content from A1 to the A3 horizon. The B22tca horizon contains the largest amount of clay within this pedon. The particle size distribution of the upper 100 cm denotes the soil to be fine-silty in textural classification. The first 60 cm of the surface of the profile contains more than 1% organic matter (Figure 3.11). The soil reaction varies from neutral to strongly basic through the depth of the profile. Exchangeable bases are in the order of Ca^{++}, Mg^{++}, Na^{++}, and K^{+} and saturate more than 56% of the total exchange capacity. Exchangeable sodium percentage is insignificant and soluble salts are absent in this pedon.

Pedon 6 (Table 2.8). This profile is a dark colored soil which gets redder with depth. The soil is formed on a slightly convex relief. The soil is poorly drained and ground water level was found at 233 cm below the surface. The A horizon is 35 cm thick with a weak fine platy to moderate medium granular structure. The B1 horizon displays a moderate medium prismatic parting to strong medium granular

TABLE 2.7

FIELD AND LABORATORY FINDINGS
PEDON 5

PROFILE DESCRIPTION:

SAMPLE NUMBER	LAB NO.	HORIZON	DEPTH	THICKNESS	COLOR(M)	TEXTURE	STRUCTURE	CONSISTENCE
70-CK-57-5-01	84	AP	0- 20CM	20CM	10.0YR 3/2	SIL	2M&CPL	MVFR,DH
70-CK-57-5-02	41	A1	20- 38CM	18CM	10.0YR 3/2	SIL	2F&MGR	MVFR,DH
70-CK-57-5-03	68	A3	38- 50CM	12CM	7.5YR 3/2	SIL	1CPR-2MGR	MFR,DH
70-CK-57-5-04	7	B1	50- 60CM	10CM	5.0YR 3/2	SICL	1CPR-2MGR	MFI,DVH
70-CK-57-5-05	51	B21T	60- 91CM	31CM	5.0YR 4/3	SICL	2MPR-2FABK	MVFI,DVH
70-CK-57-5-06	22	B22TCA	91-116CM	25CM	5.0YR 4/3	SICL	2MABK	MVFI,DEH
70-CK-57-5-07	47	B3	116-142CM	26CM	5.0YR 5/3	SICL		
70-CK-57-5-08	69	C1	142-160CM	18CM	5.0YR 5/3			
70-CK-57-5-09	39	C2	160-193CM	33CM	5.0YR 4/2			
70-CK-57-5-10	19	C3	193-220CM	27CM	5.0YR 5/2			
70-CK-57-5-11	8	C4	220-236CM	16CM	2.5YR 4/2			

PHYSICAL ANALYSIS:

SAMPLE NUMBER	LAB NO.	PER CENT GRA	VCS	CS	MS	FS	VFS	SAND	CSI	MSI	FSI	SILT	CLAY	CLASS
70-CK-57-5- 1	84	0.00	0.38	0.03	0.12	4.79	12.44	17.76	34.75	22.56	5.54	62.84	19.40	SIL
70-CK-57-5- 2	41	1.21	0.43	0.09	0.28	6.93	12.62	20.34	43.01	10.16	1.60	54.77	24.89	SIL
70-CK-57-5- 3	68	0.00	0.43	0.04	0.19	4.08	9.57	14.31	29.21	23.40	3.93	56.54	29.15	SICL
70-CK-57-5- 4	7	0.80	0.00	0.16	0.41	5.52	10.97	17.07	38.34	10.51	3.59	52.44	31.45	SICL
70-CK-57-5- 5	51	1.24	0.54	0.14	0.24	3.68	8.50	13.10	40.75	11.58	4.13	56.47	30.43	SICL
70-CK-57-5- 6	22	0.91	0.00	0.00	0.00	2.07	11.26	13.34	36.33	12.23	3.82	52.38	35.27	SICL
70-CK-57-5- 7	47	1.21	0.45	0.07	0.15	1.70	9.85	12.23	40.97	14.39	5.41	60.78	26.99	SIL
70-CK-57-5- 8	69	0.00	0.41	0.00	0.03	2.14	12.32	14.89	24.94	27.10	6.39	58.43	26.69	SIL
70-CK-57-5- 9	39	1.52	0.43	0.02	0.11	3.36	6.49	10.41	39.39	19.90	5.56	64.85	24.74	SIL
70-CK-57-5-10	19	4.80	0.00	0.05	0.00	1.51	17.69	19.25	44.30	13.48	4.47	62.25	19.17	SIL
70-CK-57-5-11	8	0.80	0.00	0.05	0.15	2.96	8.39	11.55	33.18	22.67	9.17	65.02	24.40	SIL

CHEMICAL ANALYSIS:

SAMPLE NUMBER	LAB NO.	EXTRACTABLE CATIONS MEQ/100 GMS CA	MG	K	NA	H	AL	EXCHANGEABLE CATIONS MEQ/100 GMS CA	MG	K	NA	SUM
70-CK-57-5- 1	84	7.56	1.83	0.40	0.42	5.28	0.00	7.53	1.54	0.37	0.12	9.56
70-CK-57-5- 2	41	8.18	5.44	0.19	0.37	5.78	0.00	8.18	5.26	0.19	0.31	13.94
70-CK-57-5- 3	68	7.20	3.17	0.31	0.29	6.45	0.00	7.14	3.07	0.30	0.21	10.75
70-CK-57-5- 4	7	9.36	5.80	0.20	0.07	5.98	0.00	9.31	5.68	0.18	0.07	15.24
70-CK-57-5- 5	51	8.74	6.52	0.26	0.46	5.32	0.00	8.74	6.38	0.25	0.39	15.77
70-CK-57-5- 6	22	10.91	7.81	0.20	0.92	2.80	0.00	10.89	7.75	0.19	0.91	19.73
70-CK-57-5- 7	47	11.22	6.98	0.18	0.53	2.57	0.00	11.22	6.79	0.17	0.43	18.61
70-CK-57-5- 8	69	16.00	2.76	0.22	0.40	0.61	0.00	15.57	2.38	0.21	0.25	18.42
70-CK-57-5- 9	39	17.14	5.23	0.09	0.50	0.19	0.00	16.94	4.84	0.09	0.37	22.25
70-CK-57-5-10	19	12.76	4.77	0.03	0.97	0.25	0.00	12.43	4.55	0.02	0.89	17.89
70-CK-57-5-11	8	23.21	6.16	0.08	0.28	0.28	0.00	22.96	5.93	0.07	0.16	29.12

SAMPLE NUMBER	LAB NO.	SOLUBLE CATIONS MEQ/100 GMS CA	MG	K	NA	SUM	SOLUBLE ANIONS MEQ/100 GMS CL	SO4	CO3	HCO3	SUM
70-CK-57-5- 1	84	0.02	0.30	0.03	0.31	0.66	-0.00	0.00	0.03	0.53	0.56
70-CK-57-5- 2	41	0.00	0.17	0.01	0.06	0.24	0.30	0.00	0.03	0.26	0.59
70-CK-57-5- 3	68	0.02	0.10	0.01	0.07	0.20	0.22	0.00	0.03	0.22	0.48
70-CK-57-5- 4	7	0.05	0.12	0.02	0.00	0.19	0.37	0.00	0.00	0.22	0.60
70-CK-57-5- 5	51	0.00	0.14	0.01	0.07	0.21	0.33	0.00	0.03	0.20	0.57
70-CK-57-5- 6	22	0.02	0.06	0.01	0.01	0.09	0.14	0.00	0.07	0.15	0.36
70-CK-57-5- 7	47	0.00	0.19	0.01	0.09	0.30	0.40	0.00	0.03	0.28	0.71
70-CK-57-5- 8	69	0.43	0.38	0.00	0.15	0.96	1.23	0.00	0.09	0.75	2.07
70-CK-57-5- 9	39	0.20	0.39	0.00	0.13	0.71	0.62	0.00	0.03	0.63	1.29
70-CK-57-5-10	19	0.33	0.22	0.01	0.08	0.64	0.33	0.00	0.07	0.59	0.99
70-CK-57-5-11	8	0.25	0.23	0.02	0.12	0.62	0.37	0.00	0.00	0.58	0.95

SAMPLE NUMBER	LAB NO.	PER CENT OM	PPM TOTAL P	PER CENT CACO3	PER CENT TSS	MIC MHS 1:5 EC	1:1 PH KCL	H2O	MEQ/100 GMS CEC
70-CK-57-5- 1	84	3.73	218.56	0.55	0.03	121.05	5.28	6.42	11.11
70-CK-57-5- 2	41	2.38	173.56	0.44	0.04	54.61	5.28	6.27	19.68
70-CK-57-5- 3	68	2.16	165.56	0.56	0.01	27.00	4.98	6.17	19.14
70-CK-57-5- 4	7	1.77	155.56	0.52	0.08	-2.92	5.03	6.12	20.37
70-CK-57-5- 5	51	0.87	126.56	0.43	0.00	56.00	5.13	5.92	22.45
70-CK-57-5- 6	22	0.44	99.56	0.69	0.07	4.01	5.43	6.72	21.91
70-CK-57-5- 7	47	0.32	90.56	0.48	0.02	64.24	5.88	6.97	23.01
70-CK-57-5- 8	69	0.28	94.56	0.84	0.02	138.50	7.03	8.12	20.92
70-CK-57-5- 9	39	0.34	151.56	1.43	0.03	130.67	7.38	8.42	16.49
70-CK-57-5-10	19	0.19	219.56	1.18	0.08	87.94	7.33	8.67	12.98
70-CK-57-5-11	8	0.18	[illegible]29.56	2.25	0.09	77.85	7.23	8.37	15.16

INTERPRETIVE CALCULATIONS:

SAMPLE NUMBER	LAB NO.	% CA/MG	% CEC/CLAY	ESP	SSP	SAR	% SOLUBLE/EXTRACTABLE CA	MG	% BASE SATURATION NAAC	SUM CAT
70-CK-57-5- 1	84	412.73	57.26	1.05	57.18	1.08	0.33	19.27	86.03	64.43
70-CK-57-5- 2	41	150.41	79.08	1.58	37.85	0.30	0.00	3.32	70.81	70.67
70-CK-57-5- 3	68	227.05	65.66	1.11	45.76	0.43	0.25	3.35	56.20	62.52
70-CK-57-5- 4	7	161.49	64.79	0.35	0.00	0.00	0.55	2.10	74.81	71.83
70-CK-57-5- 5	51	134.14	73.75	1.76	44.94	0.37	0.00	2.17	70.26	74.76
70-CK-57-5- 6	22	139.73	62.11	4.14	10.56	0.06	0.17	0.73	90.08	87.58
70-CK-57-5- 7	47	160.65	85.28	1.89	43.82	0.42	0.00	2.96	80.87	87.87
70-CK-57-5- 8	69	580.21	78.38	1.20	19.92	0.32	2.77	16.03	88.04	96.80
70-CK-57-5- 9	39	327.65	55.58	2.27	24.89	0.33	1.17	8.00	134.87	99.17
70-CK-57-5-10	19	267.68	67.70	6.85	15.24	0.21	2.65	4.78	137.81	98.64
70-CK-57-5-11	8	377.02	62.11	1.05	24.93	0.36	1.11	3.83	192.11	99.04

TABLE 2.8

FIELD AND LABORATORY FINDINGS
PEDON 6

PROFILE DESCRIPTION:

SAMPLE NUMBER	LAB NO.	HORIZON	DEPTH	THICKNESS	COLOR(M)	TEXTURE	STRUCTURE	CONSISTENCE
70-CK-57-6-01	32	AP1	0- 5CM	5CM	10.0YR 3/2	SIL	1FPL	MFR,DH
70-CK-57-6-02	9	AP2	5- 20CM	15CM	10.0YR 3/2	SIL	M-1MGR	MFR,DH
70-CK-57-6-03	85	A1	20- 35CM	15CM	10.0YR 3/2	SIL	2MGR	MFR,DH
70-CK-57-6-04	37	B1	35- 50CM	15CM	7.5YR 3/2	SICL	2MPR-3MGR	MFI-DH
70-CK-57-6-05	62	B21T	50- 68CM	18CM	5.0YR 4/3	SICL	1MPR-3MGR	MVFI,DVH
70-CK-57-6-06	78	B22T	68-101CM	33CM	5.0YR 4/3	SICL	2MABK	MVFI,DEH
70-CK-57-6-07	28	B23T	101-126CM	25CM	5.0YR 4/4	SIC	2MABK	MVFI,DEH
70-CK-57-6-08	1	B24CA	126-160CM	34CM	5.0YR 4/4	SIC	1MABK	MVFI,DEH
70-CK-57-6-09	56	B3	160-185CM	25CM	5.0YR 4/4	SICL	1CABK	MFI,DVH
70-CK-57-6-10	14	C1	185-205CM	20CM	5.0YR 4/4	SICL	M	MFI,DVH
70-CK-57-6-11	46	C2	205-233CM	28CM	5.0YR 7/2			
70-CK-57-6-12	38	C3	233-261CM	28CM	5.0YR 4/3			
70-CK-57-6-13	57	C4	261-279CM	18CM	5.0YR 4/3			

PHYSICAL ANALYSIS:

SAMPLE NUMBER	LAB NO.	PER CENT												CLASS
		GRA	VCS	CS	MS	FS	VFS	SAND	CSI	MSI	FSI	SILT	CLAY	
70-CK-57-6- 1	32	1.32	0.39	0.05	0.13	4.11	11.84	16.51	45.44	12.62	1.23	59.29	24.20	SIL
70-CK-57-6- 2	9	0.81	0.00	0.09	0.35	5.00	9.96	15.39	46.15	12.19	2.93	61.27	24.30	SIL
70-CK-57-6- 3	85	0.00	0.39	0.04	0.16	3.38	10.35	14.33	33.73	24.25	5.62	63.59	22.08	SIL
70-CK-57-6- 4	37	1.21	0.40	0.05	0.26	5.28	11.10	17.09	38.13	12.76	2.13	53.02	29.89	SICL
70-CK-57-6- 5	62	0.00	0.42	0.04	0.24	0.71	4.52	5.92	30.88	25.52	4.73	61.13	32.95	SICL
70-CK-57-6- 6	78	0.00	0.39	0.04	0.07	2.24	6.57	9.31	21.10	24.20	3.01	48.31	42.38	SIC
70-CK-57-6- 7	28	1.06	0.45	0.12	0.15	3.56	9.04	13.32	30.41	11.53	3.62	45.56	41.12	SIC
70-CK-57-6- 8	1	0.00	0.00	0.05	0.12	4.24	8.69	13.11	31.25	7.43	4.22	42.89	45.08	SIC
70-CK-57-6- 9	56	1.22	0.51	0.10	0.15	1.61	5.69	8.06	34.52	24.68	5.49	64.69	27.25	SICL
70-CK-57-6-10	14	0.82	0.00	0.00	0.00	1.24	10.99	12.23	36.11	13.98	6.39	56.49	32.22	SICL
70-CK-57-6-11	46	1.21	0.45	0.07	0.14	1.33	10.20	12.19	46.57	15.75	5.97	68.29	19.52	SIL
70-CK-57-6-12	38	1.20	0.44	0.05	0.10	5.80	12.53	18.92	29.03	18.46	7.83	55.32	25.76	SIL
70-CK-57-6-13	57	0.75	0.48	0.03	0.08	2.51	7.62	10.72	24.68	30.78	11.18	66.63	22.64	SIL

CHEMICAL ANALYSIS:

SAMPLE NUMBER	LAB NO.	EXTRACTABLE CATIONS MEQ/100 GMS						EXCHANGEABLE CATIONS MEQ/100 GMS				
		CA	MG	K	NA	H	AL	CA	MG	K	NA	SUM
70-CK-57-6- 1	32	11.47	2.74	0.48	0.45	5.14	0.00	11.29	3.29	0.39	0.34	15.31
70-CK-57-6- 2	9	9.93	4.20	0.19	0.04	5.35	0.00	9.76	4.00	0.17	0.04	13.97
70-CK-57-6- 3	85	7.25	2.19	0.34	0.43	5.98	0.00	7.23	1.98	0.32	0.13	9.66
70-CK-57-6- 4	37	8.90	5.13	0.25	0.41	6.57	0.00	8.90	4.96	0.24	0.34	14.44
70-CK-57-6- 5	62	9.05	3.94	0.32	0.39	7.27	0.00	9.05	3.83	0.31	0.27	13.45
70-CK-57-6- 6	78	10.34	5.18	0.44	0.77	6.53	0.00	10.34	5.13	0.43	0.43	16.33
70-CK-57-6- 7	28	14.56	6.41	0.29	1.05	3.18	0.00	14.54	6.37	0.28	0.86	22.05
70-CK-57-6- 8	1	18.22	7.44	0.35	0.57	1.96	0.00	17.87	7.20	0.34	0.32	25.74
70-CK-57-6- 9	56	15.59	6.41	0.34	0.97	1.41	0.00	15.41	6.03	0.33	0.61	22.38
70-CK-57-6-10	14	14.51	6.36	0.18	0.52	1.50	0.00	14.46	6.26	0.16	0.39	21.27
70-CK-57-6-11	46	12.71	5.23	0.15	0.95	0.33	0.00	12.66	4.84	0.15	0.56	18.21
70-CK-57-6-12	38	24.81	4.16	0.05	0.72	0.00	0.00	24.78	3.89	0.05	0.45	29.16
70-CK-57-6-13	57	30.01	5.23	0.17	0.97	0.00	0.00	29.93	4.96	0.17	0.64	35.70

SAMPLE NUMBER	LAB NO.	SOLUBLE CATIONS MEQ/100 GMS					SOLUBLE ANIONS MEQ/100 GMS				
		CA	MG	K	NA	SUM	CL	SO4	CO3	HCO3	SUM
70-CK-57-6- 1	32	0.16	0.45	0.08	0.11	0.82	0.76	0.00	0.03	0.63	1.42
70-CK-57-6- 2	9	0.17	0.20	0.02	0.00	0.39	0.40	0.00	0.00	0.30	0.70
70-CK-57-6- 3	85	0.02	0.21	0.01	0.31	0.56	0.00	0.00	0.03	0.35	0.38
70-CK-57-6- 4	37	0.00	0.17	0.01	0.07	0.24	0.31	0.00	0.03	0.24	0.58
70-CK-57-6- 5	62	0.00	0.12	0.01	0.13	0.25	0.07	0.00	0.03	0.24	0.34
70-CK-57-6- 6	78	0.00	0.05	0.01	0.34	0.40	0.05	0.00	0.03	0.24	0.32
70-CK-57-6- 7	28	0.02	0.04	0.01	0.20	0.27	0.24	0.00	0.06	0.23	0.54
70-CK-57-6- 8	1	0.35	0.24	0.02	0.24	0.85	0.59	0.00	0.00	0.76	1.35
70-CK-57-6- 9	56	0.19	0.39	0.01	0.36	0.94	0.91	0.00	0.03	0.84	1.78
70-CK-57-6-10	14	0.05	0.11	0.01	0.14	0.31	0.21	0.00	0.00	0.31	0.52
70-CK-57-6-11	46	0.04	0.39	0.00	0.38	0.83	0.71	0.00	0.03	0.77	1.51
70-CK-57-6-12	38	0.03	0.28	0.00	0.26	0.57	0.62	0.00	0.03	0.63	1.29
70-CK-57-6-13	57	0.08	0.27	0.01	0.33	0.68	0.78	0.00	0.03	0.67	1.48

SAMPLE NUMBER	LAB NO.	PER CENT	PPM	PER CENT	PER CENT	MIC MHS	1:1 PH		MEQ/100 GMS
		OM	TOTAL P	CACO3	TSS	1:5 EC	KCL	H2O	CEC
70-CK-57-6- 1	32	4.43	240.56	0.99	0.11	113.50	5.88	6.77	18.88
70-CK-57-6- 2	9	3.08	214.56	0.58	0.12	18.56	5.38	6.27	17.89
70-CK-57-6- 3	85	2.86	191.56	0.55	0.02	115.07	5.03	6.27	11.81
70-CK-57-6- 4	37	2.25	192.56	0.30	0.03	50.38	5.23	6.17	20.72
70-CK-57-6- 5	62	1.68	162.56	0.75	0.00	25.66	4.98	6.27	25.71
70-CK-57-6- 6	78	1.22	121.56	0.57	0.00	64.51	5.13	6.42	22.57
70-CK-57-6- 7	28	0.46	108.56	0.92	0.03	50.03	6.08	7.37	28.13
70-CK-57-6- 8	1	0.33	103.56	0.89	0.11	127.94	6.73	7.82	25.28
70-CK-57-6- 9	56	0.24	109.56	0.81	0.04	158.84	6.88	7.72	24.27
70-CK-57-6-10	14	0.13	127.56	0.70	0.07	28.20	6.43	7.77	21.40
70-CK-57-6-11	46	0.29	164.56	0.56	0.04	144.75	5.83	7.97	21.03
70-CK-57-6-12	38	0.05	317.56	4.34	0.04	120.70	7.43	8.47	13.16
70-CK-57-6-13	57	0.03	283.56	2.76	0.02	139.32	7.13	8.32	18.70

INTERPRETIVE CALCULATIONS:

SAMPLE NUMBER	LAB NO.	% CA/MG	% CEC/CLAY	ESP	SSP	SAR	% SOLUBLE/EXTRACTABLE CA	MG	% BASE SATURATION NAAC	SUM CAT
70-CK-57-6- 1	32	307.01	78.02	1.78	17.34	0.28	1.61	13.57	81.11	74.86
70-CK-57-6- 2	9	236.35	73.63	0.20	0.00	0.00	1.70	4.94	78.09	72.31
70-CK-57-6- 3	85	330.75	53.47	1.08	66.12	1.27	0.34	10.64	81.79	61.77
70-CK-57-6- 4	37	173.53	69.33	1.64	39.76	0.33	0.00	3.39	69.67	68.73
70-CK-57-6- 5	62	229.58	78.04	1.04	61.57	0.74	0.00	3.02	52.32	64.92
70-CK-57-6- 6	78	199.65	53.26	1.92	89.62	3.14	0.00	0.92	72.37	71.43
70-CK-57-6- 7	28	227.02	68.41	3.05	76.07	1.63	0.13	0.63	78.40	87.38
70-CK-57-6- 8	1	244.72	56.09	1.28	34.75	0.64	1.95	3.33	101.79	92.91
70-CK-57-6- 9	56	243.07	89.06	2.51	49.61	0.95	1.20	6.43	92.20	94.08
70-CK-57-6-10	14	228.04	66.40	1.80	52.25	0.69	0.35	1.69	99.38	93.39
70-CK-57-6-11	46	242.98	107.74	2.68	60.24	1.16	0.35	8.15	86.60	98.21
70-CK-57-6-12	38	596.53	51.08	3.43	60.10	0.95	0.13	7.20	221.57	100.00
70-CK-57-6-13	57	573.81	82.59	3.41	59.64	1.12	0.27	5.37	190.92	100.00

structure. Fine distinct yellowish mottles, and patchy and continuous clay films are noticable within the B horizons. A few soft masses of calcium carbonate which cause slight to strong effervescence are present in the lower level of the profile.

The laboratory analyses of the pedogenic horizons indicate the clay content increases about 20% from the A1 to the B1 horizon. The mechanical analysis of the control section places this pedon into the fine-silty textural class. Organic matter is more than 1% in the upper 100 cm of the profile (Figure 3.13). The soil reaction varies from neutral to basic and strongly basic through the profile. The conductivity of 1:5 soil water extract indicates no significant amount of soluble salts. Exchangeable bases saturate 52% of B22t and more than 69% of the exchange capacity of the other horizons. Bases are present in the descending order of Ca^{++}, Mg^{++}, Na^{++} and K^{+}. Exchangeable sodium saturates a negligible precent of the total cation exchange capacity of this pedon.

Pedon 7 (Table 2.9). This soil displays a profile which is very dark grayish brown in Ap and is dark brown in the A1 horizon. The horizons are redder toward the deeper layers of the profile. The soil is poorly drained and occurs on a slightly convex area. Ground water was not noted on the day of digging the pit but water had seeped in seven days later and accumulated at the depth of 236 cm which is 56 cm below the lower boundary of the solum. The A horizon is only 20 cm thick with a medium and coarse platy structure. The B2 subhorizons are prismatic in structure. The prisms are capped with material which is lighter in color than the prisms. Peds are coated with black stains. Patchy and continuous clay films and a few soft

TABLE 2.9

FIELD AND LABORATORY FINDINGS
PEDON 7

PROFILE DESCRIPTION:

SAMPLE NUMBER	LAB NO.	HORIZON	DEPTH	THICKNESS	COLOR(M)	TEXTURE	STRUCTURE	CONSISTENCE
70-CK-57-7-01	12	AP	0- 7CM	7CM	10.0YR 3/2	FSL	2M&CPL	MVFR,DH
70-CK-57-7-02	21	A1	7- 20CM	13CM	7.5YR 3/2	FSL	1M&CPL	MVFR,DH
70-CK-57-7-03	18	B21T	20- 35CM	15CM	7.5YR 3/2	CL	2M&CPR	MVFI,DEH
70-CK-57-7-04	60	B22T	35- 55CM	20CM	5.0YR 4/3	SICL	2MPR-3F&MABK	MVFI,DEH
70-CK-57-7-05	71	B23T	55- 71CM	16CM	5.0YR 4/3	SICL	2F&MABK	MVFI,DEH
70-CK-57-7-06	26	B31	71-104CM	33CM	5.0YR 4/4	SICL	1MABK	MVFI,DVH
70-CK-57-7-07	65	B32	104-134CM	30CM	5.0YR 4/4	SICL	1M&CABK	MVFI,DVH
70-CK-57-7-08	70	C1	134-180CM	46CM	5.0YR 4/3			
70-CK-57-7-09	52	C2	180-228CM	48CM	5.0YR 4/2			
70-CK-57-7-10	50	C3	228-243CM	15CM	5.0YR 5/3			

PHYSICAL ANALYSIS:

SAMPLE NUMBER	LAB NO.	PER CENT												
		GRA	VCS	CS	MS	FS	VFS	SAND	CSI	MSI	FSI	SILT	CLAY	CLASS
70-CK-57-7- 1	12	0.82	0.00	0.04	0.14	4.82	16.28	21.28	52.76	9.82	2.93	65.50	14.05	SIL
70-CK-57-7- 2	21	0.92	0.00	0.00	0.12	3.76	16.40	20.27	55.22	10.47	1.18	66.86	13.75	SIL
70-CK-57-7- 3	18	0.87	0.00	0.00	0.04	3.50	11.66	15.20	35.92	9.13	1.84	46.89	38.79	SICL
70-CK-57-7- 4	60	0.94	0.50	0.07	0.19	2.98	9.57	13.32	28.65	20.08	3.03	51.76	34.92	SICL
70-CK-57-7- 5	71	0.00	0.43	0.00	0.03	3.68	10.49	14.64	20.87	21.72	4.72	47.30	38.06	SICL
70-CK-57-7- 6	26	0.89	0.36	0.00	0.00	7.96	17.92	26.24	29.15	7.45	2.80	39.40	34.38	CL
70-CK-57-7- 7	65	2.54	0.45	0.00	0.06	7.60	17.31	25.42	25.40	19.26	5.57	50.23	24.36	SIL
70-CK-57-7- 8	70	0.00	0.41	0.00	0.01	5.75	12.62	18.78	17.76	30.37	8.07	56.20	25.02	SIL
70-CK-57-7- 9	52	10.20	0.74	0.17	0.26	1.84	11.34	14.36	48.67	15.30	7.11	71.09	14.55	SIL
70-CK-57-7-10	50	10.05	0.65	0.10	0.16	1.76	20.50	23.18	48.18	10.95	5.77	64.90	11.92	SIL

CHEMICAL ANALYSIS:

SAMPLE NUMBER	LAB NO.	EXTRACTABLE CATIONS MEQ/100 GMS						EXCHANGEABLE CATIONS MEQ/100 GMS				
		CA	MG	K	NA	H	AL	CA	MG	K	NA	SUM
70-CK-57-7- 1	12	6.68	2.40	0.11	0.44	2.19	0.00	6.63	2.29	0.09	0.23	9.24
70-CK-57-7- 2	21	4.78	2.71	0.04	1.91	1.01	0.00	4.73	2.68	0.03	1.45	8.89
70-CK-57-7- 3	18	5.86	4.97	0.22	9.91	0.83	0.00	5.81	4.89	0.20	8.35	19.25
70-CK-57-7- 4	60	6.07	6.16	0.43	15.07	0.97	0.00	6.07	5.91	0.41	12.11	24.50
70-CK-57-7- 5	71	4.31	4.15	0.40	15.13	0.05	0.00	4.31	4.05	0.39	11.25	20.01
70-CK-57-7- 6	26	5.24	6.21	0.20	10.93	0.00	0.00	5.22	6.19	0.19	9.18	20.79
70-CK-57-7- 7	65	10.49	3.63	0.20	7.69	0.00	0.00	10.49	3.55	0.18	5.11	19.34
70-CK-57-7- 8	70	13.79	2.71	0.23	5.60	0.00	0.00	13.79	2.62	0.22	4.04	20.67
70-CK-57-7- 9	52	29.34	3.79	0.09	1.79	0.00	0.00	29.34	3.63	0.09	1.08	34.15
70-CK-57-7-10	50	25.58	4.46	0.08	1.14	0.00	0.00	25.58	4.26	0.08	0.66	30.58

SAMPLE NUMBER	LAB NO.	SOLUBLE CATIONS MEQ/100 GMS					SOLUBLE ANIONS MEQ/100 GMS				
		CA	MG	K	NA	SUM	CL	SO4	CO3	HCO3	SUM
70-CK-57-7- 1	12	0.05	0.11	0.03	0.21	0.40	0.39	0.00	0.00	0.42	0.81
70-CK-57-7- 2	21	0.05	0.03	0.01	0.45	0.55	0.56	0.00	0.07	0.51	1.14
70-CK-57-7- 3	18	0.05	0.08	0.02	1.56	1.71	1.60	0.00	0.07	0.83	2.50
70-CK-57-7- 4	60	0.00	0.24	0.02	2.96	3.22	1.90	0.00	0.03	1.16	3.09
70-CK-57-7- 5	71	0.00	0.10	0.01	3.88	3.99	1.81	0.00	0.03	1.23	3.07
70-CK-57-7- 6	26	0.02	0.02	0.01	1.75	1.79	1.21	0.00	0.12	0.99	2.32
70-CK-57-7- 7	65	0.00	0.08	0.01	2.58	2.67	1.88	0.00	0.17	1.72	3.77
70-CK-57-7- 8	70	0.00	0.09	0.01	1.56	1.66	1.03	0.00	0.11	1.36	2.50
70-CK-57-7- 9	52	0.00	0.16	0.00	0.71	0.87	0.85	0.00	0.03	0.91	1.78
70-CK-57-7-10	50	0.00	0.20	0.01	0.48	0.69	0.93	0.00	0.03	0.75	1.72

SAMPLE NUMBER	LAB NO.	PER CENT	PPM	PER CENT	PER CENT	MIC MHS	1:1 PH		MEQ/100 GMS
		OM	TOTAL P	CACO3	TSS	1:5 EC	KCL	H2O	CEC
70-CK-57-7- 1	12	2.65	153.56	0.38	0.11	41.78	5.83	6.92	9.55
70-CK-57-7- 2	21	1.69	126.56	0.60	0.13	92.29	6.33	7.87	8.14
70-CK-57-7- 3	18	1.89	130.56	0.89	0.24	335.53	6.93	8.42	22.33
70-CK-57-7- 4	60	1.61	123.56	1.00	0.24	662.59	7.38	8.47	27.14
70-CK-57-7- 5	71	1.03	110.56	0.96	0.25	733.32	7.38	8.42	24.76
70-CK-57-7- 6	26	0.51	93.56	1.10	0.16	315.90	7.28	8.67	20.92
70-CK-57-7- 7	65	0.32	78.56	1.78	0.17	479.64	7.48	8.77	19.23
70-CK-57-7- 8	70	0.35	117.56	1.26	0.11	287.96	7.18	8.92	19.99
70-CK-57-7- 9	52	0.21	225.56	16.80	0.04	156.88	7.58	8.82	15.29
70-CK-57-7-10	50	0.18	93.56	6.24	0.04	138.91	7.43	8.72	11.31

INTERPRETIVE CALCULATIONS:

SAMPLE NUMBER	LAB NO.	% CA/MG	% CEC/CLAY	ESP	SSP	SAR	% SOLUBLE/EXTRACTABLE		% BASE SATURATION	
							CA	MG	NAAC	SUM CAT
70-CK-57-7- 1	12	278.71	67.92	2.40	58.81	1.05	0.77	4.77	96.76	80.81
70-CK-57-7- 2	21	176.51	59.17	17.93	84.37	3.24	1.08	1.02	109.28	89.81
70-CK-57-7- 3	18	117.83	57.57	37.39	92.72	8.52	0.88	1.70	86.20	95.88
70-CK-57-7- 4	60	98.51	77.73	44.63	94.70	12.00	0.00	4.12	90.26	96.18
70-CK-57-7- 5	71	103.99	65.05	45.43	98.10	25.05	0.00	2.37	80.81	99.73
70-CK-57-7- 6	26	84.42	60.86	43.90	97.43	18.48	0.35	0.28	99.37	100.00
70-CK-57-7- 7	65	288.79	78.88	26.60	97.50	17.88	0.00	2.34	100.58	100.00
70-CK-57-7- 8	70	509.44	79.90	20.21	96.03	10.44	0.00	3.42	103.38	100.00
70-CK-57-7- 9	52	774.55	105.07	7.09	88.70	3.59	0.00	4.27	223.32	100.00
70-CK-57-7-10	50	573.89	94.89	5.84	80.39	2.16	0.00	4.72	270.33	100.00

masses of calcium carbonate are observable in subsurface horizons.

The quantitative analysis of this pedon indicates that clay increases from 13 to 38% from the A to B horizon. The physical analysis of the control section denotes that this soil belongs to the fine textural class in family grouping. Organic matter decreases with depth, and the upper 71 cm indicates more than 1% organic matter (Figure 3.16). The soil reaction is neutral in Ap, basic in A1 and strongly basic throughout the rest of the profile. The chemical analysis of the soil water extract shows that; although soluble salt content is not significantly high, the major salts are sodium bicarbonates. The exchangeable Ca^{++}, Mg^{++}, Na^{+}, and K^{+} occupy more than 80% of the total cation exchange capacity of this profile. Exchangeable sodium content is very high in subsurface horizons and saturates up to 45% of the exchange complex.

Clay Mineralogy

The X-ray diffraction patterns for the selected A, B and C horizons of the selected pedons 1, 4, and 7 are given in this section separately. The cation exchange capacity and K_2O content of fine and coarse clays are presented in this section (Table 2.10). The CEC/clay ratio can be found in the tables presenting the morphology and laboratory findings (Tables 2.3 through 2.9). The following paragraphs explain the clay mineralogy of the selected pedons.

Pedon 1. The fine/coarse clay ratio increases from 0.72 in A1 to 1.35 in B23t, but decreases in the B3 and C horizons. The cation exchange capacity of the coarse fractions vary from 40-56, and for the fine fractions from 59-79 meq/100. The K_2O content of coarse clay

TABLE 2.10

LABORATORY ANALYSIS OF THE CLAY SUBFRACTIONS

		Coarse Clay 2.0-0.2 μ			Fine Clay <0.2 μ			
Horizon	Lab. No.	Percent	% K_2O	CEC	Percent	% K_2O	CEC	FC/CC
				PEDON 1				
A1	30	58.16	2.71	44.75	41.84	1.04	78.98	0.72
B23t	16	42.58	2.54	40.16	57.42	1.20	75.25	1.35
B3	34	51.73	2.20	56.63	48.27	0.99	75.71	0.93
C	6	75.40	2.16	46.88	24.59	1.28	59.55	0.33
				PEDON 4				
Ap	40	54.28	2.02	58.56	45.72	1.15	62.82	0.84
B22t	66	38.36	2.08	40.43	61.64	1.05	64.48	1.61
B31	15	67.08	2.32	58.60	32.92	1.01	58.58	0.49
C2	45	71.01	3.04	34.93	28.91	2.41	49.28	0.41
				PEDON 7				
Ap	12	61.63	2.27	64.55	38.37	0.81	70.36	0.62
B21t	18	48.39	1.81	49.48	51.61	0.59	64.38	1.06
B23t	71	52.82	1.76	59.95	47.18	1.08	56.43	0.89
C3	50	82.07	2.23	55.09	17.92	1.88	72.22	0.21

decreases with depth from 2.7% in A1 to 2.0% in the C horizon.

The x-ray diffraction patterns (Figure 2.2) showed the coarse and fine clay maxima of A1 to be 15.76A^o which did not expand as the specimen was solvated with glycerol. This reflects the presence of micaceous clays. A diffraction spacing of 10.15A^o was found for the B23t indicating the presence of illite. The fine clay particles of B23t showed the maxima of 7.24A^o which is obtained from metaholloysite. The B3 horizon is very similar to the B23t horizon and contains illite and metaholloysite. In the C horizon the coarse and fine clay maxima are at approximately 14A^o, with glycerol coarse clay expands to 17.65A^o but fine clays remain the same. This indicates the presence of some montmorillonite in the coarse subfractions and of vermiculite in the fine subfractions of the C horizons.

Pedon 4. The fine/coarse clay ratio increases from 0.84 in AP to 1.61 in B22t and then decreases by depth. The cation exchange capacity of the coarse fractions varies from 58 in Ap to 34 in the C2 horizon and in the fine fractions it varies from 62 in Ap to 49 in C2. The K_2O content of the coarse clay increases with depth from 2.0% in Ap to 3.0% in the C2 horizon.

The x-ray diffraction patterns indicate (Figure 2.3) a diffraction spacing of approximately 18.39A^o for the mg-saturated specimens of Ap. The fine and coarse specimens did not expand when solvated with glycerol. This reflects considerable low angle scatter due to interlayered montmorillonite in coarse and fine subfractions. The x-ray diffraction patterns of B22t are similar to Ap. The coarse clay of B31 has a good 14.01A^o and 7.24A^o which collapses when heated to 500^{o}C. This indicates the presence of vermiculite and kaolinite.

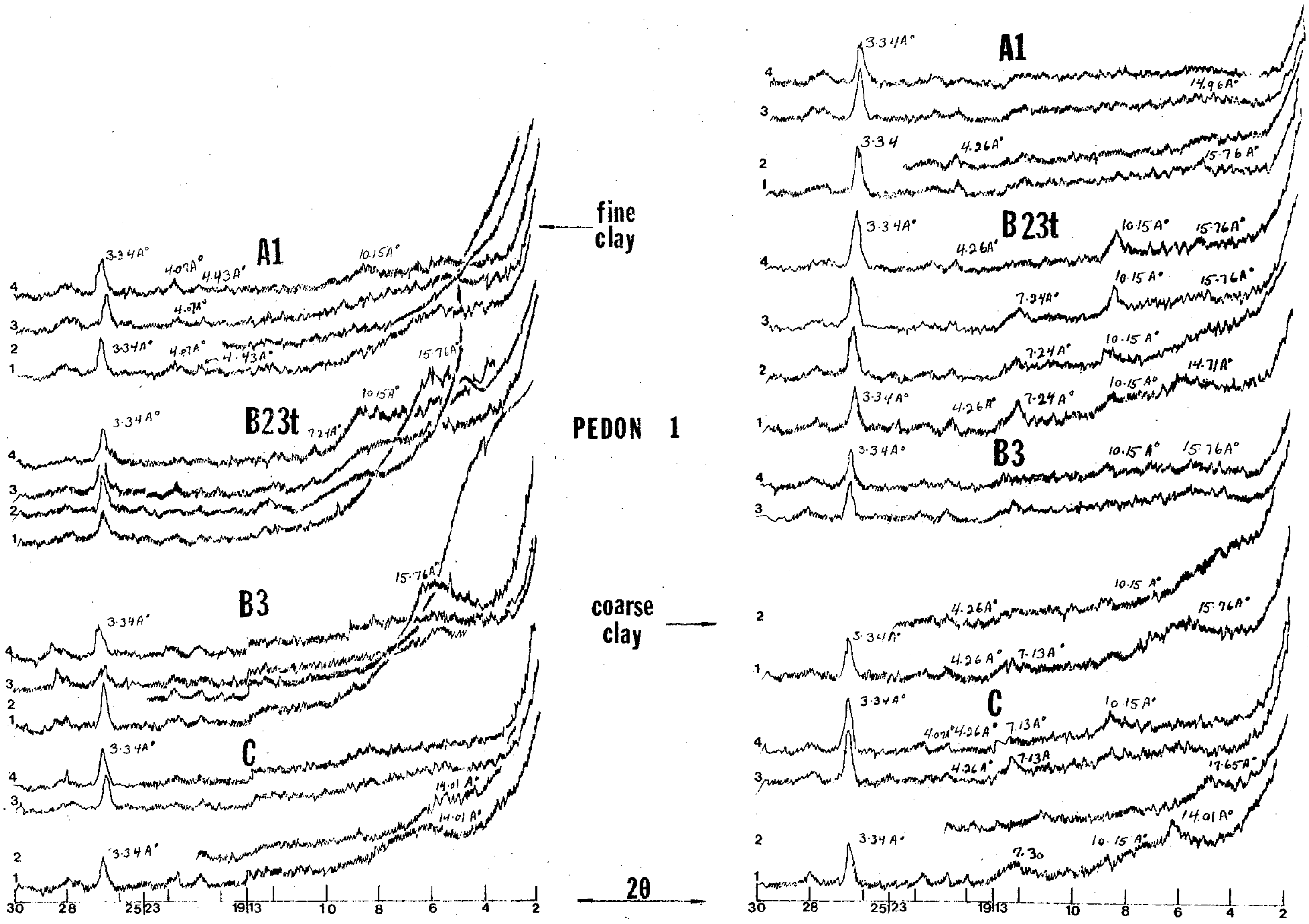


Figure 2.2. X-ray Diffractograms for Pedon 1;(1) Mg-Saturated, (2) Glycerol Solvated, (3) K-Saturated and, (4) Heated to 500°C

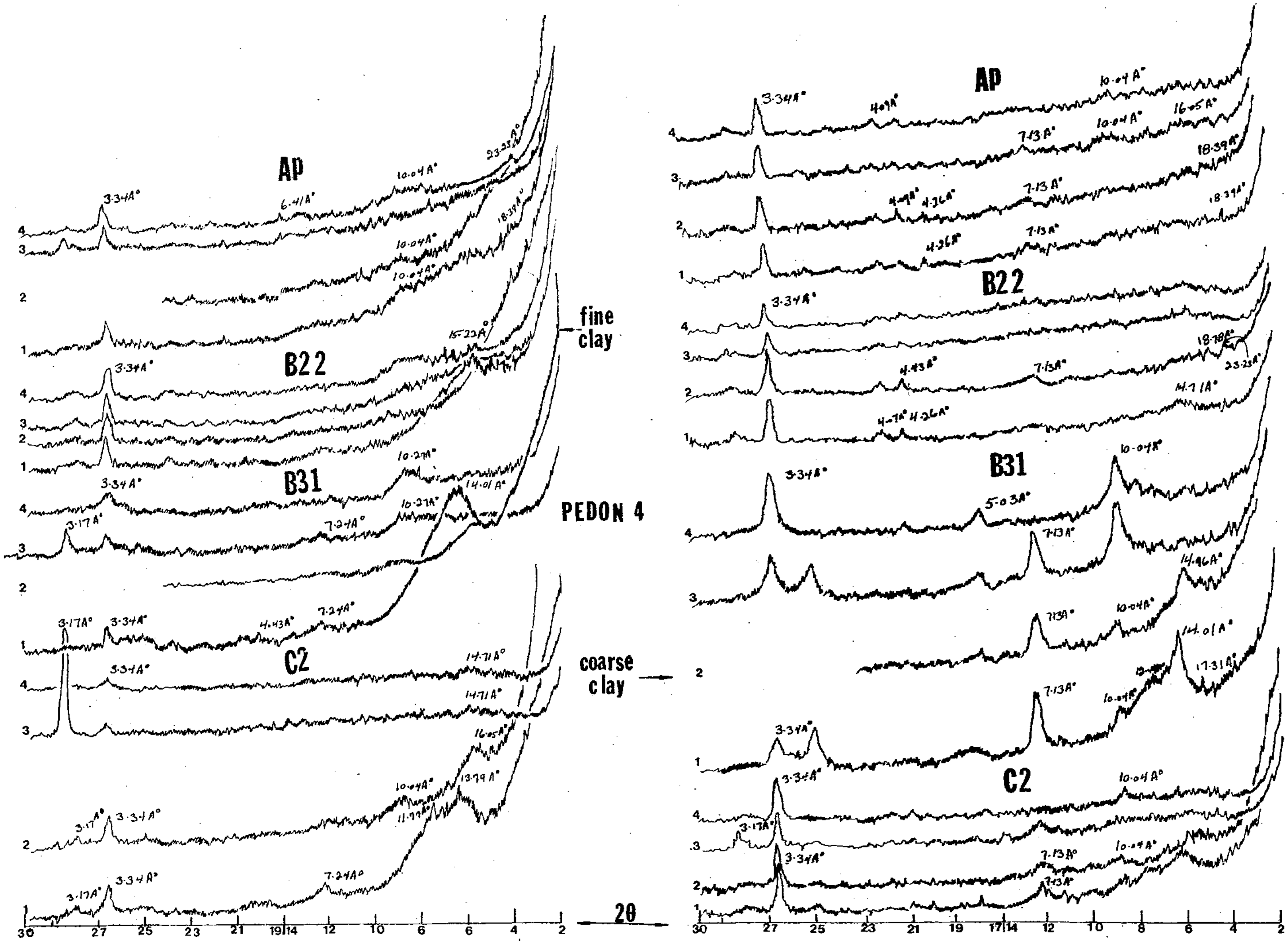


Figure 2.3. X-ray Diffractograms for Pedon 4; (1) Mg-Saturated, (2) Glycerol Solvated, (3) K-Saturated and , (4) Heated to 500°C

The good 10.04A° maximum is sharpened when saturated with K^+ and remained sharp when heated to 500°C. This reflects the contracted mica. The clear 7.31A° maximum demonstrates the presence of kaolinite.

Pedon 7 . The fine/coarse clay ratio increases form 0.62 in Ap to 1.06 in B21t. The cation exchange capacity of the coarse fractions varies from 64 in Ap to 49 in B21t. For the fine fractions CEC varies from 56 in B23t to 72 in C3. The K_2O content of the coarse fractions is 2.2% in Ap.

X-ray diffraction patterns (Figure 2.4) indicate that a diffraction spacing of approximately 15A° was obtained from Mg-saturated fine and coarse clay of the Ap horizon. When the specimen was solvated with glycerol the diffraction spacing expanded to approximately 17.0A° for fine clay, but remained the same for coarse fractions. The fine and coarse clay maxima at approximately 15A° for the Mg-saturated specimens of the B21t horizon indicates the presence of montmorillonite, vermiculite and chlorite. As the samples were solvated with glycerol expansion occurred in the coarse clay but not in the fine clay samples. This reflects the presence of montmorillonite in the coarse clay and its absence in the fine clay fractions. In the B23t horizon chlorite, vermiculite, and kaolinite were the major clay fractions, montmorillonite was not found. In C3 the x-ray diffraction patterns at 17.31A° for the Mg-saturated specimen of fine clay remained the same in the glycerol solvated specimen. In the coarse clay fractions of the same horizon the maxima of 15.76A° for mg-saturated samples also remained the same when solvated with glycerol. This denotes probably the interlayered Mg in fine clay and the presence of vermiculite and mica in the coarse

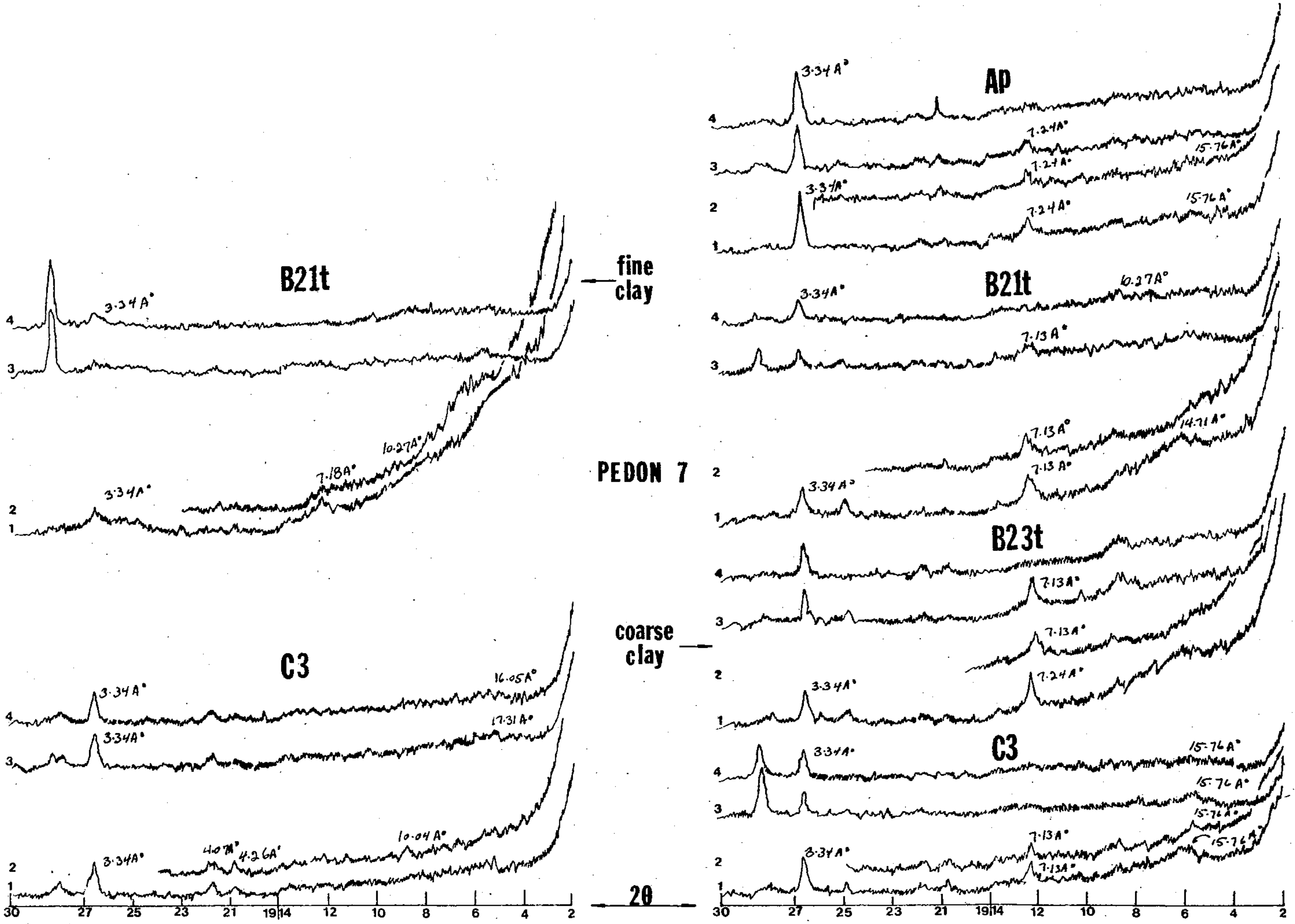


Figure 2.4. X-ray Diffractograms for Pedon 7; (1) Mg-Saturated, (2) Glycerol Solvated, (3) K-Saturated and, (4) Heated to 500°C

fractions.

Analysis of all of the above information indicates a mixture of micaceous and montmorillonitic minerals in all of the selected horizons. Of particular significance in this determination is the x-ray diffraction patterns, the cation exchange capacity of less than 80 meq/100 and the K_2O content of less than 4% of either fine or coarse clay particles.

Discussion

Soil characterization is the measurement of soil properties for the better understanding of soil genesis and taxonomy. The quantitative values which the experimenter uses to judge a character under investigation may not be a single measurement. It may be a derived number or some function of several measurements under time to time laboratory conditions. The slipped block design removes day to day errors of measurements when treatment effects are adjusted for block effects. A disadvantage of this design is the difficulties in handling the samples in the laboratory. If a single sample is damaged that particular analysis has to be repeated for the entire block which contains the spoiled sample. Calculations for this design are also time consuming and computers have to be applied to enhance the computation processes. It was also noticed that for some characters the sum of the treatment effect and the unadjusted overall mean was negative. In such cases the measured quantity was reported as zero. In clustering the horizons, the treatment effects were used, and no manipulations were necessary.

The morphology and laboratory data indicate the presence of mollic epipedons and argillic horizons (Figure 2.5). Organic matter, value and chroma, base saturation and the total thickness of the surface horizons are in the range of those for mollic epipedons. Clay distribution curves, fine/coarse clay ratios of greater than one, and the presence of clay skins around the peds prove the existance of argillic horizons. By considering ESP values for the upper 40 cm of the argillic horizons, some diagnostic, subsurface horizons will be recognized as natric horizons.

For the purposes of numerical taxonomy all the laboratory and interpretative data are considered in clustering the pedogenic horizons. The following criteria are suggested by the author for distinguishing the salt affected soils from non-salt affected soils. These criteria are somewhat similar to those used for Australian soils as explained by Northcothe and Skene (1972).

Salinity. The conductivity values of the 1:5 soil water extract at 25°C have been chosen in order to represent the salinity classes. These limits are based on the soluble salt content which have a bearing on the performance of many, although not all, agricultural crops.

Class 1. Non-Saline : $ECX10^6 \leq 800$

Class 2. Saline : $800 < ECX10^6 < 1600$

Class 3. Strongly Saline : $1600 \leq ECX10^6$

Alkalinity. The values of pH of a 1:1 soil water paste express the alkalinity of a soil. The pH values of 8.0 to 9.0 reflect significant amounts of exchangeable sodium held in the exchange complex (Figure 2.6). Soils with pH 9.0 are invariably strongly alkaline and soluble carbonates are present in the water extract.

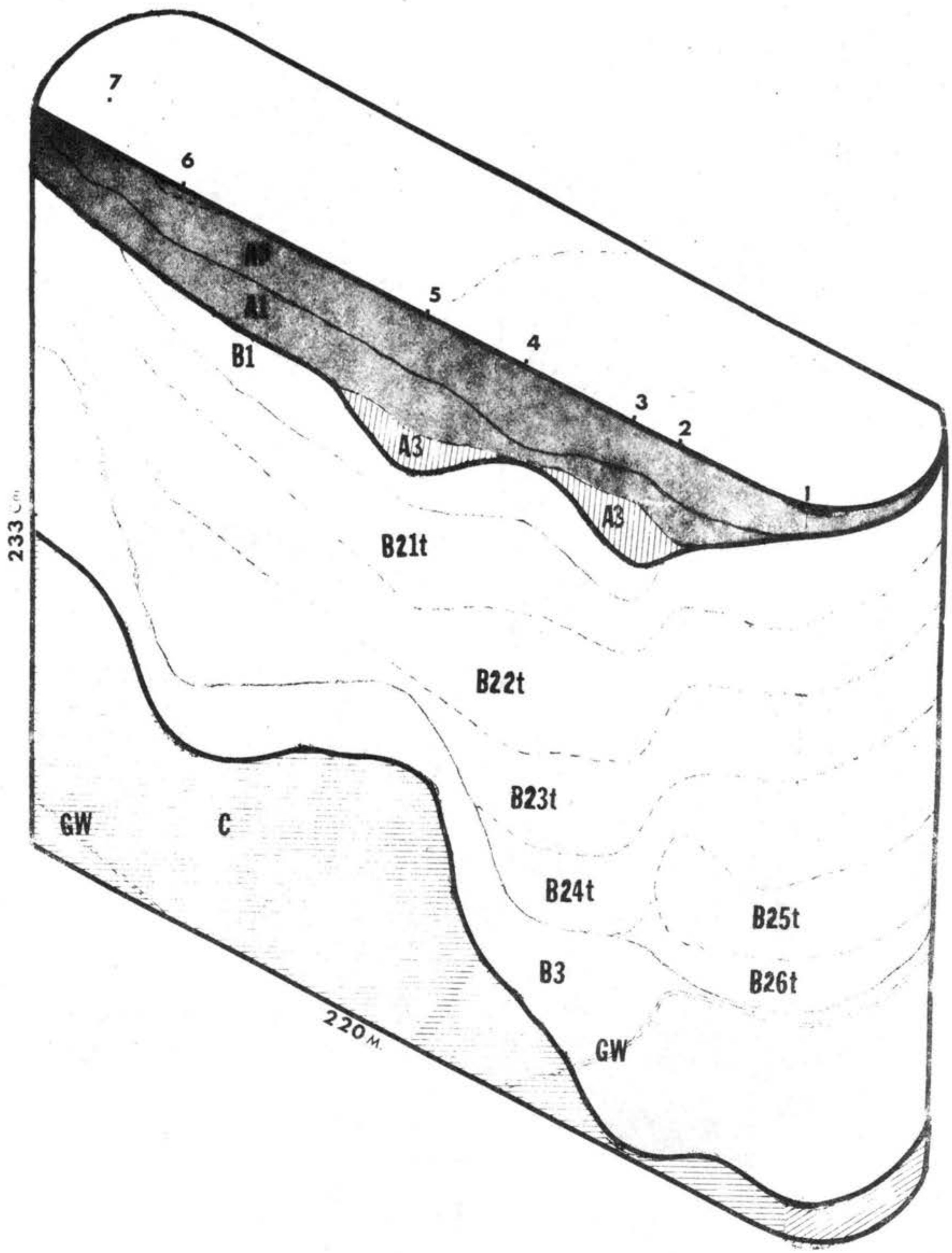


Figure 2.5. The Morphology of the Sampling Pedons

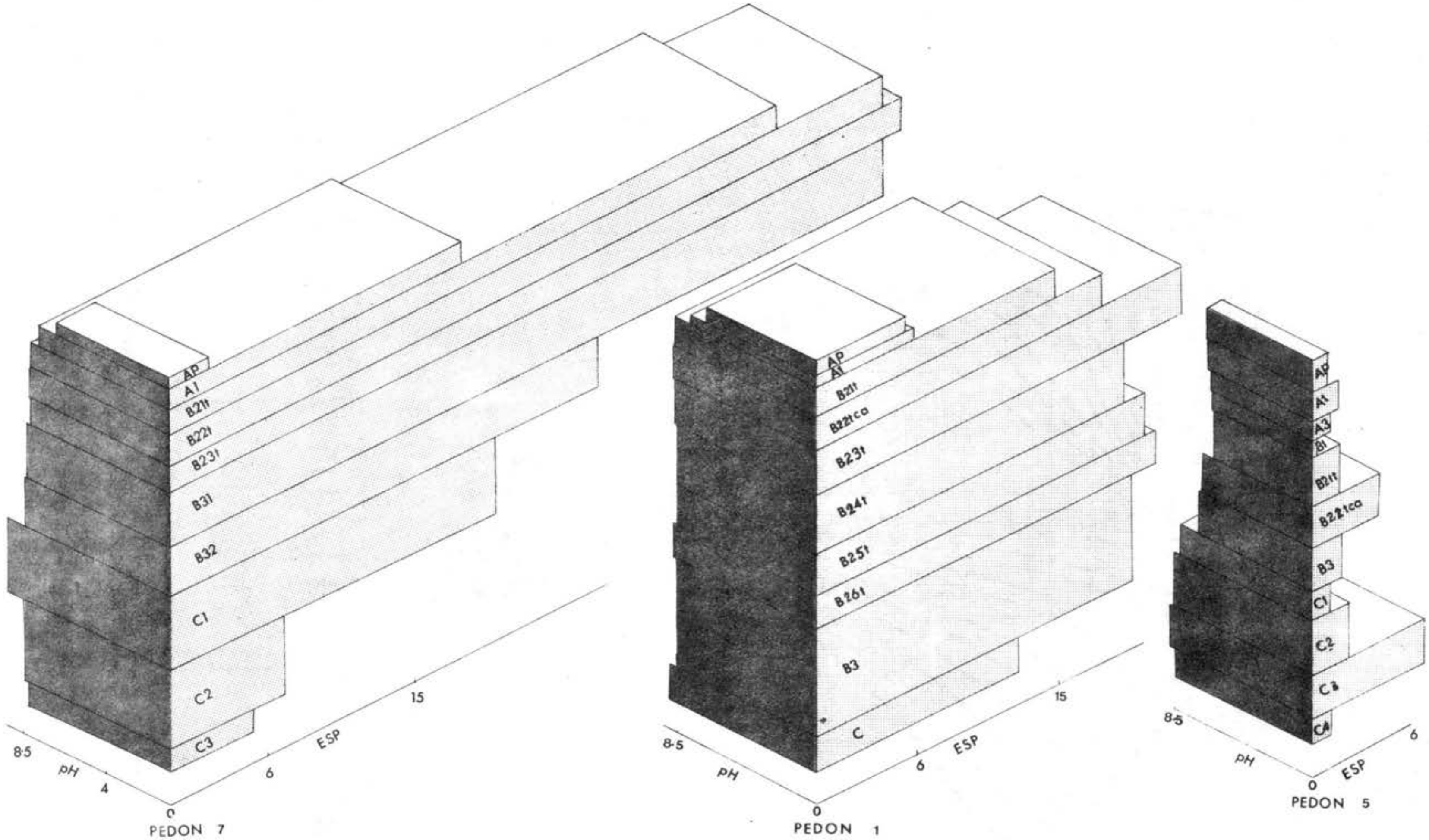


Figure 2.6. Variation of pH and ESP Within Depth for Pedons 7, 1 and 5

Class 1. Non-alkaline : pH ≤8.0

Class 2. Alkaline : 8.0 <pH. <9.0

Class 3. Strongly Alkaline : 9.0 ≤pH

<u>Sodicity</u>. The percent of exchangeable sodium reflects the processes of soil formation as well as having agricultural importance. Values of less than 6 indicated no change in the morphology of the profiles. Those subsurface horizons with ESP of 6 or more reflect particular morphological features like dispersion of soil colloids and formation of prismatic structure parting to blocky structure. When ESP exceeds 15, soils exhibit adverse properties due to dominance of exchangeable sodium. Soil colloids disperse almost completely, prismatic and columnar structures are capped with silty material due to removal of clay particles. The changes in physical properties decreases the soil productivity and produces the slickspots on the surface.

Class 1. Non-Sodic : ESP ≤6

Class 2. Sodic : 6 ESP <15

Class 3. Strongly sodic: 15 ≤ESP

One meter is the profile depth adopted for consideration and maximum values for ECX10^6, pH, and ESP within this profile, irrespective of the position of the horizon is taken to be diagnostic. Using the three criteria: salinity, alkalinity and sodicity, a salt affected soil is classified according to the most highly salt affected category it fits into within the criteria. All of the pedons under investigation belong to the non-saline class. Within this class pedons 1, 2, 4, and 7 fit into the alkaline - strongly sodic class which indicates a pH of 8.0 to 9.0 and an ESP of 15 or more for the upper one meter of the profile.

CHAPTER III

GENESIS OF SODIC SOILS AND THE ORIGIN OF SODIUM IN THEIR PROFILES

Abstract

High sodium is one of the properties of some soils of North Central Oklahoma. Sodium content may be a function of the initial state of the system or the external flux potential; influenced by the age of the system. Selected pedons from a toposequence of sodic soils in a mollisol area were examined in order to understand their genesis. In addition to characterization data, total digestible bases were measured in all horizons. Absence of coarse fragments, trace amounts of soluble salts, and uniform distribution of total digestible bases were observed within all of the pedons. Micaceous clays were found to be the major clay mineral. These similarities support the hypothesis that the soils were developed from Colluvial soil materials, originated from shale and silty shale materials on the higher slopes. Under the climatic conditions of North Central Oklahoma sulfate and chlorides of calcium, sodium, and potassium were leached into the ground water. Some calcium was combined with CO_2 and secondary calcium carbonates were formed which retarded the process of leaching. As the leaching rate slowed, the Na-rich

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feldspars were hydrolyzed and contributed Na^+ to the exchange complex of the soil.

Additional Key Words for Indexing: slickspots, North Central Oklahoma, Natrustolls, Argiustolls.

Review of Literature

Concepts of soil development are related to the interaction of physical, chemical, and biological processes controlled by the geomorphic features during a period of time. These processes are significantly influenced by the relationship of soils to their environmental conditions. Arnold (1965) states that the relationship of the soils and their environments provide the building blocks for the genetic concepts of soils. Jenny (1961) introduces the general state factor equation which indicates that ecosystem properties l, soil properties s, vegetation properties v, and animal properties a, are the functions of the initial state of the system Lo, external flux potential Px, and the age of the system t: l, s, v, a = f (Lo, Px, t)

If soil alone is chosen then each soil property is the function of the three state factors. Subgroups of the initial state of the soil, Lo, are the mineral and organic matrix of the soil, p, affected by the configuration of the system, that is, its topographic features, especially slope and exposure which is designated as r. Subgroups of the external flux potential, Px, are climates, particularly precipitation and the temperature defined as the external climate, cl. The second subgroup of Px is identified as biotic factor, o, which includes all the active or dormant species, which may migrate or be carried into the system. In addition to climatic and biotic factors there are numerous other factors such as dust, storms, flood or annual additions of fertilizer etc., which are to be included as Px features. Accordingly for soil properties:

$$s = f\ (cl,\ o,\ r,\ p,\ t,\ \ldots)$$

High sodium is one of the properties of salt affected soils. Sodium content may be a function of the initial state of the system, that is it originated in the parent material, or the external flux potential; it is added to the soil by the external agents like irrigation water etc. In either case, weathering of the sodium containing material and/or its distribution is strongly affected by the aging of the system.

Murphy and Daniels (1935) explain that the presence of alkali spots are probably due to the accumulation of sodium salts in the sediments laid down by receding seas. Wilding et al. (1963) found that the source of sodium in solonetzic soils of Illinois was the Na-rich feldspars of the parent loess. They also indicate that the other possible source of extractable Na^+ is ocean spray salts from rain. The sea deposited salts and Na-rich feldspars are components of the initial state of the system, and the sprayed salts from the rain are to be considered as results of the actions of the external potential fluxes which contribute sodium to the soils.

When the soluble sodium salts react with the exchange complex of the soil, sodium clays form. Under dispersive effects of sodium, organic matter moves from the A to the B horizon. With further reaction of sodium with the exchange complex the process of eluviation of the layer-lattice silicate clays is enhanced.

The presence of significant amounts of sodium in the exchange complex of the soil is a feature which reflects genetic influences as well as having agricultural importance. A knowledge of the origin of sodium in the slickspots is also important in planning reclamation programs and protecting the surrounding "normal" soils.

The objective of this manuscript is to obtain knowledge about the genesis of the sodium affected soils of North Central Oklahoma and the source of sodium in their profiles. In order to do this, seven sampling pedons were characterized and the data obtained offered in the previous paper. Special investigations were yet to be carried out in order to establish a scientific model explaining the genesis of Ustolls and the source of sodium in Natrustolls and some Argiustolls in North Cental Oklahoma.

Procedures Applied

The total digestible sodium and potassium were determined in the total soil samples and in the particles finer than 50μ for all of the pedogenic horizons, using a slipped block design developed by Timon (1962). The structural bases were also determined in the clay samples from selected horizons of pedons 1, 4, and 7.

The digestion procedure was identical to the one used by Webber and Shivas (1953). One gram portions of the soil, or 25-ml aliquots of suspensions, were transfered into teflon beakers. The suspensions were dried before digestion processes were applied. Digestion of the specimens was carried out under a perchloric hood using a sand bath containing medium and fine sand particles. The specimens were treated with 10 ml of 48% HF and 2 ml of 5% H_2SO_4, and heated to dryness. The treatment was repeated until the color turned to a reddish brown. Then

10 ml of 5% HNO_3 was added, and heated to dryness. If the color of the specimen was not white or yellowish white then another HNO_3 treatment was necessary. Two treatments with HNO_3 was usually sufficient. After cooling the samples under the hood, about 25 ml of 0.1 N HCl was added to the beakers and left for at least 12 hours. The solutions were then mixed throughly with rubber tipped stirring rods and filtered through Whatman 42 filter papers into 100-ml volumetric flasks. The filter papers were washed with 0.1 N HCl. The solutions were made to volume with distilled water. Then sodium and potassium were determined with a Coleman model 21 flame photometer. The regression of Y (the concentration of the standard solutions), on the X (the scale reading of the equipment), was determined for each of the bases separately and then the regression equations were used to compute the unknowns.

The clay components in selected pedons were difficult to identify using standard x-ray diffraction techniques. The diffraction maxima corresponding to 001 spacing were diffuse and weak. Removing inter-layered K^+ aided in identification of 2:1 layered silicates in mixed-layered micaceous soil clays. Parashiva Murthy et al. (1973) used this procedure in some Texas soils. Removal of interlayered K^+ was accomplished by treating the fine and coarse clay particles with lithium nitrate. A 25-ml aliquot of the Sr-saturated clay suspension was dried in a platinum crucible, placed in a furnace for 18 hours at 300°C. After fusion, the samples were washed free of excess salts, and x-ray diffraction patterns were obtained from Mg-saturated, glycerol-solvated specimens mounted on ceramic slides.

A correlation type similarity was computed between the pedogenic horizons. This was based upon their 39 laboratory and four morphological properties. The data obtained from the digestion of the soil particles were not included in the computation of the pairwise similarities of the horizons. In order to compute the correlation type similarities the 79 x 43 data matrix was standardized within each column and the correlation matrix among rows (horizons) was computed. Sokal and Sneath (1963) explain the procedure of standardization. These pairwise similarities help the researcher to determine the interconnection of the solum and the parent material at the study site.

Results

This section presents those laboratory findings and their interpretations which help the investigator illustrate possible procedures in development of Ustolls in North Central Oklahoma.

Coefficients of similarities between every two pedogenic horizons in the sequence (Table 3.1) indicate dissimilarities between B3 and C horizons for Pedons 1, 5, and 7 and very insignificant similarities for Pedons 2, 3, 4, and 6.

The following pages present the distribution of the structural bases within the individual pedons. The amount of total digestible calcium was very small and insignificant except in the $CaCO_3$ rich horizons. The evaluation of the interconnection of the structural sodium and extractable Na^+ is the primary objective of these analyses.

In this paper, because of the trace amounts of soluble constituents, the term extractable, which means soluble plus exchangeable, has been used to represent the amount of bases sorbed in the exchange complex of the soils. The term structural bases means the total digestible bases minus the amount, in percent, of extractable

TABLE 3.1

INDICATION OF CORRELATION TYPE SIMILARITIES BETWEEN THE PEDOGENIC HORIZONS OF THE SAMPLING PEDONS

Pedon 1		Pedon 2		Pedon 3		Pedon 4		Pedon 5		Pedon 6		Pedon 7	
Horizon	Corr.*	Horizon	Corr.*	Horizon	Corr.*	Horizon	Corr.*	Horizon	Corr.*	Horizon	Corr.*	Horizon	Corr.*
Ap		Ap		Ap		Ap		Ap		Ap1		AP	
	0.75		0.62		0.77		0.53		0.58		0.63		0.79
A1		A1		A1		A1		A1		AP2		A1	
	0.04		0.30		0.83		0.74		0.69		0.57		0.44
B21t		B21t		A3		B1		A3		A1		B21t	
	0.84		0.42		0.49		0.39		0.53		0.69		0.77
B22tca		B22t		B1		B21t		B1		B1		B22t	
	0.65		0.17		0.89		0.81		0.54		0.44		0.95
B23t		B23t		B21t		B22t		B21t		B21t		B23t	
	0.59		0.87		0.72		0.49		0.55		0.77		0.64
B24t		B24tca		B22t		B22tca		B22tca		B22t		B31	
	0.44		0.75		0.34		0.70		0.62		0.58		0.81
B25t		B25tca		B23t		B23tca		B3		B23t		B32	
	0.75		0.66		0.90		0.51		-0.41		0.28		-0.12
B26t		B26t		B24t		B24t		C1		B24tca		C1	
	0.51		0.46		0.17		0.47		0.66		0.30		0.15
B3		B3		B25t		B31		C2		B3		C2	
	0.01		0.42		0.58		0.65		0.63		0.21		0.70
C		C		B26t		B32ca		C3		C1		C3	
					0.52		0.39		0.57		0.26		
				B31		C1		C4		C2			
					0.43		0.69				0.38		
				C		C2				C3			
							0.85				0.72		
						C3				C4			

* Correlation Type Similarity

bases. Structural sodium and potassium have been reported in % Na_2O and % K_2O, based upon the analysis of the total soils. In this manuscript, fine particles refers to particles finer than 50μ, and coarse particles refers to particles 2mm - 50μ in size.

Pedon 1 (Table 3.2). The structural Na content of this soil is significantly high and varies within the profile. In the surface horizons coarse particles contain more sodium in their structure than do fine particles. In the deeper parts of the profile the two subfractions are closely correlated. This reflects that probably fine and coarse feldspars have been equally subjected to intense weathering. The x-ray diffraction patterns of the $LiNO_3$ treated clay samples indicate a very sharp maximum of approximately 17A° for the B3 and C horizons. This indicates a predominance of micaceous clays in the solum and the soil parent material (Figure 3.1). The clay distribution curve (Figure 3.2) and the distribution pattern of the extractable Na^+ (Figure 3.3) are very similar and are indicators of ESP variation within the profile. Although B26t and underlying horizons occur below the ground water, they do not contain any higher amount of Na^+ than the B subhorizons about the water table.

Pedon 2 (Table 3.3). The analysis of the digested soil samples indicate a high content of Na-rich minerals. The coarser fractions are found to contain more sodium in their structure than the fine particles. These fine textured feldspars have been subjected to weathering and they have contributed a great amount of Na^+ to the profile. The structural potassium content of the finer soil subfractions are much higher than the coarse fractions of the soil. This is due to an abundance of micaceous clays in this pedon. A high

TABLE 3.2

ANALYSIS OF STRUCTURAL BASES
PEDON 1

	%Na_2O			%K_2O		
Horizons	Total	>50μ	<50μ	Total	>50μ	<50μ
Ap	1.29	1.05	.23	1.91	.20	1.71
A1	1.67	1.26	.40	2.51	.32	2.19
B21t	1.05	0.64	.40	1.75	.09	1.65
B22tca	1.44	0.84	.60	2.77	.28	2.49
B23t	0.90	0.52	.38	1.96	.14	1.82
B24t	1.16	0.60	.56	1.81	.18	1.62
B25t	0.99	0.56	.43	1.66	.19	1.46
B26t	1.15	0.65	.50	2.32	.18	2.13
B3	1.28	0.65	.63	1.89	.28	1.61
C	0.57	0.32	.24	0.85	.04	0.80

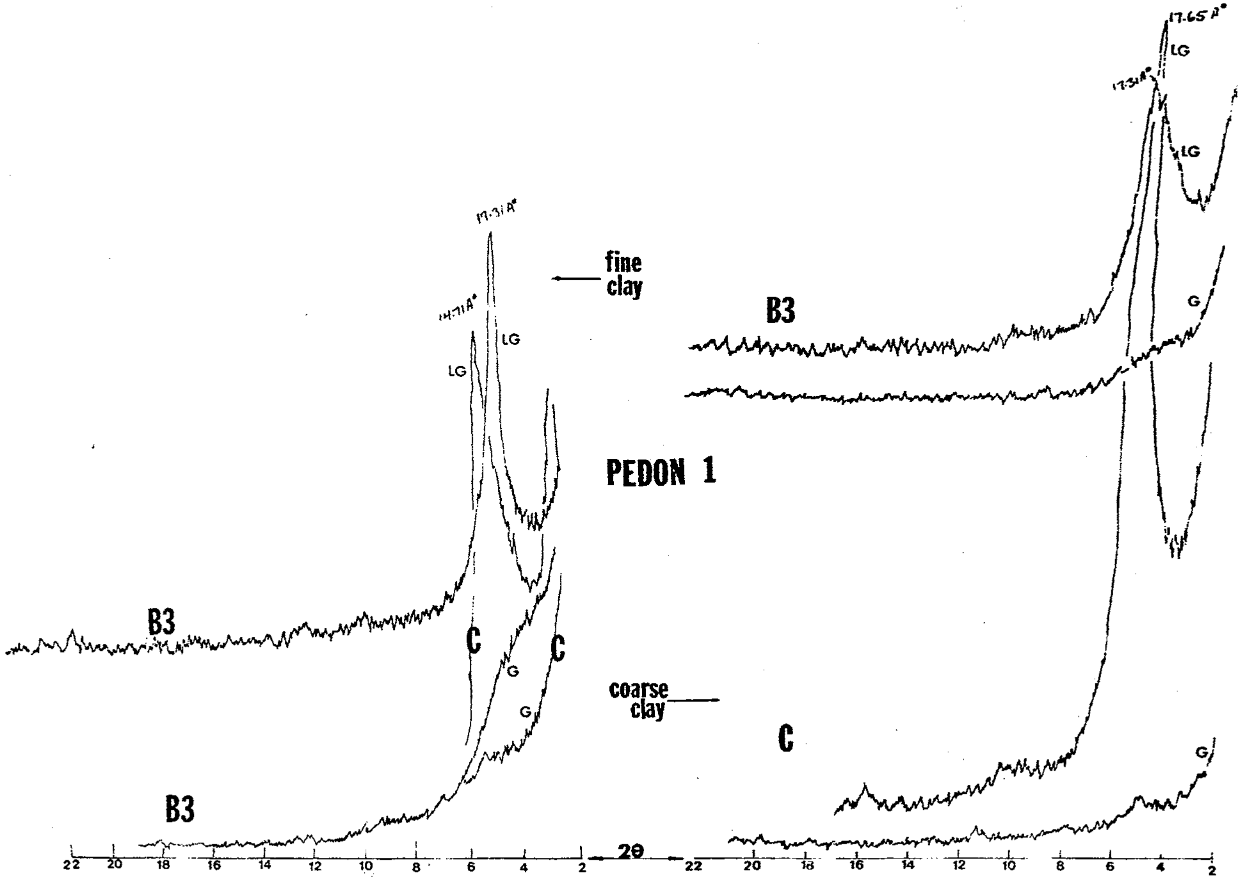

Figure 3.1. X-ray Diffractograms, Pedon 1. (G) Control, and (LG) $LiNO_3$ Treated

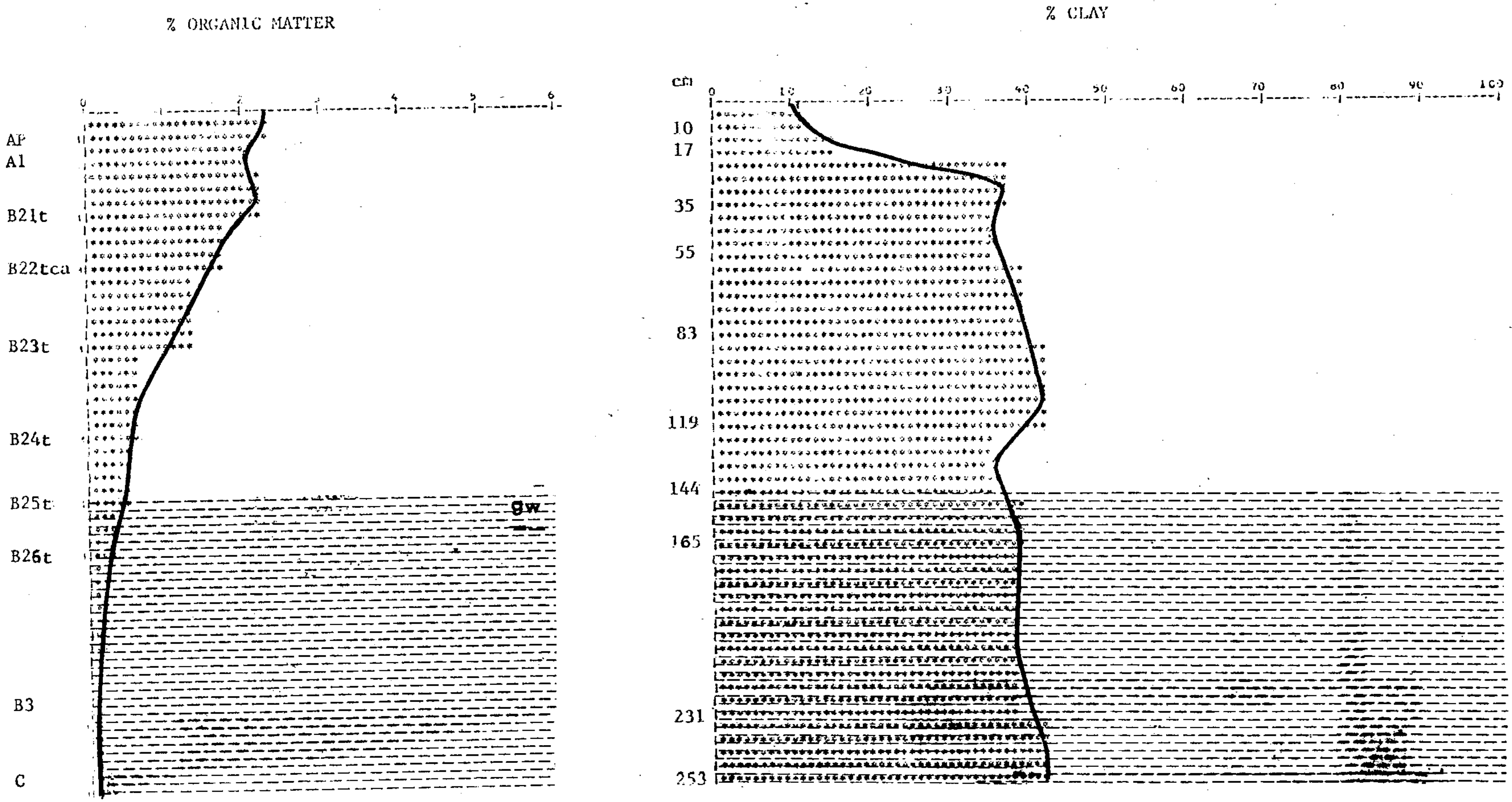

Figure 3.2. Graph Analyses of Organic Matter and Clay Content, Pedon 1

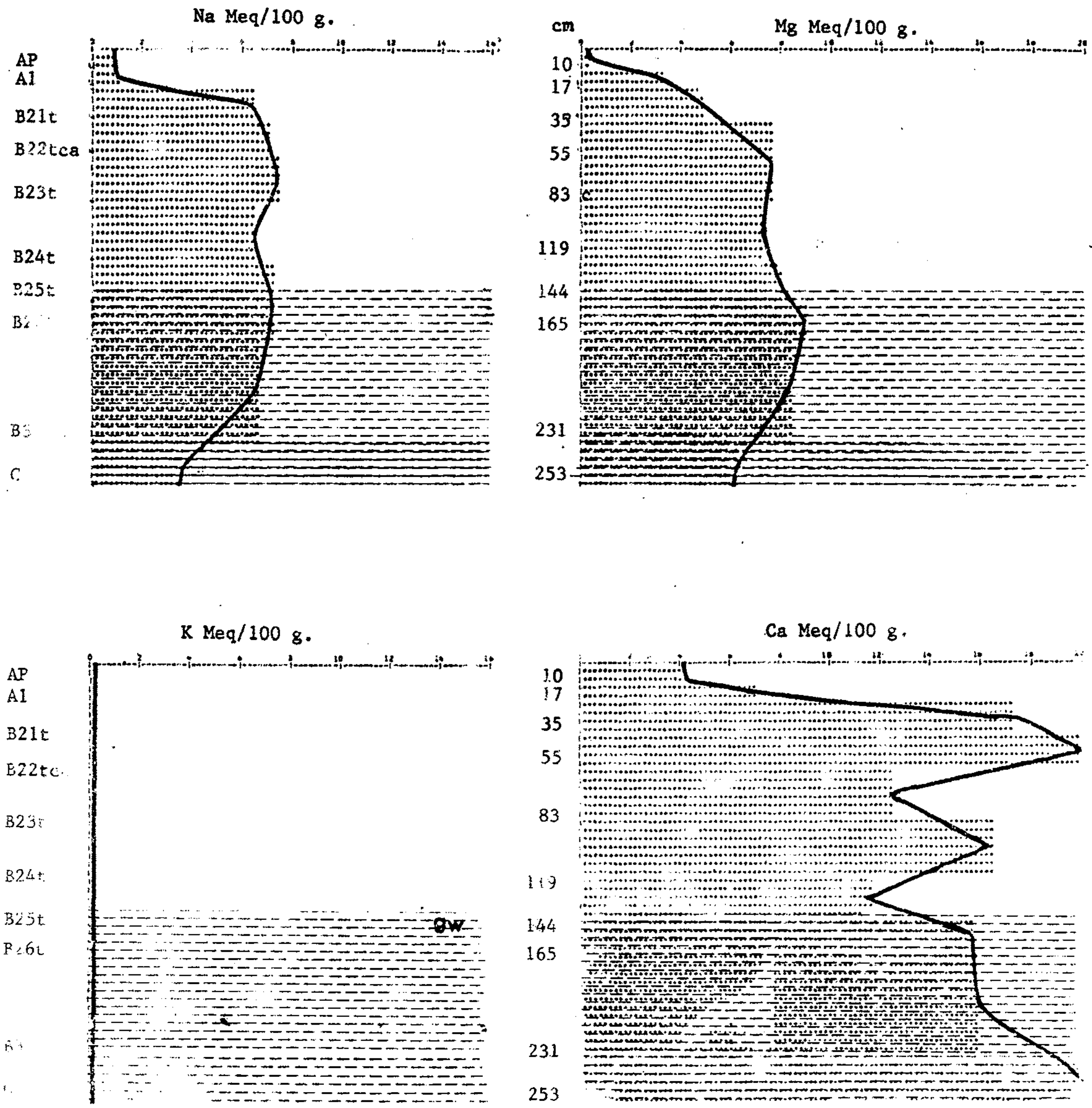

Figure 3.3. Graph Analyses of Extractable Bases, Pedon 1

TABLE 3.3

ANALYSIS OF STRUCTURAL BASES
PEDON 2

Horizons	%Na_2O			%K_2O		
	Total	>50μ	<50μ	Total	>50μ	<50μ
Ap	1.43	1.07	.36	2.25	.18	2.07
A1	1.36	0.95	.41	1.63	.22	1.41
B21t	1.04	0.70	.33	1.51	.15	1.36
B22t	0.96	0.54	.42	1.57	.19	1.37
B23t	1.18	0.67	.50	2.13	.12	2.00
B24tca	1.12	0.63	.49	2.18	.18	2.00
B25tca	1.29	0.67	.61	1.97	.30	1.67
B26t	0.88	0.49	.39	1.62	.21	1.40
B3	1.05	0.64	.40	1.34	.15	1.18
C	0.91	0.55	.35	1.33	.22	1.11

conformity exists between total clay content and extractable sodium content. The clay distribution pattern (Figure 3.4) and extractable Na^+ distribution curve (Figure 3.5) illustrates this interrelation. The horizon B3 and C occurs below the water table, but they contain even less Na^+ in their exchange complex than the B subhorizons above the water level. This indicates that ground water is the recipient of the released Na^+ resulting from the weathering of Na rich feldspars.

Pedon 3 (Table 3.4). The structural Na content in the total soil is less than the previous pedons. The fine and coarse soil particles are almost identical in the amount of sodium content in their structure. This phenomenon, together with the absence of significant amounts of exchangeable Na^+ in the exchange complex of the soil, indicates that this pedon has not been subjected to intense weathering. The K_2O content of the fine soil subfractions is higher than in the coarse soil subfractions. The B26t and underlying strata of this pedon occur below the water table and indicate a higher ESP than the upper horizons. This reflects the hydrolysis of Na-feldspars which are in contact with ground water. The distribution patterns of clay (Figure 3.6) and extractable Na^+ (Figure 3.7) agree although ESP is not noticeably high within this pedon.

Pedon 4 (Table 3.5). The content of the structural sodium in the total soil is identical to pedon 3, but this pedon has been subjected to more intense weathering and hence more release of Na^+ from Na-feldspars. The fine soil particles of the surface horizons contain less Na in their structure than in the coarse particles. Below the surface horizons the pattern is reversed with the coarse particles containing less sodium in their structure. This shows that both the

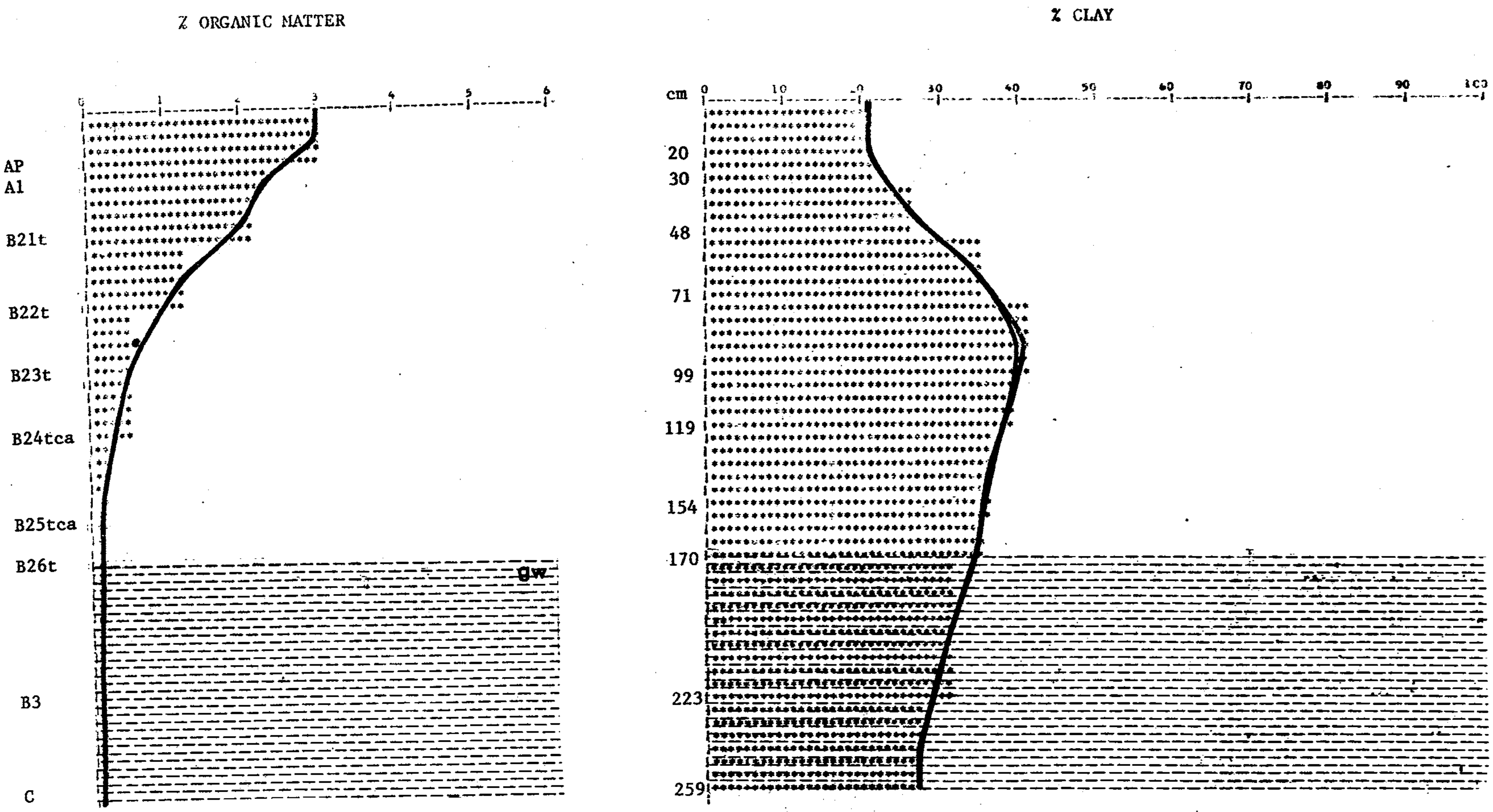

Figure 3.4. Graph Analyses of Organic Matter and Clay Content, Pedon 2

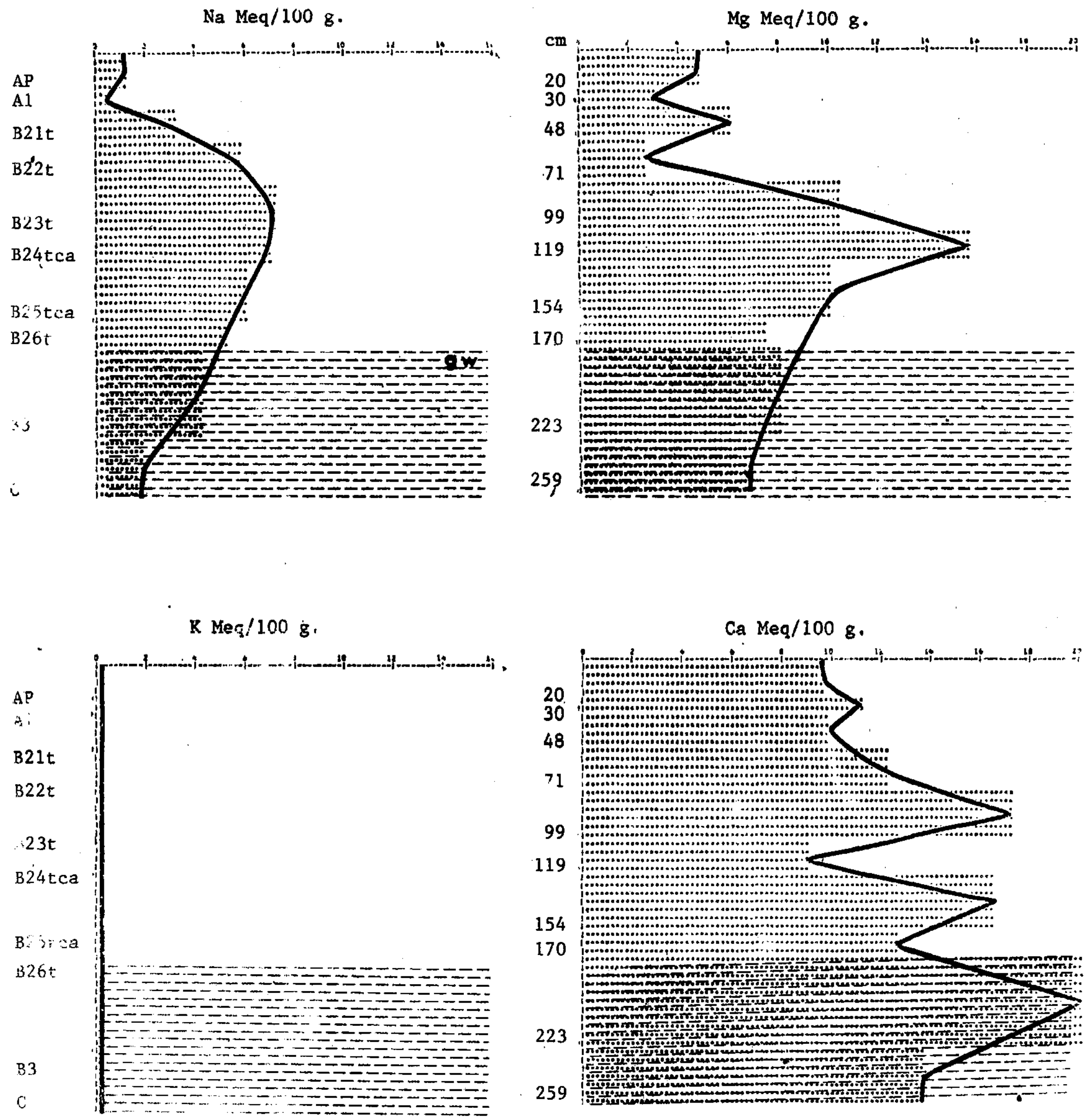

Figure 3.5. Graph Analyses of Extractable Bases, Pedon 2

TABLE 3.4

ANALYSIS OF STRUCTURAL BASES
PEDON 3

	%Na_2O			%K_2O		
Horizons	Total	>50μ	<50μ	Total	>50μ	<50μ
Ap	0.93	0.62	.30	1.47	.21	1.26
A1	0.86	0.56	.29	1.79	.19	1.59
A3	0.99	0.57	.42	1.61	.21	1.40
B1	0.95	0.59	.35	1.60	.19	1.41
B21t	0.90	0.58	.31	1.46	.12	1.33
B22t	0.88	0.51	.37	1.71	.20	1.51
B23t	0.96	0.46	.50	1.53	.18	1.35
B24t	0.73	0.38	.34	1.58	.20	1.38
B25tca	0.80	0.42	.38	1.55	.20	1.35
B26t	0.82	0.39	.43	1.92	.26	1.66
B31	1.10	0.54	.56	2.07	.36	1.70
C	0.64	0.33	.31	1.55	.29	1.25

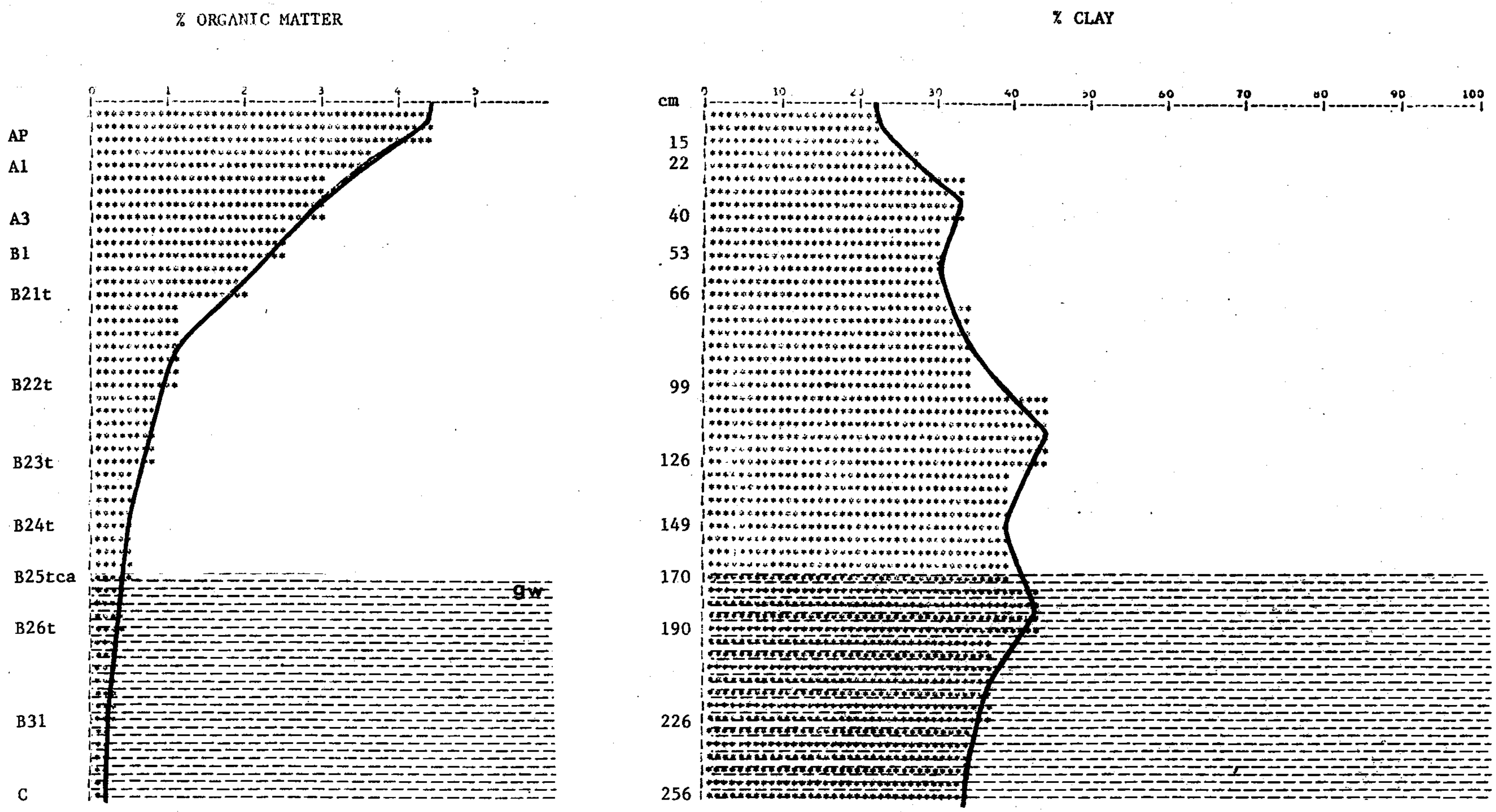

Figure 3.6. Graph Analyses for Organic Matter and Clay Content, Pedon 3

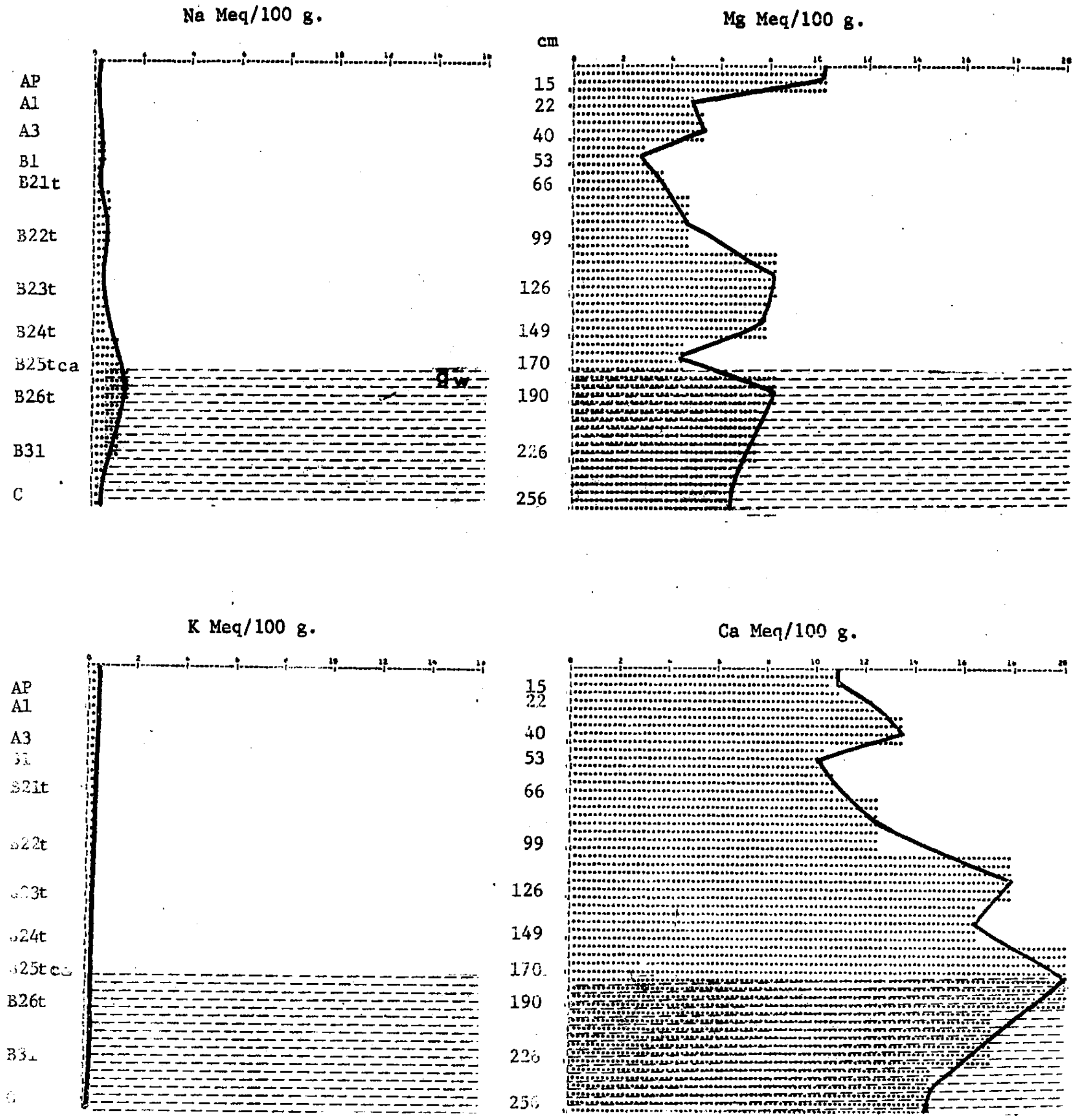

Figure 3.7. Graph Analyses of Extractable Bases, Pedon 3

TABLE 3.5

ANALYSIS OF STRUCTURAL BASES
PEDON 4

	$\%Na_2O$			$\%K_2O$		
Horizons	Total	>50μ	<50μ	Total	>50μ	<50μ
Ap	1.31	0.87	.44	1.71	.33	1.38
A1	1.03	0.68	.35	1.50	.30	1.20
B1	0.90	0.54	.35	1.31	.17	1.13
B21t	0.81	0.49	.31	1.18	.08	1.10
B22t	0.88	0.52	.36	1.47	.12	1.35
B22tca	0.82	0.47	.35	1.45	.15	1.29
B23tca	1.04	0.48	.56	1.91	.28	1.63
B24t	0.66	0.32	.34	1.55	.19	1.35
B31	0.51	0.24	.26	1.77	.09	1.67
B32ca	0.48	0.23	.24	1.83	.03	1.79
C1	0.48	0.20	.28	1.93	.22	1.70
C2	0.19	0.03	.15	2.41	.10	2.30
C3	0.71	0.18	.52	3.91	.30	3.61

silt and the coarser particles have been contributors of Na^+ to this profile. Coarse clay fractions of the selected horizons indicate insignificant amounts of Na in their structure as well as the fine clay fractions. The x-ray diffraction patterns of $LiNO_3$ treated clay specimens (Figure 3.8) indicate very sharp maxima at 17.6A^o for the B22t horizon and at 15.5A^o for the C horizon. This reflects the abundance of micaceous clays in the solum and initial material. This phenomenon is supported by uniformly distributed K_2O content of this profile. The distribution pattern of the clay content (Figure 3.9) and extractable Na^+ content (Figure 3.10) do not closely agree because of the abrupt increase of clay in the lower layers of the profile. This pedon has a high water holding capacity which is suitable for hydrolysis of the Na-rich feldspars.

Pedon 5 (Table 3.6). The structural sodium content of the fine particles are less than the coarse particles. The richness of the soil in fine textured feldspars, together with the absence of extractable Na^+, indicate that the Na-feldspars have not been subjected to intense weathering. A close agreement does not exist between the clay distribution curve (Figure 3.11) and the pattern of distribution of extractable Na^+ (Figure 3.12). The structural potassium is uniformly distributed within the profile and the fine particles contain more K than the coarse particles.

Pedon 6 (Table 3.7). The Na content of the soil minerals is higher in the surface than in the bottom of the solum. Particles coarser than silt contain more sodium in their structure than the finer particles in the pedon. This criterion plus the absence of extractable Na^+, indicates an absence of weathering of Na-rich

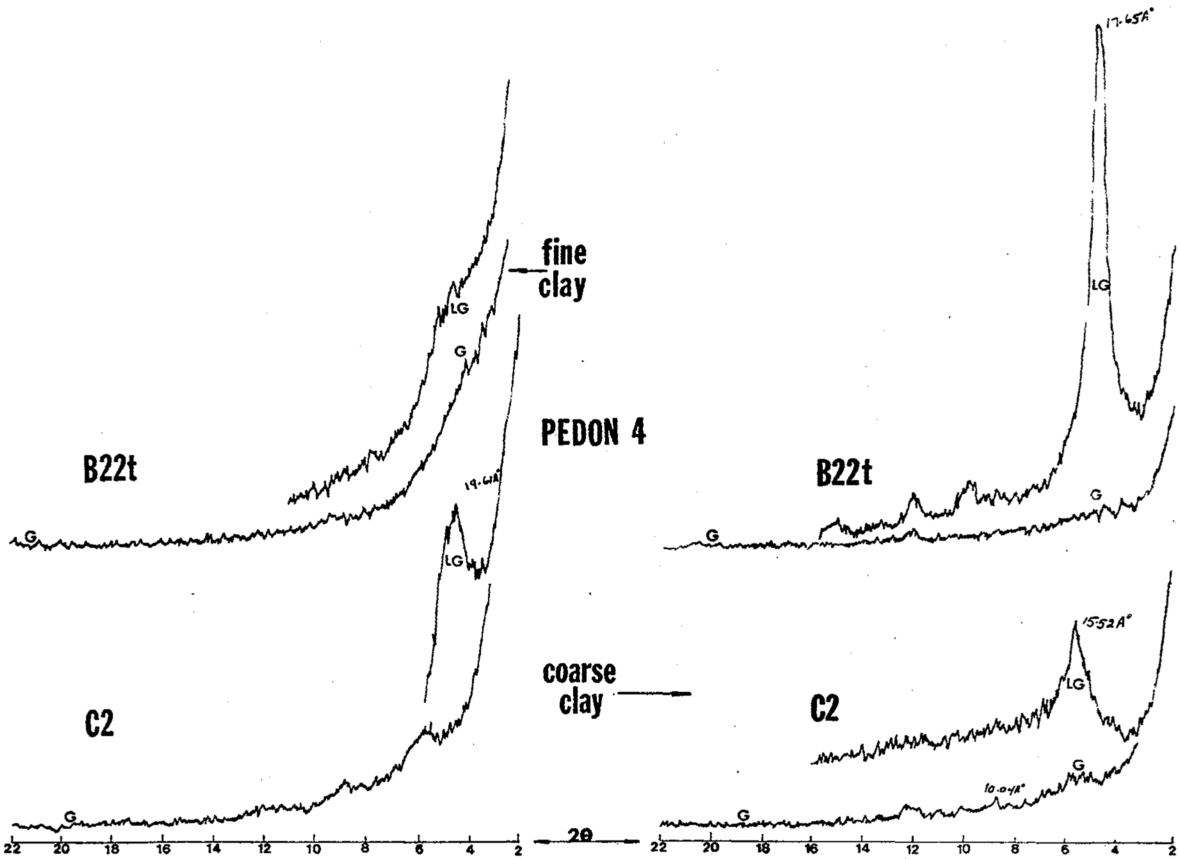

Figure 3.8. X-ray Diffractograms, Pedon 4 (G) Control, and (LG) $LiNO_3$ Treated

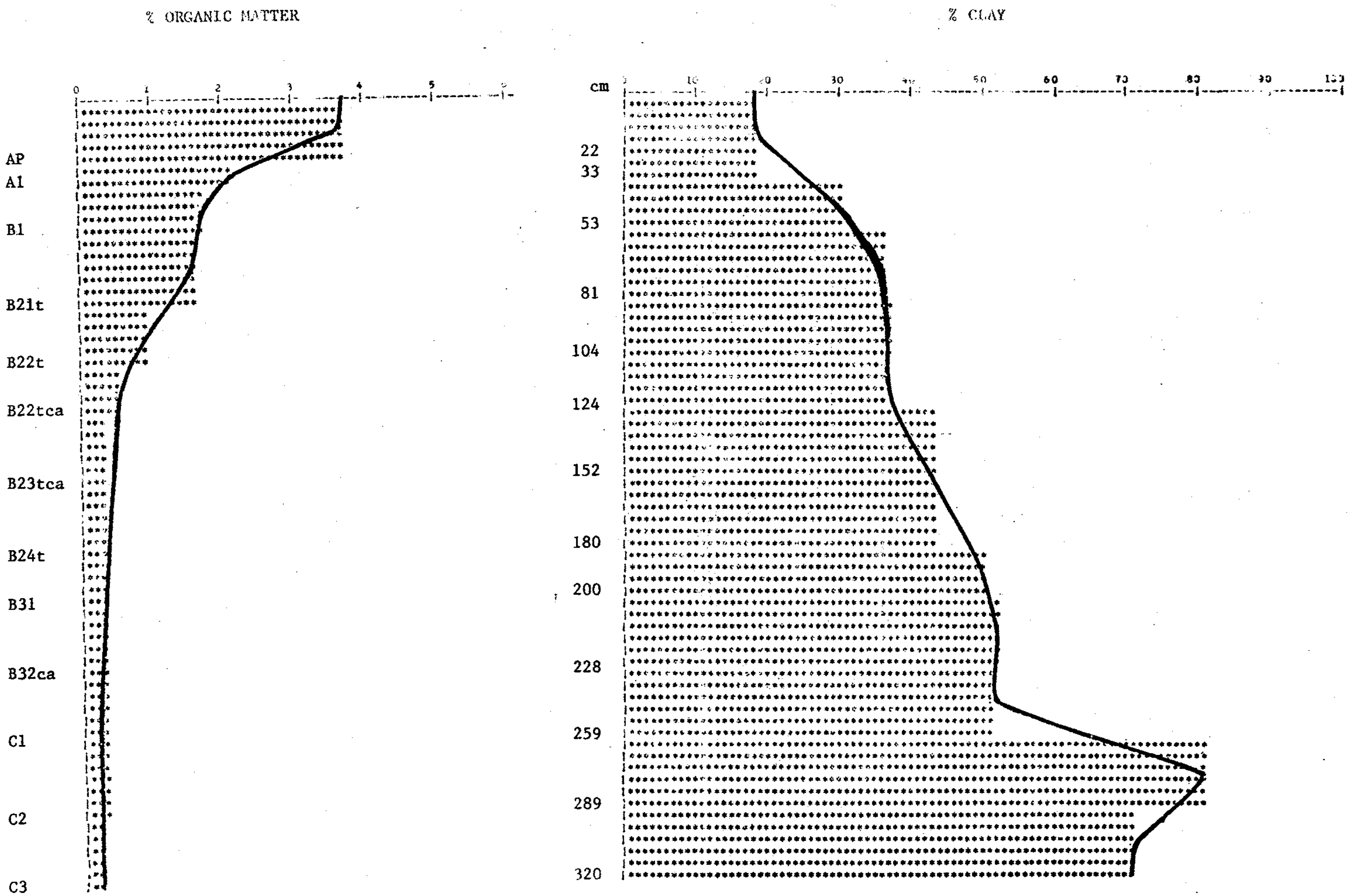

Figure 3.9. Graph Analyses of Organic Matter and Clay Content, Pedon 4

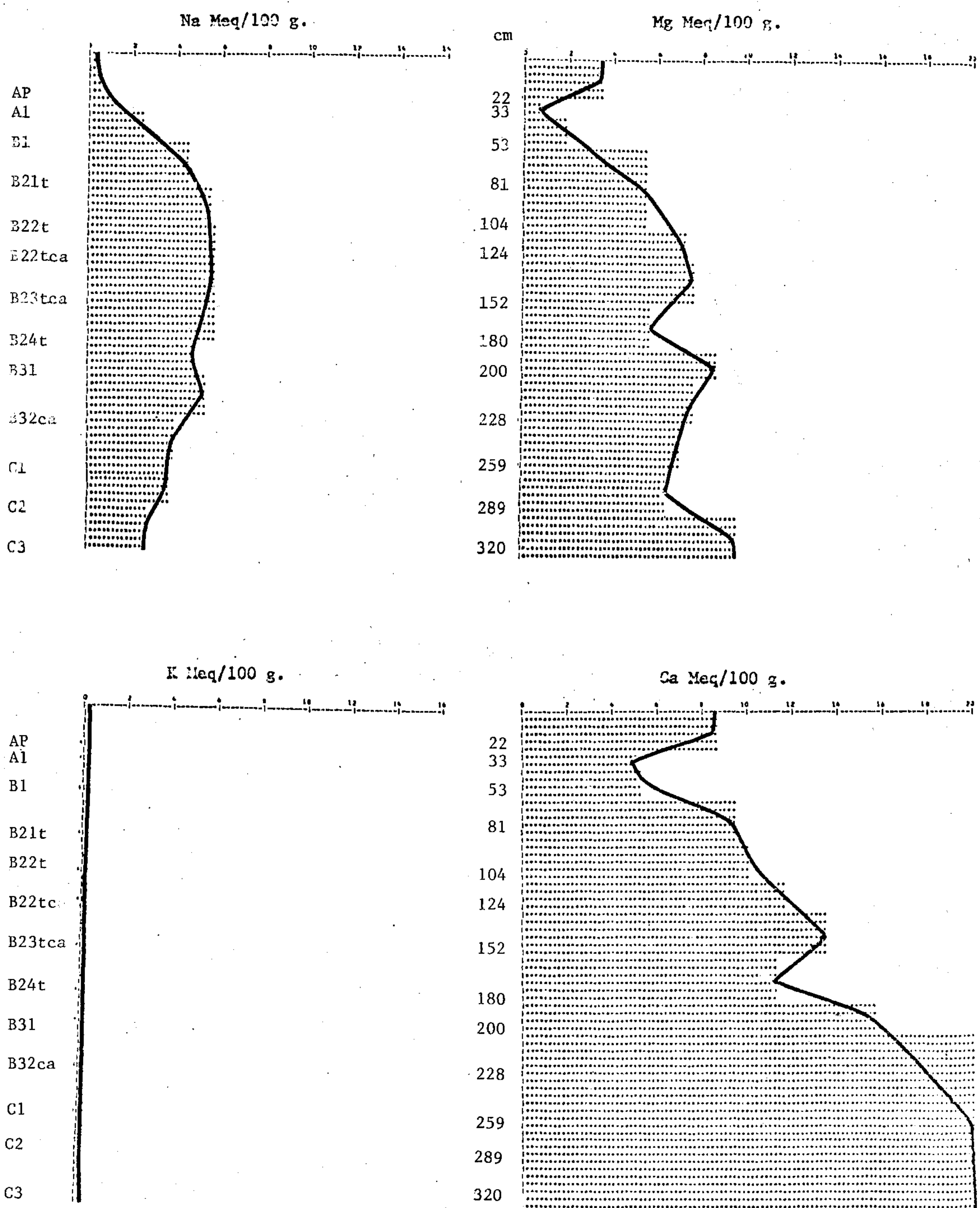

Figure 3.10. Graph Analyses of Extractable Bases, Pedon 4

TABLE 3.6

ANALYSIS OF STRUCTURAL BASES
PEDON 5

	$\%Na_2O$			$\%K_2O$		
Horizons	Total	>50μ	<50μ	Total	>50μ	<50μ
Ap	0.87	0.57	.30	1.45	.29	1.15
A1	0.83	0.47	.35	1.30	.29	1.00
A3	0.77	0.45	.31	1.34	.22	1.12
B1	0.60	0.33	.27	1.24	.23	1.01
B21t	0.68	0.40	.28	1.22	.19	1.03
B22tca	0.87	0.47	.39	1.43	.21	1.22
B3	0.81	0.51	.30	0.93	.13	0.79
C1	0.91	0.55	.35	1.09	.19	0.90
C2	1.39	0.94	.45	1.20	.15	1.04
C3	1.26	0.81	.44	1.16	.24	0.92
C4	1.04	0.70	.33	1.53	.20	1.33

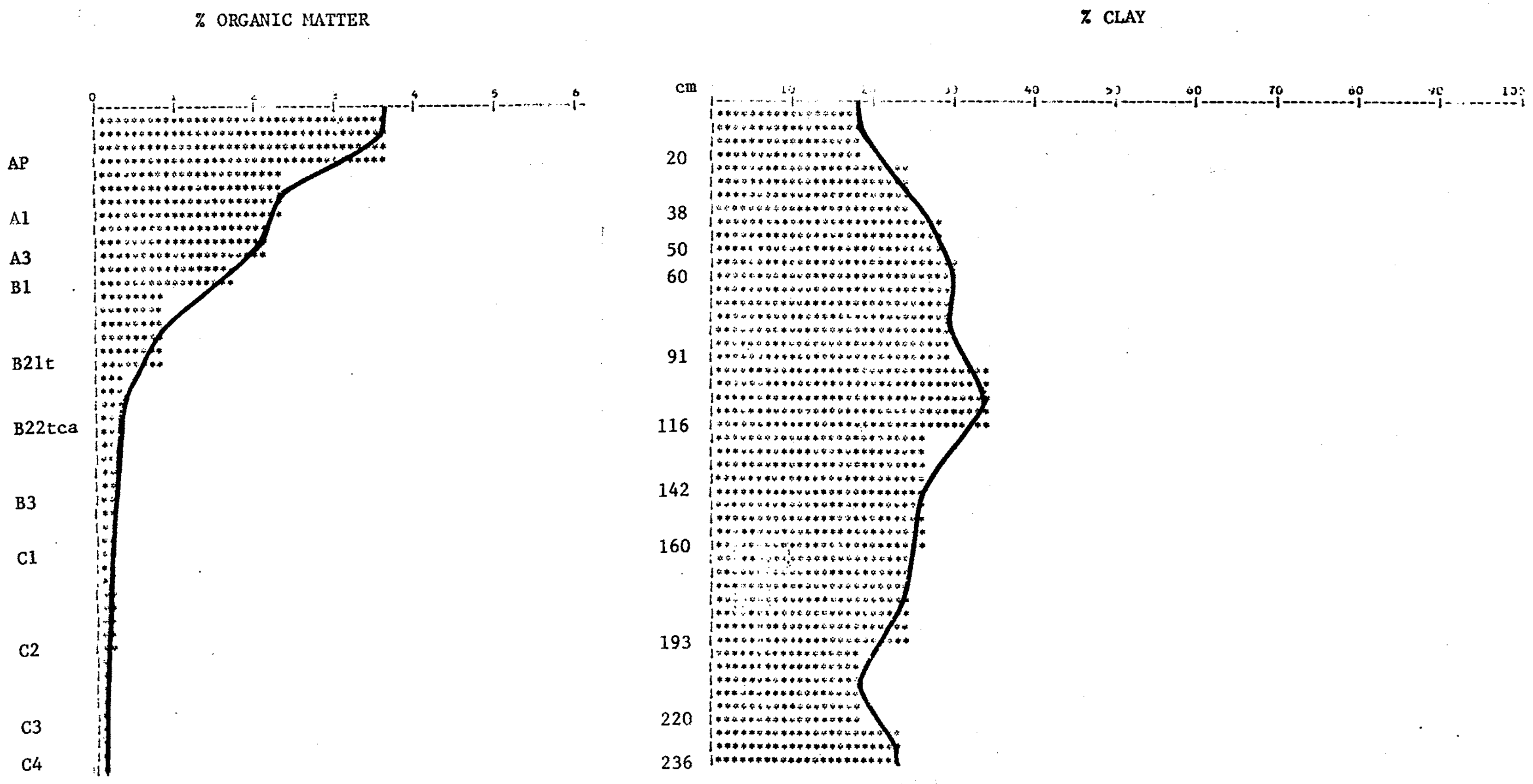

Figure 3.11. Graph Analyses of Organic Matter and Clay Content, Pedon 5

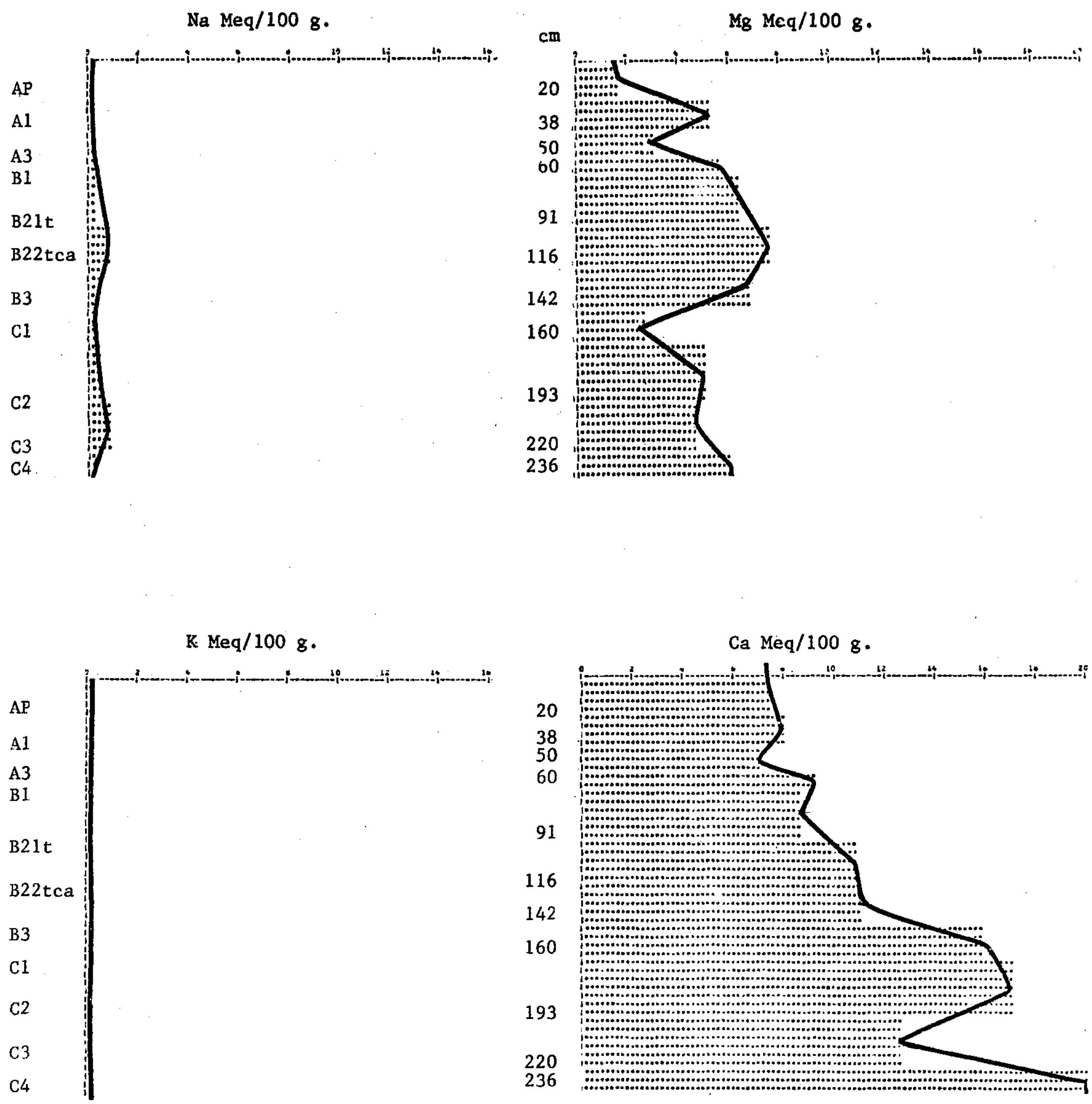

Figure 3.12. Graph Analyses of Extractable Bases,
Pedon 5

TABLE 3.7

ANALYSIS OF STRUCTURAL BASES
PEDON 6

	$\%Na_2O$			$\%K_2O$		
Horizons	Total	>50μ	<50μ	Total	>50μ	<50μ
Ap1	1.28	.79	.48	1.95	.37	1.58
Ap2	0.83	.53	.30	1.58	.26	1.31
A1	0.90	.59	.30	1.47	.24	1.33
B1	1.16	.64	.51	1.89	.36	1.52
B21t	0.83	.53	.30	1.41	.09	1.04
B22t	0.82	.41	.40	1.68	.19	1.49
B23t	0.91	.43	.47	2.09	.33	1.76
B24ca	0.77	.35	.42	1.30	.18	1.11
B3	0.87	.58	.28	1.12	.11	1.00
C1	0.69	.41	.28	1.28	.17	1.10
C2	1.07	.76	.31	0.89	.13	0.76
C3	1.32	.76	.55	1.28	.27	1.01
C4	1.14	.78	.35	1.47	.19	1.27

feldspars. The clay distribution pattern (Figure 3.13) indicates a decrease in clay content in the C3 and C4 horizons, but extractable Na^+ increases very gradually within this pedon (Figure 3.14). Those horizons which are occurring below the water table are identical in the extractable Na^+ content to those B horizons above the level of the ground water. Sodium bicarbonate seems to be the major salt in the ground water.

Pedon 7 (Table 3.8). This pedon is not as rich in structural sodium as pedons 1 and 2. The fine particles contain less sodium than the coarse particles. These phenomena together with the abundance of $NaHCO_3$ in the ground water indicate that the soil has been subjected to intense weathering of the Na-rich feldspars, probably albite. Coarse and fine clay particles contain insignificant amounts of Na in their structures. The K_2O content of the fine soil subfractions decrease within the profile. This criterion closely agrees with the clay analysis of this pedon. X-ray diffraction patterns (Figure 3.15) of $LiNO_3$ treated clay specimens indicate a very sharp maximum at 17A° for B21t and B3 horizons. This reflects the predominance of the micaceous clays in the solum and in the initial material. Extractable Na^+ which was released through hydrolysis of the Na-rich feldspars, has been mainly sorbed on the clay minerals. The clay distribution curve (Figures 3.16) and the distribution pattern of extractable Na^+ (Figure 3.17) agree closely and support this phenomenon.

The data presented for each individual pedon indicate that all of the seven pedons are rich in Na-rich feldspars. The profiles of the sodium affected soils (Pedons 1, 2, 4, and 7) have been subjected to intense weathering, and have released significant amounts of Na^+.

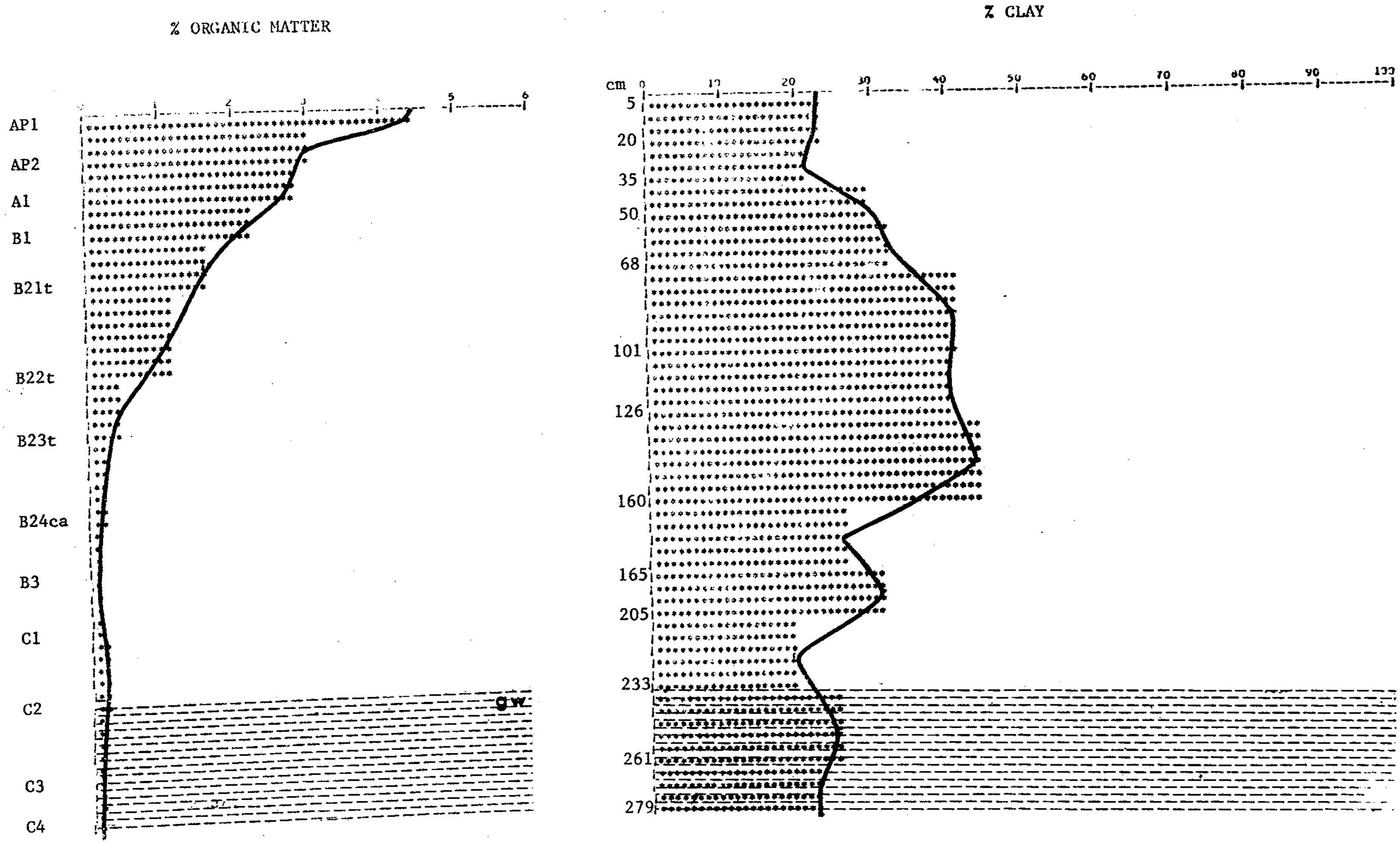

Figure 3.13. Graph Analyses of Organic Matter and Clay Content, Pedon 6

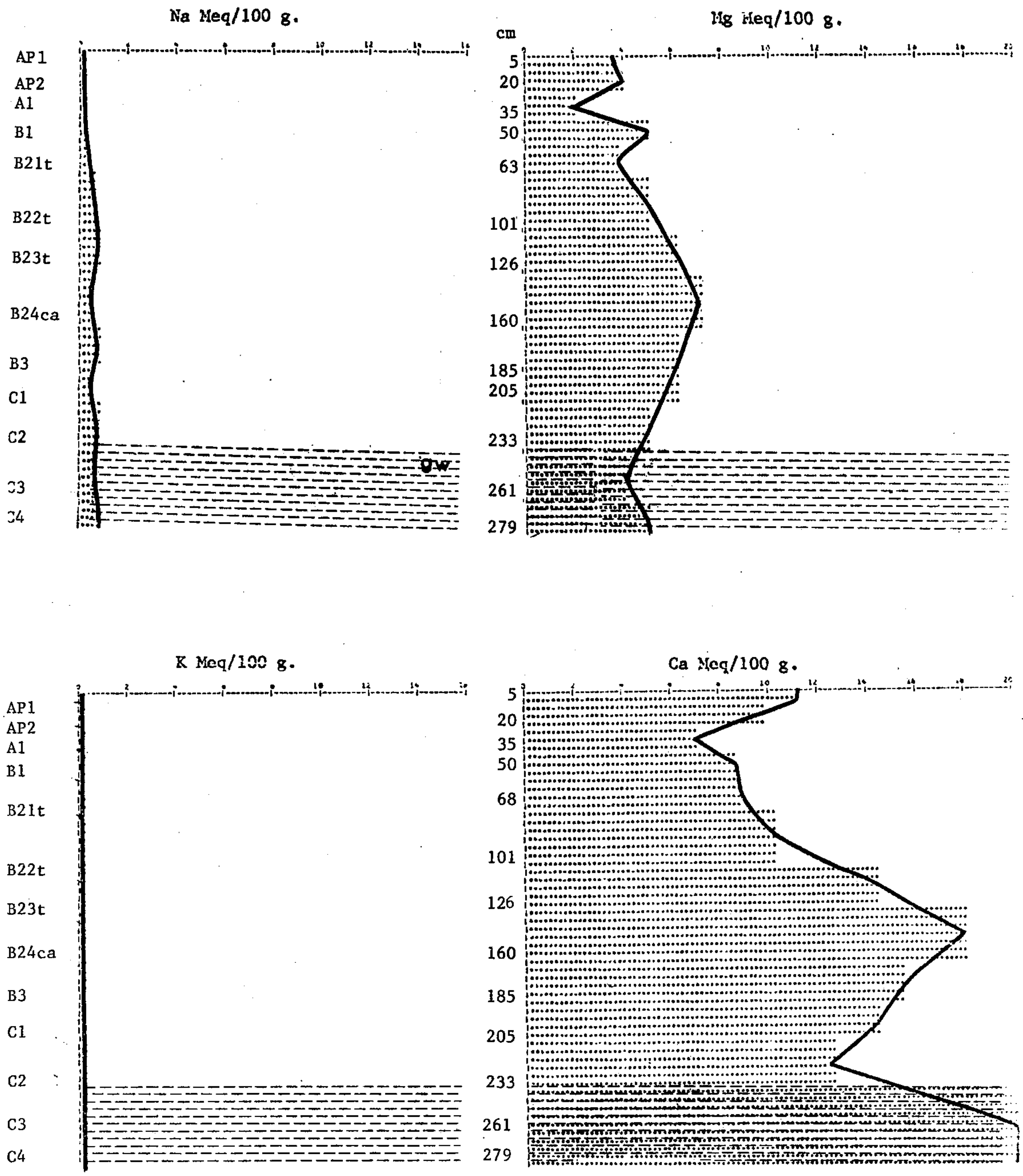

Figure 3.14. Graph Analyses of Extractable Bases, Pedon 6

TABLE 3.8

ANALYSIS OF THE STRUCTURAL BASES
PEDON 7

	$\%Na_2O$			$\%K_2O$		
Horizons	Total	>50μ	<50μ	Total	>50μ	<50μ
Ap	0.88	.60	.28	1.38	.31	1.06
A1	1.14	.79	.35	1.67	.36	1.30
B21t	1.02	.50	.52	1.51	.25	1.26
B22t	0.66	.36	.30	1.11	.17	0.93
B23t	0.69	.34	.34	1.25	.21	1.04
B31	0.98	.41	.57	1.23	.35	0.87
B32t	0.81	.42	.38	0.74	.20	0.54
C1	0.78	.45	.32	1.07	.22	0.84
C2	1.06	.78	.28	0.77	.13	0.64
C3	1.05	.71	.34	0.67	.17	0.49

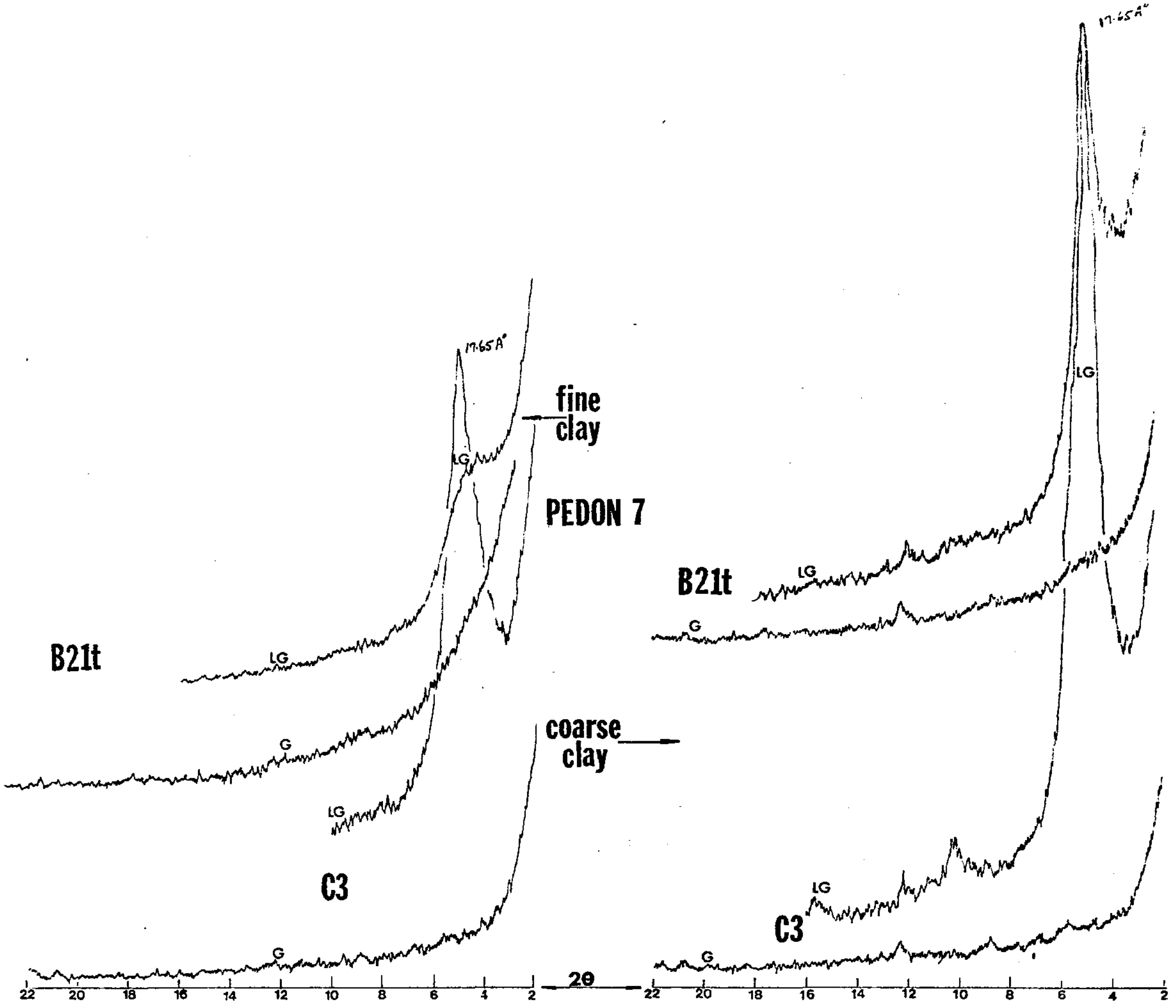

Figure 3.15. X-ray Diffractograms, Pedon 7. (G) Control, and (LG) $LiNO_3$ Treated

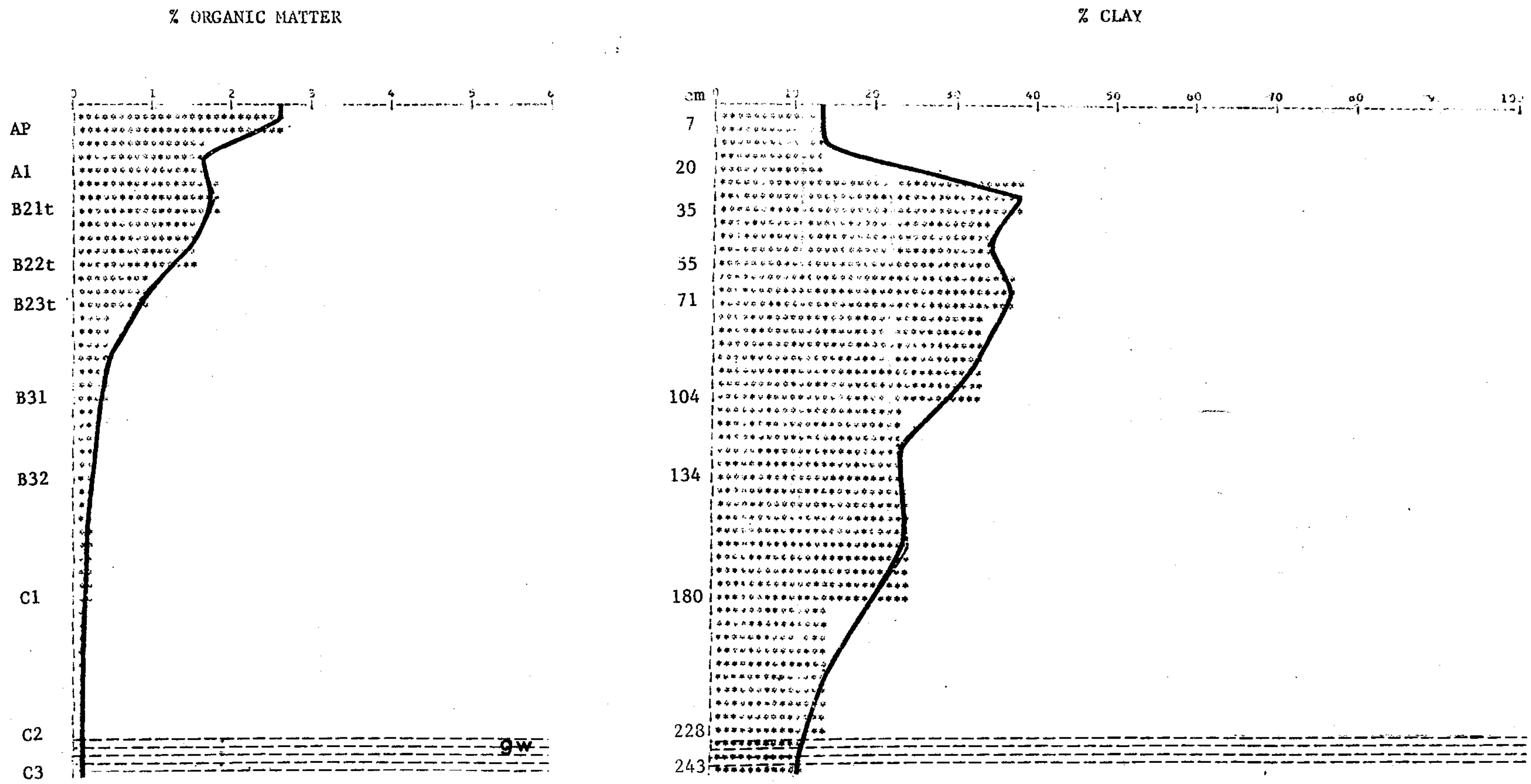

Figure 3.16. Graph Analyses of Organic Matter and Clay Content, Pedon 7

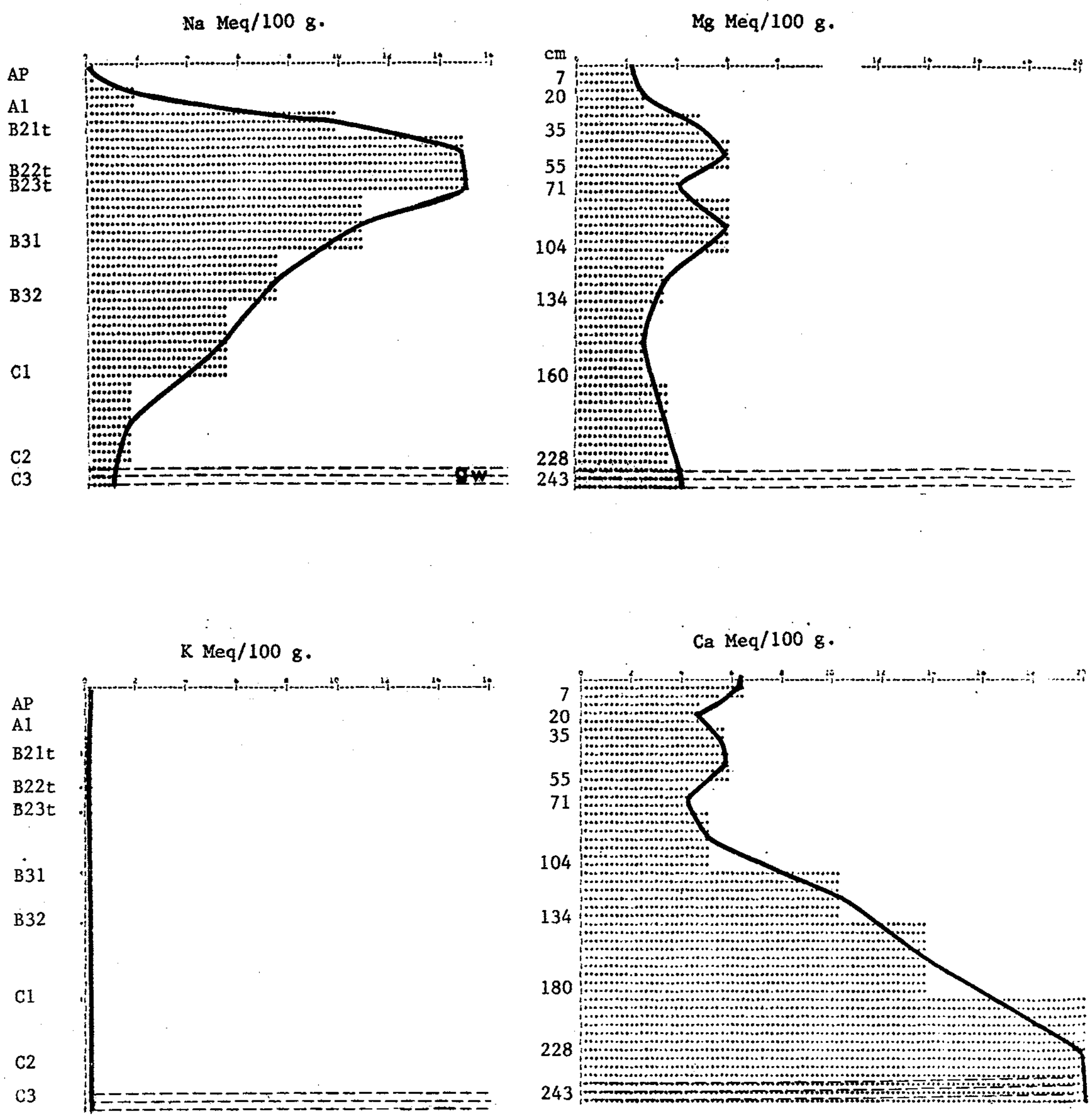

Figure 3.17. Graph Analyses of Extractable Bases, Pedon 7

The intensity of weathering is only a function of the micro relief and soil climatic condition of the pedon. The soils occurring on flat surfaces or depressions and the soils with low permeability indicate less structural Na in the particles finer than very fine sand and more extractable Na^+ sorbed as their exchange complex.

Discussion

The geologic history of North Central Oklahoma is rather uncertain because a great deal of disconformity is observed in the permian deposits of the entire area. To this date a viable hypothesis to explain the genesis of slickspots, and the source of sodium in their profiles has not been formulated. It has been hypothesized that these spots are the result of the accumulation of sodium salts in the sediments laid down by a receding sea. Another possible source of sodium has been thought to be the ocean spray salts carried in from the Gulf of Mexico and dropped in the area by storm. It has also been suggested that the salt distribution in the profiles is related to the fluctuating water table. These suggestions are disputed by observable evidence. Extractable K^+ and micaceous clays are uniformly distributed within the profile. Extractable Na^+, particularly in Na-rich pedons, decreases in the lower layers of the profiles, even below ground water level. The most important evidence which disputes these earlier hypotheses is that soluble anions; sulfate and chlorides and cations are present only as traces or completely absent within the profiles of both slickspots and normal mollisols. At the same time the abundance of sodium bicarbonate in the ground water suggests the hydrolysis of albite which may form clay minerals with the release of Na^+.

$$2\ NaAlSi_3O_8 + 2\ H_2O + CO_2 \longrightarrow H_4Si_2Al_2O_9 + 4\ SiO_2 + Na_2CO_3$$

$$Na_2CO_3 + H_2O \longrightarrow NaHCO_3 + NaOH$$

All of these evidences reject the hypotheses that these spots are originated from soluble sediments deposited by a sea or the ocean spray from rain. The rejection of the above hypotheses permits the author to explain the following hypothetical model for formation of Argiustolls and at least some of the Natrustolls in North Central Oklahoma.

The particle size distributions within the profiles indicated an irregular accumulation and stratification of the soil parent material. The C horizons contain from 11% to 82% clay. Statistically dissimilarities or insignificant similarities exist between the lower part of the B3 horizons and the upper layer of the C horizons in the sampling pedons.

The x-ray analyses of the pedogenic horizons indicate that the predominant clay minerals in the solum and in the underlaying strata are micaceous clays.

The geologic formations which crop out and underlie the soils of the study site are reddish colored shales or silty shales. The dissimilarities between the solum and the underlying strata verify that the geologic formations laid down by a receding sea, have been subjected to surface additions and removals by external agents. The irregular stratification, the absence of coarse fragments, and the trace amounts of soluble salts in all of the layers are indicative of colluvial soil material which originated from shale or silty shales occurring on the higher slopes. The gradual growth of vegetative covers has retarded the removal of material from the surface, and more extensive growth of grasses has stabilized the geomorphic surface of the area. Therefore our model of soil formation is based upon the assumption that when the formation of the Ustolls began the geomorphic surface was relatively stabilized.

Stage 1. At this stage the plants are developing, the roots are alive, and are not a constituent of the initial state of the system. In the initial state, the soil parent materials were clayey, and interstratified with irregular layers of silty material. This is the minimal stage of soil development, in which no losses or gains are assumed. As growth of vegetative cover continues, some plants die, decay and become a component of the soil system. The continuation of these processes enhances the contribution of organic matter, the aggregation of soil particles, and thus, the formation of surface horizons enriched in organic matter. Under the climatic conditions of North Central Oklahoma the soluble sulfate, the chloride and some of the soluble cations of the original geologic formation are leached into the ground water. Some of the cations combine with CO_2 produced by the organic cycle, forming secondary carbonates and bicarbonates. Percolating water moves the insoluble calcium carbonates as bicarbonates to the depth of vertical water movement. The accumulation of calcium carbonates retards the rate of percolating water. This enhances the hydrolysis of the Ca-rich feldspars and releases more Ca^{++}. At this stage the micas of the primary rocks weather directly, by exchange of cations, to clay minerals of 2:1 structural type or similar structure, but they become relatively more stable under soil conditions. The clay minerals such as illite and vermiculite are probably derived from primary micas (Figure 3.18a).

Stage 2. The slow downward movement of water takes the silicate clays from the surface to the subsurface horizons. A weak cambic horizon containing a little more clay than the surface layers dominates the beginnings of the medial stage of soil development. The continued addition of organic matter at the surface together with the penetration of roots produces a friable, dark colored mollic epipedon with an organic matter content of 2% or more. The leaching of bases from the surface causes a slightly acid to neutral condition which increases the rate of weathering. The eluviation of inherited fine clays through desication cracks, pores and channels produced by fibrous grasses, forms an enriched clay zone, and the beginning of an argillic horizon. During this stage of soil development, those Na-rich feldspars (albite) hydrolyze, and hydrogen ions replace their sodium and contribute Na^+ to the soil solution. Laboratory analyses indicate that all of the soil particles are contributors of sodium to the pedons of sodium affected soils. Silt fractions are possibly the major contributor of this cation (Figure 2.18b).

Stage 3. When the argillic horizon is enriched in clay, the permeability rate is reduced and percolation of water downward through the profile is severely restricted. Water remains near the surface creating a more humic micro climate which accelerates soil weathering. This is the beginning of the maximal stage of soil development.

In the Na-rich soils, sodium reacts with the exchange complex of the soil and forms Na-humate and/or Na-clay which are both mobile enough to be moved to the subsurface horizons through the vertical channels. Because of the slow movement of these dispersed particles some of them settle on the walls of the vertical cracks and cover a mass of micro aggregates with clay skins and organic stains. These macro aggregates are the columnar or prismatic units of the soil structure. Usually they are richer in Na^+ toward the outside of the columns or prisms. The maximum developed prisms are capped with material which is lighter in texture and color than the prisms themselves. This phenomenon is possibly explained by the removal of clay particles from the top of the prisms through the cracks, with the coarser material, which is usually silt loam in texture, remaining.

The presence of sodium in the exchange complex not only affects the physical properties of the soil but also reduces the rate of the uptake of other bases and indirectly retards plant growth. In this case the rate of contribution of organic matter is not in equilibrium with the rate of removal of dispersed organic matter. This causes a significant loss of organic matter from the surface of the soil. The sodium affected soils therefore cannot support tall grasses and the short grasses dominate. As a result slickspots support short grasses in a tall grass area (Figure 3.18c).

The slickspots are found in different sized spots from a few square feet to several acres. The size of the sodic spots is highly dependent upon the extent of Na-rich feldspars. The intensity of weathering and release of extractable Na^+ highly depends upon the suitability of the weathering conditions. Micro relief and internal drainage are the very important factors in enhancing the hydrolysis of the sodium feldspars.

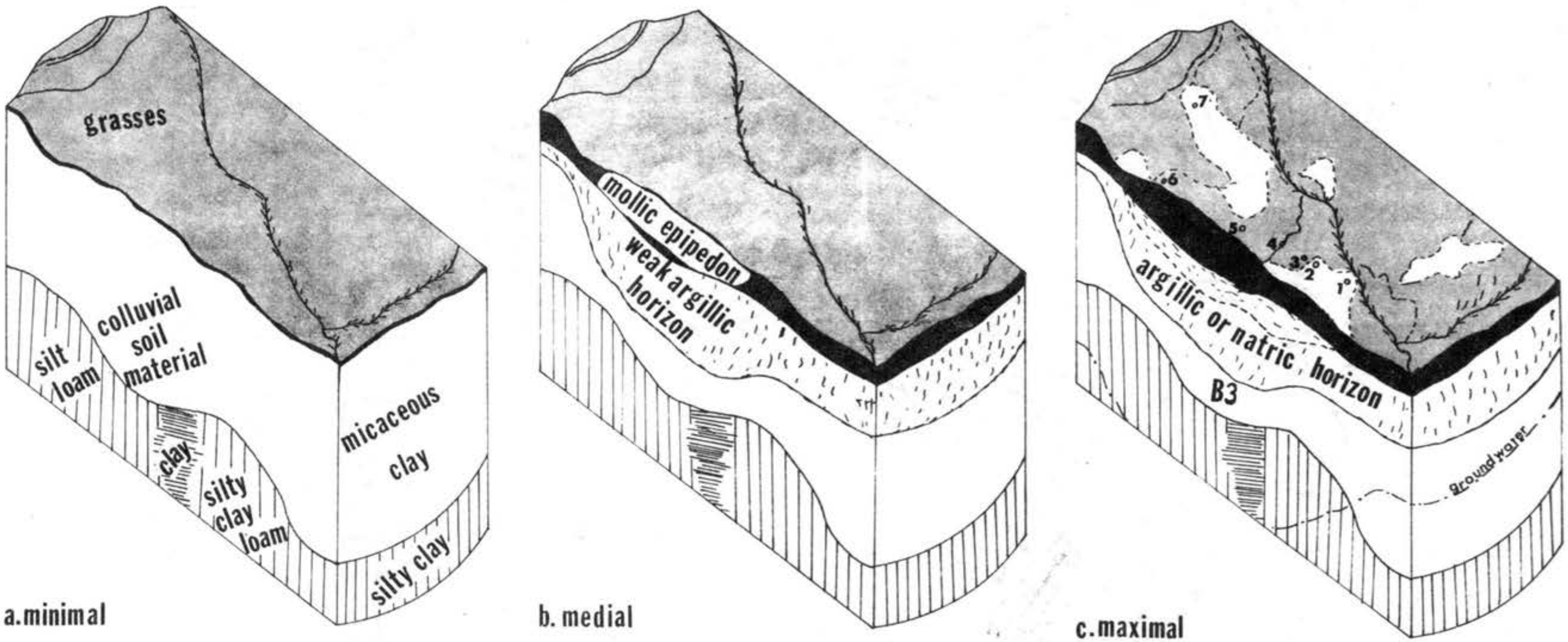

Figure 3.18. Proposed Hypothetical Model for Formation of Ustolls in North Central Oklahoma

CHAPTER IV

A STATISTICAL PROCEDURE IN TAXONOMY OF SODIC SOILS[1/]

Abstract

A taxonomy of sodic soils of North Central Oklahoma, based on quantitative data was the objective of this report. The data matrix has 79 rows and 43 columns. Rows indicate the number of horizons which were sampled from seven sampling pedons. Columns indicate a total of 39 laboratory data, either measurable or interpretative; together with hue, value, chroma, and the thickness of each horizon. A computer program was used to construct the dendograph based upon the result of clustering using the unweighted pair-group method. In order to use the program, the coefficient of similarity between every two horizons in the data matrix was computed. The lower triangle of the 79 X 79 symmetrical similarity matrix was punched on the I.B.M. cards. The 79 soil samples were clustered into 19 groups. A correlation type similarity of .58 or more existed within each group. Soils were clustered disregarding their relative position within the pedons. Transition matrices with 19 rows and 19 columns were built for each pedon separately. The transition matrix approach was

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[1/]Article co-authored with Fenton Gray and William D. Warde and to be submitted for publication in Soil Science Society of America Proceedings.

was followed in order to separate the seven sampling pedons into groups. Five groups were recognized which were comparable with the subgroups in conventional taxonomy.

Additional Key Words for Indexing: slickspots, North Central Oklahoma

Introduction and Review of Literature

Kellogg (1959) states that the purpose of soil classification is to aid the soil scientists in determining the significant characteristics of soils, to assemble data, to show the relationship of soils to each other and their environment, and to promote development of principles which can explain the behavior of soils and their response to manipulation. Developing a system of taxonomy is a logical process. The classes, or taxa are not inherent in nature but are defined by taxonomists based upon significant combinations of soil characteristics. A taxon is a group of soils with many common properties.

Smith (1963) points out that in soil classification some soils are of particular significance because of their areal extent, unique properties or genesis. The author of this report believes that salt affected soils are among those which have particular significance. All salt affected soils possess morphological features which influence plant growth. Sodic soils are salt affected soils from which soluble salts have been removed. The abundance of exchangeable sodium in Sodic Soils has a marked influence upon their physical and chemical properties.

The purpose of this paper is to explore statistical procedures in the taxonomy of sodic soils. Procedures in conventional and/or numerical taxonomy are based upon taxonomic characters. A problem in numerical taxonomy is the number of characters that must be used to obtain reliable results. Michener and Sokal (1957) have ventured to suggest the use of not less than sixty characters. Their idea was based upon a statistical consideration that the confidence limits of correlation coefficient became too wide below that sample size. Simonson (1952) stated that the construction of a classification is circumscribed by the knowledge of soils and their genesis held by soil scientists responsible for the scheme of soil classification. In this inquiry only those properties closely related to genesis of Sodic Soils have been considered. Detailed characterization data including the distinctive quantitative value of sodium content has been considered for each horizon in the seven pedons from a toposequence of slickspots and Mollisols.

Unidimensional dendograms, which illustrate similarities between groups, are normally used to represent the results of numerical taxonomy. According to McCammon (1968) dendographs are two dimensional graphic forms which show the similarities within groups as well as between groups of ordered objects. A dendograph, when compared to a dendogram, tends to lessen distortial effects inherent in any portrayal of data in fewer than the original number of dimensions. In this research a computer program was used to construct a dendograph for numerical taxonomy as developed by McCammon and Wenninger (1970).

Norris and Dale (1971) used the transition matrix approach in numerical classification of twenty profiles. They considered the relative position of the samples in the profiles and characterized each profile according to morphological and laboratory data collected in ten depth increments of 10 cm each. In the present inquiry the transition matrices are constructed using the relative position of the pedogenic horizons as described and sampled according to the guidelines in "7th Approximation."

Procedures Applied

A preliminary analysis of aerial photographs of North Central Oklahoma clearly indicated the presence of Sodic Soils commonly called slickspots. These spots were subsequently examined in the field. After a preliminary test of sodium content of the spots and the surrounding area, seven sampling pedons were located on a toposequence of slickspots, transitional, and normal mollisols.

A total of 79 samples from the pedogenic horizons were analyzed, using a slipped block design in handling the samples in the soil characterization laboratory. This statistical design was developed by Timon (1962). The least square procedure was used to adjust the treatment effects according to block effects assuming that the sum of the treatment effects was equal to zero.

The thickness of the horizons, hue, value, and chroma in addition to the treatment effects of 39 laboratory characters, which could be either positive or negative values, were punched on I.B.M. cards. Hue was the only character which was coded: 5Y = 01, 10 YR = 04, 7.5YR = 08, 5YR = 16, and 2.5 YR = 32. The laboratory characters which were used in primary clustering are illustrated in Table 4.1.

The data matrix was a $t \cdot n$ matrix where t is the number of rows or the horizons which were sampled and is equal to 79, n is the number of characteristics associated with each horizon and is equal to 43. This

TABLE 4.1

A LIST OF THE CHARACTERISTICS USED IN CLUSTERING THE PEDOGENIC HORIZONS

1 - Thickness	23 - Extractable H
2 - Hue	24 - Extractable Al
3 - Value	25 - Extractable Ca
4 - Chroma	26 - Extractable Mg
5 - Gravel	27 - Extractable Na
6 - Very Coarse Sand	28 - Extractable K
7 - Coarse Sand	29 - Exchangeable Ca
8 - Medium Sand	30 - Exchangeable Mg
9 - Fine Sand	31 - Exchangeable Na
10 - Very Fine Sand	32 - Exchangeable K
11 - Total Sand	33 - 1:5 Soil:Water Ca
12 - Coarse Silt	34 - 1:5 Soil:Water Mg
13 - Medium Silt	35 - 1:5 Soil: Water Na
14 - Fine Silt	36 - 1:5 Soil:Water K
15 - Total Silt	37 - 1:5 Soil:Water SO_4
16 - Total Clay	38 - 1:5 Soil:Water CO_3
17 - Organic Matter	39 - 1:5 Soil:Water HCO_3
18 - Calcium Carbonate Equivalent	40 - 1:5 Soil:Water Cl
19 - Total Soluble Salts	41 - 1:1 Soil: H_2O pH
20 - Total Phosphorus	42 - 1:1 Soil:KCl pH
21 - Electrical Conductivity	43 - Exchangeable Sodium Percent
22 - Cation Exchange Capacity	

data matrix was used in a computer program, "Dendograph", to construct a dendograph as developed by McCammon and Wenninger (1970). The construction is based upon the results of clustering using the unweighted pair-group method. According to the authors to make the program as usable as possible, the assumption was made that the user previously would have calculated or somehow estimated the pairwise similarities of the items which he wishes to arrange in a hierarchical order. The option existed for the user to enter either correlation coefficient or distance function as the measure of pairwise similarity between every two horizons. In order to use this program, the t·n data matrix was standardized within each column (characteristics) and the correlation matrix among rows (horizons was computed. According to Sokal and Sneath (1963) the standardized values of the characteristics were obtained by:

$$Z_{ij} = \frac{X_{ij} - \bar{X}_i}{S_{x_i}}$$

where Z_{ij} is the standardized value of the i^{th} characteristic in the j^{th} horizon

X_{ij} is the original value of the i^{th} characteristic in the j^{th} horizon

$\bar{X}_i$ is the mean of the i^{th} characteristic

S_{x_i} is the standard deviation of the i^{th} characteristic

The lower triangle of this 79 x79 similarity matrix was punched onto I.B.M. cards. McCammon and Wenninger (1970) explain the program operation which includes the program dimensions and order of input cards. A plotter available in the computer center at Oklahoma State University was used to produce the dendograph. Figure 4.1 contains

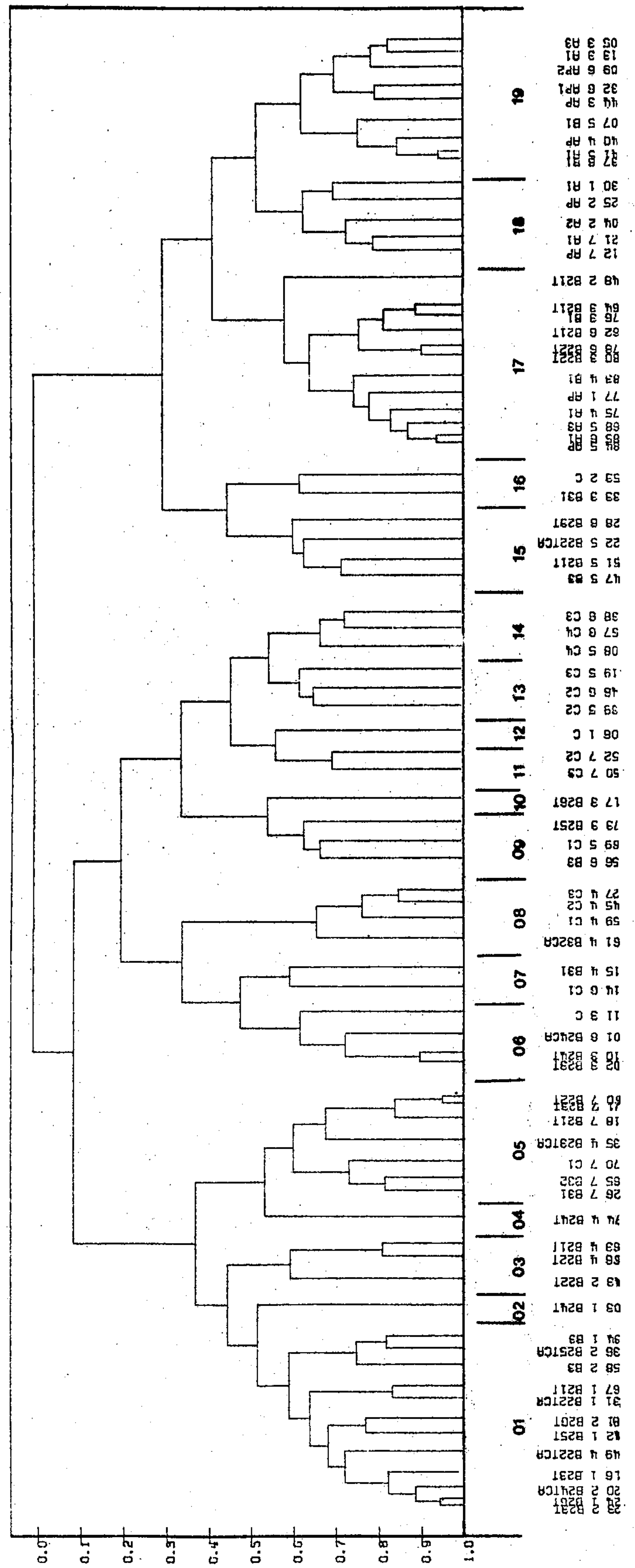

Figure 4.1. Dendograph Cluster Analysis of the Pedogenic Horizons

the dendograph produced for 79 pedogenic horizons from a selected toposequence of Sodic Soils in a mollisol area.

The numerical analysis of pedons was based upon the results of the above primary dendograph and the relative position of the pedogenic horizons in the profiles. Hence the numerical taxonomy of pedons proceeded through several stages. Four stages were employed in the initial classification of the pedogenic horizons as described below.

1) The 79 samples from seven pedons were classified into 19 groups based upon the 43 characters but irrespective of the pedons from which they were taken. The groups were numbered from 01 to 19.

2) A table of profile description was formed for each pedon in the form of a sequence of the horizons in the profile. Each horizon was assigned a number from 01 to 19. This number was the number of the group into which that sample had been clustered. Table 4.2 contains the information which describes the pedons.

3) The sequence of the numbers describing each profile was converted to a transition matrix. Each transition matrix recorded the number of times each number followed every other down the sequence. For example the number "4" recorded in row 1, column 1, of the matrix pedon 1 in Table 4.3 indicates that a "1" is followed by "1" four times.

4) The seven transition matrices, each representing one pedon, were classified. Figure 4.2 contains the dendograph produced for 7 pedons, based on the primary grouping of their horizons, and the relative position of their horizons in the profiles.

Norris and Dale (1971) have explained the method of determining the information content "I" of these matrices:

TABLE 4.2

PROFILE DESCRIPTIONS BASED UPON PRIMARY CLUSTERING
OF THE PEDOGENIC HORIZONS

Pedon 1		Pedon 2		Pedon 3		Pedon 4		Pedon 5		Pedon 6		Pedon 7	
Horizon	Group	Horizon	Group	Horizon	Group	Horizon	Group	Horizon	Group	Horizon	Group	Horizon	Group
Ap	17	Ap	18	Ap	19	Ap	19	Ap	17	Ap1	19	Ap	18
A1	18	A2	18	A1	19	A1	17	A1	19	Ap2	19	A1	18
B21t	01	B21t	17	A3	19	B1	17	A3	17	A1	17	B21t	05
B22tca	01	B22t	03	B1	17	B21t	03	B1	19	B1	19	B22t	05
B23t	01	B23t	01	B21t	17	B22t	03	B21t	15	B21t	17	B23t	05
B24t	02	B24tca	01	B22t	17	B22tca	01	B22tca	15	B22t	17	B31	05
B25t	01	B25tca	01	B23t	06	B23tca	05	B3	15	B23t	15	B32	05
B26t	01	B26t	01	B24t	06	B24t	04	C1	09	B24tca	06	C1	05
B3	01	B3	01	B25t	09	B31	07	C2	13	B3	09	C2	11
C	12	C	16	B26t	10	B32ca	08	C3	13	C1	07	C3	11
				B31	16	C1	08	C4	14	C2	13		
				C	06	C2	08			C3	14		
						C3	08			C4	14		

TABLE 4.3

TRANSITION MATRICES PRODUCED FORM THE TABLES OF PROFILE DESCRIPTION

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
01	4	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
02	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PEDON 1

	01	02	03	04	05	06	70	80	09	10	11	12	13	14	15	16	17	18	19
01	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PEDON 2

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2

PEDON 3

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
05	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

PEDON 4

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0

PEDON 5

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
07	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
15	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	1	0	1
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1

PEDON 6

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05	0	0	0	0	5	0	0	0	0	0	1	0	0	0	0	0	0	0	0
06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PEDON 7

$$I = (\Sigma_i \Sigma_j X_{ij}) \ln (\Sigma_i \Sigma_j X_{ij}) - \Sigma\Sigma X_{ij} \ln X_{ij}$$

For Transition matrix Pedon 1:

$I_1 = 9 \ln 9 - (4 \ln 4 + 1 \ln 1 + 1 \ln 1 + 1 \ln 1 + 1 \ln 1 + 1 \ln 1)$

Two transition matrices of pedons M and N compared by calculating I_M, I_N and $I_{(M+N)}$, where M+N is the matrix sum of M and N. ΔI is the measure of information gain where:

$$\Delta I = I_{(M+N)} - (I_M + I_N)$$

That pair of matrices giving minimum information gain on addition are joined to form a new composite matrix. The process of group formations proceeded: applying a FORTRAN Program developed for this purpose using "Dendograph" as a subroutine (Appendix C).

Results

According to McCammon and Wenninger (1970), the pyramid shape of the dendograph is not an accident. As seen in Figures 4.1 and 4.2, it greatly enhances the interpretative quality of the dendograph. The similarities within groups are displayed as well as the similarities between groups.

In analyzing the dendograph, Figure 4.1, it is apparent that surface and subsurface pedogenic horizons have been separated based upon their particular differentiating properties. The 79 samples have been divided into 19 groups. A similarity type coefficient of 0.58 or more exists within each group. The first 16 groups contain 53 subsurface, and the last three groups contain 26 surface pedogenic horizons. Groups one through five are mostly composed of subhorizons of B, which have a highly significant amount of exchangeable sodium. The exchangeable sodium percentage of these groups varies from 14 to 45.

Groups 6 through 16 are also subhorizons of B with the ESP of 1 to 14. The sub-divisions of the C horizons and lower layers of the B horizons are clustered in groups 11 through 16. Groups 17, 18, and 19 are composed primarily of subhorizons of A and the upper parts of B which are high in organic matter. Considering the above results, it is obvious that the main differentiating properties were those of surface and subsurface diagnostic horizons. Hue, value, chroma, and clay content, and organic matter content appear to be among the most important properties. The subsurface horizons were also separated into groups of high and low sodium content. The exchangeable sodium at the break point seemed to be 14 percent which is comparable to the border between argillic and natric horizons.

During the morphological study of the pedons in the field, enough evidence was collected to prove the presence of mollic epipedons and underlaying illuvial horizons. Tall and short grasses had contributed significant amounts of organic matter to the surface layers to place the value and chroma of the top soils in the range of mollic epipedons. White concretions of calcium carbonate in the profiles were also noted particularly in the lower B horizons and below. Carbonates seemed to have accumulated under an ustic moisture regime and to have an effective role in stopping the movement of clay and the formation of clay skins around the peds. Illuvial horizons were identified by the color, clay distribution patterns and presence of illuviated clay particles. Laboratory data supported the presence of mollic epipedons and illuvial horizons.

Dendograph Figure 4.2 illustrates the final grouping of the seven pedons. The ordinate indicates the similarity type coefficient which

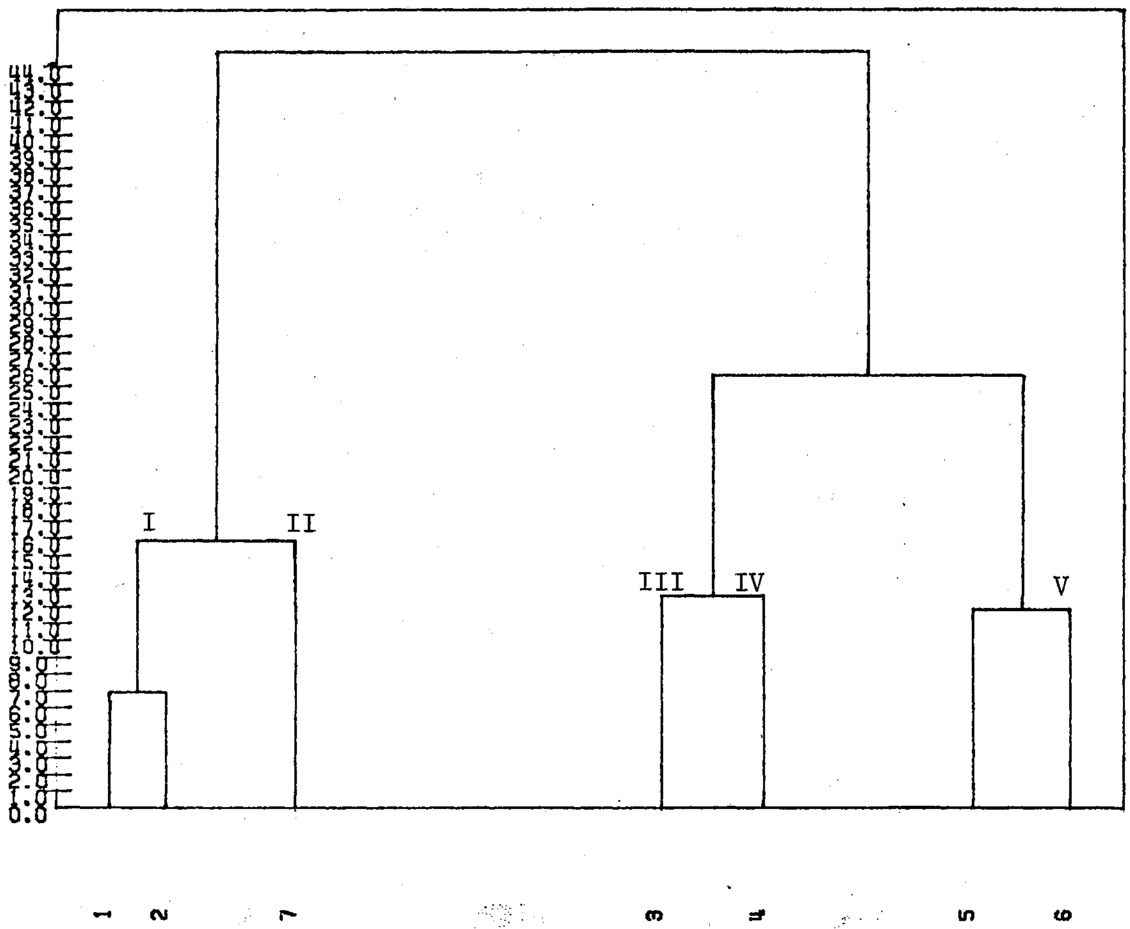

Figure 4.2. Dendograph Cluster Analysis of the Pedons

is inversely proportional to the similarity between groups. These groups are indirectly based upon the internal properties of the profiles which have been reflected in the transition matrices. The dendograph indicates three major groups. A similarity type coefficient of 16 or less exists within each group.

Group I Pedons 1, 2, and 7

Group II Pedons 3 and 4

Group III Pedons 5 and 6

According to Soil Survey Staff (1970), Paleustolls are Ustolls on old stable surfaces with thick reddish argillic horizons. Particle analysis of the study toposequence indicates that the surface has not been stable but has been subject to addition and removal of material by the external agents. Considering this fact, using conventional classification, the seven pedons fit into two taxa; Natrustolls and Argiustolls.

1. Natrustolls: Pedons 1, 2, and 7 are Natrustolls, Ustolls with a natric horizon. These Typic Natrustolls are characterized by short grass vegetation and having more than 15% of the exchange complex of the upper 40 cm of their argillic horizon saturated with sodium. They have developed prismatic structures. Prisms are capped with material lighter in texture and color than the Prisms.

2. Argiustolls: Pedons 3, 4, 5, and 6 are Argiustolls, Ustolls which have an argillic horizon. Pedons 3, 5, and 6 belong to Pachic Argiustoll subgroup which is charcterized by a mollic epipedon more than 50 cm thick and with soft powdery secondary lime within the upper 125 cm of the profile. The author of this manuscript is introducing a new taxon "Nazdic Argiustoll". The word nazdic is

originally from the Persian language and means near. If the (na) from natric and (zdic) from nazdic are combined the subgroup formative element "Nazdic" is developed. Nazdic Argiustolls are Argiustolls which have more than 6% of their cation exchange capacity within 40 cm of the upper boundary of argillic horizon saturated with sodium. The physical or chemical properties of these soils have not influenced the plant growth as much as Typic Natrustolls. The prismatic or columnar structure is not fully developed and it breaks into a blocky structure. Organic matter has been dispersed and scattered below the depth of 25 cm. Nazdic Argiustolls are usually characterized with mixed grasses. These soils act as a transitional linkage and connect the Argiustolls to the Natrustolls. Pedon 4 which displays these properties belongs to the Nazdic Argiustoll subgroups. This pedon is also associated with an absence of ground water.

Analyzing the dendograph, Figure 4.2 and a similarity type coefficient of 13, then five groups of soils will be recognized which are comparable to the results of conventional classification. Table 4.4 indicates the results of numerical and conventional taxonomy of the seven selected pedons from toposequence of slickspots and Mollisols in North Central Oklahoma.

Discussion

The problem in numerical taxonomy is the number and type of the characters required to obtain reliable results. Sarkar, Bidwell and Marcus (1966) concluded that a large number of unselected characters may not be superior to a much smaller group selected through the correlation criterion. In this research 43 characters were used to

TABLE 4.4

COMPARISON OF NUMERICAL AND CONVENTIONAL TAXONOMY

Pedon	Numerical Taxonomy Group	Conventional Taxonomy	
		Subgroup	Family
1	I	Typic Natrustoll	fine, mixed, thermic
2	I	Typic Natrustoll	fine, mixed, thermic
3	III	Pachic Argiustoll	fine, silty, mixed, thermic
4	IV	Nazdic Argiustoll	fine, mixed, thermic
5	V	Pachic Argiustoll	fine, silty, mixed, thermic
6	V	Pachic Argiustoll	fine, silty, mixed, thermic
7	II	Typic Natrustoll	fine, mixed, thermic

construct the classification of the pedogenic horizons. The selection of properties was a basic problem in this study. The researcher tried to choose those properties which related soils to their genesis. The first dendograph indicates that some properties, such as organic matter content and clay content, strongly influence the clustering of pedogenic horizons.

The transition matrix approach for clustering the pedons seems to be satisfactory. In this research the natural relative position of the pedogenic horizons was used for constructing the transition matrices. The presence of a horizon in a profile was indirectly considered as a property of the pedon. The information content of a transition matrix greatly depends upon the number of horizons in the pedon. For this reason it may be more reasonable to consider those horizons within the solum rather than the whole profile including C horizon. If for some reason the C horizon is to be considered then a certain uniform depth should be selected for all of the profiles under study. In this case the information content "I" will be based upon the number of pedogenic horizons in a certain depth which determines the degree of differentiation of the horizons. This relates the classification of the soils to their genesis. The author concludes that the computer program "Dendograph" is a capable program in clustering soils based upon those properties associated with salt affected soils.

CHAPTER V

SUMMARY AND CONCLUSION

Slickspots give a recognizable light tone to aerial photographs. These light spots correspond to areas dominated by short grasses within a predominantly tall grass area. The morphology and laboratory data indicate the presence of mollic epipedons and argillic or natric horizons in selected pedons of a toposequence of slickspots and Mollisols.

The following criteria were recognized as suitable for distinguishing salt affected soils from non-salt affected soils.

The electrical conductivities in micro mhos of 1:5 soil:water extracts at 25^{o}C determine the salinity classes; the values of pH of 1:1 Soil water mixture express the alkalinity classes. The ESP values based upon the direct measurement of CEC characterize the sodicity classes. Using these three criteria, a salt affected soil is classified according to the highest category it fits into within any one of these criteria.

The geologic history of the study site is rather uncertain. The particle size distribution within the pedons indicates an irregular accumulation and stratification of the initial material. Statistically dissimilarities or insignificant similarities exist between the lower parts of the B3 horizon and the underlying C horizons in all of the sampling pedons. The above evidences in addition to the presence of trace amounts of soluble salts and the absence of coarse fragments in the entire profile are indicators of colluvial soil material which originated from shale or silty shales occurring on the higher slopes. The quantitative analysis of the soil particles reflect the abundance of sodium in the soil structure. This pehnomenon plus the presence of $NaHCO_3$ in the ground water as the major salts, supporting the hypothesis of _in situ_ weathering of Na-rich feldspars which contributes Na^+ to the exchange complex of the soil and ground water.

A statistical approach was used in order to classify the slickspots and the normal Mollisols in the study site. A computer program was used to construct the dendograph based upon the results of clustering using an unweighted pair-group method. The 79 Pedogenic horizons were clustered into 19 groups. Five groups were recognized which were comparable with the subgroups in conventional taxonomy. A subgroup "Nazdic Argiustoll" was found to be a linkage between Pachic Argiustolls and Typic Natrustolls.

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APPENDIX A

COMPUTER PROGRAM FOR COMPUTING THE

SOIL CHARACTERISTICS

```
$JOB TIME=100
1         DIMENSION LOC(20),CO(20), SN(13), HOR(13), THK(13)
2         DIMENSION SN(4),HOR(13,2),COL(3),TEX(2),STR(3),CON(4),LN(13),
         1GRA(13),PCGRA(13),VCS(13),PCVCS(13),CS(13),PCCS(13),MS(13),
         2PCMS(13),FS(13),PCFS(13),VFS(13),PCVFS(13),SAND(13),PCSAND(13),
         3CSI(13),MSI(13),FSI(13),SILT(13),PCCSI(13),PCMSI(13),PCFSI(13),
         4PCSILT(13),CLAY(13),PCCLAY(13),EXTCA(13),EXTMG(13),EXTK(13),
         5EXTNA(13),EXTH(13),EXTAL(13),EXCA(13),EXMG(13),EXCK(13)
3         DIMENSION EXCNA(13), EXCSUM(13),MEEXCA(13),MEEXMG(13),MEEXK(13),
         1MEEXNA(13),SCA(13),MESCA(13),SMG(13),MESMG(13),SK(13),MESK(13),
         2SNA(13),MESNA(13),SUMCAT(13),SCL(13),MESCL(13),SSO4(13),
         3MESSO4(13),SCO3(13),MESCO3(13),SHCO3(13),MEHCO3(13),SUMAN(13)
4         DIMENSION OM(13),PCOM(13),PPPM(13),PPMP(13),CACO3(13),PCCO3(13),
         1TSS(13),PCTSS(13),EC(13),ECUMHS(13),KCLPH(13),PHKCL(13),H2OPH(13),
         2PHH2O(13),CEC(13),MECEC(13),CAMG(13),CC(13),PPMSNA(13),PPMSK(13),
         3PPMSCA(13),PPMSMG(13),ESP(13),S(13),SSP(13),SQ(13),SQR(13),SAR(13)
         4,C(13),M(13),TEXT(13),DEP2(13),DEPCM2(13)
5         DIMENSION  SUB1(13),SUB2(13),LAN(13), MEEXH(13), MEEXAL(13)
6         REAL MS,MSI,MEEXCA,MEEXMG,MEEXK,MEEXNA,MESCA,MESMG,MESK,MESNA
7         REAL MESCL, MESSO4,MESCO3,MEHCO3,KCLPH,MECEC,M,MEEXH, MEEXAL
8         REAL NAAC
9         INTEGER YR,PIT,DEP1,DEP2,THK1,DEPCM1,DEPCM2,THK2
10    100 FORMAT(I2,I2,I1/(20A4))
11    101 FORMAT(4A4,I2,2A4,2I3,11A4)
12    102 FORMAT(16X,I2,6X,F10.8,1X,F10.8,1X,F10.8,1X,F11.8,1X,F10.8)
13    103 FORMAT(24X,F11.8,1X,F10.8,1X,F11.8,1X,F10.8,1X,F10.8)
14    104 FORMAT(24X,F11.8,1X,F11.8,1X,F10.8,1X,F10.8,1X,F10.8)
15    105 FORMAT(24X,F11.8,1X,F11.8,1X,F10.8,1X,F10.8,1X,F10.8)
16    106 FORMAT(24X,F11.8,1X,F10.8,1X,F10.8,1X,F10.8,1X,F10.8)
17    107 FORMAT(24X,F10.8,1X,F10.8,1X,F10.8,1X,F10.8,1X,F10.8)
18    108 FORMAT(24X,F10.8,1X,F10.8,1X,F10.8,1X,F12.8)
19    200 FORMAT('1',20A4/' ',20A4)
20    201 FORMAT('0PROFILE DESCRIPTION:'/' ','SAMPLE NUMBER',3X,'LAB NO.',
         1   2X,'HORIZON',5X,'DEPTH',4X,'THICKNESS',4X,'COLOR(M)',5X,
         2   'TEXTURE',4X,'STRUCTURE',6X,'CONSISTENCE')
21    202 FORMAT(' ',4A4,2X,I2,5X,2A4,I3,'-',I3,'CM',3X,I3,'CM',6X,3A4,2X,
         1   2A4,3X,3A4,3X,4A4)
22    203 FORMAT(//'0PHYSICAL ANALYSIS:'/' SAMPLE NUMBER',2X,'LAB NO.',
         1   40X,'PER CENT')
23    204 FORMAT('+',25X,82('_'))
24    205 FORMAT(' ',26X,'GRA',4X,'VCS',5X,'CS',5X,'MS',5X,'FS',4X,'VFS',3X,
         1   'SAND',4X,'CSI',4X,'MSI',4X,'FSI',3X,'SILT',3X,'CLAY',2X,
         2   'CLASS')
25    206 FORMAT(//'0CHEMICAL ANALYSIS:'/' SAMPLE NUMBER',2X,'LAB NO.',13X,
         1   'EXTRACTABLE CATIONS MEQ/100 GMS',14X,'EXCHANGEABLE CATIONS ',
         2   'MEQ/100 GMS')
26    207 FORMAT('+',27X,45('_'),5X,38('_'))
27    208 FORMAT(' ',29X,'CA',6X,'MG',6X,'K',7X,'NA',5X,'H',7X,'AL',8X,'CA',
         1   6X,'MG',6X,'K',7X,'NA',6X,'SUM')
28    209 FORMAT(//'0SAMPLE NUMBER',2X,'LAB NO.', 7X,'SOLUBLE CATIONS '
         1   'MEQ/100 GMS',19X,'SOLUBLE ANIONS MEQ/100 GMS')
29    210 FORMAT('+',28X,35('_'),11X,34('_'))
30    211 FORMAT(' ',29X,'CA',4X,'MG',5X,'K',5X,'NA',7X,'SUM',12X,'CL',5X,
         1   'SO4',4X,'CO3',4X,'HCO3',5X,'SUM')
31    212 FORMAT(//'0SAMPLE NUMBER',2X,'LAB NO.',6X,'PER CENT',4X,'PPM',
         1   6X,'PER CENT',4X,'PER CENT',5X,'MIC MHS',9X,'1:1 PH',4X,
         2   'MEQ/100 GMS')
32    213 FORMAT('+',28X,8('_'),2X,7('_'),4X,8('_'),4X,8('_'),5X,7('_'),6X,
         1   11('_'),2X,11('_'))
33    214 FORMAT(' ',30X,'OM',6X,'TOTAL P',5X,'CACO3',8X,'TSS',8X,
         1   '1:5 EC',7X,'KCL',3X,'H2O',8X,'CEC')
34    215 FORMAT(//' INTERPRETIVE CALCULATIONS:',4X,'%',9X,'%',38X,'%',
         1   20X,'%',/,'0SAMPLE NUMBER',2X,
         2   'LAB NO.',6X,'CA/MG',4X,'CEC/CLAY', 4X,'ESP', 4X,'SSP', 4X,
         3   'SAR', 4X,'SOLUBLE/EXTRACTABLE',4X,'BASE SATURATION')
35    216 FORMAT(' ',74X,'CA',6X,'MG',9X,'NAAC',4X,'SUM CAT')
36    217 FORMAT(' ',I2,'-OK-57-',I1,'-',I2,4X,I2,6X,F5.2,2X,F5.2,2X,F5.2,
         1   2X,F5.2,2X,F5.2,2X,F5.2,2X,F5.2,2X,F5.2,2X,F5.2,2X,F5.2,2X,
         2   F5.2,2X,F5.2,2X,A4)
37    218 FORMAT(' ',I2,'-OK-57-',I1,'-',I2,4X,I2,8X,F5.2,3X,F5.2,3X,F5.2,
         1   3X,F5.2,3X,F5.2,3X,F5.2,5X,F5.2,3X,F5.2,3X,F5.2,3X,F5.2, 4X,
         2   F5.2)
38    219 FORMAT(' ',I2,'-OK-57-',I1,'-',I2,4X,I2,8X,F5.2,1X,F5.2,2X,F5.2,
         1   2X,F5.2,4X,F5.2,10X,F5.2,2X,F5.2,2X,F5.2,2X,F5.2,4X,F5.2)
39    220 FORMAT(' ',I2,'-OK-57-',I1,'-',I2,4X,I2, 9X,F5.2,4X,F7.2,6X,F5.2,
         1   8X,F5.2,6X,F6.2,7X,F4.2,2X,F4.2,6X,F5.2)
40    221 FORMAT(' ',I2,'-OK-57-',I1,'-',I2,4X,I2,7X,F7.2, 3X,F6.2, 5X,F5.2,
         1   3X,F5.2, 2X,F5.2, 5X,F5.2,3X,F5.2,7X,F6.2,3X,F6.2)
41    222 FORMAT('1',60X,'PERCENT CLAY')
42    223 FORMAT('0',35X,'CLAY DISTRIBUTION VS. DEPTH'
         1   '                    PEDON NO. ',I1)
43    224 FORMAT('1',54X,'PERCENT ORGANIC MATTER')
44    225 FORMAT('0',30X,'DISTRIBUTION OF ORGANIC MATTER VS. DEPTH'
         1   '                    PEDON NO. ',I1)
45    226 FORMAT('1',56X,'PPM TOTAL PHOSPHORUS')
46    227 FORMAT('0',30X,'PHOSPHORUS DISTRIBUTION VS. DEPTH'
         1   '                    PEDON NO. ',I1)
47    228 FORMAT('1',40X,'CATION EXCHANGE CAPACITY/CLAY RATIO')
48    229 FORMAT('0',25X,'CATION EXCHANGE CAPACITY/CLAY RATIO VS. DEPTH'
         1   '                    PEDON NO. ',I1)
49    230 FORMAT('1')
50    231 FORMAT('1',59X,'EXTRACTABLE NA')
51    232 FORMAT('0',30X,'DISTRIBUTION OF EXTRACTABLE NA VS. DEPTH'
         1   '                    PEDON NO. ',I1)
52    241 FORMAT('1',55X,'EXTRACTABLE CA')
53    242 FORMAT('0',30X,'DISTRIBUTION OF EXTRACTABLE CA VS. DEPTH'
         1   '                    PEDON NO. ',I1)
54    251 FORMAT('1',59X,'EXTRACTABLE K ')
55    252 FORMAT('0',30X,'DISTRIBUTION OF EXTRACTABLE K  VS. DEPTH'
         1   '                    PEDON NO. ',I1)
56    261 FORMAT('1',59X,'EXTRACTABLE MG')
57    262 FORMAT('0',30X,'DISTRIBUTION OF EXTRACTABLE MG VS. &EPTH'
         1   '                    PEDON NO. ',I1)
58        DATA TEXT1,TEXT2,TEXT3,TEXT4/'S','LS','SL','L'/
59        DATA TEXT5, TEXT6, TEXT7,TEXT8/'SIL','SI', 'SCL', 'CL'/
60        DATA TEXT9, TEXT10, TEXT11, TEXT12/'SICL', 'SC', 'SIC', 'C'/
61        READ(5,100)KC,YR,PIT,LOC,CO
62        WRITE(6,200)LOC,CO
63        WRITE(6,201)
64        DO 10 L = 1,KC
65        READ(5,101)(SN(I),I=1,4),LN,(HOR(L,J),J=1,2),DEP1,DEP2(L),
         1   (COL(K),K=1,3),(TEX(II),II=1,2),(STR(JJ),JJ=1,3),
         2   (CON(IJ),IJ=1,4)
66        DEPCM1 = DEP1 * 2.54
67        DEPCM2(L) = DEP2(L) * 2.54
68        THK1(L) = DEP2(L) - DEP1
69        THK2(L) = DEPCM2(L) - DEPCM1
70     10 WRITE(6,202)(SN(I),I=1,4),LN,(HOR(L,J),J=1,2),DEPCM1,DEPCM2(L),
         1   THK2(L),(COL(K),K=1,3),(TEX(M),M=1,2),(STR(N),N=1,3),
         2   (CON(N),N=1,4)
71        DO 20 L = 1, KC
72        READ(5,102)LAN(L),MEEXMG(L),MEEXK(L),MEEXNA(L),MEEXCA(L),MEEXAL(L)
73        READ(5,103)PPMP(L),PHH2O(L),MECEC(L),MEEXH(L),PHKCL(L)
74        READ(5,104)PCCSI(L),PCMSI(L),PCOM(L),PCTSS(L),PCCO3(L)
75        READ(5,105)PCCLAY(L),PCSILT(L),PCGRA(L),PCVCS(L),PCCS(L)
76        READ(5,106)PCSAND(L),PCMS(L),PCFS(L),PCVFS(L),PCFSI(L)
77        READ(5,107)MESK(L),MESNA(L),MESCA(L),MESMG(L),MESCL(L)
78     20 READ(5,108)MESSO4(L),MESCO3(L),MEHCO3(L),ECUMHS(L)
79        DO 30 L = 1,KC
80        GRA(L)=PCGRA(L)+0.937522549
81        VCS(L)=PCVCS(L) + 0.139252146
82        CS(L)=PCCS(L)+0.108003366
83        MS(L)=PCMS(L)+0.178763322
84        FS(L)=PCFS(L)+2.87635437
85        VFS(L)=PCVFS(L)+ 7.96961676
86        SAND(L)=VCS(L)+CS(L)+MS(L)+FS(L)+VFS(L)
87        CSI(L) = PCCSI(L)+ 32.2714524
88        MSI(L)=PCMSI(L) + 17.5122897
89        FSI(L) = PCFSI(L) + 5.59724873
90        SILT(L)=CSI(L)+MSI(L)+FSI(L)
91        CLAY(L) = PCCLAY(L) + 33.3570187
92        SCA(L) = MESCA(L) + 0.0518220588
93        SMG(L) = MESMG(L) + 0.158612745
94        SK(L) = MESK(L) + 0.0140087929
95        SNA(L) = MESNA(L) + 0.704270511
96        SUMCAT(L) = SK(L) + SNA(L) + SCA(L) + SMG(L)
97        SCL(L) = MESCL(L) + 0.704915441
98        SSO4(L) = MESSO4(L) + 0.000000000
99        SCO3(L) = MESCO3(L) + 0.01265
100       SHCO3(L) = MEHCO3(L) + 0.72075000
101       SUMAN(L) = SCL(L) + SSO4(L) + SCO3(L) + SHCO3(L)
102       EXTCA(L) = MEEXCA(L) + 15.8276667
103       EXTMG(L) = MEEXMG(L) + 5.75396373
104       EXTK(L) = MEEXK(L) + 0.274264266
105       EXTNA(L) = MEEXNA(L) + 2.95568690
106       EXTH(L) = MEEXH(L) + 1.46375647
```

```
      EXTAL(L) = MEEXAL(L) + 0.00000000
      EXCCA(L) = EXTCA(L) - SCA(L)
      EXCMG(L) = EXTMG(L) - SMG(L)
      EXCK(L) = EXTK(L) - SK(L)
      EXCNA(L) = EXTNA(L) - SNA(L)
      EXCSUM(L) = EXCCA(L) + EXCMG(L) + EXCK(L) + EXCNA(L)
      SQ(L) = ((2.0 * SCA(L) + 2.0 * SMG(L))/2.0)
      SQR(L)=SQRT(SQ(L))
      SAR(L) = 2.0 * SNA(L) / SQR(L)
      C(L) = SCA(L)*100./EXCCA(L)
      CM(L) = PCOM(L) + 1.16517363
      PPPM(L) = PPMP(L) + 171.225490
      CACO3(L) = PCCO3(L) + 2.04883373
      TSS(L) = PCTSS(L) + 0.0816544118
      EC(L) = ECUMHS(L) + 164.358239
      KCLPH(L) = PHKCL(L) + 6.47892157
      H2OPH(L) = PHH2O(L) + 7.70343137
      CEC(L) = MECEC(L) + 22.6706101
      CAMG(L) =(EXTCA(L) / EXTMG(L)) * 100.0
      CC(L) =(CEC(L) / CLAY(L)) * 100.0
      PPMSNA(L) = SNA(L) * 22.9398
      PPMSK(L) = SK(L) * 39.102
      PPMSCA(L) = SCA(L) * 20.04
      PPMSMG(L) = SMG(L) * 12.16
      ESP(L) = EXCNA(L) * 100.0/CEC(L)
      S(L) = PPMSK(L) + PPMSNA(L) + PPMSMG(L) + PPMSCA(L)
      SSP(L) = PPMSNA(L)  * 100.00/S(L)
      NAAC(L) = EXCSUM(L) * 100.0/CFC(L)
      SSCC(L) = EXCSUM(L) * 100.0/(EXCSUM(L) + EXTH(L))
   30 M(L) = SMG(L) * 100. / EXCMG(L)
      DO 90 L = 1, KO
      SUB1(L) = SILT(L) + 1.5 * CLAY(L)
      IF(SAND(L).GE.85.0.AND.SUB1(L).LE.15.0)TEXT(L) = TEXT1
      SUB2(L) = SILT(L) + 2. * CLAY(L)
      IF(SAND(L).LE.90.0.AND.SUB1(L).GE.15.0.AND.SAND(L).GE.70.0.
     1 AND.SUB2(L).LE.30.0)TEXT(L) = TEXT2
      IF(CLAY(L).LE.20.0.AND.SUB2(L).GT.30.0.AND.SAND(L).GE.52.0.OR.
     1   CLAY(L).LT.7.0.AND.SILT(L).LT.50.0.AND.SAND(L).GT.43.0.AND.
     2   SAND(L).LT.52.0) TEXT(L) = TEXT3
      IF(CLAY(L).GE.7.0.AND.CLAY(L).LE.27.0.AND.SILT(L).GE.28.0.AND.
     1   SILT(L).LE.50.0.AND.SAND(L).LT.52.0) TEXT(L) = TEXT4
      IF(SILT(L).GE.50.0.AND.CLAY(L).GE.12.0.AND.CLAY(L).LE.27.0.OR.
     1   SILT(L).GE.50.0.AND.SILT(L).LE.80.0.AND.CLAY(L).LT.12.0)
     2   TEXT(L) = TEXT5
      IF(SILT(L).GE.80.0.AND.CLAY(L).LE.12.0) TEXT(L)=TEXT6
      IF(CLAY(L).GE.20.0.AND.CLAY(L).LE.35.0.AND.SILT(L).LT.28.0.AND.
     1   SAND(L).GE.45.0)TEXT(L) = TEXT7
      IF(CLAY(L).GE.27.0.AND.CLAY(L).LE.40.0.AND.SAND(L).GE.20.0.AND.
     1   SAND(L).LE.45.0) TEXT(L) = TEXT8
      IF(CLAY(L).GE.27.0.AND.CLAY(L).LE.40.0.AND.SAND(L).LT.20.0)
     1   TEXT(L) = TEXT9
      IF(CLAY(L).GE.35.0.AND.SAND(L).GE.45.0) TEXT(L) = TEXT10
      IF(CLAY(L).GE.40.0.AND.SILT(L).GE.40.0) TEXT(L) = TEXT11
      IF(CLAY(L).GE.40.0.AND.SAND(L).LT.45.0.AND.SILT(L).LT.40.0)
     1   TEXT(L)=TEXT12
   90 CONTINUE
      WRITE(6,203)
      WRITE(6,204)
      WRITE(6,205)
      DO 40 L = 1,KO
   40 WRITE(6,217)YR,PIT,L,LAN(L),GRA(L),VCS(L),CS(L),MS(L),FS(L),
     1   VFS(L),SAND(L),CSI(L),MSI(L),FSI(L),SILT(L),CLAY(L),TEXT(L)
      WRITE(6,206)
      WRITE(6,207)
      WRITE(6,208)
      DO 50 L = 1,KO
   50 WRITE(6,218)YR,PIT,L,LAN(L),EXTCA(L),EXTMG(L),EXTK(L),EXTNA(L),
     1   EXTH(L),EXTAL(L),EXCCA(L),EXCMG(L),EXCK(L),EXCNA(L),EXCSUM(L)
      WRITE(6,209)
      WRITE(5,210)
      WRITE(6,211)
      DO 60 L = 1,KO
   60 WRITE(6,219)YR,PIT,L,LAN(L),SCA(L),SMG(L),SK(L),SNA(L),SUMCAT(L),
     1   SCL(L),SSO4(L),SCO3(L),SHCO3(L),SUMAN(L)
      WRITE(6,212)
      WRITE(6,213)
      WRITE(6,214)
      DO 70 L = 1,KO
   70 WRITE(6,220)YR,PIT,L,LAN(L),OM(L),PPPM(L),CACO3(L),TSS(L),EC(L),
     1   KCLPH(L),H2OPH(L),CEC(L)
      WRITE(6,215)
      WRITE(6,215)
      DO 80 L = 1,KO
   80 WRITE(6,221)YR,PIT,L,LAN(L),CAMG(L),CC(L),ESP(L),SSP(L),SAR(L),
     1   C(L),M(L),NAAC(L),SSCC(L)
      WRITE(6,222)
      CALL HISTO(THK1,CLAY,HOR,DEPCM2,KO,10.0,2.0)
      WRITE(6,223)PIT
      WRITE(6,224)
      CALL HISTO(THK1,OM,HOR,DEPCM2,KO,1.0,2.0)
      WRITE(6,225)PIT
      WRITE(6,225)
      CALL HISTO(THK1,PPPM,HOR,DEPCM2,KO,50.0,2.0)
      WRITE(6,227)PIT
      WRITE(6,228)
      CALL HISTO(THK1,CC,HOR,DEPCM2,KC,10.0,2.0)
      WRITE(6,229)PIT
      WRITE(6,230)
      WRITE(6,231)
      CALL HISTO(THK1,EXTNA,HOR,DEPCM2,KO,2.0,2.0)
      WRITE(6,232)PIT
      WRITE(6,241)
      CALL HISTO(THK1,EXTCA,HOR,DEPCM2,KO,2.0,2.0)
      WRITE(6,242)PIT
      WRITE(6,251)
      CALL HISTO(THK1,EXTK ,HOR,DEPCM2,KO,2.0,2.0)
      WRITE(6,252)PIT
      WRITE(6,251)
      CALL HISTO(THK1,EXTMG,HOR,DEPCM2,KO,2.0,2.0)
      WRITE(6,262)PIT
      STOP
      END

      SUBROUTINE  HISTO(TROWS,XVALUS,RANGID,N2,NGRPS,XSCALE,YSCALE)
       INTEGER SCALE,TROWS
      DIMENSION TROWS(13),XVALUS(13),RANGID(13,2),ROW(101),SCALE(11),
     1   N2(13)
      DATA AST,BLK,HYPH,VERT/'*',' ','-','|'/
      DO 10 I = 1,101
   10 ROW(I) = HYPH
      DO 20 I = 1,101,10
   20 ROW(I) = VERT
      DO 30 I = 1,11
   30 SCALE(I) = (I-1) * XSCALE + 0.5
      WRITE(6,100)SCALE
  100 FORMAT('0',11X,11I10)
      WRITE(6,101)ROW
  101 FORMAT(' ',20X,102A1)
      ROW(1) = VERT
      DO 70 L = 1,NGRPS
      DO 40 I = 2,101
   40 ROW(I) = BLK
      IF(XVALUS(L).EQ.0.)GO TO 802
  601 NCOLS = (XVALUS(L)/XSCALE)*10.0+.5
      NCOLS=MINO(NCOLS,101)
      IF(NCOLS-1)800,800,801
  800 NCOLS = 2
  801 DO 50 I = 2,NCOLS
   50 ROW(I) = AST
  802 LINES = TROWS(L)/YSCALE+.5
      DO 60 I = 1,LINES
   60 WRITE(6,101)ROW
      WRITE(6,102)(RANGID(L,J),J=1,2),N2(L)
  102 FORMAT('+',7X,2A4,I3,'CM')
   70 CONTINUF
      RETURN
      END

$ENTRY
```

APPENDIX B

FIELD DESCRIPTION FOR INDIVIDUAL PEDONS LOCATED

IN NW¼ OF SECTION 17. T. 25 N., R. 5 E.

OSAGE COUNTY OKLAHOMA

Pedon 1

Physiography: Upland Footslope
Relief: slightly concave
Slope: 1.5%
Aspect: southwest
Erosion: None to slight
Permeability: very slow
Drainage: Poorly drained
Ground water: 165 cm below surface
Moisture: Dry to 84 cm.

(Colors are for moist conditions unless noted otherwise)

Horizon	cm	
Ap	0-10	10 YR 3/2 very fine sandy loam, 10 YR 5/2 dry; weak medium and coarse platy structure; very friable, hard; few fine pores; many fine and medium roots; pH 6.5; clear smooth boundary.
A1	10-17	10 YR 3/1 silt loam, 10 YR 5/2 dry; weak medium platy structure; very friable, hard; common fine pores; many fine and common medium roots; pH 7.0; abrupt smooth boundary.
B21t	17-35	10 YR 2/1 silty clay, 10 YR 4/1 dry; strong medium prismatic parting to strong fine angular blocky structure; upper 2.5 cm of prisms are capped with 10 YR 4/1 silt loam, 10 YR 6/2 dry; very firm, extremely hard; common fine pores; many fine and few medium roots; continuous clay films; few fine crystals of salts in lower part; few fine soft masses of CO_3 in lower part; pH 8.0; clear wavy boundary.
B22tca	35-55	10 YR 3/2 silty clay, 10 YR 4/2 dry; common fine faint 7.5 YR 5/6 mottles and common medium distinct 10 YR 3/1 coatings on some ped exteriors; weak coarse prismatic parting to moderate fine angular blocky structure; very firm, extremely hard; few fine pores; common fine fine and few medium roots; patchy clay films; few fine black concretions; few fine crystals of salts; many fine and medium soft masses of $CaCO_3$; disseminated $CaCO_3$ in some peds; pH 8.0; gradual smooth boundary.

Horizon	cm	
B23t	55-83	10 YR 4/2 heavy silty clay loam, 10 YR 5/3 dry; many fine and medium distinct 7.5 YR 5/6 mottles; weak coarse prismatic parting to moderate fine and medium angular blocky structure; very firm, extremely hard; common fine and few medium pores; common fine roots; continuous clay films; many fine black concretions; some segregated $CaCO_3$ in thread-like forms; slight effervescence in spots; pH 8.2; gradual smooth boundary.
B24t	83-119	10 YR 4/2 heavy silty clay loam, 10 YR 5/3 dry; many fine and medium distinct 7.5 YR 5/6 mottles; weak medium angular blocky structure; very firm, extremely hard; common fine and few medium pores; few fine roots; continuous clay films; many fine black concretions; common very fine specks of soluble salts; few medium hard lime concretions; slight effervescence around some pores; pH 8.2; gradual smooth boundary.
B25t	119-144	7.5 YR 4/2 heavy silty clay loam, 7.5 YR 5/3 dry; common coarse distinct 10 YR 7/4 and many fine and medium distinct 7.5 YR 5/6 mottles; weak medium angular blocky structure; very firm, extremely hard; few fine pores; few fine roots; continuous clay films; common fine black concretions; few medium hard $CaCO_3$' concretions; slight effervescence around some pores; pH 8.3; gradual smooth boundary.
B26t	144-165	7.5 YR 4/2 light silty clay, 7.5 YR 5/3 dry; common coarse distinct 10 YR 7/4 and many fine and medium distinct 7.5 YR 5/6 mottles; weak fine and medium angular block structure; very firm, extremely hard; common fine and few medium pores; continuous clay films; many fine black concretions; slight effervescence around some pores; pH 8.3; gradual smooth boundary.

Horizon	cm	
B3	165-231	7.5 YR 4/2 silty clay, 7.5 YR 5/3 dry, many fine and medium distinct 7.5 YR 5/6 and few fine distinct 10 YR 5/2 mottles; weak medium angular blocky structure; very firm, extremely hard; few fine pores; patchy clay films; many fine black concretions with few larger than 2 mm; slight effervescence around some pores; water table at 165 cm pH 8.3 clear boundary.
C	231-253	Partially weathered reddish fine grain sandstone of Permian Age.

Pedon 2

Physiography: Upland footslope
Relief: smooth
Slope: 1.5%
Aspect: Southwest
Erosion: None to slight
Permeability: Very slow
Drainage: Poorly drained
Ground water: 170 cm to watertable
Moisture: Dry to 99 cm.

(Colors are for moist conditions unless noted otherwise)

Horizon	cm	
Ap	0-20	10 YR 3/1 very fine sandy loam, 10 YR 5/1 dry; weak medium and coarse platy parting to weak medium granular structure; very friable, hard; common fine and few medium pores; many fine and medium roots; many worm casts; pH 6.5; clear smooth boundary.
A1	20-30	10 YR 3/1 silt loam, 10 YR 5/2 dry; massive; very friable, hard; many fine and few medium and coarse pores; many fine and common medium roots; many worm casts; pH 6.8; abrupt smooth boundary.
B21t	30-48	10 YR 2/2 heavy silty clay loam, 10 YR 4/2 dry; few fine faint 7.5 YR 5/6 mottles; strong medium prismatic parting to moderate medium angular blocky structure; upper 2.5 cm of prisms capped and sides of prisms coated with 10 YR 3/2 silt loam. 10 YR 5/2 dry; firm; very hard; many fine, common medium, and few coarse pores; many fine and common medium roots; patchy clay

Horizon	cm	
B21t (con't)		films; many worm casts; pH 6.8; gradual smooth boundary.
B22t	48-71	10 YR 3/2 heavy silty clay loam, 10 YR 4/2 dry; common fine distinct 7.5 YR 5/6 mottles; some peds coated with organic stains of 10 YR 3/1; moderate medium prismatic parting to moderate fine and medium angular blocky structure; very firm, extremely hard; common fine pores; many fine and few medium roots; nearly continuous clay films; few fine black concretions; common worm casts; pH 8.0; gradual smooth boundary.
B23t	71-99	10 YR 4/2 light silty clay, 10 YR 4/2 dry; few fine distinct 7.5 YR 5/6 mottles; about 50 percent of peds coated with 10 YR 4/3 and few peds coated with organic stains of 10 YR 3/1; weak coarse prismatic parting to weak medium angular blocky structure; very firm, extremely hard; many fine pores; common fine and few medium roots; continuous clay films; few fine black concretions; few medium hard $CaCO_3$ concretions; slight effervescence in spots; pH 8.0; gradual smooth boundary.
B24tca	99-119	10 YR 4/2 silty clay, 10 YR 4/2 dry; few fine distinct 7.5 YR 5/6 mottles; about 50 percent of peds coated with 10 YR 4/3 and few peds coated with organic stains of 10 YR 3/1; weak medium angular blocky structure; very firm, extremely hard; common fine pores; common fine roots; continuous clay films; common fine black concretions; few soluble salts in thread like forms; common medium hard $CaCO_3$ concretion; slight effervescence around some pores; pH 8.0; gradual smooth boundary.
B25tca	119-154	10 YR 4/2 silty clay, 10 YR 5/3 dry; common medium and coarse distinct 10 YR 6/4 and common fine distinct 7.5 YR 5/6 mottles; weak fine and medium angular blockystructure; very firm, extremely hard; common fine and few medium pores; few fine roots; continuous clay films; many fine black concretions with few larger than 2 mm; few thread-like forms

Horizon	cm	
B25tca (con't)		of soluble salts; common medium hard $CaCO_3$ concretions; slight effervescence around some pores; pH 8.3; gradual smooth boundary.
B26t	154-170	10 YR 4/2 silty clay, 10 YR 5/3 dry; many medium and coarse distinct 7.5 YR 5/6 and common fine distinct 2.5 Y 5/2 mottles; weak medium angular blocky structure; very firm, extremely hard; common fine and few medium pores; continuous clay films; many fine black concretions; pH 8.3; gradual smooth boundary.
B3	170-223	Varigated 10 YR 4/3, 7.5 YR 5/6 and 2.5 Y 5/2 silty clay; weak medium and coarse angular blocky structure; very firm, extremely hard; few fine pores; patchy clay films; common fine black concretions; pH 8.3; gradual boundary
C	223-259	No Description - 10 YR 4/3 moist.

Pedon 3

Physiography: Upland sideslope
Relief: Smooth
Slope: 2%
Aspect: Southwest
Erosion: None to slight
Permeability: Slow
Drainage: Moderately well drained
Ground water: 190 cm below surface
Moisture: Dry to 66 cm

(Colors are for moist conditions unless otherwise noted)

Horizon	cm	
Ap	0-15	10 YR 2/1 silt loam, 10 YR 4/1 dry; weak medium subangular blocky parting to moderate medium granular structure; very friable, hard; common fine, few medium pores; many fine and medium roots; common worm casts; pH 7.0; clear smooth boundary.
A1	15-22	10 YR 2/1 silt loam, 10 YR 4/1 dry; moderate medium granular structure; very friable, hard; many fine, few medium pores; many fine common medium roots; many worm casts; pH 6.3; clear smooth boundary.

Horizon	cm	
A3	22-40	10 YR 2/2 heavy silt loam, 10 YR 4/2 dry; weak coarse prismatic parting to moderate medium granular structure; friable, hard; many fine, few medium pores; many fine, few medium roots; many worm casts; pH 6.3; clear wavy boundary.
B1	40-53	10 YR 3/2 light silty clay loam, 10 YR 4/2 dry; few fine faint 7.5 YR 5/6 mottles; weak medium and coarse prismatic parting to moderate medium granular structure; friable, very hard; many fine, few medium pores; common fine, few medium roots; patchy clay films; few fine black concretions; many worm casts; pH 6.3; clear smooth boundary.
B21t	53-66	7.5 YR 3/2 silty clay loam; 7.5 YR 4/2 dry; common fine and medium distinct 7.5 YR 5/6 mottles; moderate medium prismatic parting to moderate medium granular structure; firm, very hard; many fine, common medium pores; common fine, few medium roots; continuous clay films; few fine black concretions; common worm casts; pH 6.8; clear smooth boundary.
B22t	66-99	7.5 YR 4/2 heavy silty clay loam, 7.5 YR 5/2 dry; common fine and medium distinct 5 YR 4/6 mottles; moderate medium prismatic parting to moderate fine and medium angular blocky structure; very firm, extremely hard; many fine, few medium pores; common fine roots; continuous clay films; common fine black concretions with few larger than 2 mm; few slickensides; few worm casts; pH 7.5; gradual wavy boundary.
B23t	99-126	7.5 YR 4/2 silty clay, 7.5 YR 5/2 dry; many fine and medium distinct 5 YR 4/6 mottles; weak medium prismatic parting to moderate medium angular blocky structure; very firm, extremely hard; common fine pores; common fine roots; continuous clay films; many fine black concretions with few larger than 2 mm; common noninter-secting slickensides; pH 8.0; gradual wavy boundary.

Horizon	cm	
B24t	126-149	7.5 YR 4/2 silty clay, 7.5 YR 5/4 dry; many fine and medium distinct 7.5 YR 5/8 and few fine distinct 10 YR 5/1 mottles; weak medium and coarse angular blocky structure; very firm, extremely hard; common fine pores; few fine roots; continuous clay films; many fine black concretions with few greater than 2 mm; few medium hard lime concretions; few nonintersecting slickensides; few fine fragments of sandstone; pH 8.0; gradual wavy boundary.
B25tca	149-170	7.5 YR 4/2 silty clay, 7.5 YR 5/4 dry; many medium and coarse distinct 7.5 YR 5/6 and common medium distinct 10 YR 5/1 mottles; weak medium and coarse angular blocky structure; very firm, extremely hard; common fine pores; few fine roots; continuous clay films; many fine black concretions with few larger than 2 mm; common fine and medium hard $CaCO_3$ concretions; few nonintersecting slickensides; noncalcareous; pH 8.0; gradual wavy boundary.
B26t	170-190	7.5 YR 4/4 silty clay, 7.5 YR 5/4 dry; many medium and coarse distinct 7.5 YR 4/6 and 10 YR 5/1 mottles; weak medium and coarse angular blocky structure; very firm, extremely hard; few fine pores; few fine roots; continuous clay films; many fine black concretions; few medium hard $CaCO_3$ concretions; noncarcareous; pH 8.2; gradual boundary.
B31	190-226	7.5 YR 5/4 silty clay, 7.5 YR 6/4 dry; many medium and coarse distinct 7.5 YR 4/6 and 10 YR 5/1 mottles; weak coarse angular blocky structure; very firm, extremely hard; few fine pores; patchy clay films; many fine black concretions; noncalcareous; water table at 190 cm, pH 8.3; gradual boundary.
C	226-256	5 YR 5/6 heavy silty clay loam, 5 YR 6/6 dry; common medium distinct 5 YR 5/8 mottles; massive; very firm, extremely hard; common fine black concretions; few weathered fragments of sandstone; noncalcareous; pH 7.7.
R	256+	Hard reddish fine grain sandstone.

Pedon 4

Physiography: Upland sideslope
Relief: Single or smooth
Slope: 2%
Aspect: Southwest
Erosion: None to slight
Permeability: slow or very slow
Drainage: poorly drained
Ground water: >320 cm

(Colors are for moist conditions unless otherwise noted)

Horizon	cm	
Ap	0-22	10 YR 2/2 silt loam, 10 YR 4/2 dry; weak medium and coarse platy; very friable, hard; few medium, few fine pores; many fine, few medium roots; many worm casts; pH 6.3; clear smooth boundary.
A1	22-33	10 YR 3/2 silt loam, 10 YR 5/2 dry; weak coarse platy structure; very friable, hard; many fine, common medium pores; many fine, common medium roots; many worm casts; pH 6.3; abrupt wavy boundary.
B1	33-53	10 YR 4/3 light silty clay loam, 10 YR 5/3 dry; many fine and medium distinct 5 YR 5/6 mottles; moderate coarse prismatic parting to moderate medium angular blocky structure; prisms are coated and have 2.5 cm caps of 10 YR 3/2 silt loam, 10 YR 5/2 dry; firm, extremely hard; many fine, few medium pores; many fine, common medium roots; patchy clay films; common worm casts; pH 6.5; gradual smooth boundary.
B21t	53-81	7.5 YR 3/2 heavy silty clay loam, 7.5 YR 4/2 dry; many fine and medium distinct 5 YR 5/6 mottles; many prisms coated with 10 YR 4/3, 6/4 dry; moderate medium prismatic parting to strong fine and medium angular blocky structure; very firm, extremely hard; few fine, few medium pores; many fine, common medium roots; continuous clay films; organic stains (10 YR 2/2) on many ped faces; few worm casts; pH 8.0; gradual smooth boundary.

Horizon	cm	
B22t	81-104	7.5 YR 4/2 heavy silty clay loam, 7.5 YR 5/4 dry; common fine and medium distinct 5 YR 5/6 mottles; prisms coated with 10 YR 4/3, 6/4 dry; weak coarse prismatic parting to moderate fine and medium angular blocky structure; very firm, extremely hard; few fine pores; common fine roots; continuous clay films; common fine black concretions; organic stains (10 YR 2/2) on some ped faces; pH 8.3; gradual wavy boundary.
B22tca	104-124	7.5 YR 4/4 heavy silty clay loam, 7.5 YR 5/4 dry; common medium and coarse distinct 5 YR 5/6; mottles; about 50% of peds coated with 10 YR 4/3, 6/4 dry; moderate medium angular blocky structure; very firm, extremely hard; few fine pores; few fine roots; continuous clay films; many fine black concretions; few fine soft masses and few coarse hard concretions of $CaCO_3$; noncalcareous; pH 8.3; gradual wavy boundary.
B23tca	124-152	5 YR 4/4 heavy silty clay loam 5 YR 5/4 dry; few fine faint 5 YR 5/8 mottles; weak medium angular blocky structure; firm, extremely hard; few fine pores; continuous clay films; many fine black concretions; few medium hard $CaCO_3$ concretions; pH 8.3; gradual wavy boundary.
B24t	152-180	5 YR 4/6 heavy silty clay loam, 5 YR 5/6 dry; common medium distinct 2.5 Y 5/2 and few fine faint 5 YR 5/8; weak medium angular blocky structure; firm, extremely hard; common fine, few medium pores; nearly continuous clay films; common fine black concretions; few coarse fine grain sandstone fragments; non-calcareous; pH 8.3; gradual wavy boundary.
B31	180-200	2.5 YR 4/4 silty clay, 2.5 YR 5/4 dry; common medium distinct 2.5 Y 6/2 and common distinct 2.5 Y 6/6; weak medium and coarse angular blocky structure; firm, extremely hard; common fine pores; nearly continuous clay films; many fine black concretions; few fine and medium sandstone fragments; slight effervescence; pH 8.3; gradual smooth boundary.

Horizon	cm	
B32ca	200-228	Varigated 5 YR 4/6, 2.5 Y 6/2, 2.5 YR 4/4, and 2.5 Y 5/2 silty clay loam; weakly laminated and weak medium angular blocky structure; firm, very hard; common fine pores; patchy clay films; common fine black concretions; $CaCO_3$ occurring in disseminated forms and as few hard concretions; violent effervescence; pH 8.3; gradual boundary.
C1	228-259	5 YR 4/4 and 5 Y 6/2 weakly laminated clay; very firm, extremely hard; common fine black concretions; strong effervescence; pH 8.2; gradual boundary.
C2	259-289	5 YR 4/4 and 5 Y 6/2 weakly laminated clay; common fine lime coated sandstone fragments; strong effervescence; pH 8.1; gradual boundary.
C3	289-320	5 YR 4/4 and 5 Y 6/2 weakly laminated clay; slight effervescence; pH 8.0

Pedon 5

Physiography: Upland sideslope
Relief: Slightly convex
Slope: 2%
Aspect: Southwest
Erosion: none to slight
Permeability: slow
Drainage: Moderately well drained
Ground water: >236 cm below surface
Moisture: dry to 50 cm

(Colors are for moist conditions unless otherwise noted)

Horizon	cm	
Ap	0-20	10 YR 3/2 silt loam, 10 YR 5/2 dry; moderate medium and coarse platy structure; very friable, hard; few fine, few medium pores; many fine, common medium roots; pH 6.0 abrupt smooth boundary.
A1	20-38	10 YR 3/2 silt loam, 10 YR 4/2 dry; moderate fine and medium granular structure; very friable, hard; many fine, common medium pores; many fine, few medium roots; many worm casts; pH 6.0; clear smooth boundary.

Horizon	cm	
A3	38-50	7.5 YR 3/2 heavy silt loam, 7.5 YR 4/2 dry; weak coarse prismatic parting to moderate medium granular structure; friable, hard; many fine, few medium pores; many fine, few medium roots; many worm casts; pH 6.0; clear smooth boundary.
B1	50-60	5 YR 3/2 silty clay loam, 5 YR 4/2 dry; weak coarse prismatic parting to moderate medium structure; firm, very hard; many fine and medium pores; many fine, few medium roots; patchy clay films; common worm casts; pH 6.0; clear smooth boundary.
B21t	60-91	5 YR 4/3 silty clay loam, 5 YR 5/3 dry; common medium distinct 5 YR 4/6 mottles; moderate medium prismatic parting to moderate fine angular blocky structure; very firm, very hard; many fine, common medium pores; many fine, few medium roots; continuous clay films; few fine black concretions; pH 6.2; gradual smooth boundary.
B22tca	91-116	5 YR 4/3 silty clay loam, 5 YR 5/3 dry; common coarse distinct 10 YR 5/2 and few coarse distinct 5 YR 4/6 mottles; moderate medium angular blocky structure; very firm, extremely hard; few fine, common medium pores; common fine roots; continuous clay films; many fine black concretions; few fine soft masses of $CaCO_3$; few worm casts; pH 6.7; gradual smooth boundary.
B3	116-142	Varigated 5 YR 5/3, 10 YR 5/6, 10 YR 6/3, 10 YR 3/2, and 2.5 Y 6/2 silty clay loam and weakly laminated siltstone and shale; many fine, common medium pores; few fine roots; patchy clay films; noncalcareous; pH 8.2; clear smooth boundary.
C1	142-160	Varigated 5 YR 5/3, 10 YR 5/6, 10 YR 6/3, 10 YR 3/2, 7.5 YR 5/8, and 2.5 Y 6/2 weakly laminated siltstone, shale and fine grain sandstone; few fine roots; slight effervescence; pH 8.0; clear smooth boundary.

Horizon	cm	
C2	160-193	Varigated 5 YR 4/2, 2.5 Y 5/2, 2.5 Y 6/6; laminated shale, siltstone, and fine grain sandstone; noncalcareous; pH 8.0; clear smooth boundary.
C3	193-220	Varigated 5 YR 5/2, 2.5 Y 5/2, and 10 YR 6/8 laminated silt stone or fine grain sandstone; black coatings on clevage plains; noncalcareous; pH 8.0; clear smooth boundary.
C4	220-236	2.5 YR and 10 YR 4/3 laminated siltstone and fine grain sandstone; noncalcareous; pH 8.2; aburpt smooth boundary.
R	236+	Hard reddish fine grain sandstone of Permian Age; unsampled.

Pedon 6

Physiography: Upland ridge crest
Relief: Slightly convex
Slope: 1.5%
Aspect: Southwest
Erosion: None to slight
Permeability: Slow
Drainage: Moderately well drained
Ground water: 233 cm below surface (in auger hole)
Moisture: Dry to 51 cm

(Colors are for moist conditions unless otherwise noted)

Horizon	cm	
Ap1	0-5	10 YR 3/2 silt loam, 10 YR 4/2 dry; weak fine platy; friable, hard; few medium pores; many fine and medium roots; pH 6.2; abrupt smooth boundary.
Ap2	5-20	10 YR 3/2 silt loam, 10 YR 4/2 dry; massive or weak medium granular structure; friable, hard; few medium pores; many fine and medium roots; many worm casts; pH 6.2; clear smooth boundary.
A1	20-35	10 YR 3/2 heavy silt loam, 10 YR 4/2 dry; moderate medium granular structure; friable, hard; many fine, few medium pores; many fine and medium roots; many worm casts; pH 6.4; clear smooth boundary

Horizon	cm	
B1	35-50	7.5 YR 3/2 silty clay loam, 7.5 YR 4/2 dry; common fine distinct 5 YR 4/6 mottles; moderate medium prismatic parting to strong medium granular structure; firm, hard; many fine, few medium pores; common fine and medium roots; patchy clay films; pH 6.4; gradual smooth boundary.
B21t	50-68	5 YR 4/3 silty clay loam, 5 YR 5/3 dry; common fine and medium distinct 5 YR 4/6 mottles; weak medium prismatic parting to strong medium granular structure; very firm, very hard; common fine, few medium pores; common fine, few medium roots; nearly continuous clay films; pH 6.5; gradual wavy boundary.
B22t	68-101	5 YR 4/3 heavy silty clay loam, 5 YR 4/3 dry; many coarse distinct 5 YR 5/6 mottles; moderate medium angular blocky structure; very firm, extremely hard; common fine pores; common fine, few medium roots; continuous clay films; many fine black concretions; few organic stains on surface of peds; pH 6.8; gradual smooth boundary.
B23t	101-126	5 YR 4/4 silty clay, 5 YR 5/4 dry; common coarse distinct 5 YR 5/6 and few fine distinct 10 YR 5/2 mottles; moderate medium angular blocky structure; very firm, extremely hard; few fine pores; few fine roots; continuous clay films; common nonintersecting slickensides; many fine black concretions; black stains in root channels; few krotovinas; few soft masses of $CaCO_3$; noncalcareous; pH 8.0; gradual smooth boundary.
B24ca	126-160	5 YR 4/4 silty clay, 5 YR 5/4 dry; many coarse distinct 5 YR 5/6, common medium distinct 10 YR 5/2, and common fine distinct 5 YR 5/8 mottles; weak medium angular blocky structure; very firm, extremely hard; few fine pores; few fine roots; nearly continuous clay films; common fine black concretions; black stains in root channels; common medium and coarse hard $CaCO_3$ concretions; slight effervescence; pH 8.3; gradual smooth boundary.

Horizon	cm	
B3	160-185	Varigated 5 YR 4/4, 7.5 YR 4/4 and 3/2, 10 YR 6/8 and 5/3, and 2.5 Y 6/2 silty clay loam; weak coarse angular blocky structure; firm, very hard; common fine pores; few fine roots; few patchy clay films; few fine black concretions; slight effervescence; pH 8.2; gradual smooth boundary.
C1	185-205	Varigated 5 YR 4/4 and 5/3, 7.5 YR 6/4, 2.5 YR 6/4, and 10 YR 5/6 and 5/3 light silty clay loam; massive; firm, very hard; common fine, few medium pores; noncalcareous; pH 8.1; gradual smooth boundary.
C2	205-233	Varigated 5 YR 7/2 and 5/3, 5 Y 7/2 and 8/2, 7.5 YR 5/8 and 6/8, 10 YR 5/6 and 2.5 Y 6/2 weakly laminated interbedded siltstone, shale, and fine grain sandstone; slight effervescence in spots; gradual boundary.
C3	233-261	5 YR 4/3 shale interbedded with 5 Y 6/3 fine grain sandstone; slight effervescence; clear boundary.
C4	261-279	5 YR 4/3 and 5 Y 6/3 laminated shale; strong effervescence; clear boundary.
R	279"+	Hard massive reddish fine grain sandstone.

Pedon 7

Physiography: Upland ridge crest
Relief: Slightly convex
Slope: 1.5%
Aspect: Southwest
Erosion: None to slight
Permeability: Very slow
Drainage: Poorly drained
Ground water: 236 cm below surface
Moisture: Dry to 70 cm

(Colors are for moist conditions unless otherwise noted)

Horizon	cm	
Ap	0-7	10 YR 3/2 very fine sandy loam, 10 YR 5/2 dry; moderate medium and coarse platy structure; very friable, hard; many fine, common medium pores; many fine, common medium roots; pH 6.8; clear smooth boundary.

Horizon	cm	
A1	7-20	7.5 YR 3/2 very fine sandy loam 7.5 YR 5/2 dry; weak medium and coarse platy structure; very friable, hard; many fine, common medium roots; few worm casts; pH 8.0; abrupt smooth boundary.
B21t	20-35	7.5 YR 3/2 clay loam 7.5 YR 4/2 dry; prisms capped with 7.5 YR 4/2 and 5/4 dry; moderate medium and coarse prismatic parting to moderate fine and medium angular blocky structure; very firm, extremely hard; few fine and medium pores; many fine, common medium roots; patchy clay films; prisms are coated with black 10 YR 2/1 stains; common worm casts; noncalcareous; pH 8.3; clear smooth boundary.
B22t	35-55	5 YR 4/3 heavy silty clay loam, 5 YR 4/3 dry; moderate medium prismatic parting to strong fine and medium angular blocky structure; very firm, extremely hard; few fine and medium pores; many fine, common medium roots; continuous clay films; most ped surfaces are coated with 10 YR 2/2 organic stains and some are coated with 7.5 YR 5/4 material along vertical cracks that washed down from A horizons; few soft masses of $CaCO_3$; few small sandstone pebbles; noncalcareous; pH 8.3; gradual smooth boundary.
B23t	55-71	5 YR 4/3 heavy silty clay loam, 5 YR 4/3 dry; moderate fine and medium angular blocky structure; very firm, extremely hard; few fine and medium pores; few fine roots; continuous clay films; common fine black concretions; few soft masses of $CaCO_3$ some vertical ped surfaces coated with 7.5 YR 5/4 that has wash down cracks from A horizons; noncalcareous; pH 8.3 gradual smooth boundary.
B3	71-104	5 YR 4/4 heavy silty clay loam, 5 YR 4/4 dry; weak medium angular blocky structure; very firm, very hard; common meidum, few fine pores; few fine roots; patchy clay films; few fine black concretions; common fine and medium 10 YR 6/6 sandstone fragments; slight effervescence in spots; pH 8.3; gradual smooth boundary.

Horizon	cm	
B32	104-134	5 YR 4/4 silty clay loam, 5 YR 4/4 dry; weak medium and coarse angular blocky structure; very firm, very hard; common fine, few medium pores; patchy clay films; few fine black concretions; many fine and medium 10 YR 6/6 sandstone fragments; slight effervescence; pH 8.3; clear wavy boundary.
C1	134-180	Varigated 5 YR 4/3, 10 YR 7/4, 6/6, and 2/1 interbedded fine grain sandstone and shale; weakly laminated; slight effervescence; pH 8.3; gradual wavy boundary.
C2	180-228	Varigated 5 YR 4/2, 10 YR 7/4 and 5/6 partially weathered fine grain sandstone and interbedded shale; strong effervescence; pH 8.1; clear wavy boundary.
C3	228-243	5 YR 5/3 siltstone interbedded with 5 Y 7/3 fine grain sandstone; slight effervescence; pH 8.2; clear boundary.
R	243"+	Hard massive reddish brown fine grain sandstone.

APPENDIX C

COMPUTER PROGRAM WHICH USED THE "DENDOGRAPH" AS A SUBROUTINE FOR CLUSTERING THE PEDONS

```
      DIMENSION LAB(10),LAC(10),DAB(10),LAA(10),LAV(10),LAD(10),LAR(10)
      DIMENSION JAA(10),JAB(10)
      DIMENSION LRD(10),IORD(10),WGR(10),BGR(10),A(18),ALIN(10)
      DIMENSION NAME(4,10)
      DIMENSION AI(100),BI(100),CI(100),DI(100),EI(100),IC(100),
     1 IJ(100),IR(100),JC(100),JR(100),JN(100),LL(100),N(100),NN(100)
      READ(5,998) (A(I),I=1,18)
C    INPUT DATA MATRICES - ID #, ROW #, COLUMN #, ENTRY
      I=0
    5 I=I+1
      READ(5,900,END=10) IJ(I),IR(I),IC(I),N(I)
      GO TO 5
   10 K=IJ(I-1)
      M=I-1
      IJ(I)=99
      KKK=K*(K-1)/2
      III=1
      WRITE(6,905) III
      L=1
      LL(L)=1
      II=1
      JJ=1
      I=0
      X=0.
      AY=0.
C    COMPUTE INFORMATION MEASURE I(A) FOR ALL KA OF THE INPUT MATRICES.
   20 I=I+1
      IF(IJ(I).EQ.JJ) GO TO 30
      AI(II)=AY*ALOG(AY) - X
      JJ=IJ(I)
      II=II+1
      L=L+1
      LL(L)=I
      IF(II.GT.K) GO TO 40
      X=0.
      AY=0.
   30 AN=N(I)
      X=X+AN*ALOG(AN)
      AY=AY+AN
      GO TO 20
   40 WRITE(6,903)
      DO 50 I=1,K
   50 WRITE(6,901) I,AI(I)
      KA=K
      MM=M
      K1=K+1
      LL(K1)=M+1
      WRITE(6,914) (LL(I),I=1,K1)
      II=0
      KR=K-1
      DO 110 I=1,KR
      KC=I+1
      L1=LL(I)
      L2=LL(I+1)-1
      DO 110 J=KC,K
C  COMPUTE A(I) + A(J) FOR ALL PAIRS OF INPUT MATRICES, A(I),I=1,KA
      II=II+1
      L=0
      DO 60 KK=L1,L2
      L=L+1
      JR(L)=IR(KK)
      JC(L)=IC(KK)
   60 JN(L)= N(KK)
      K1=LL(J)
      K2=LL(J+1)-1
      KO=K1-1
   70 KO=KO+1
      IF(KO.GT.K2) GO TO 90
      KCH=0
      DO 80 KK=L1,L2
      IF((IR(KO).NE.IR(KK)).OR.(IC(KO).NE.IC(KK))) GO TO 80
      LI=KK-L1+1
      JN(LI)=JN(LI)+N(KO)
      KCH=KCH+1
   80 CONTINUE
      IF(KCH.EQ.1) GO TO 70
      L=L+1
      JN(L)=N(KO)
      JC(L)=IC(KO)
      JR(L)=IR(KO)
      GO TO 70
C  COMPUTE INFORMATION MEASURE I(A(I) + A(J)) FOR ALL PAIRS OF MATRICES.
   90 X=0.
      AY=0.
      DO 100 JJ=1,L
      AN=JN(JJ)
      X=X+AN*ALOG(AN)
  100 AY=AY+AN
      BI(II)=AY*ALOG(AY) - X
      NN(II)=100*I + J
  110 CONTINUE
C  COMPUTE CHANGE IN INFORMATION, DELTA I, FOR ALL PAIRS OF MATRICES.
      DA=100.
      DO 120 I=1,KKK
      N1=NN(I)/100
      N2=NN(I)-100*N1
      DI(I)=BI(I)-AI(N1)-AI(N2)
C  RECORD IDENTITY OF PAIR OF MATRICES YIELDING SMALLEST DELTA I.
      IF(DI(I).GT.DA) GO TO 120
      DA=DI(I)
      NA1=N1
      NA2=N2
      NAA=I
  120 CONTINUE
      LAB(1)=NA1
      LAC(1)=NA2
      DAB(1)=DA
      WRITE(6,904)
      WRITE(6,913) (I,NN(I),BI(I),DI(I),I=1,KKK)
C  STORE RELEVENT I(A) MEASURES AFTER STAGE 1 CLUSTERING.
  121 AI(NA1) = BI(NAA)
      III=III+1
      IF(III.EQ.KA) GO TO 340
      WRITE(6,905) III
      KO=K-1
      IF(NA2.EQ.K) GO TO 126
      DO 125 I=NA2,KO
  125 AI(I)=AI(I+1)
  126 L1=LL(NA1)
      L2=LL(NA1+1)-1
      K1=LL(NA2)
      K2=LL(NA2+1)-1
      L=0
C  COMPUTE AND STORE RELEVENT A MATRICES AFTER STAGE 1 CLUSTERING.
C       NOTE.  ONE OF THESE WILL BE A(I) + A(J) CORRESPONDING TO THE PAIR
C              OF MATRICES WHICH YIELDED THE SMALLEST DELTA I.
      WRITE(6,903)
      WRITE(6,901) (I,AI(I),I=1,KO)
C  130 LOOP. NA1 MATRIX STORED IN DUMMY J VECTORS.
      DO 130 I=L1,L2
      L=L+1
      JN(L)=N(I)
```

```
      JC(L)=IC(I)
  130 JR(L)=IR(I)
      LI=L
C  150 LOOP. NA2 MATRIX 'ADDED' TO NA1 MATRIX IN DUMMY J VECTORS.
      DO 150 J=K1,K2
      KCH=0
      DO 140 I=1,LI
      IF((IR(J).NE.JR(I)).OR.(IC(J).NE.JC(I))) GO TO 140
      JN(I)=JN(I)+N(J)
      KCH=KCH+1
  140 CONTINUE
      IF(KCH.EQ.1) GO TO 150
      L=L+1
      JN(L)=N(J)
      JC(L)=IC(J)
      JR(L)=IR(J)
  150 CONTINUE
      LI=L-L2+L1-1
      KI=K2-K1-LI+1
      II=K2-KI+1
      JJ=M-KI
C  160 LOOP. MOVE 'TAIL' OF IR,IC,N VECTORS 'UP' VECTOR.
      IF(JJ.LT.II) GO TO 161
      DO 160 I=II,JJ
      IR(I)=IR(I+KI)
      IC(I)=IC(I+KI)
  160  N(I)= N(I+KI)
  161 II=K1-L2-1
      IF(II.LT.1) GO TO 171
      JJ=K1+LI
C  170 LOOP. MOVE 'MIDDLE' OF IR,IC,N VECTORS 'DOWN' VECTOR.
      DO 170 I=1,II
      J=JJ-I
      IR(J)=IR(K1-I)
      IC(J)=IC(K1-I)
  170  N(J)= N(K1-I)
  171 JJ=L2+LI
C  180 LOOP. MOVE J VECTOR INTO IR,IC,N VECTOR IN THE NA1 + POSITION.
        DO 180 I=L1,JJ
      IR(I)=JR(I-L1+1)
      IC(I)=JC(I-L1+1)
  180  N(I)=JN(I-L1+1)

C   RECORD INITIAL LOCATION OF STORED STAGE 2 MATRICES IN VECTORS.
      L1=NA1+1
      L2=NA2-1
      DO 190 I=L1,L2
  190 LL(I)=LL(I)+LI
      DO 200 I=NA2,K
  200 LL(I)=LL(I+1)-KI
      WRITE(6,914) (LL(I),I=1,K)
      KI=K-1
      II=0
      KJ=KI-1
      DO 205 I=1,KJ
      KL=I+1
      DO 205 J=KL,KI
      II=II+1
  205 NN(II)=100*I+J
      M=M-1
      JJ=0
      II=0
C  STORE NEXT STAGE BI AND DI VECTORS BY MOVING, DELETING OR
C         RECOMPUTING AS NECESSARY.
      DO 300 I=1,KI
      J1=I+1
      DO 300 J=J1,K
      JJ=JJ+1
C   DELETION STEP.
      IF((I.EQ.NA2).OR.(J.EQ.NA2)) GO TO 300
      II=II+1
      IF((I.EQ.NA1).OR.(J.EQ.NA1)) GO TO 210
C   MOVE OLD LOCATION TO NEW LOCATION.
      CI(II)=BI(JJ)
      EI(II)=DI(JJ)
      GO TO 300
C   RECOMPUTE INFORMATION MEASURE AND DELTA I.
  210 L=0
C  COMPUTE A(I) + A(J).
      L1=LL(I)
      L2=LL(I+1)-1
      DO 220 KK=L1,L2
      L=L+1
      JR(L)=IR(KK)
      JC(L)=IC(KK)
  220 JN(L)= N(KK)
      J1=J
      IF(J.GT.NA2) J1=J-1
      K1=LL(J1)
      K2=LL(J1+1)-1
      K0=K1-1
  230 K0=K0+1
      IF(K0.GT.K2) GO TO 250
      KCH=0
      DO 240 KK=L1,L2
      IF((IR(K0).NE.IR(KK)).OR.(IC(K0).NE.IC(KK))) GO TO 240
      LI=KK-L1+1
      JN(LI)=JN(LI)+ N(K0)
  222 KCH=KCH+1
  240 CONTINUE
      IF(KCH.EQ.1) GO TO 230
      L=L+1
      JN(L)=N(K0)
      GO TO 230
C  COMPUTE I(A(I) + A(J))
  250 X=0.
      AY=0.
      DO 260 N1=1,L
      AN=JN(N1)
      X=X+AN*ALOG(AN)
  260 AY=AY+JN(N1)
      CI(II)=AY*ALOG(AY)-X
C  COMPUTE DELTA I(A(I) + A(J))
      N1=NN(II)/100
      N2=NN(II)-100*N1
      EI(II)=CI(II)-AI(N1)-AI(N2)
  300 CONTINUE
      K=K-1
      KKK=K*(K-1)/2
C  RECORD IDENTITY OF PAIR OF MATRICES WITH SMALLEST DELTA I MEASURE.
      DA=100.
      DO 310 I=1,KKK
      BI(I)=CI(I)
      DI(I)=EI(I)
      IF(DI(I).GT.DA) GO TO 310
      DA=DI(I)
      NAA=I
  310 CONTINUE
      WRITE(6,904)
      WRITE(6,913) (I,NN(I),BI(I),DI(I),I=1,KKK)
      JJ=NAA
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```
      NAI=0
      DO 320 I=1,K
      JJ=JJ-K+I
      NA1=NA1+1
      IF(JJ.LE.0) GO TO 330
  320 CONTINUE
  330 NA2=K+JJ
      LAB(III)=NA1
      LAC(III)=NA2
      DAB(III)=DA
      GO TO 121
C  TERMINATE ITERATIONS AND COMMENCE SUMMARY.
  340 KO=KA-1
      CALL PLOTS
       XORG=0.
      AENG=10.
      AHI=7.
      FNCR=1.
      LBKOD=1
      MT=KA
      WRITE(6,902) (I,LAB(I),LAC(I),DAB(I),I=1,KO)
      K=KA
C  INITIALIZE.  LAA = LABEL OF OTU IN ORDER
C               LAD = # OTU'S CURRENTLY IN CLUSTER NAMED BY LAD VALUE
C               LAV = ENTRY LABEL FOR FIRST ELEMENT OF NEXT CLUSTER
      DO 350 I=1,KA
      JAB(I)=0
      LAA(I)=I

      LRD(I)=I
      LAD(I)=1
  350 LAV(I)=I
      DO 500 I=1,KO
      L1=LAB(I)
      LI=LAV(L1)
      N1=LI+1
      L2=LAC(I)
      N2=LAV(L2)
      KK=N2-LI-LAD(LI)
      LLI=LAD(LI)
      LAD(LI)=LAD(LI)+LAD(N2)
      L=LAD(N2)
      LAD(N2)=0
      IF(KK.LE.0) GO TO 390
C  STORE ELEMENTS (LAD,LAA) OF LOWER GROUP IN (LAE,LAR)
      DO 360 J=1,L
      M=N2+J-1
  360 LAR(J)=LAA(M)
C  MOVE ELEMENTS OF (LAD,LAA) BETWEEN TWO GROUPS DOWN VECTOR
      DO 370 II=1,KK
      J=N2-II+L
      JJ=J-L
      LAD(J)=LAD(JJ)
  370 LAA(J)=LAA(JJ)
C  PLACE (LAE,LAR) NEXT TO UPPER GROUP
      DO 380 J=1,L
      II=LI+LLI+J-1
      LAD(II)=0
  380 LAA(II)=LAR(J)
  390 KL=0
C  AMEND LAV VECTOR TO RECORD ENTRY POINTS TO CLUSTERS
      DO 400 J=1,KA
      IF(LAD(J).EQ.0) GO TO 400
      KL=KL+1
      LAV(KL)=J
  400 CONTINUE
      WRITE(6,921) I
      WRITE(6,920) (LAA(J),LAD(J),LAV(J),JAB(J),J=1,KA)
  460 LJ=L-1
      IF(LJ.EQ.0) GO TO 495
C  STORE JAB ELEMENTS OF GP2 IF MORE THAN 1 ELEMENT IN GP.
      DO 470 II=1,LJ
      KL=N2+II-1
  470 JAA(II)=JAB(KL)
C  MOVE JAB ELEMENTS IF NECESSARY DUE TO MORE THAN 1 ELEMENT IN GP2.
      KN=N2-LI-LLI
      IF(KN.EQ.0) GO TO 485
      KL=LI+LLI+L-1
      KM=N2+L-2
      DO 480 II=KL,KM
      IL=KM+KL-II
      JJ=IL-L
  480 JAB(IL)=JAB(JJ)
C  INSERT STORED JAB ELEMENTS INTO APPROPRIATE LOCATIONS.
  485 DO 490 II=1,LJ
      KL=LI+LLI+II-1
  490 JAB(KL)=JAA(II)

  495 KL=LI+LLI-1
      IF(JAB(KL).EQ.0) GO TO 445
      LV=KL+1
      JAB(LV)=JAB(KL)
  445 JAB(KL)=I
  500 CONTINUE
      WRITE(6,920) (LAA(J),LAD(J),LAV(J),JAB(J),J=1,KA)
      WRITE(6,907)
      WRITE(6,906) LAA(1)
      DO 420 I=2,KA
      J=LAA(I)
      J1=JAB(I-1)
      WRITE(6,908) LRD(J1),DAB(J1),DAB(J1)
      IORD(I)=LRD(J1)
      WGR(I)=DAB(J1)
      BGR(I)=DAB(J1)
  420 WRITE(6,906) J
      CALL DENDRO(WGR,BGR,LAA,IORD,NAME,ALIN,KA,FNCR,AENG,AHI,MT,A,LBKOD
     .,XORG)
       XORG=XORG+AENG
      CALL PLOT(5.,-10.,-3)
      STOP
  900 FORMAT(4I2)
  901 FORMAT(10X,I10,F16.5)
  902 FORMAT(1H1,9X,'SUMMARY' // 10X,'ORDER',7X,'LAB',7X,'LAC',7X,'DELTA I'
     1 I' // (10X,I3,8X,I3,7X,I3,F16.5 /))
  903 FORMAT(//16X,'MATRIX ',3X,'INFORMATION' /)
  904 FORMAT(//18X,'IO',6X,'PAIR',7X,'INFORMATION',6X,'DELTA I' /)
  905 FORMAT(//20X,'BEGINNING OF ITERATION # ',I5 //)
  906 FORMAT(10X,I3)
  907 FORMAT(10X,'SUMMARY' // 10X,'NAME',9X,'ORDER',10X,'WGR',18X,'BGR'
     . //)
  908 FORMAT(23X,I3,F20.5, F21.5)
  913 FORMAT (10X,2I10,2F16.5)
  914 FORMAT(//4X,'LL',4X,8I10 //)
  920 FORMAT(10X,4I10)
  921 FORMAT(//10X,'ITERATION # ',I2 //)
  998 FORMAT(20A4)
      END
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VITA

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