COMPARATIVE STUDY OF SLICKSPOTS

IN GRANT COUNTY, OKLAHOMA

by

THOMAS GLYNN REINSCH

Bachelor of Science

Brigham Young University

Provo, Utah

1978

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
December, 1979

COMPARATIVE STUDY OF SLICKSPOTS

IN GRANT COUNTY, OKLAHOMA

Thesis approved:

Fenton Gray
Thesis Adviser

D L Weeks[?]

Lester W. Reed

John E. Stone

Norman N Durham
Dean of Graduate College

PREFACE

This thesis was organized to achieve the two parts of the objective without duplicating Chapter II. Consequently, Chapters III and IV deal with the objective of comparing a slickspot and two slightly-affected soils with an adjacent soil unaffected by salts. Chapters V and VI pertain to the second objective of comparing four different slickspots which have developed on different parent materials and physiographic locations.

The author wishes to thank the Agronomy Department for the use of their facilities and financial assistance provided for this study.

Special thanks are due to Dr. Fenton Gray, the major adviser. The author also appreciates the help of the committee members: Dr. Lester Reed, Dr. David Nofziger, and Dr. John Stone.

The author is grateful for the aid of the following individuals: Earl Nance, Hassan Roozitilab, Ed Horn, Glenn Williams, and Everett Cole, who helped collect and describe the pedons. The help of Jeanne Fell and Godfrey Uzochukwu with the laboratory analyses is also appreciated.

Finally, the author is indebted to Susan, his wife, for typing the manuscript and encouraging him every step of the way.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

LIST OF FIGURES

Figure Page

LIST OF SYMBOLS

Texture:

sil	-silt loam
cl	-clay loam
sicl	-silty clay loam
sic	-silty clay
c	-clay

Structure:

1. Grade

1	-weak
2	-moderate
3	-strong

2. Size

f	-fine
m	-medium
c	-coarse

3. Type

pl	-platy
pr	-prismatic
cpr	-columnar
abk	-angular blocky
sbk	-subangular blocky
gr	-granular

Consistence:

Moist soil

mvfr	-very friable
mfr	-friable
mfi	-firm
mvfi	-very firm
mefi	-extremely firm

Boundary:

Distinctness

a	-abrupt
c	-clear
g	-gradual
d	-diffuse

Effervescence with HCl:

e	-slight
es	-strong
ev	-violent

*Thus weak, medium, blocky structure is noted 1mbk; moderate, coarse, platy is 2cpl, etc.

CHAPTER I

INTRODUCTION

Slickspots are irregular areas of salt-affected soils which occur in many areas of the Midwest. Slickspots are found in nearly all physiographic positions. They are frequently found in depressions, on sideslopes, or summits. Slickspots are most often related to drainage and water movement. According to the Soil Survey Manual (23), slickspots are defined as

> Areas having a puddled or crusted, very smooth, nearly impervious surface. Slickspots support little or no vegetation. The underlying material is dense and massive. The material ranges from extremely acid to very strongly alkaline and from sand to clay (p. 324).

Soil scientists mapping areas containing slickspots in Grant County, Oklahoma have found a wide variation in characteristics associated with slickspots. Sodium salts are believed to be the major cause of slickspot formation. Research by White (26 and 27) concluded that minor morphological characteristics may be related to the chemical status of a profile in a particular genetic environment. He also reported that the presence of extractable sodium in the B horizon can be estimated from the morphology. The unique morphological and physical characteristics, which include the formation of columnar structure, have been attributed to the present or past presence of exchangeable sodium (14). Therefore, by examining the morphology of a pedon and associated topography, soil scientists should be able to determine the presence of sodium present in the pedon. Sodium is also present in the pedon in different mineral forms. It may also be possible to relate the mineral forms of sodium present in the pedon by examining microdifferences of the soil morphology and the associated landscape.

A number of papers (1, 7, 11, and 26) have been published in the United States dealing with small, salt-affected areas, but most do not include a comparison between slickspots of the same region. A comprehensive review of the problem of classifying salt areas was treated by Kelley (14) and later by White (27).

Previous research in Oklahoma concerning salt-affected soils will now be discussed. Harper (9) concluded from his research that there was little difference in texture between salt-affected and unaffected areas. Plice (18) presented information concerning general features of slickspots. Reed (19), Singh (21), and Mehta (15) in different projects reported on the chemical constituents of salt-affected areas from selected samples. Stewart (22) examined the vegetation, morphology, and genesis of two, salt-affected areas of Permian and Pennsylvania age and classified them according to Soil Taxonomy (24). Bahktar (2) studied the genesis and classification of slickspots in a toposequence of North Central Oklahoma in which he proposed the formation of a subgroup to be included in the classification of salt-affected areas.

In soil surveys, slickspots are usually mapped as complexes or their position indicated by the greek letter, phi (ϕ). The determination of slickspots is usually based on the previous experience of the soil scientist mapping the area. A preliminary study showed that in adjacent counties salt-affected areas were mapped differently. In one county, all areas were mapped as saline spots while in the adjacent county all areas were mapped as slickspots.

Salt-affected areas can usually be recognized from aerial photographs; and on-site investigation of vegetation provides adequate evidence of salt accumulation. Since these areas are not difficult to recognize, they are often mapped quickly and uniformly. The purpose of this research is to examine slickspots from different locations and compare the chemical and morphological data in order to establish information regarding the uniformity or variability of slickspots. If a distinction between slickspots exists, the difference should be recognized in order to provide more information concerning management and land use capabilities.

In order to obtain data to compare morphology and chemical composition of slickspots, four areas of different parent materials were selected from Grant County. From each area, an unaffected and affected pedon were chosen on the basis of vegetation. Soil descriptions were made and samples brought to the laboratory for analyses. Samples were analyzed to characterize them according to Soil Taxonomy (24). Data were obtained to classify the soils into salinity classes using the parameters established by Handbook 60 (20). Types of salt present in each profile were determined. The data obtained in the laboratory were compared with the soil descriptions obtained in the field and findings of the research were applied to solve mapping problems involving salt-affected soils in Grant County, Oklahoma.

CHAPTER II

MATERIALS AND METHODS

Materials

Five factors or variables of soil formation, as stated by Jenny (12 and 13), include time, topography, organisms, climate, and parent materials. The soils studied in Grant County are well-developed and mature soils. The soils have developed on nearly level uplands, interfluves, or terraces. All but one of the soils have been cultivated. The native vegetation is presumed to have been a mixed prairie vegetation.

The climate of Grant County is classified as a warm, temperate, subhumid, continental climate. The annual average air temperature is 15.3° C with the average annual extremes being 28.8° C and 0.4° C. The average annual precipitation is 81.9 cm. The majority of the precipitation occurs during the growing season. This climate favors a mixed prairie vegetation.

The parent materials on which the soils in this study have developed (Figures 1, 2, and 3) are a terrace deposit of Quaternary age and Garber, Wellington, and Hennessey Units of the Permian "Redbeds". The Quaternary terrace has been deposited by the Salt Fork of the Arkansas River. Depth of the deposit ranges from 10 to 30 m. The deposit has probably been reworked by wind. The Garber Unit is composed of red clay

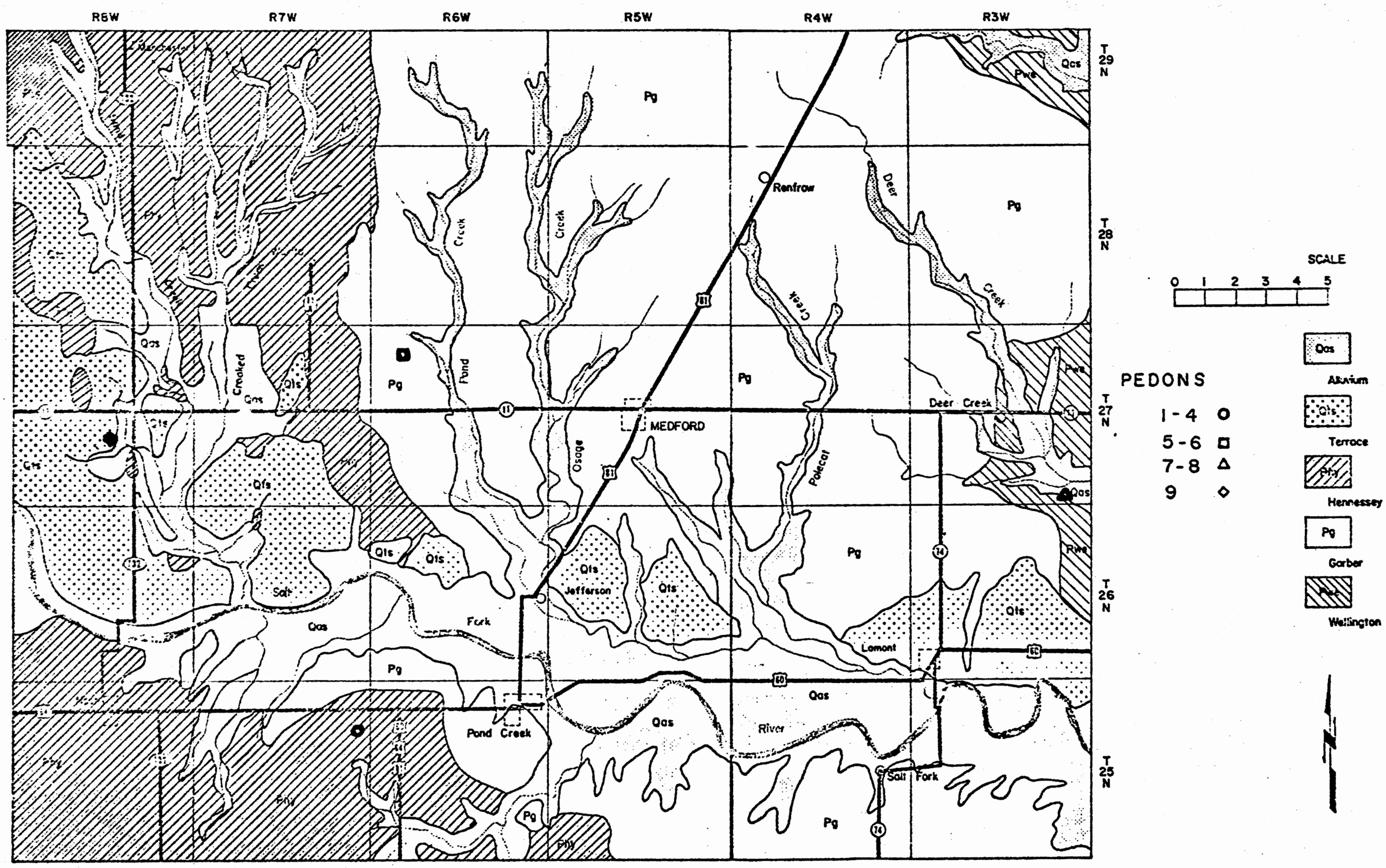

Figure 1. Location of Pedons on Geologic Units of Grant County.

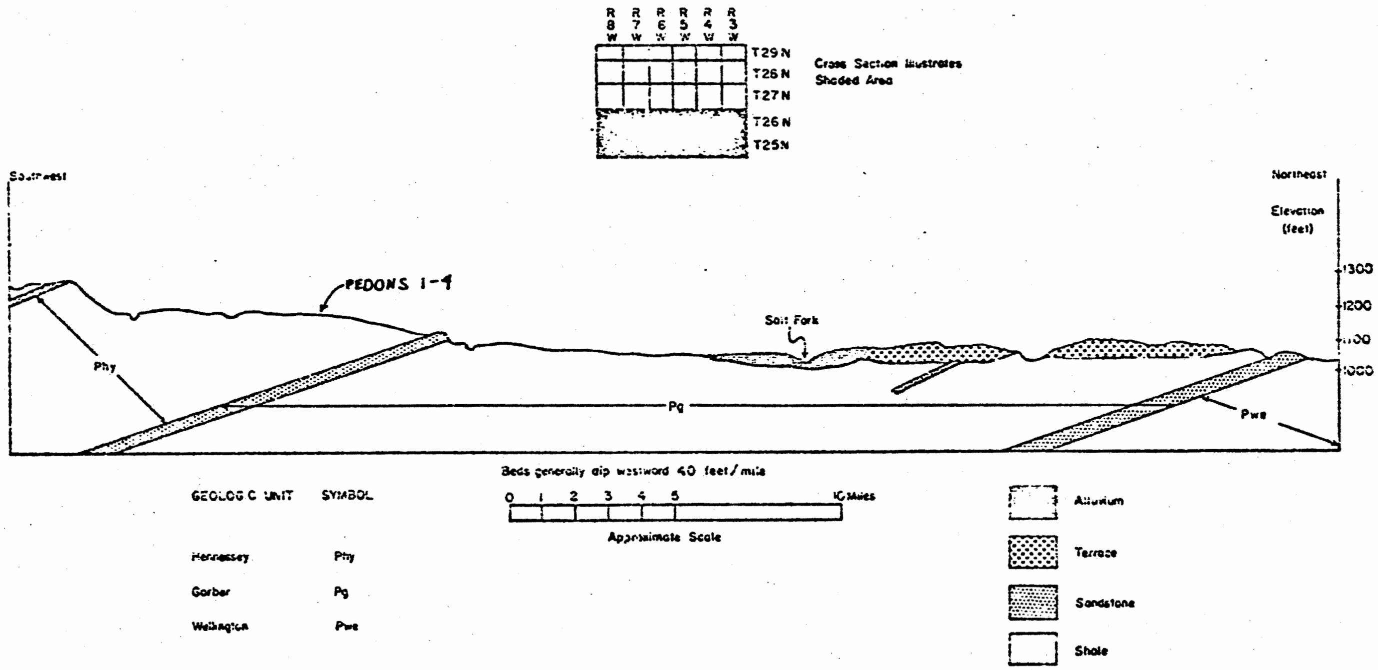

Figure 2. Idealized Cross-Section of Grant County and Pedon Locations (Southwest to Northeast).

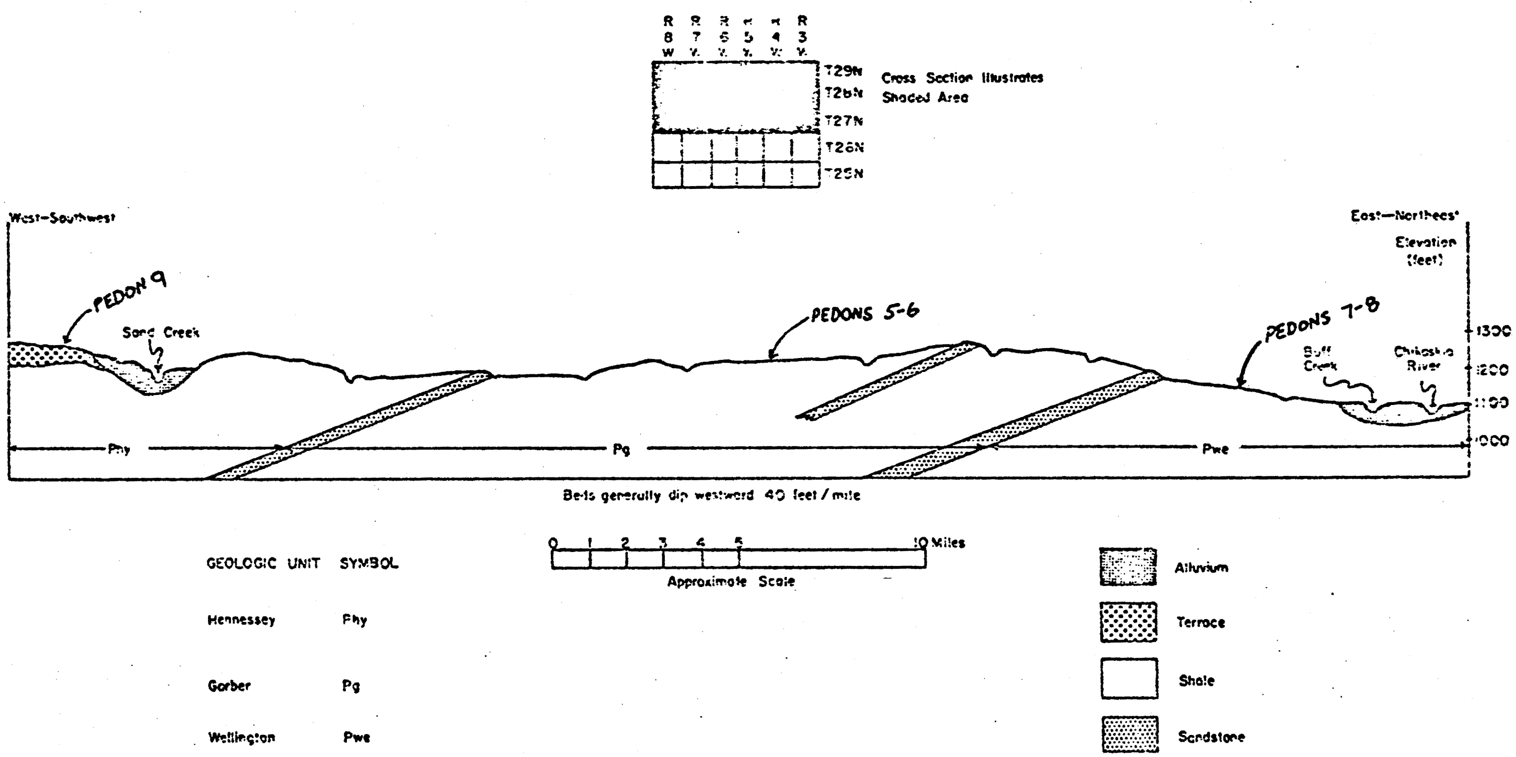

Figure 3. Idealized Cross-Section of Grant County and Pedon Locations (West-Southwest to East-Northeast).

and red, sandy shales. This Unit also includes red massive, commonly cross-bedded lenticular sandstones. In Grant County the shales dominate the Garber Unit. The thickness of the Garber unit is greater than 183 m. The Wellington Unit is approximately 30 m thick and is dominated by red, maroon and gray, blocky shales. Minor amounts of sandstone, gypsum, and limestone are included in the unit description. Recent work by Culver (6) includes additional information on soils unaffected by salts which have developed in the Wellington Unit. The Hennessey Unit is about 91 m thick. It consists of red, platy to blocky clay shales, mudstones, siltstone, and silty shale. The red clay shale and silty shale are characterized by numerous bands or streaks of white or light green color ranging from a few centimeters to one meter thick (10).

The soil pedons were described and sampled with the aid of a soil probe in October of 1978. Approximately 2 kilograms of soil were collected from each horizon for laboratory analyses. The profiles were described according to the procedure outlined in the Soil Survey Manual (23). The depth of sampling was determined by the soil penetrability of the soil probe.

Procedures

Physical Analysis

Air-dried, natural pedons from each horizon were used to determine particle size. Each sample was decarbonated, oxidized, dispersed, and placed in one liter cylinders. Clay was determined by a hydrometer, the sand was fractionated using graduated seives and silt was calculated by difference (4).

Chemical Analyses

Air-dried samples were ground to pass a two mm seive and stored for chemical analyses. The pH of the soil samples was determined on a 1:1 mixture of soil and water and soil and 1N KCl. The pH was measured on a Corning Model #7 pH meter. Cation exchange capacity (CEC) was determined as outlined by Bower (3). Sodium acetate solution of pH 8.2 was used to minimize calcium carbonate interference. Exchangeable H^+ was determined by leaching with $BaCl_2$ - TEA, pH 8.0, and titrating with HCl (17). Exchangeable aluminum and extractable aluminum were determined as described by McLean (16) using 1N KCl and 1N NH_4Ac, pH 4.8, respectively.

Extractable cations, Na^+, K^+, Mg^{2+}, and Ca^{2+}, were removed by 1N NH_4Ac, pH 7. Concentrations of Na^+ and K^+ were determined by atomic absorption spectraphotometry and Mg^{2+} and Ca^{2+} by the Versenate titration (20). Percentage organic matter was determined by a modification of Walkley's rapid method as described by Richards (20).

An extraction from a 1:1 soil and water suspension was analyzed for soluble salts. Na^+ and K^+ were determined using a Perkins Elmer Spectraphotometer, Model 403. Mg^{2+} and Ca^{2+} were determined by the Versenate titration. Cl^- was measured by using the Mohr titration. Handbook 60, Saline and Alkali Soils (20), describes the method used for CO_3^{2-} and HCO_3^- determination except HCl was used in the place of H_2SO_4.

Soluble SO_4^{2-} was determined by passing ten ml of solution through seven cm of cation exchange resin to remove interferring cations. The leaching was diluted and 95% ethanol was added to create a non-aqueous solution. $Ba(ClO_4)_2$, pH 3.8, was used to titrate the soluble SO_4^{2-} with thorin as an indicator (8).

Electrical conductivity was measured using a YSI Model 31 Conductivity Bridge.

CHAPTER III

RESULTS AND DISCUSSION OF COMPARING A SLICKSPOT WITH ADJACENT SOILS

This chapter will deal with a comparison of morphological and chemical data of one salt-affected pedon and two intermediate pedons with an unaffected pedon. The criteria used to determine the salinity status of each pedon is found in Saline and Alkali Soils, Handbook 60 of the U.S.D.A. (20). The parameters established therein are as follows:

Class	EC	ESP	pH
Saline	>4	<15	<8.5
Saline-sodic	>4	>15	<8.5
Nonsaline-sodic	<4	>15	>8.5

The aforementioned groups and parameters are not rigorous definitions of saline soils as they occur in nature, but are categories which will aid in the presentation of the data.

Morphological Data

The morphology of pedons 1, 2, 3, and 4 are given in Tables I and II. These pedons are from the same area which is located approximately nine km west of Pond Creek, Grant County on the farm of Mr. Evans. The

TABLE I

MORPHOLOGY OF PEDONS 1 AND 2

Horizon	Depth (cm)	Color (moist)	Texture*	Structure*	Consistence*	Boundary*	Effervescence with HCl*
			Pedon 1. Mollic Natrustalfs; fine-silty, mixed, thermic				
Ap	0-12	5YR 3/4	sil	2mpl	mfr	a	--
B21t	12-34	5YR 3/2	sil	2ccpr	mfr	g	--
B22t	34-54	5YR 3/3	sicl	2msbk	mfi	g	--
B3	54-82	5YR 4/4	sil	2cpr	mfi	c	--
C	82-93	5YR 4/4	sil	m	---	-	es
			Pedon 2. Typic Natrustolls; fine, mixed, thermic				
Ap	0-11	5YR 3/2	sil	2fgr	mfr	c	--
B21t	11-31	5YR 3/2	sicl	3msbk	mfr	g	--
B22t	31-51	5YR 3/3	sicl	2msbk	mfi	g	e
B3	51-76	5Y 6/3	sil	1msbk	mfi	c	es
C	76-88	5YR 4/4	sil	m	---	-	es

*commonly used soil survey abbreviations

TABLE II

MORPHOLOGY OF PEDONS 3 AND 4

Horizon	Depth (cm)	Color (moist)	Texture*	Structure*	Consistence*	Boundary*	Effervescence With HCl*
			Pedon 3. Typic Argiustolls; fine-silty, mixed, thermic				
Ap	0-8	7.5YR 3/2	sil	1fgr	mfr	c	--
A12	8-23	7.5YR 3/2	sil	2msbk	mfr	c	--
B21t	23-38	5YR 3/3	sicl	2mpr	mfr	g	--
B22t	38-65	2.5YR 4/6	sicl	2mpr	mfi	g	es
B3	65-102	2.5YR 3/6	sicl	1msbk	mfi	c	es
C	102-113	2.5YR 3/4	sil	m	---	-	es
			Pedon 4. Typic Natrustolls; fine, mixed, thermic				
Ap	0-11	7.5YR 3/2	sil	2mpl	mfr	c	--
B21t	11-26	5YR 3/2	sic	2mpr	mfi	c	--
B22t	26-48	2.5YR 3/4	sic	2mpr	mvfi	g	e
B31	48-112	2.5YR 3/6	sicl	1cpr	mfi	c	e
B32	112-133	5G 6/1	sil	3cpr	mvfi	a	es
C	133-148	2.5YR 3/4	sil	m	---	-	es

*commonly used soil survey abbreviations

four pedons are located within an area less than 0.5 ha. The parent material is siltstone of the Hennessey Unit. The classification of each pedon according to Soil Taxonomy (27) is also provided on Tables I and II.

Pedon 1 is the most severely affected by salt accumulation. The B21t horizon has columnar structure which is associated with sodium accumulation. A near-mollic epipedon has also developed. The depth of leaching is related to the depth of carbonate deposition which is 82 cm. The beginning of the argillic horizon at 12 cm was determined from the presence of clay films on the ped surfaces.

Pedon 2 is an intermediate soil (determined by the vegetation response to the presence of salt). The depth of leaching is approximately 31 cm. The argillic horizon, which is 40 cm thick, begins at 11 cm. The unusual hue of 5Y in the B3 horizon is due to geologic process and is not related to pedogenesis.

Pedon 3 is not affected by salt. Wheat planted in this location appeared to have vigorous growth. The solum extends to a depth of 102 cm. A mollic epipedon has developed and an argillic horizon extends from 23 to 65 cm. The depth of leaching is established at 38 cm.

Pedon 4 is also an intermediate soil and is associated with Pedon 2. It is located in a nearly-level interfluve and at a slightly lower elevation than the other three pedons sampled in this area. A strong argillic horizon from 11 to 48 cm has developed as well as a mollic epipedon. The depth of leaching is approximately 26 cm. Carbonate bodies are visible at this depth. The hue of 5G which occurs in the B32 horizon is presumed to be unrelated to pedogenetic processes, but to geologic processes.

Chemical and Physical Data

Figure 4 shows how the dominant soluble constituents and clay vary with depth in Pedon 1. The profile is dominated by sodium and chlorine ions in the soluble component. Sodium and chloride ions reach a maximum accumulation in the surface horizon. Soluble sodium and exchangeable sodium together have a maximum peak in concert with clay accumulation in the argillic horizon. Additional data (see Appendix) shows that high amounts of exchangeable calcium exist in the lower horizons of the profile, the most of which is related to the formation of $CaCO_3$. The measured electrical conductivity (EC) was greater than 4.0 mmhos/cm and the exchangeable sodium percentage (ESP)† is greater than 15 in every horizon. In addition, the pH approaches 8.0 in all but the Ap horizon in which the pH is 5.8. Disregarding the low pH in the Ap horizon, the profile exhibits characteristics of a saline-sodic soil.

In addition to the chemical characteristics, Pedon 1 has obvious physical properties which were observed in the field. The most remarkable feature is the development of a nearly impervious, thin (3mm), smooth crust on the surface of the slickspot. This crust appears to have less clay than the underlying Ap horizon. Also the crust is very light-colored except in small areas where dispersed clay and organic matter have accumulated causing dark patches on the crust.

The variation of the dominant soluble fractions and percent of clay with depth of Pedon 2 are shown in Figure 5. A relationship of soluble Na^+ and clay appears to exist as both reach maximums in nearly the same area. The dominant fractions are soluble sodium and chloride ions. The

† $ESP = (\text{Exchangeable } Na^+)\ (CEC)^{-1} \times 100$.

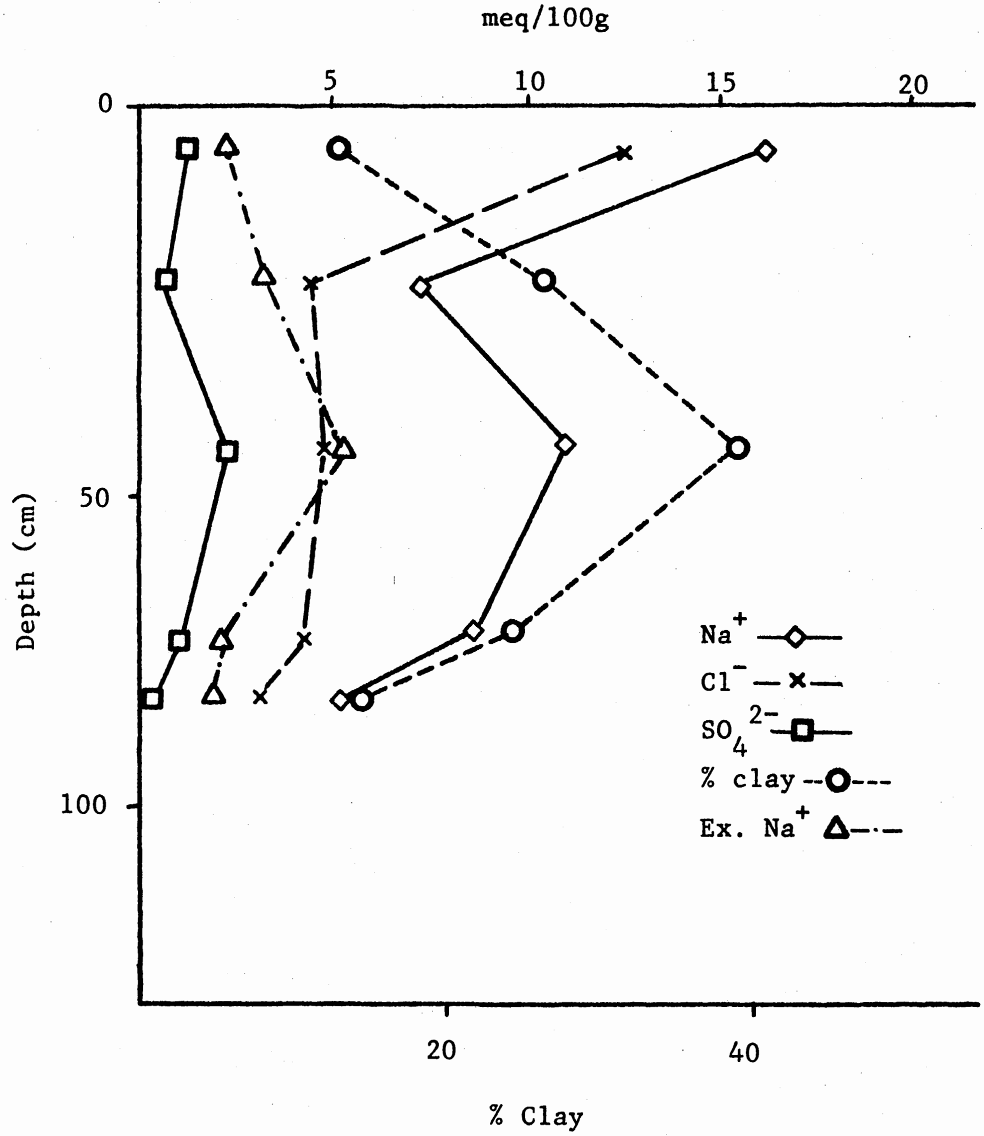

Figure 4. Major Chemical Constituents and % Clay vs. Depth - Pedon 1.

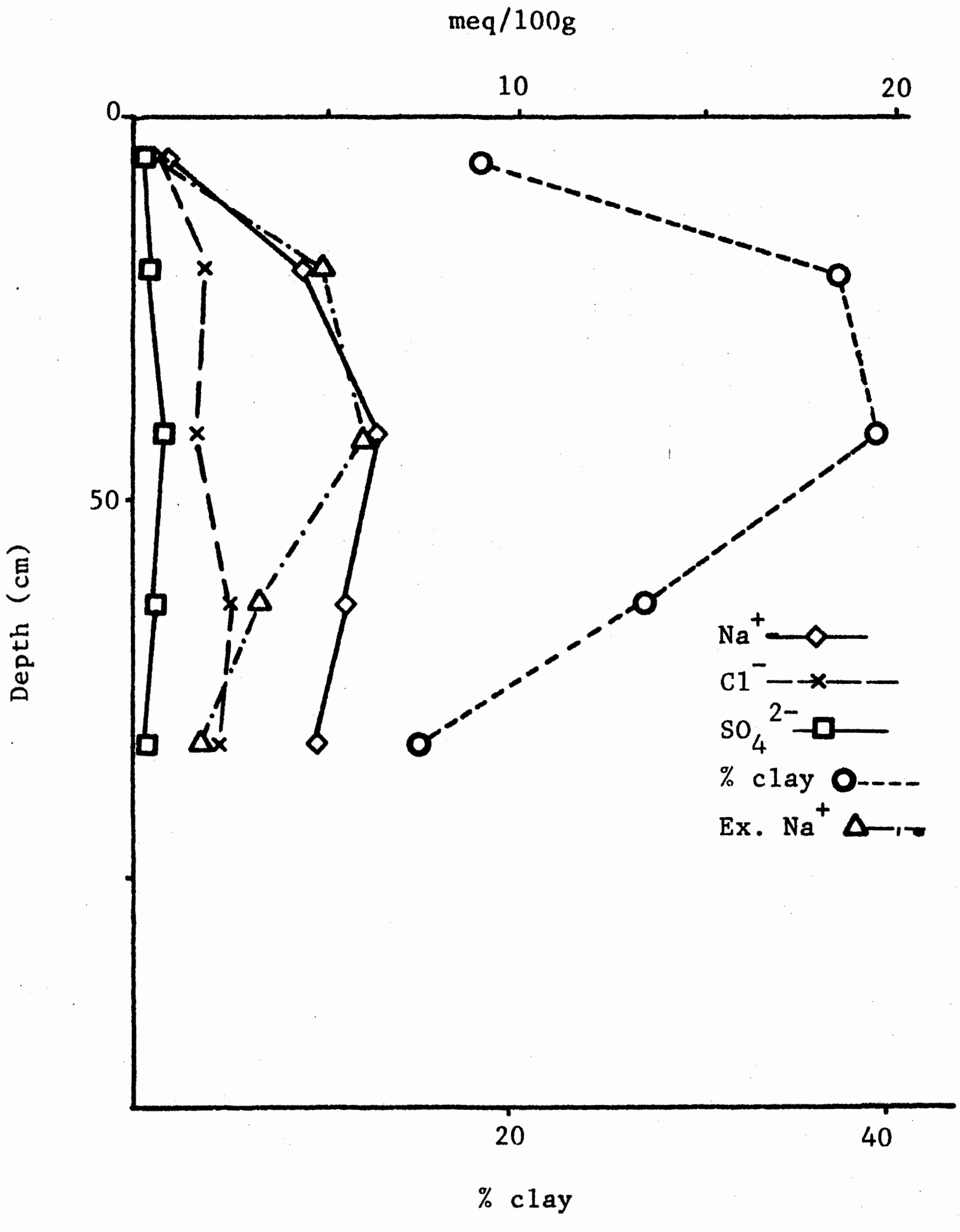

Figure 5. Major Chemical Constituents and % Clay vs Depth - Pedon 2.

surface horizon does not have the characteristics of a salt-affected soil except for a tendency to form a weak crust. However, the subsurface, from 11-88 cm, surpasses the nominal characteristics of a saline-sodic soil. The pH approaches 8.2 (the B3 and C horizons are greater than 8.2), the EC is greater than 4 mmhos/cm and the ESP is greater than 15.

Information concerning Na^+, Cl^-, SO_4^{2-}, and clay variation with depth for Pedon 3 is shown in Figure 6. This pedon is the least affected by salt accumulation. The chemical data shows the absence of salt or sodium accumulation with the profile. The highest EC reported was 2.1 mmhos/cm. However, at the deepest horizon sampled, the C horizon, the pH is 8.7 and the ESP is greater than 15. These high values may be related to residual sodium in the parent material. High amounts of exchangeable calcium were discovered in the profile which corresponds with $CaCO_3$ accumulation.

The chemical and physical properties of Pedon 4 will now be discussed. Figure 7 shows the variation of the dominant soluble constituents and clay with depth. Soluble sodium and chloride ions are the dominant ions found to be present in the profile. The maximum values for soluble sodium and clay nearly coincide. Additional data show that the pH approaches 8.0 in all but the Ap horizon in which it is 6.3 and the B32 and C horizons in which the pH is greater than 8.2. The EC has a value greater than 4.0 mmhos/cm between 0-112 cm. EC values close to 3.0 mmhos/cm occur in the B32 and C horizons. The ESP is greater than 15 except in the Ap horizon. This horizon has an ESP value of 11. By the criteria established, this soil can also be classified as a saline-sodic soil.

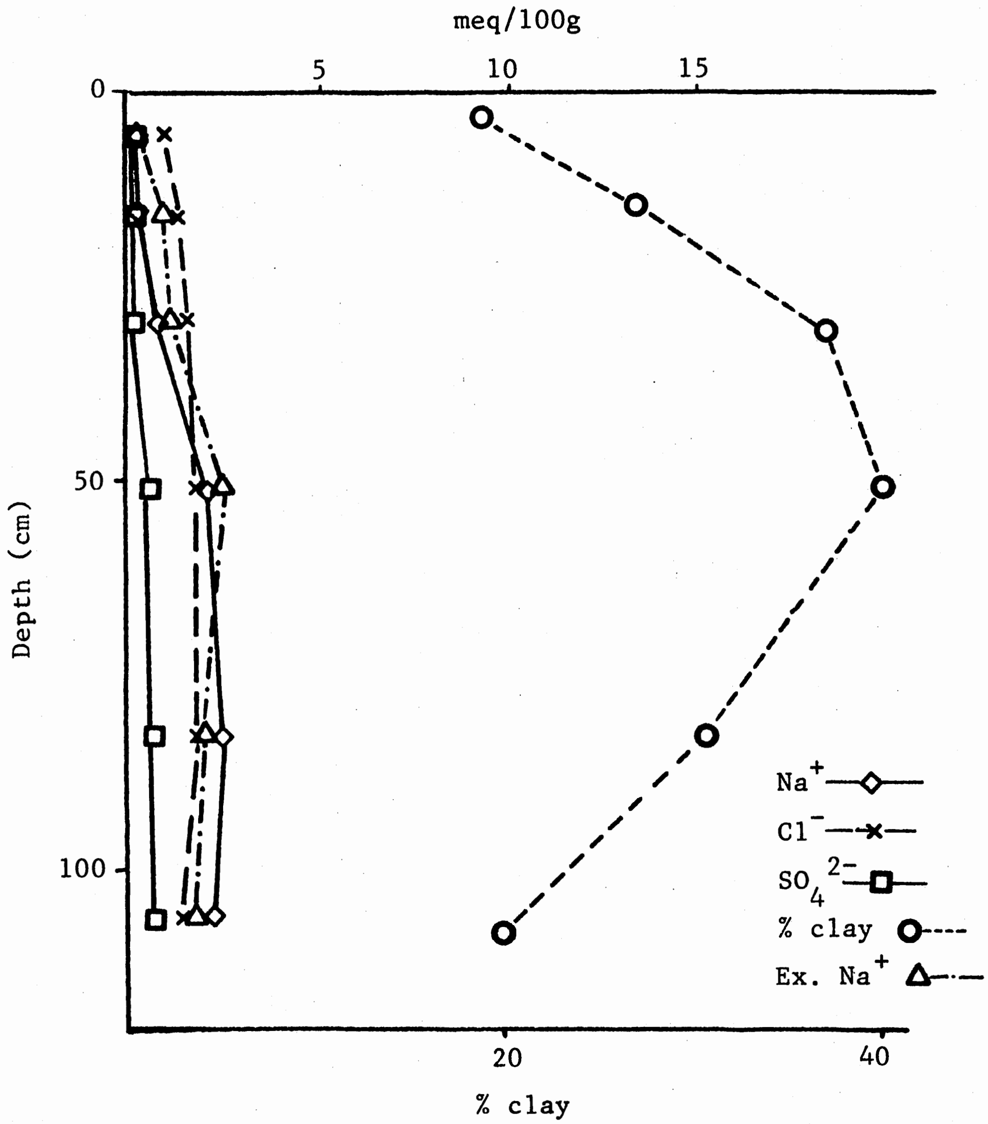

Figure 6. Major Chemical Constituents and % Clay vs. Depth - Pedon 3.

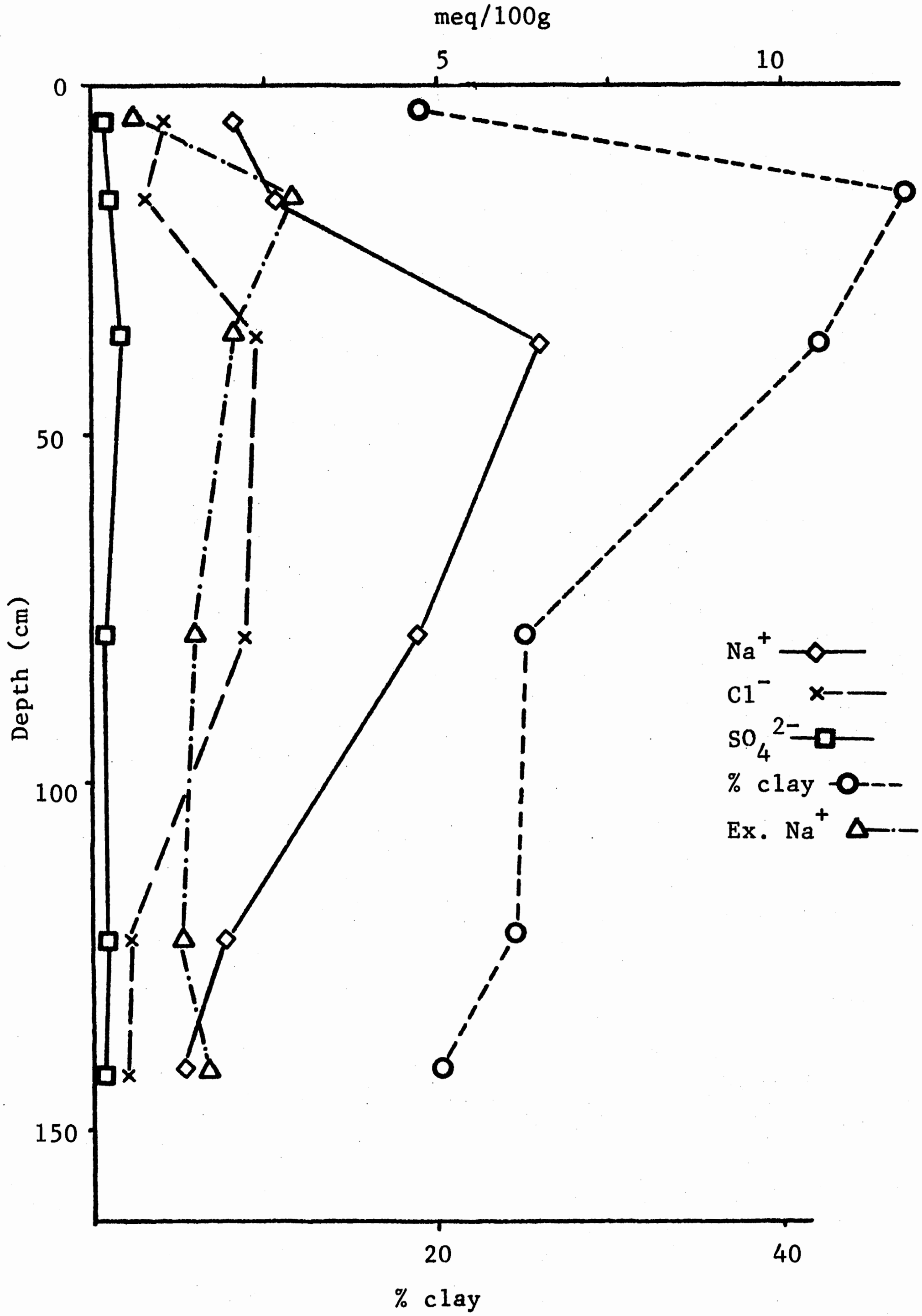

Figure 7. Major Chemical Constituents and % Clay vs. Depth - Pedon 4.

Discussion

A comparison of Pedons 1, 2, 3, and 4 provides several useful details. The morphology of each pedon is unique and expresses differences caused by variation of soil-forming factors. According to U.S. D.A. Handbook 60 (20), the most useful parameters to compare chemical data are pH, EC, and the sodium adsorption ratio (SAR).†

Pedon 1, which is most affected by salts, exhibits the characteristic columnar structure and abrupt boundary separating the Ap and B21t horizons usually associated with high sodium content. The chemical data shows that there is a high concentration of sodium present. Pedons 2 and 4, which are not as affected as Pedon 1, do not show the characteristic morphological features which should be present according to the data provided by chemical analysis. However, when Pedons 2 and 4 are compared with Pedon 3, one can observe that Pedon 3 has developed a thicker A horizon. This increase in depth of the A horizon can probably be attributed to vigorous plant growth allowing melanization to take place at a faster rate. The argillic horizon of each pedon is approximately the same thickness. This relationship expresses that weathering and development of the argillic horizon has occurred at nearly the same rate, but at different intensities.

A sketch of elevation differences (Figure 8) will help elucidate the following discussion. Remember that Pedon 4 is located in a nearly level interfluve and is externally drained. One will note that the maximum runoff water accumulation occurs at Pedon 4 and then is removed

†SAR = $Na^{+} \left[(Ca^{2+} + Mg^{2+})/2\right]^{-\frac{1}{2}}$ where Na^{+}, Ca^{2+}, and Mg^{2+} are soluble ions expressed in meq/l.

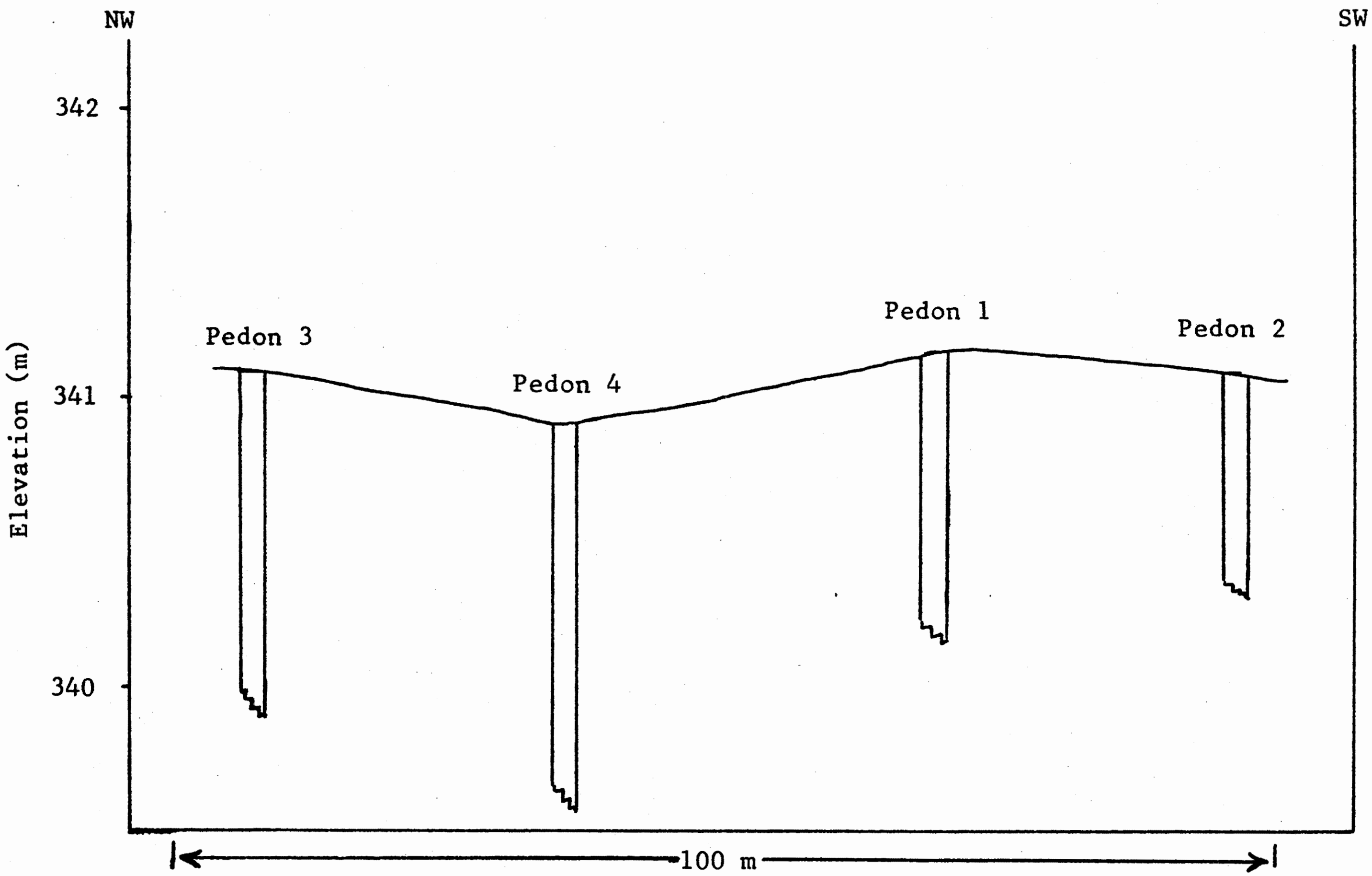

Figure 8. Profile of Pedons 1, 2, 3, and 4.

by external drainage. Pedon 1 occupies the highest location of the samples taken in the field. The highest clay content in the argillic horizon occurs in Pedon 4 and Pedon 1 has the least amount of clay in the argillic horizon. This is due to the greater weathering intensity found in Pedon 4. However, the depth of carbonates, which is a leaching indicator, is the inverse of what is expected. The increase of infiltrating water should remove the carbonates found in Pedon 4. Carbonates accumulating in Pedon 4 may be a result of an influx of carbonates by carbonate-saturated water moving into this low area by lateral movement of water or the depth of calcium carbonate may indicate that differential erosion is now occurring due to the formation of the more clayey subsurface horizon in Pedon 1.

A comparison of the chemical data will now be presented. The pH of Pedons 1, 2, 3, and 4, as a function of depth, appears in Figure 9. The general trend of the pH is to increase with depth. The low pH values in the A horizon is probably related to cultural practices or a degradation of clay species. Clearly, the high pH values are related to the high sodium concentration found in this locale. Sampling at a greater depth would be prerequisite to establishing the contribution of the parent material to the high pH values.

Figure 10 shows the change in EC with depth of Pedons 1, 2, 3, and 4. A study of the figures showing data from the individual pedons shows that the variation of EC with depth is closely related to the variation of sodium with depth. All four pedons show a slight to strong maximum accumulation in the argillic horizon. It is presumed that the occurance of this maximum value is related to a decrease in the hydraulic

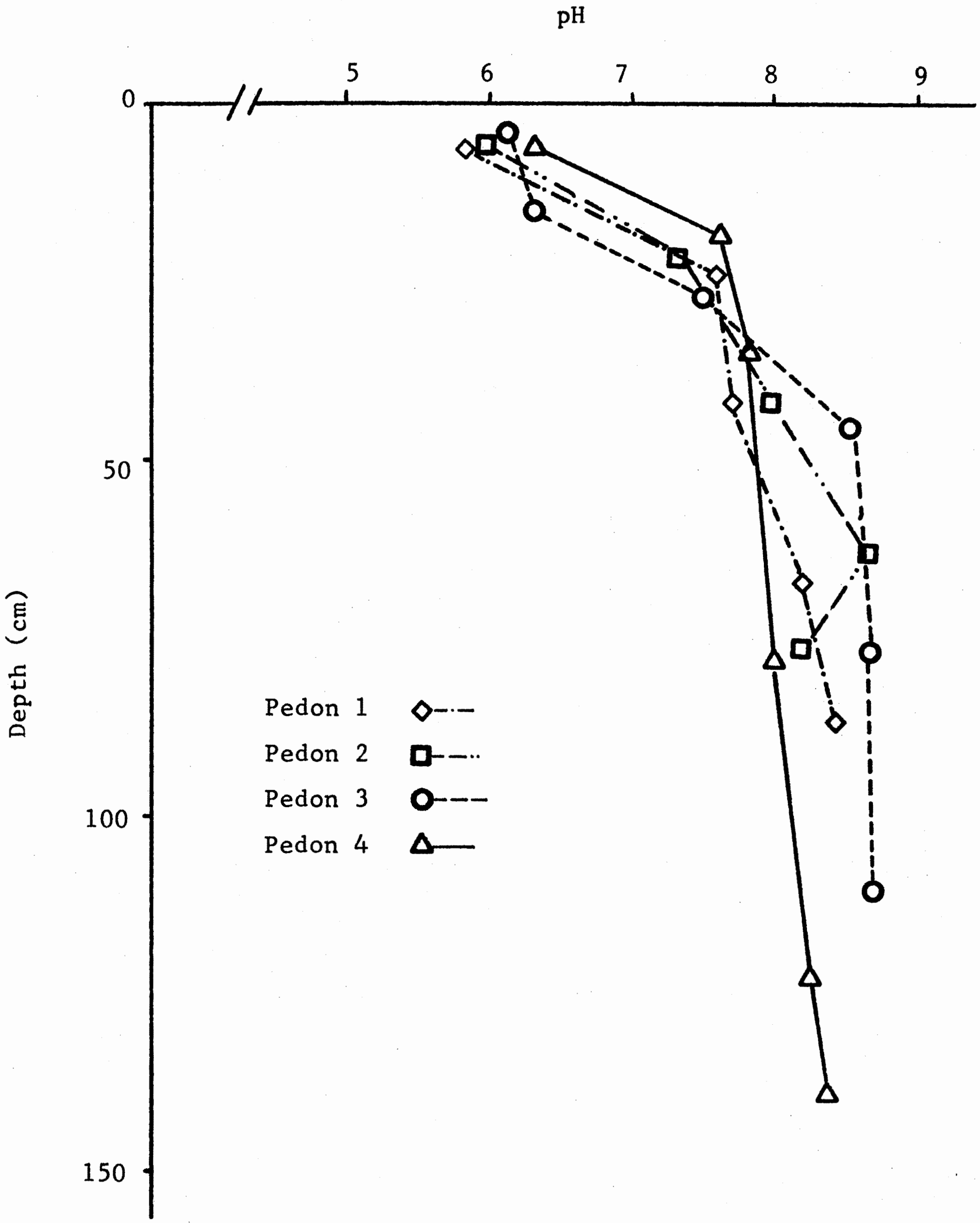

Figure 9. pH vs. Depth - Pedons 1, 2, 3, and 4.

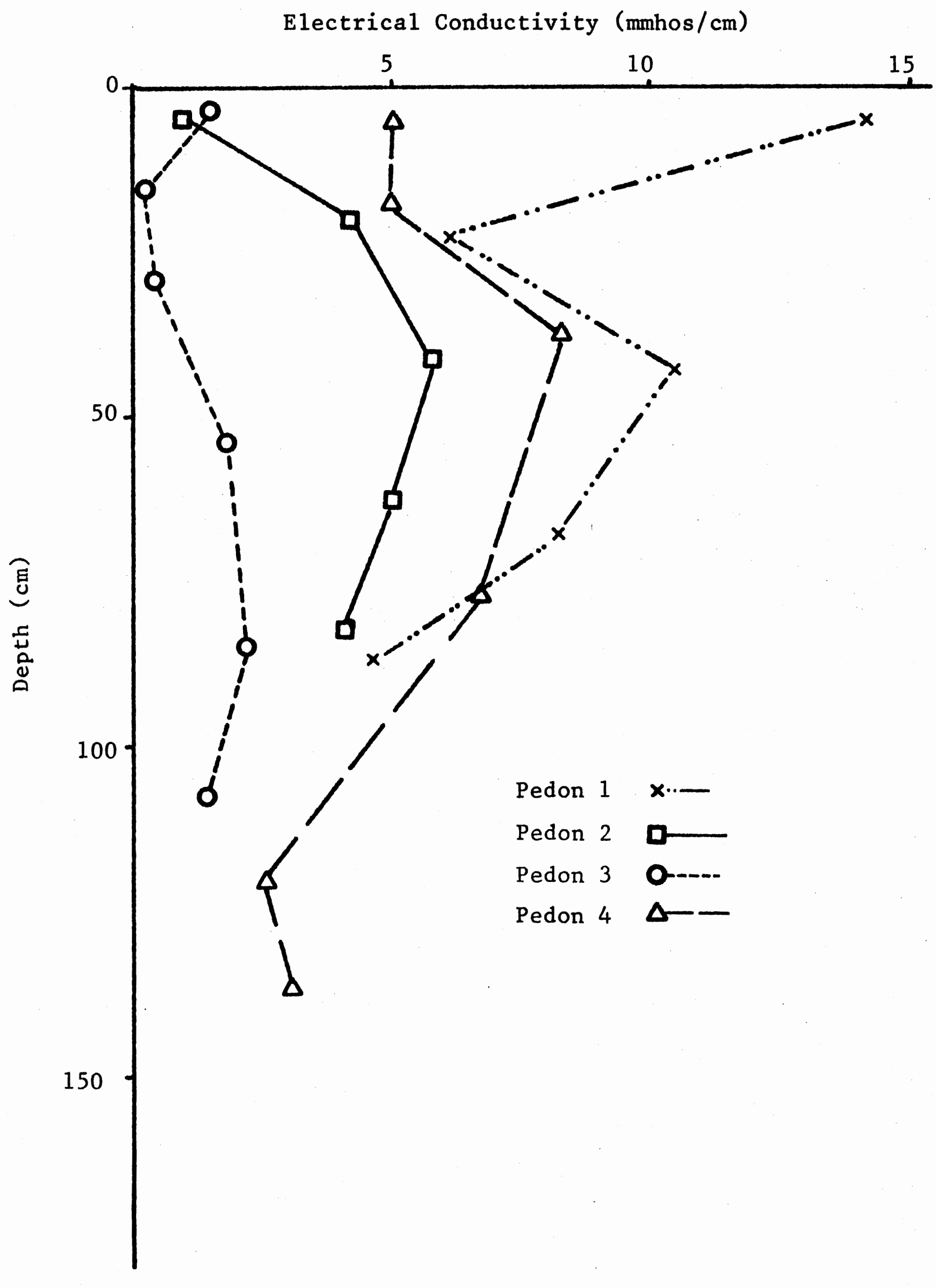

Figure 10. EC vs. Depth - Pedons 1, 2, 3, and 4.

conductivity of the pedon as water percolates through the more clayey argillic horizon. More data would definitely be required to substantiate this hypothesis.

Further study of Figure 10 indicates that the maximum accumulation of salts occur in the A horizon of Pedon 1 with the highest concentration of salts existing in the crust. It is supposed that the transportation of salts within a pedon is closely related to water movement within that pedon. If this is true, then the accumulation of salts at the surface is due to upward movement of the water in the profile and subsequent evaporation at the surface. Data should be collected of water movement within the pedon during the course of time and may provide a basis for rejecting or not rejecting this hypothesis.

The sodium adsorption ratio (SAR), as a function of depth, is shown in Figure 11. Pedon 1 exhibits the highest SAR values. The minimum values for Pedon 1, which occur in the B22t and B3 horizons, is due to an increase in soluble calcium. Other than the minimum occurring in Pedon 1, the SAR values for the horizons increase with depth. A SAR value in excess of 15 is detrimental to vegetation. All pedons have SAR values greater than 15 in the lower horizons.

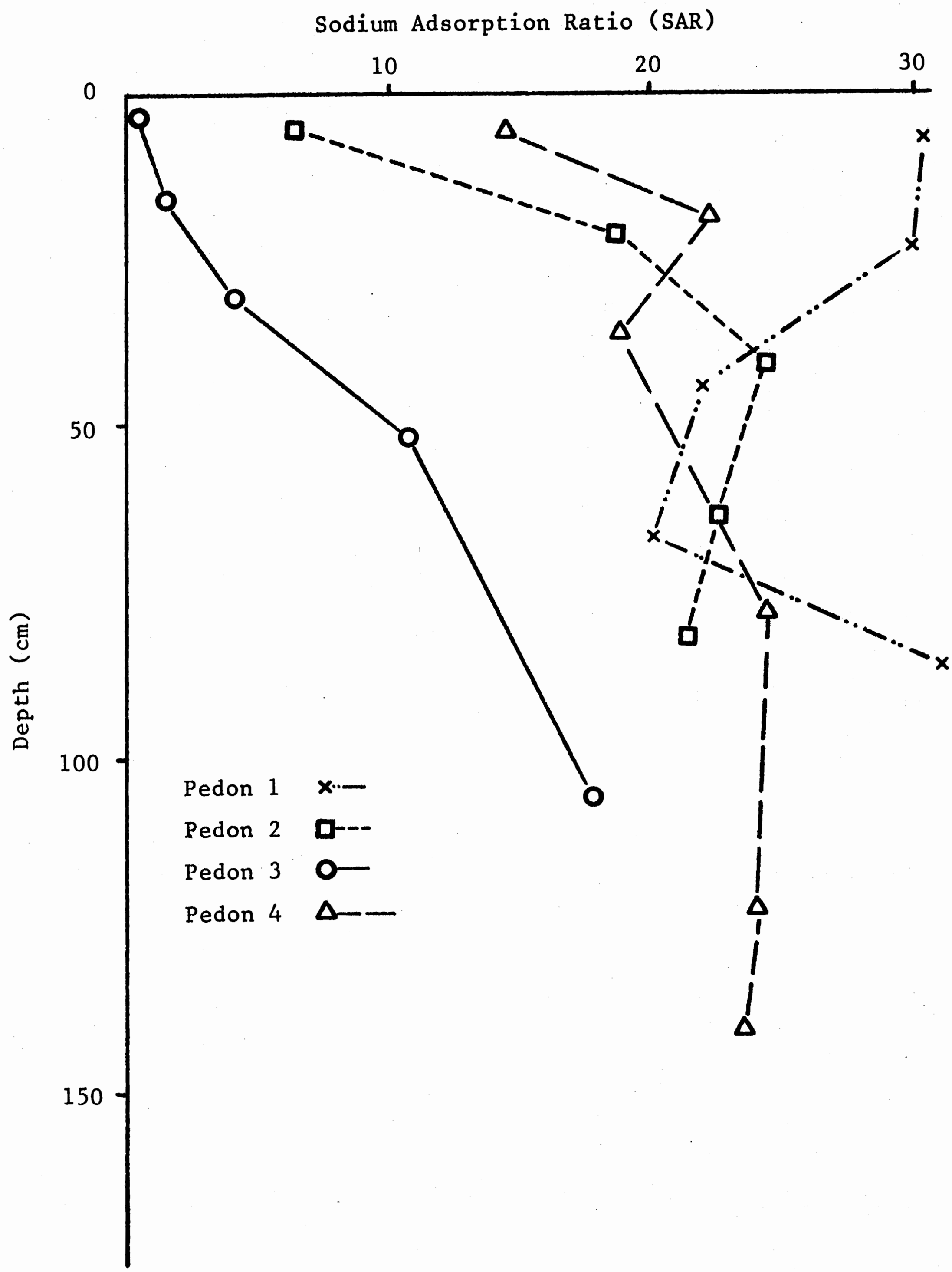

Figure 11. SAR vs. Depth - Pedons 1, 2, 3, and 4.

CHAPTER IV

CONCLUSIONS OF COMPARING A SLICKSPOT WITH ADJACENT SOILS

The results from studying the morphology and chemical data from one area are as follows:

1. The soil most affected by sodium accumulation developed columnar structure in the argillic horizon, has platy structure in the Ap horizon, a smooth, nearly impervious crust when undisturbed, and supports little or no vegetation.

2. The location of slickspots is not confined to depressions or drainage areas.

3. Lateral movement of water is the most probable cause of salt accumulation in Pedon 1.

4. Salt concentrated in the surface horizon during periods of desiccation of the soil pedon.

5. Calcium carbonate accumulation is deepest in the most affected soil.

6. Conclusive evidence is lacking for general application, therefore more samples must be taken to gather supportive evidence.

CHAPTER V

RESULTS AND DISCUSSION OF COMPARING FOUR SLICKSPOTS

Morphology

This section deals with a comparison of four slickspots (Pedons 1, 5, 7, and 9) from different areas. Data from three unaffected soils (Pedons 3, 6, and 8) adjacent to three of the slickspots are also included for comparison.

Pedons 1 and 3 are located approximately 9.6 km west of Pond Creek, Grant County and have developed on a nearly level upland position in the Hennessey Unit of the Permian "Redbeds". Pedon 1 (Table III) exhibits characteristic morphology of a sodium-affected soil. Columnar structure has developed as well as an abrupt boundary between the Ap and B21t horizons. A near mollic epipedon has developed, but is excluded because of a color deficiency in the first 12 cm.

The morphology of Pedon 3 is also shown in Table III. This is an unaffected soil and therefore has no morphology characteristic to salt-affected soils. A mollic epipedon has developed as well as an argillic horizon.

Pedons 5 and 6 are located about 8.3 km west, northwest of Medford, Grant County. The parent material is silty shale of the Garber Unit of

TABLE III

MORPHOLOGY OF PEDONS 1 AND 3

Horizon	Depth (cm)	Color (moist)	Texture*	Structure*	Consistence*	Boundary*	Effervescence with HCl*
		Pedon 1. Mollic Natrustalfs; fine-silty, mixed, thermic					
Ap	0-12	5YR 3/4	sil	2mpl	mfr	a	--
B21t	12-34	5YR 3/2	sil	2ccpr	mfr	g	--
B22t	34-54	5YR 3/3	sicl	2msbk	mfi	g	--
B3	54-82	5YR 4/4	sil	2cpr	mfi	c	--
C	82-92	5YR 4/4	sil	m	-	-	es
		Pedon 3. Typic Argiustolls; fine-silty, mixed, thermic					
Ap	0-8	7.5YR 3/2	sil	1fgr	mfr	c	--
A12	8-23	7.5YR 3/2	sil	2msbk	mfr	c	--
B21t	23-38	5YR 3/3	sicl	2mpr	mfr	g	--
B22t	38-65	2.5YR 4/6	sicl	2mpr	mfi	g	es
B3	65-102	2.5YR 3/6	sicl	1msbk	mfi	c	es
C	102-112	2.5YR 3/4	sil	m	mfi	-	es

*commonly used soil survey abbreviations

the Permian system. Pedon 6 is located on an upland slope while Pedon 5 is found near a nearly level interfluve.

The morphology of Pedons 5 and 6 is shown on Table IV. An examination of the morphology of Pedons 5 reveals that characteristics normally associated with salt-affected soils are not present. However, upon examination of the pedon location, the presence of a thin, light-colored crust is readily apparent. Also the lack of a vigorous stand of vegetation indicates the presence of a plant inhibitor. Other morphology data of interest are the development of a near mollic epipedon. Although an extremely thick argillic horizon has not developed, the clay in the B23t horizon approaches 60 percent.

Pedon 6 represents a soil adjacent to Pedon 5 which is not affected by salts. The A horizon has been truncated, so the presence of an argillic horizon is not readily apparent. The argillic horizon was determined by the discovery of clay films on the ped surfaces of the first horizon. It will be noted that in both Pedons 5 and 6, the depth of leaching is shallow, 13 and 23 cm respectively, when using the presence of calcium carbonate as a leaching indicator.

Pedons 7 and 8 are located 4.2 km southeast of Deer Creek, Grant County. They are located near a small stream, but rarely are flooded. Pedon 7 is located on a concave-shaped slope. Water frequently ponds in this area for a short time after rain storms. Table V shows the morphology of Pedons 7 and 8. Pedon 7 was selected to represent the salt-affected soils developed on the Wellington Unit of Permian age deposits. No apparent morphological characteristics of sodium or salt-affected soils is readily observed. The presence of a weak, light-colored crust and poor vegetative response were used to determine the

TABLE IV

MORPHOLOGY OF PEDONS 5 AND 6

Horizon	Depth (cm)	Color (moist)	Texture*	Structure*	Consistence*	Boundary*	Effervescence with HCl*
			Pedon 5. Mollic Natrustalfs; fine, mixed, thermic				
Ap	0-13	10YR 3/4	sicl	2mgr	mfr	c	--
B21t	13-38	7.5YR 3/2	sic	2mpr	mfi	c	e
B22t	38-66	5YR 3/4	sic	2mpr	mvfi	g	e
B23t	66-112	5YR 4/4	c	1mpr	mvfi	g	e
B3	112-165	5YR 4/4	sic	1mpr	mvfi	g	es
IIC	165-175	2.5YR 4/4	sicl	m	--	-	es
			Pedon 6. Typic Haplustalfs; fine, mixed, thermic				
Ap	0-23	7.5YR 3/2	sic	2msbk	mfi	a	--
B22t	23-51	5YR 3/4	sic	2msbk	mvfi	g	e
B23t	51-84	5YR 4/6	sic	3cbk	mefi	g	e
B24t	84-137	5YR 4/6	sic	1mbk	mvfi	g	e
B3	137-193	5Y 6/1	sicl	m	mvfi	c	e
C	193-205	not sampled					

*commonly used soil survey abbreviations

TABLE V

MORPHOLOGY OF PEDONS 7 AND 8

Horizon	Depth (cm)	Color (moist)	Texture*	Structure*	Consistence*	Boundary*	Effervescence With HCl*
		Pedon 7. Mollic Natrustalfs; fine-silty, mixed, thermic					
Ap	0-13	10YR 2/3	sil	2msbk	mfr	a	--
B21t	13-33	5YR 2/2	sicl	2mpr	mfr	c	--
B22t	33-71	5YR 3/4	sicl	2mpr	mfi	g	--
B3	71-185	5YR 3/4	sicl	2mpr	mvfi	g	e
C	185-197	2.5YR 3/6	sil	m	-	-	e
		Pedon 8. Udic Haplustalfs; fine-silty, mixed, thermic					
Ap	0-15	10YR 2/3	sil	1msbk	mvfr	a	--
B1	15-53	7.5YR 3/2	sil	1msbk	mfr	c	--
B21t	53-84	7.5YR 3/3	sil	2cpr	mfr	g	--
IIB22t	84-112	5YR 2/4	sil	2cpr	mfi	g	--
IIB31	112-165	5YR 3/4	sicl	2cpr	mfi	g	--
IIB32	165-216	5YR 3/4	sicl	2cpr	mvfi	-	--

*commonly used soil survey abbreviations

location of the slickspot. Pedon 8 is unaffected by salts and has been leached of carbonates to a depth of 216 cm. The argillic horizon was detected by the presence of clay films on the ped surfaces. The epipedon did not qualify for the mollic category due to insufficient organic matter in the surface horizon. The lithological discontinuity at 84 cm was detected by analysing the particle size distribution on a clay-free basis.

Pedon 9 is located 29 km west of Medford, Grant County. This pedon developed in Quaternary alluvium which was deposited by the Salt Fork of the Arkansas River and probably reworked by wind. Pedon 9 is located in an area which is somewhat poorly drained. Water is frequently ponded for several weeks following rain storms. An unaffected soil was not sampled due to the extensiveness of this salt-affected area. Table VI gives the morphology of Pedon 9. The A1 horizon is very thin and extremely dark. The argillic horizon from 6-117 cm has a clay concentration of close to 40%. The accumulation of runoff water seems to increase the intensity of weathering and hence the genesis of clay.

Chemical Data

The following section presents data significant to establishing the position of each soil within the parameters used to determine the salinity status of each soil. Additional chemical and physical data for each pedon is found in the Appendix.

Figures expressing the major chemical constituents Na^+, Cl^-, SO_4^{2-}, exchangeable Na^+ (Ex. Na^+), and clay, as a function of depth of Pedons 1, 3, 5, 6, 7, 8, and 9, are Figures 4 (see p. 16), 6 (see p.19), 12, 13,

TABLE VI

MORPHOLOGY OF PEDON 9

Horizon	Depth (cm)	Color (moist)	Texture*	Structure*	Consistence*	Boundary*	Effervescence with HCl*
			Pedon 9. Typic Natrustalfs; fine-silty, mixed, thermic				
A1	0-6	10YR 2/2	sil	1mgr	mfr	c	--
B21t	6-41	10YR 4/2	cl	2cbk	mefi	g	es
B22t	41-64	10YR 3/2	cl	2cbk	mefi	g	es
IIB23t	64-86	10YR 3/2	sicl	1cbk	mvfi	g	es
IIB24t	86-117	5YR 3/2	sic	1cbk	mvfi	d	es
IIC	117-183	10YR 3/2	sicl	m	mefi	-	es

*commonly used soil survey abbreviations

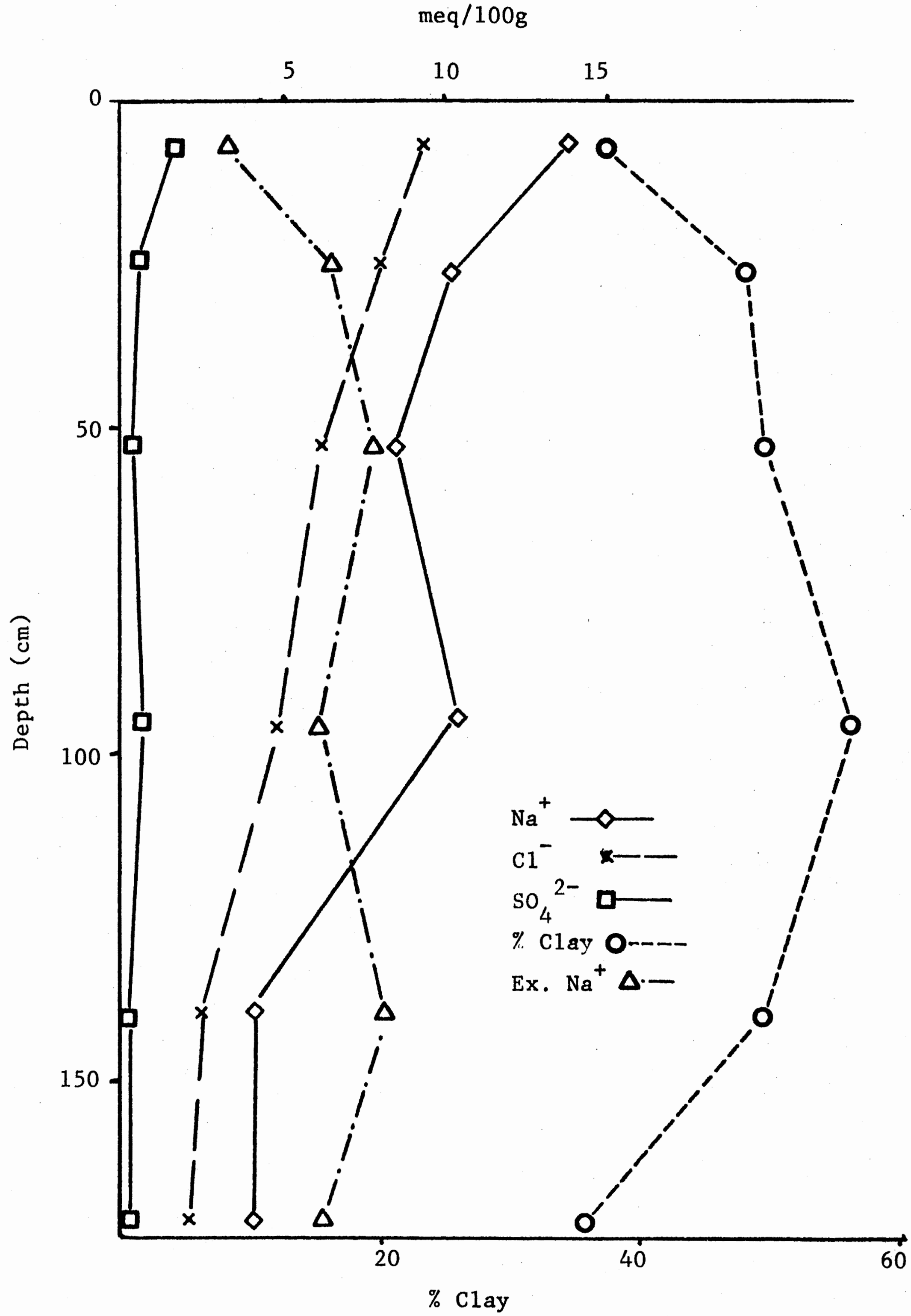

Figure 12. Major Chemical Constituents and % Clay vs. Depth - Pedon 5.

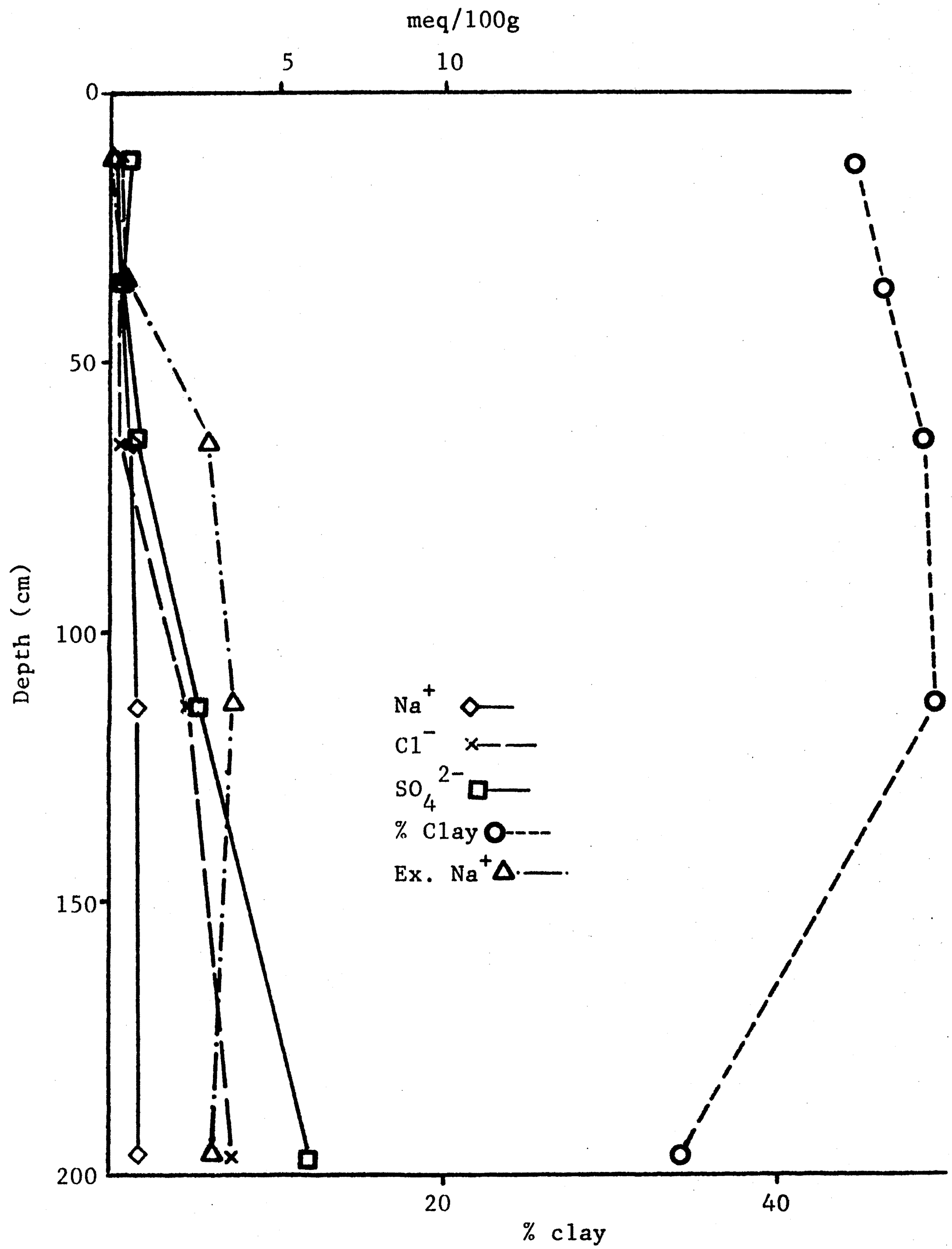

Figure 13. Major Chemical Constituents and % Clay vs. Depth - Pedon 6.

14, 15, and 16, respectively. Note that Pedons 1, 5, 7, and 9 are soils affected by salt or sodium accumulation.

The parameters set forth by the Salinity Laboratory Staff (20) indicate that all of the affected soils should be classified as saline-sodic soils. The unaffected soils do not fit into the categories established.

Discussion

A comparison of the four areas reveals the variability of slick-spots studied in Grant County.

Pedons 1 and 5 (Figures 4, and 12) are located on upland positions adjacent to nearly-level interfluves. Surface runoff does not pond on these areas, but they do seem to be influenced by runoff water through the interfluves. Pedons 1 and 5 are dominated by sodium and chloride ions. Both pedons have the highest concentration of NaCl occurring in the surface horizon. It is assumed that this accumulation is concentrated in the crust which had developed. Also a secondary maximum of soluble sodium occurs in conjunction with the argillic horizon.

Pedons 7 and 9 (Figures 14 and 16) are found in depressions in which runoff water accumulates and have no external drainage. These two pedons are dominated by sodium and sulfate ions. All salts approach a minimum at the surface. The sulfate concentration is greater than the concentration of sodium which indicates that other sulfate salts are present, but Na_2SO_4 is the dominant salt. Na_2SO_4 seems to have a maximum concentration in the argillic horizon.

The soluble constituents are expressed in the electrical conductivity (EC). It will be remembered that 4.0 mmhos/cm has been established

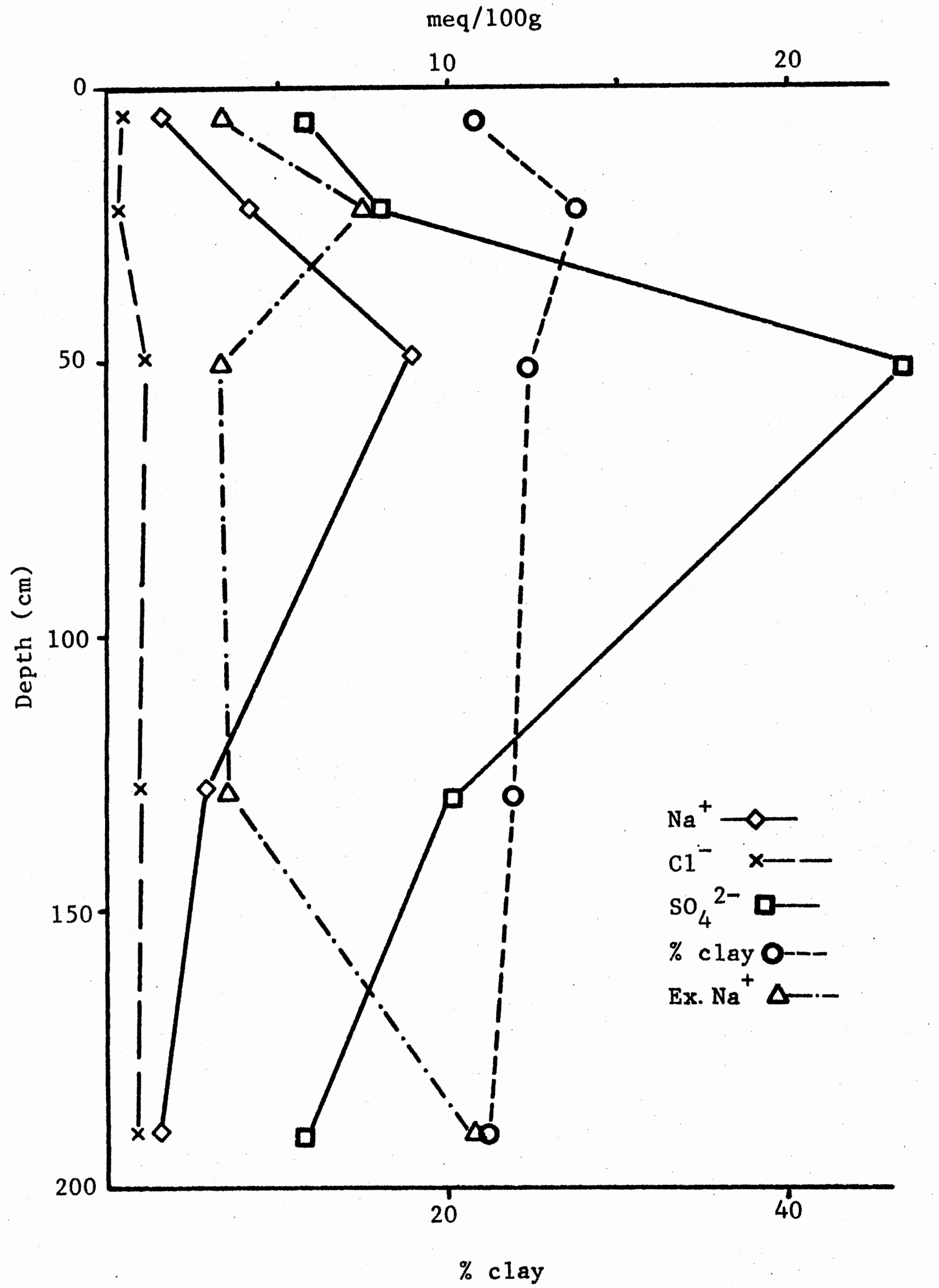

Figure 14. Major Chemical Constituents and % Clay vs. Depth - Pedon 7.

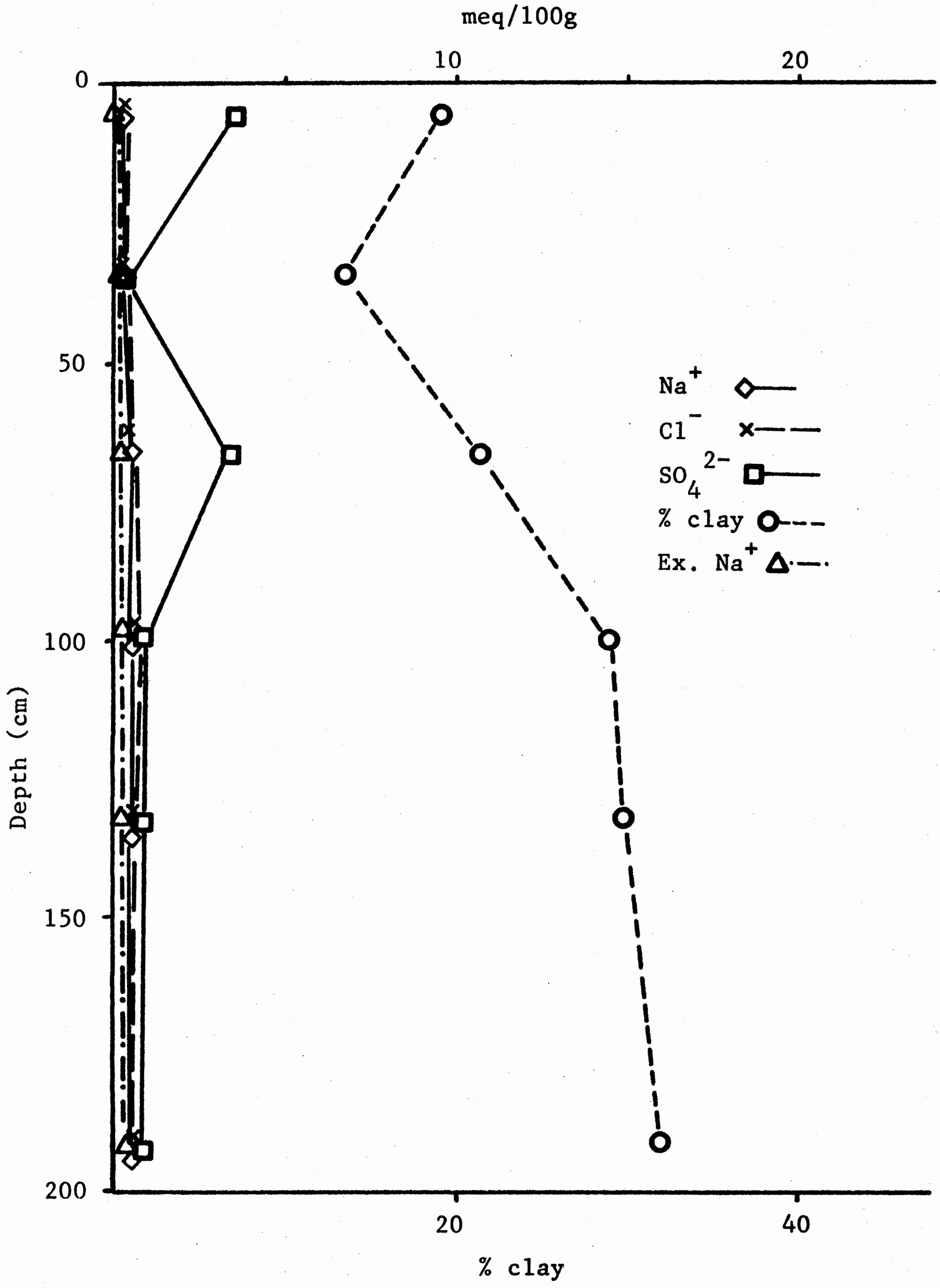

Figure 15. Major Chemical Constituents and % Clay vs. Depth - Pedon 8.

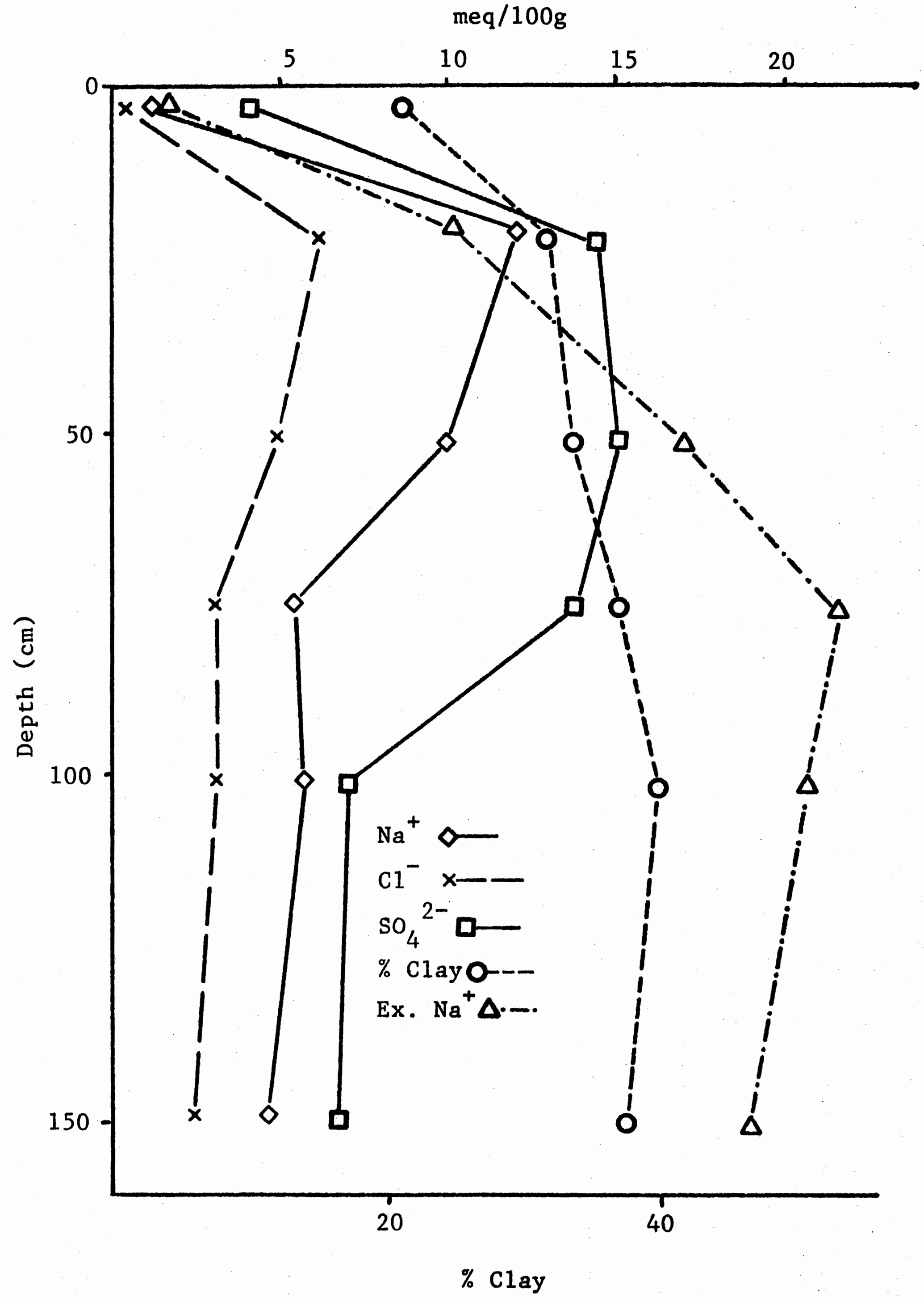

Figure 16. Major Chemical Constituents and % Clay vs. Depth - Pedon 9.

as a boundary dividing saline and non-saline soils. Figure 17 shows that Pedons 3, 6, and 8 all have an EC value less than 4.0 mmhos/cm and are clearly non-saline.

Figures 18 and 19 show EC as it varies with depth for Pedons 1 and 5 and for Pedons 7 and 9, respectively. The EC of Pedons 1 and 5 follow the same general pattern, which is an accumulation of salt in the surface horizon and a secondary accumulation of salt in the argillic horizon. Pedons 7 and 9 are also closely related to each other with respect to the pattern of their respective EC values. Both have minimum values in the surface horizon and a maximum value in the argillic horizon. The EC values for all four affected areas decrease with depth to the depth of penetrability by the soil probe used to gather samples.

The dynamic nature of soluble salts (and EC) requires that the parameter of exchangeable sodium percentage (ESP) be examined. The function of exchangeable sodium with depth will first be examined followed by an examination of the sodium adsorption ratio (SAR) which is closely related to the ESP. The SAR value of 15 separates sodic from non-sodic soils.

The reader will again examine Figures 4, 12, 14, and 16 and compare the amount of exchangeable Na^+ with the other data presented in the four figures. The general pattern appears to be an increase of exchangeable sodium with depth to a maximum value in the argillic horizon and then exchangeable sodium decreases with depth. Pedons 5 and 7 show an increase near 150 cm. All affected pedons exhibit the maximum concentration of soluble sodium occurring where the concentration of exchangeable sodium is lower.

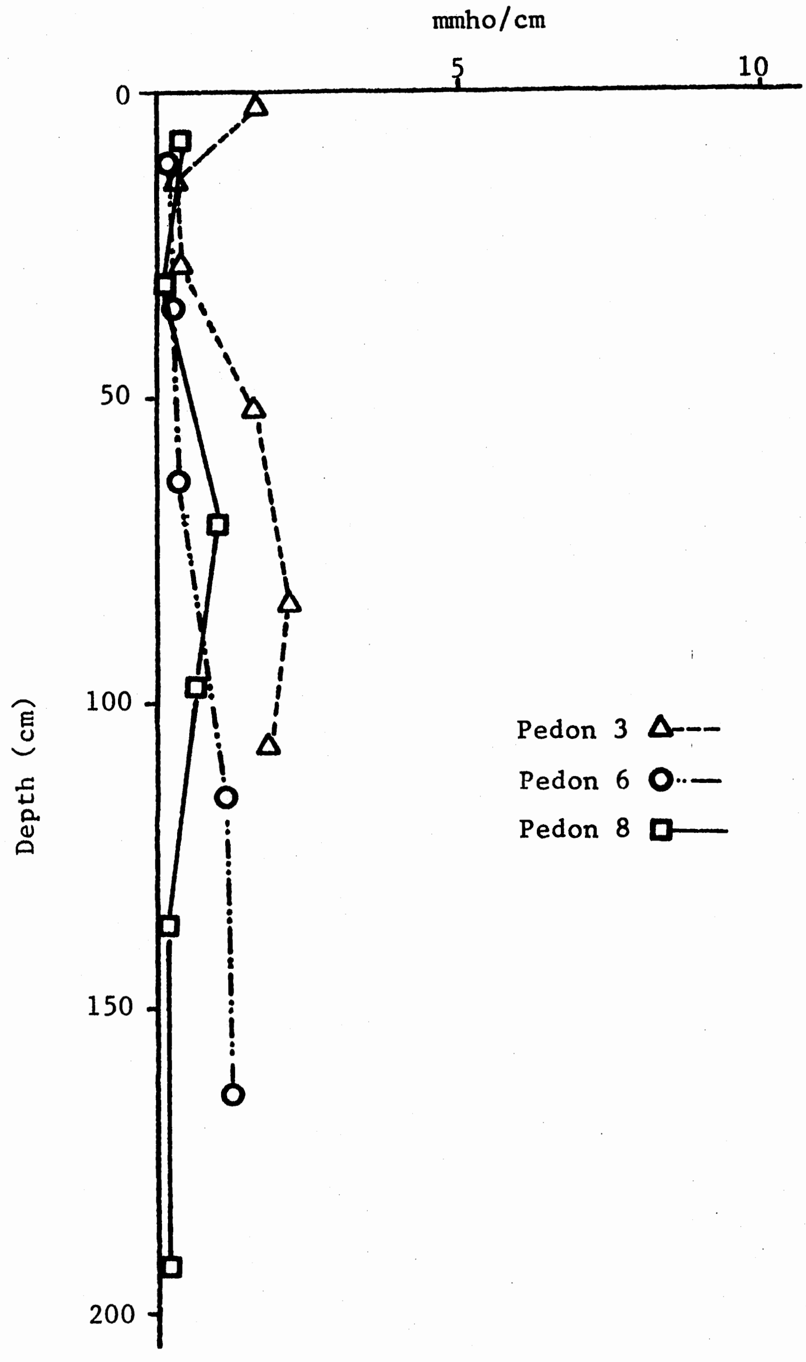

Figure 17. Electrical Conductivity - Pedons 3, 6, and 8.

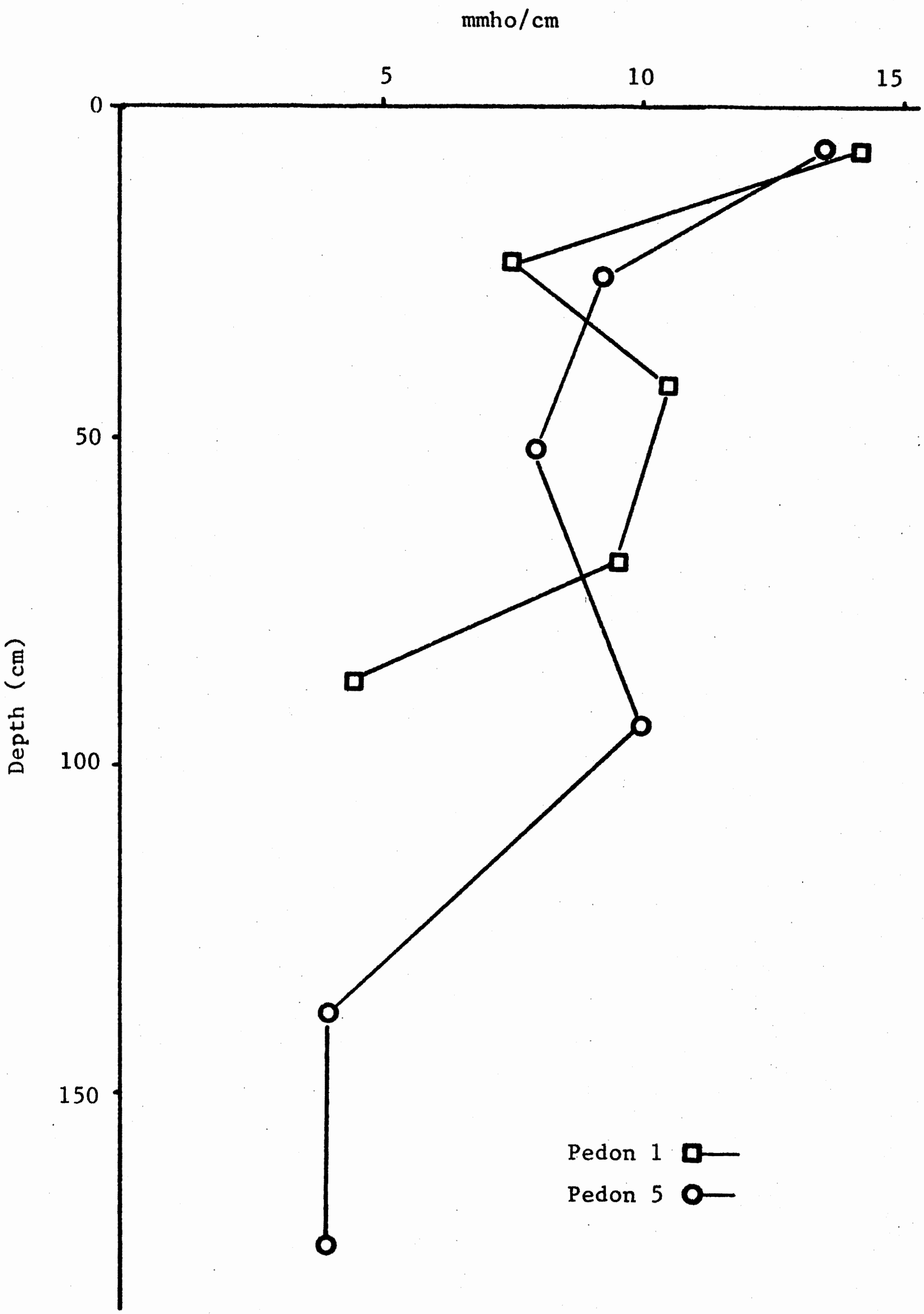

Figure 18. Electrical Conductivity - Pedons 1 and 5.

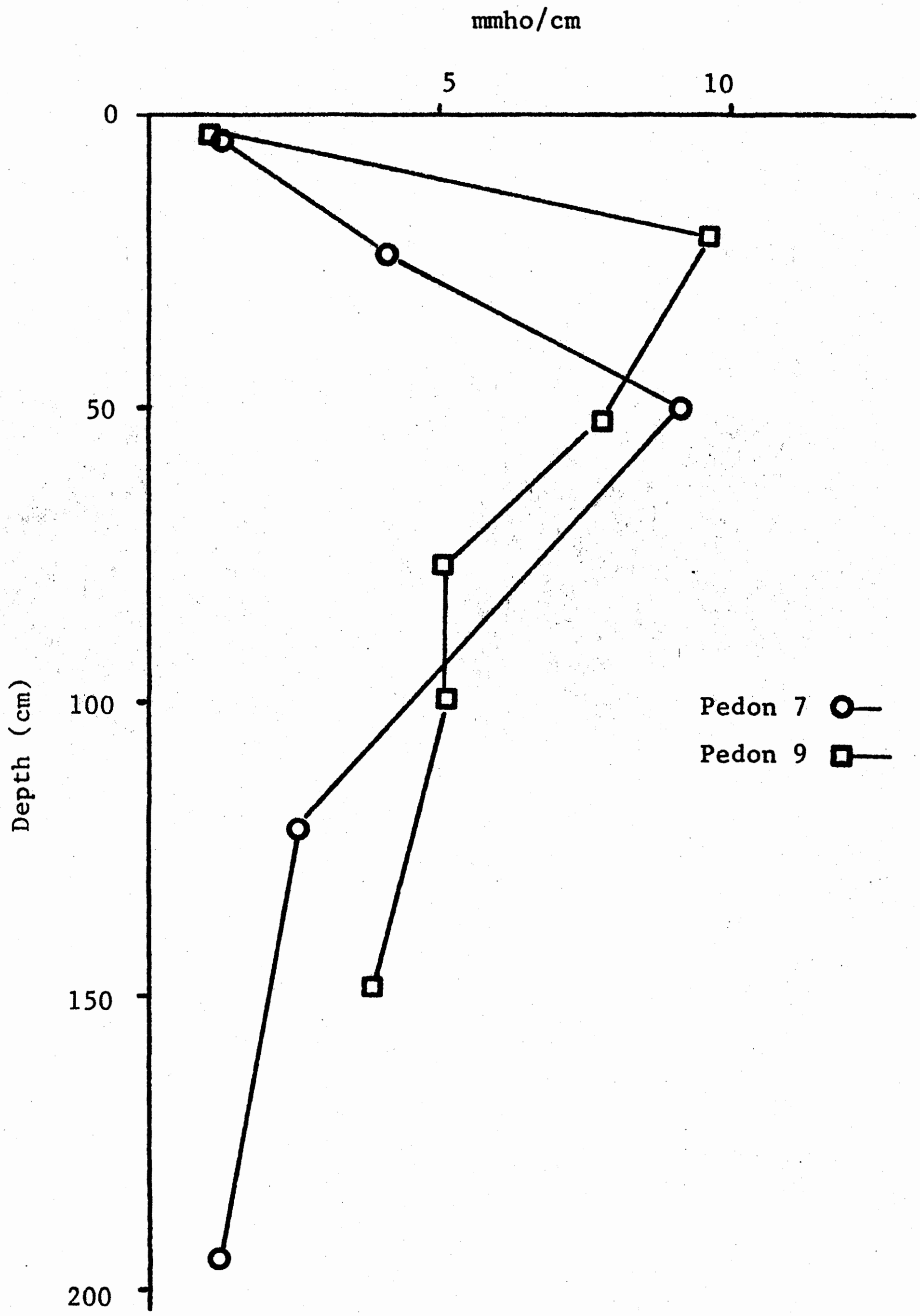

Figure 19. Electrical Conductivity - Pedons 7 and 9.

The variation of SAR with depth is shown in Figures 20 to 22. The unaffected soils have SAR values less than 15 (Figure 20). The SAR values for Pedons 1, 5, 7, and 9 exhibit no generalized pattern. Both Pedons 1 and 5 (Figure 21) have surface SAR values greater than Pedons 7 and 9 (Figure 22) due to the accumulation of Na^+ in the surface horizon of Pedons 1 and 5. The unusually large SAR values for Pedon 9 are a result of a high concentration of Na^+ and low concentration of Ca^{2+} and Mg^{2+}. All affected pedons have SAR values greater than 15 in most of the profile and are clearly sodic soils.

The last parameter to be discussed will be pH. A pH value of 8.5 has been determined to be significant in separating affected from unaffected soils. The pH shown in Figure 23 was determined on a 1:1 mixture of soil and water and shows a general trend of increasing pH values to values between 8 and 8.5 for both affected and unaffected soils. It is believed that the pH is not higher than 8.5 for all samples due to the influence of the $CaCO_3$ found in nearly all samples. $CaCO_3$ has a reported pH value near 8.2. The low surface pH values for Pedons 1 and 3 are probably related to cultural practices. The low pH value for Pedon 8 has no apparent explanation other than it is probably a contribution of the silty overburden which is low in carbonate minerals.

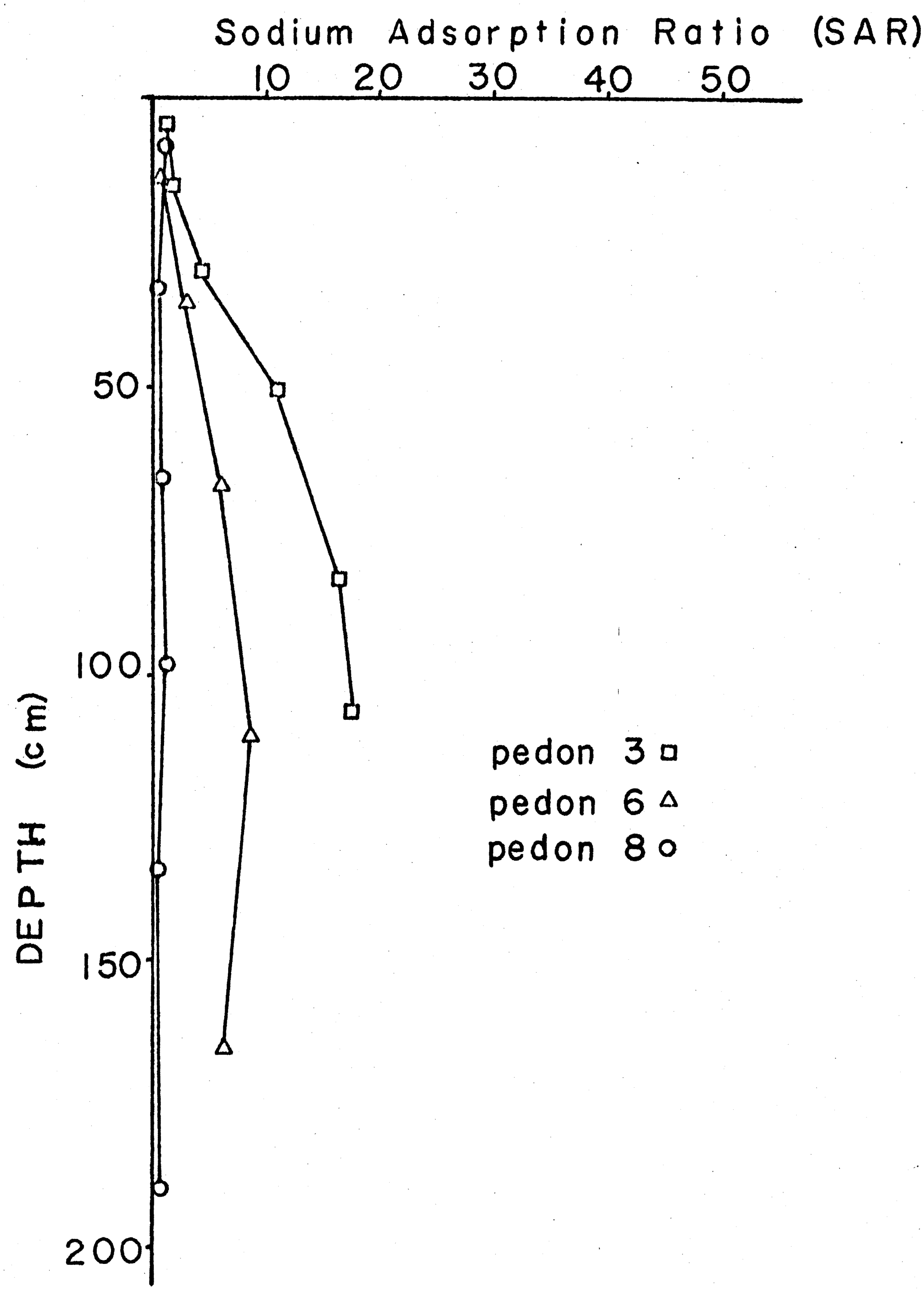

Figure 20. SAR of Pedons 3, 6, and 8.

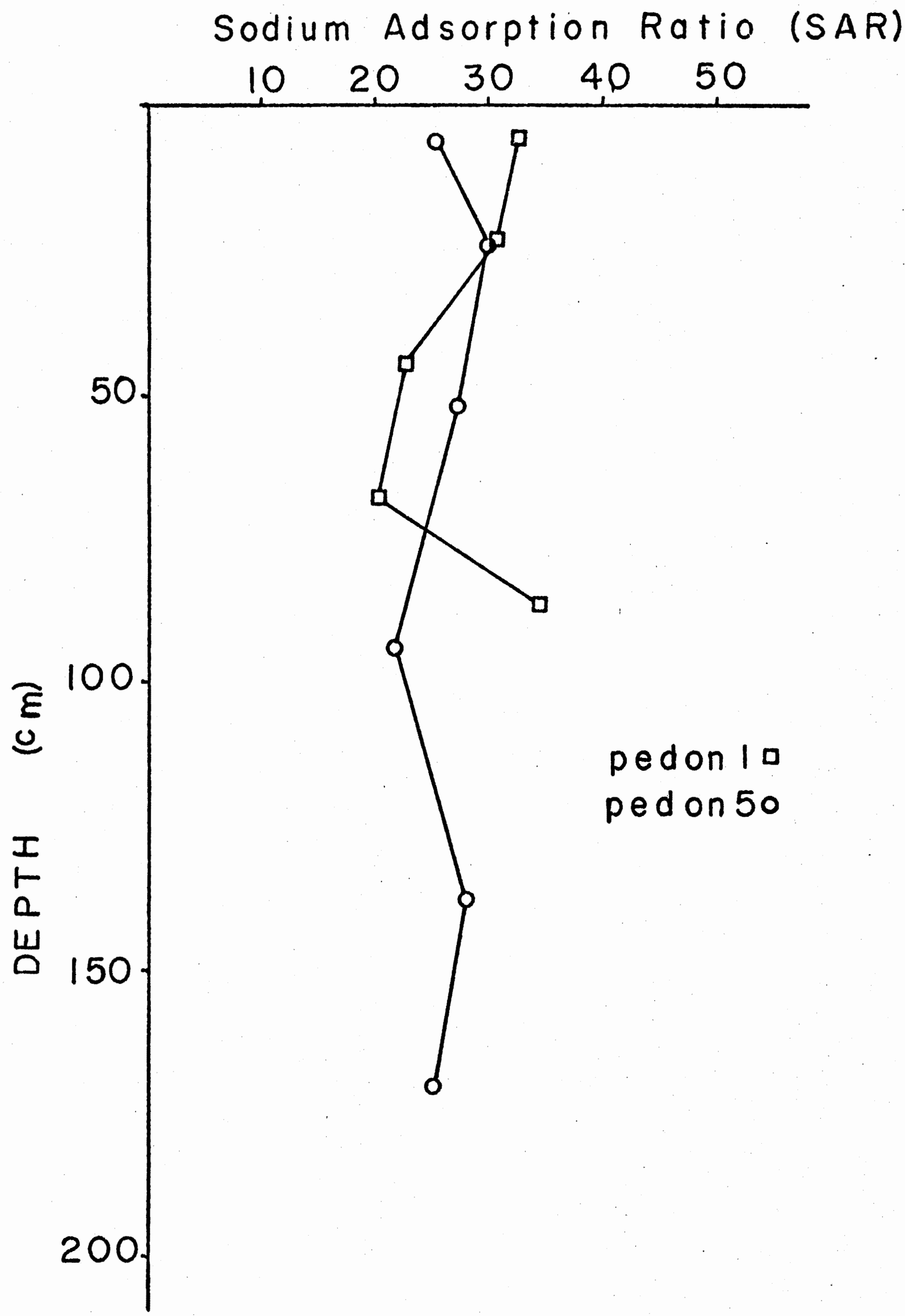

Figure 21. SAR of Pedons 1 and 5.

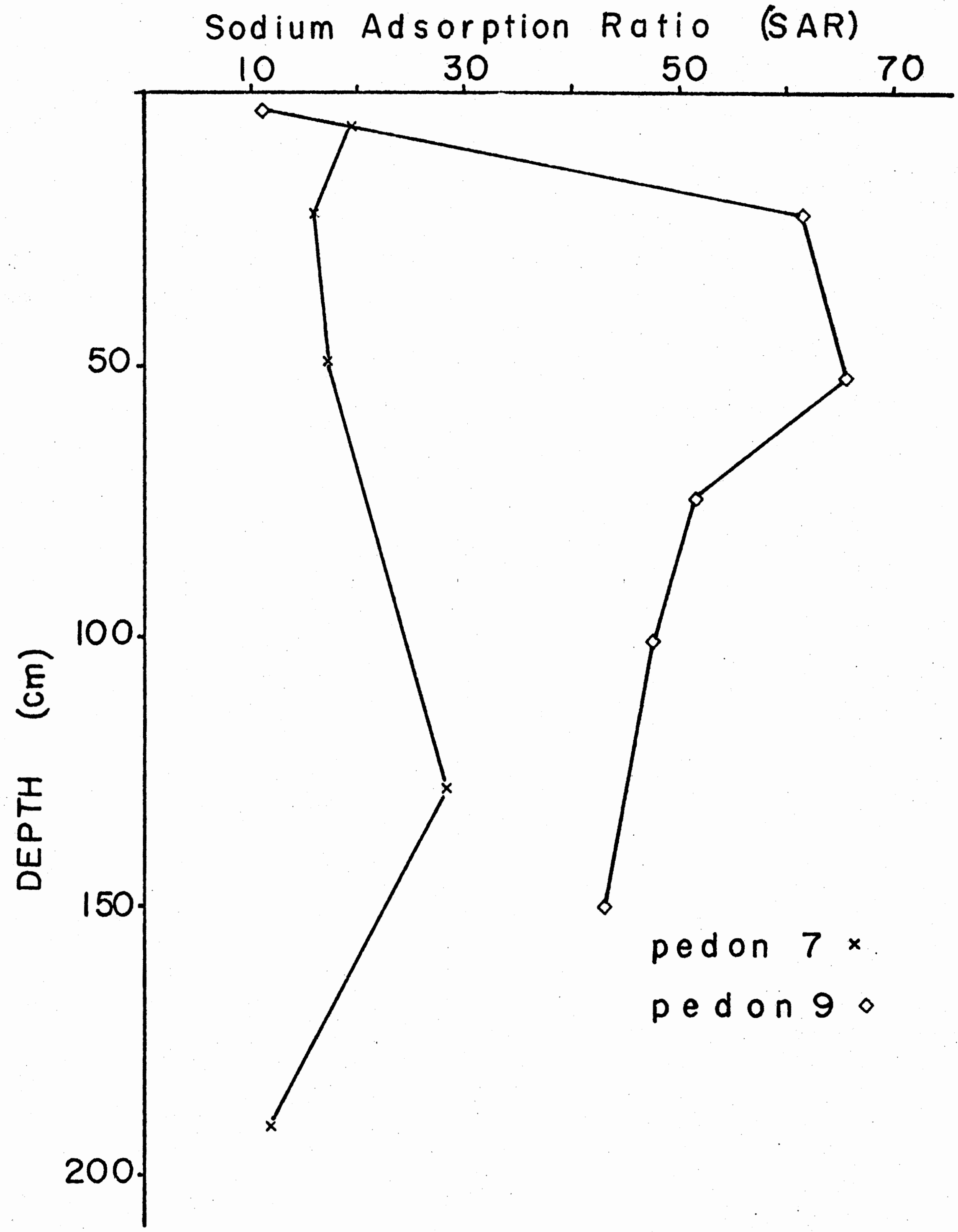

Figure 22. SAR of Pedons 7 and 9.

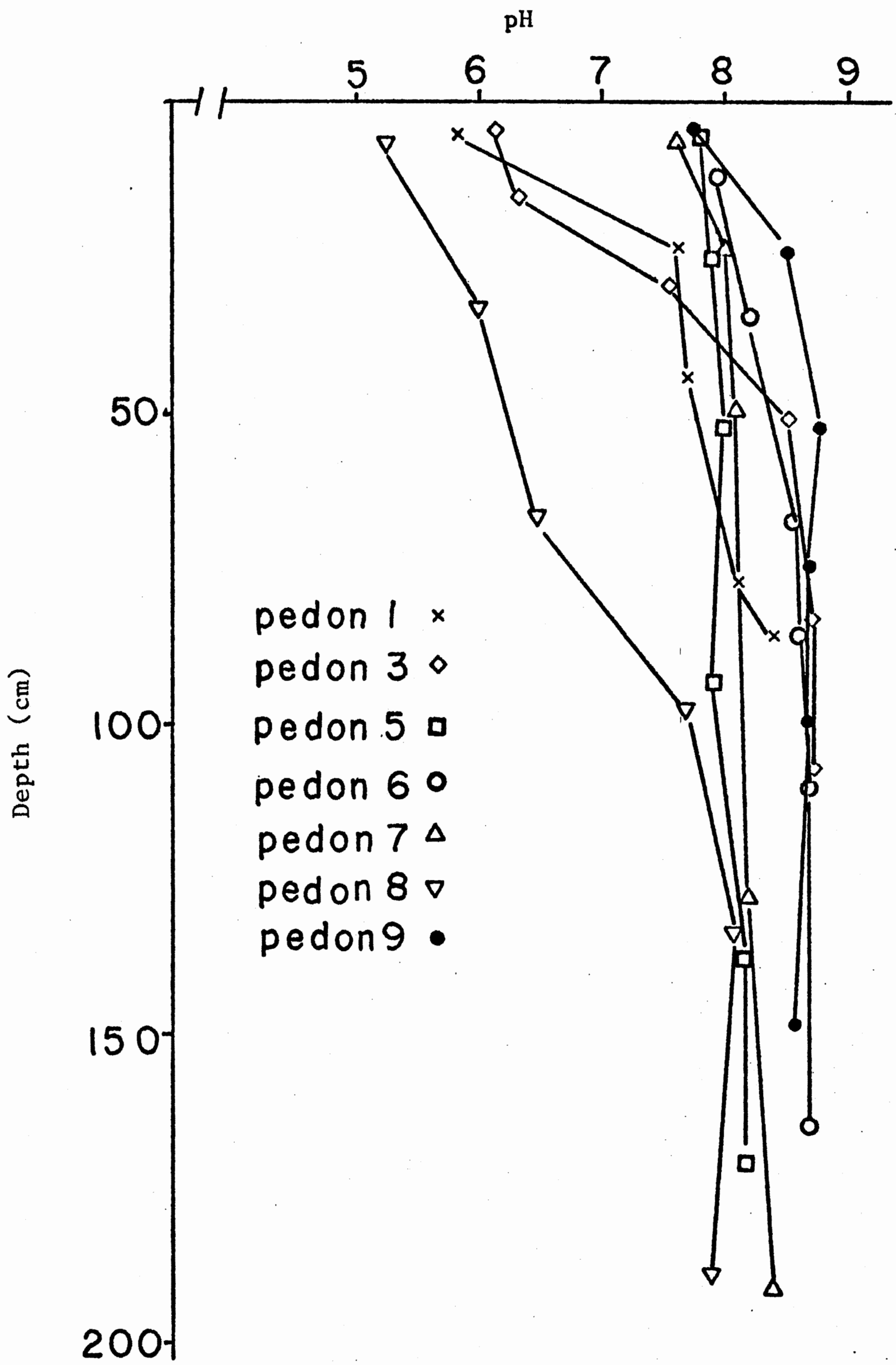

Figure 23. pH vs. Depth of Pedons 1, 3, 5, 6, 7, 8, and 9.

CHAPTER VI

CONCLUSIONS OF COMPARING FOUR SLICKSPOTS

The result of examining the morphological and chemical data shows that a difference exists between slickspot soils. It also showed that the present morphologic characteristics normally associated with saline-sodic soils are not always present and cannot be used to determine the concentration of sodium. For example, the presence of columnar structure indicates the presence of sodium, but the absence of that structure does not exclude the presence of sodium. Sodium may still be present in sufficient amounts to affect vegetation.

Important characteristics which aided in locating saline-sodic soils were the presence of a thin, smooth, light-colored, nearly-impervious crust. The lack of a strong stand of vegetation, and the dark (chroma less than the surface horizon) subsurface horizon.

Two types of salts were found to be associated with the observed soils. The soils located on upland slopes with external drainage were dominated by NaCl while salt-affected soils found on areas without external drainage were dominated by Na_2SO_4. Further research will be necessary to conclude the universality of this hypothesis. All of the saline-sodic soils investigated did have high amounts of exchangeable sodium in sufficient amounts to adversely affect growth of plants.

The results of this study also show that the term slickspots is extremely general and has been used to include areas affected by salts regardless of salt species and concentration. With additional data, a classification scheme could be devised to aid soil scientists as well as users of soil surveys to interpret correct land use potentials for soils affected by high salt and sodium concentrations. It is also hoped that this study will provide the information needed by soil scientists in Grant County to map soils which are affected by salt.

LITERATURE CITED

1. Ahi, S. M. and W. H. Metzger. 1936. Comparative physical and chemical properties of an alkali spot and an adjoining normal soil of the prairie soils group. Report Am. Soil Survey Assoc. Proc. 17:9-12.

2. Bakhtar, D. 1973. Characterization, genesis, and numerical taxonomy of sodic soils in North Central Oklahoma. (unpublished Ph.D. thesis, Oklahoma State University).

3. Bower, C. A., R. F. Reitemeier, and M. Fireman. 1952. Exchangeable cation analysis of saline and alkali soils. Soil Sci. 73:251-261.

4. Black, C. A. (Ed.). 1965. Methods of Soil Analysis. Part 1 and 2. Agronomy Monogram No. 9. American Society of Agronomy, Madison, Wisconsin.

5. Cheng, K. L. and R. H. Bray. 1951. Determination of calcium and magnesium in soil and plant material. Soil Sci. 72:449-458.

6. Culver, J. R. and F. Gray. 1968. Morphology and genesis of some grayish and claypan soils in Oklahoma: I. Morphology, chemical and physical measurement; and II. Mineralogy and genesis. Soil Sci. Soc. Amer. Proc. 32:845-857.

7. Fehrenbacher, J. B., L. P. Wilding, R. T. Odell, and S. W. Melsted. 1963. Characteristics of solonetzic soils in Illinois. Soil Sci. Soc. Amer. Proc. 27:421-431.

8. Fritz, J. S. and S. A. Yamanura. 1955. Rapid microdetermination of sulfate. Analytical Chemistry 27:1461-1464.

9. Harper, H. J. and O. E. Stout. 1949. Physical and chemical characteristics of "slickspot" soils. Okla. Agr. Exp. Station Manuscript Report No. MR-2.

10. Hartronft, B. C., C. J. Hayes, and W. McCasland. 1967. Engineering classification of geologic materials and (related soils). Division four. Prepared by Research and Development Division of Oklahoma Highway Department, in cooperation with the U.S. Bureau of Public Roads.

11. Horn, M. E., E. M. Rutledge, H. C. Dean, and M. Lawson. 1964. Classification and genesis of solonetz (sodic) soils in Eastern Arkansas. Soil Sci. Soc. Amer. Proc. 28:688-692.

12. Jenny, H. 1941. Factors of soil formation. McGraw-Hill Book Co., New York and London.

13. Jenny, H. 1961. Derivation of state factor equation of soil ecosystems. Soil Sci. Soc. Amer. Proc. 25:385-388.

14. Kelley, W. P. 1951. Alkali soils. Reinhold Publ. Corp., New York.

15. Mehta, K. M. 1954. Comparative physical and chemical properties of a "slickspot" and adjoining soil of the reddish prairie soil area. (unpublished M.S. thesis, Oklahoma State University).

16. McLean, E. O. 1965. Aluminum. Methods of Soil Analysis. Agronomy Monograph, No. 9. Part II, American Society of Agronomy, Madison, Wisconsin. pp. 986-994.

17. Peech, M., L. T. Alexander, L. A. Dean, and J. F. Reed. 1947. Methods of soil analysis for soil-fertility investigations. U. S. Dept. Agr. Cir. 757, 22 pp.

18. Plice, M. J. and R. L. Emerson. 1947. Some economic and other characteristics of slick-spot soils in Oklahoma. Okla. Acad. Sci. 27:97-101.

19. Reed, L. W. 1962. A study of saline-alkali soils in Oklahoma. Processed Series P-430, Oklahoma State University, pp. 37.

20. Richards, L. A. 1954. Diagnosis and improvement of saline and alkali soils. U. S. Dept. Agr. Handbook No. 60.

21. Singh, S. S. 1959. Chemical Characterization of some "alkali spot" soils in Oklahoma. (unpublished M.S. thesis, Oklahoma State University).

22. Stewart, B. G. 1969. Morphology, genesis, and classification of saline-sodic soils in North Central Oklahoma. (unpublished M.S. thesis, Oklahoma State University).

23. Soil Survey Staff. 1951. Soil Survey Manual U.S. Dept. Agr. Handbook No. 18.

24. Soil Survey Staff, SCS, U.S. Dept. Agr. 1960. Soil classification: A comprehensive system. 7th Approximation, as ammended in June 1964.

25. Soil Survey Staff. 1972. Soil survey laboratory methods and procedures for collecting soil samples. U.S. Dept. Agr. Report No. 1.

26. White, E. M. 1964. Morphological-chemical relationships of some thin A horizon solodized solonetz soils derived from moderately fine material on a well-drained slope. Soil Sci. 98:256-263.

27. White, E. M. 1964. The morphological-chemical problem in solodized soils. Soil Sci. 98:187-191.

APPENDIX

PEDON 1

Classification: Unnamed series; Fine-silty, mixed, thermic, Mollic Natrustalfs.

Location: 559 m south and 135 m east of northwest corner of section 12, T. 25 N., R. 7 W.

Physiographic position: level upland, backslope, southwest aspect, 1% linear slope, elevation 341 m.

Drainage: Well-drained.

Vegetation: Few wheat plants, some koshia.

Parent material: Hennessey Unit of Permian "Redbeds," silty shale.

Remarks: smooth, nearly impervious crust develops during dry periods, crust is mostly sand and silt.

(Colors are for moist soils)

Ap ----- 0-12 cm -- dark reddish-brown (5 YR 3/4); silt loam; moderate, medium, platy structure; friable; many pores; medium acid (pH 5.8); abrupt boundary.

B21t --- 12-34 cm -- dark reddish-brown (5 YR 3/2); silt loam; moderate, coarse, columnar breaking to subangular blocky structure; friable; many pores, clay films on ped surfaces; mildly alkaline (pH 7.6); gradual boundary.

B22t --- 34-54 cm -- dark reddish-brown (5 YR 3/3); silty clay loam; moderate, medium, subangular blocky structure; firm; common, fine pores; clay films on ped surfaces; few gypsum mycelia; mildly alkaline (pH 7.7); gradual boundary.

B3 ----- 54-82 cm -- reddish-brown (5 YR 4/4); silt loam; moderate, coarse, prismatic breaking to subangular blocky structure;

firm; few pores; clay films on ped surfaces; few gypsum mycelia; moderately alkaline (pH 8.2); clear boundary.

C ------ 82-93 cm; reddish-brown (5 YR 4/4); silt loam; unconsolidated silty shale; strong effervescence; moderately alkaline (pH 8.4).

PEDON 2

Classification: Deandale series; Fine, mixed, thermic, Typic Natrustolls.

Location: 557 m south and 176 m east of northwest corner of section 12, T. 25 N., R. 7 W.

Physiographic position: level upland, backslope, 2% convex slope, southwest aspect, elevation 341 m.

Drainage: Well-drained.

Vegetation: sparse wheat.

Parent Material: Hennessey Unit of Permian "Redbeds," siltstone.

Remarks: Weak crust develops during dry season.

(Colors are for moist soils)

Ap ----- 0-11 cm -- dark reddish-brown (5 YR 3/2); silt loam; moderate, fine, granular structure; friable; many pores; medium acid (pH 6.0); clear boundary.

B21t --- 11-31 cm -- dark reddish-brown (5 YR 3/2); silty clay loam; moderate to strong, fine, subangular blocky structure; friable to slightly firm; many pores; clay films on ped surfaces; neutral (pH 7.3); gradual boundary.

B22t --- 31-51 cm -- dark reddish-brown (5 YR 3/3); silty clay loam; moderate, fine, subangular blocky structure; firm;

common pores; clay films on ped surfaces; very slight effervescence; moderately alkaline (pH 8.0); gradual boundary.

B3 ----- 51-76 cm -- olive-yellow (5 Y 6/3); silt loam; weak, medium, subangular blocky structure; firm; few pores; strong effervescence; strongly alkaline (pH 8.7); clear boundary.

C ------ 76-88 cm -- reddish-brown (5 YR 4/4) silt loam; strong effervescence; moderately alkaline (pH 8.2); unconsolidated siltstone.

PEDON 3

Classification: Carey series; Fine-silty, mixed, thermic Typic Argiustolls.

Location: 488 m north and 85 m east of northwest corner of section 12, T. 25 N., R. 7 W.

Physiographic position: level upland, backslope, southwest aspect, 0.5% linear slope, elevation 341 m.

Drainage: Well-drained.

Vegetation: Wheat.

Parent Material: Hennessey Unit of Permian "Redbeds," silty shale.

Remarks: None.

(Colors are for moist soils)

Ap ----- 0-8 cm -- dark brown (7.5 YR 3/2); silt loam; weak, fine, granular structure; friable; many roots; many pores; slightly acid (pH 6.1); clear boundary.

A12 ---- 8-23 cm -- dark brown (7.5 YR 3/2); silt loam; moderate, medium, subangular, blocky breaking to granular structure; friable; many roots; many pores; slightly acid (pH 6.3); clear boundary.

B21t --- 23-38 cm -- dark reddish-brown (5 YR 3/3); silty clay loam; moderate, medium, prismatic structure; friable, common pores; clay films on ped surfaces; mildly alkaline (pH 7.5); gradual boundary.

B22t --- 38-65 cm -- red (2.5 YR 4/6); silty clay loam; medium, moderate, prismatic breaking to subangular blocky structure; firm; common pores; clay films on ped surfaces; strong effervescence; strongly alkaline (pH 8.5); gradual boundary.

B3 ----- 65-102 cm -- dark red (2.5 YR 3/6); silty clay loam; weak, medium subangular blocky structure; firm; few pores; clay films on ped surfaces; strong effervescence; strongly alkaline (pH 8.7); clear boundary.

C ------ 102-113 cm -- dark reddish-brown (2.5 YR 3/4); silt loam; strong effervescence; strongly alkaline (pH 8.7).

PEDON 4

Classification: Deandale series; Fine, mixed, thermic, typic Natrustolls.

Location: 495 m south and 116 m east of northwest corner of section 12, T. 25 N., R. 7 W.

Physiographic position: undulating upland, nearly level interfluve southeast aspect, 1% concave slope, elevation 341 m.

Drainage: Moderately well-drained.

Vegetation: Wheat.

Parent Material: Hennessey Unit of Permian "Redbeds," siltstone.

Remarks: The B32 horizon has the appearance of a gleyed horizon, but it is believed that the color is related to geologic and not pedogenic processes.

(Colors are for moist soils)

Ap ----- 0-11 cm -- dark brown (7.5 YR 3/2); silt loam; moderate, medium, platy structure breaking to granular structure; friable; common roots; common pores; slightly acid (pH 6.3); clear boundary.

B21t --- 11-26 cm -- dark reddish brown (5 YR 3/2); silty clay; moderate, medium prismatic breaking to subangular blocky structure; firm; common pores; clay films on ped surfaces; mildly alkaline (pH 7.6); clear boundary.

B22t --- 26-48 cm -- dark reddish brown (2.5 YR 3/4); silty clay; moderate, medium, prismatic breaking to subangular blocky structure; very firm; common pores; clay films on ped surfaces; few, fine carbonate mycelia; slight effervescence; common black bodies; few mycelia threads of salt or gypsum; mildly alkaline (pH 7.8); gradual boundary.

B31 ---- 48-112 cm -- dark red (2.5 YR 3/6); silty clay loam; weak, coarse, prismatic structure; firm; few pores; slight effervescence; moderately alkaline (pH 8.0); clear boundary.

B32 ---- 112-133 cm -- greenish gray; (5 G 6/1); silt loam; strong, coarse, prismatic structure; very firm; strong effervescence; moderately alkaline (pH 8.3); abrupt boundary.

C ------ 133-148 cm -- dark reddish brown (2.5 YR 3/4); silt loam; unconsolidated siltstone; strong effervescence; moderately alkaline; (pH 8.4).

PEDON 5

Classification: Drummond series; Fine, mixed, thermic, Mollic Natrustalfs.

Location: 160 m north and 26 m east of southwest corner of section 5, T. 27 N., R. 6 W.

Physiographic position: nearly level upland, nearly level interfluve, east aspect, 0-2% concave slope, elevation 336 m.

Drainage: Moderately well-drained.

Vegetation: Tall wheat grass and koshia.

Parent material: Garber Unit of Permian "Redbeds."

Remarks: Gypsum crystals were found on the surface of the pedon.

(Colors are for moist soils)

Ap ----- 0-13 cm -- dark yellowish-brown (10 YR 3/4); silty clay loam; moderate, medium, granular structure; friable; common fine roots; mildly alkaline (pH 7.8); clear boundary.

B21t --- 13-38 cm -- dark brown (7.5 YR 3/2); silty clay; moderate, medium, prismatic breaking to subangular, blocky structure; firm; common fine roots; clay film on ped surfaces; common, medium, white concretions; few, fine black bodies; very slight effervescence; moderately alkaline (pH 7.9); clear boundary.

B22t --- 38-66 cm -- dark reddish brown (5 YR 3/4); silty clay; moderate, medium, prismatic breaking to subangular blocky structure; very firm; few fine pores; clay films on ped surfaces; common, medium, white concretions; few, fine black bodies; few calcium carbonate mycelia; slight effervescence; moderately alkaline (pH 8.0); gradual boundary.

B23t --- 66-112 cm -- reddish brown (5 YR 4/4); clay; weak, medium, prismatic breaking to subangular blocky structure; very firm; few fine pores; clay films on ped surfaces; few, fine black bodies; common, fine, calcium carbonate concretions; slight effervescence; moderately alkaline (pH 7.9); gradual boundary.

B3 ----- 112-165 cm -- reddish brown (5 YR 4/4); silty clay; weak, medium prismatic breaking to subangular blocky structure; very firm; few, fine pores; common, prominent, coarse, pink, light reddish brown (5 YR 7.3, 2.5 YR 6/4), red (2.5 YR 5/6) and reddish brown (2/5 YR 5/4) mottles; few, fine black bodies; few, medium calcium carbonate concretions; strong effervescence; moderately alkaline (pH 8.2); gradual boundary.

IIC ---- 165-175 cm -- reddish brown (2.5 YR 4/4); silty clay loam; unconsolidated shale; strong effervescence; moderately alkaline (pH 8.2).

PEDON 6

Classification: Variant of Kirkland series; Fine, mixed, thermic, Typic Haplustalfs.

Location: 152 m north and 46 m west of southeast corner of section 6, T. 27 N., R. 6 W.

Physiographic position: level upland, southeast aspect, 2% linear slope, elevation 337 m.

Drainage: Well-drained.

Vegetation: Wheat.

Parent Material: Garber Unit of Permian "Redbeds," shale.

Remarks: color of B3 horizon due to geologic process, A horizon has been eroded and melanization of B2 horizon has begun.

(Colors are for moist soils).

Ap ----- 0-23 cm -- dark brown (7.5 YR 3/2); silty clay; moderate, medium, subangular blocky structure; firm; moderately alkaline (pH 7.9); abrupt, smooth boundary.

B22t --- 23-51 cm -- dark reddish brown (5 YR 3/4); silty clay; moderate, medium, subangular blocky structure; very firm; clay films on ped surfaces; organic stains on ped surfaces; few, medium-soft bodies; slight effervescence; moderately alkaline (pH 3.2); gradual, smooth boundary.

B23t --- 51-84 cm -- yellowish red (5 YR 4/6); silty clay; strong, coarse, subangular blocky structure; extremely firm; organic stains on ped surfaces; few, medium and fine-soft bodies and calcium carbonate concretions; slickensides; slight effervescence; strongly alkaline (pH 8.6); gradual smooth boundary.

B24t --- 84-137 cm -- yellowish-red (5 YR 4/6); silty clay; weak, medium, subangular blocky structure; very firm; slight effervescence; strongly alkaline (pH 8.7); gradual boundary.

B3 ----- 137-193 cm -- gray (5 YR 4/6); silty clay loam; massive; very firm; slight effervescence; strongly alkaline (pH 8.7); clear boundary.

C ------ 193-205 cm -- unconsolidated massive shale.

PEDON 7

Classification: Unnamed series; Fine-silty, mixed, thermic, Mollic Natrustalfs.

Location: 192 m west and 306 m north of southeast corner of section 36, T. 27 N., R. 3 W.

Physiographic position: Nearly level upland, nearly level interfluve; east aspect, 0-1% concave slope; elevation 310 m.

Drainage: Well-drained; floods occasionally.

Vegetation: Sparse wheat.

Parent Material: Wellington Unit of Permian "Redbeds;" siltstone.

Remarks: Water is frequently ponded in this area after rainstorms.

(Colors are for moist soils)

Ap ----- 0-13 cm -- very dark brown (10 YR 2/3); silt loam; weak, medium, subangular blocky breaking to granular structure; friable; few fine pores; vesicular; organic coatings on ped surfaces; mildly alkaline (pH 7.6); abrupt boundary.

B21t --- 13-33 cm -- dark reddish brown (5 YR 2/2); silty clay loam; moderate, medium, prismatic breaking to subangular blocky structure; friable; few pores; clay films on ped surfaces; fine gypsum or salt mycelia; moderately alkaline (pH 8.0); clear boundary.

B22t --- 33-71 cm -- dark reddish brown (5 YR 3/4); silty clay loam; moderate, medium prismatic breaking to subangular blocky structure; firm; few pores; clay films on ped surfaces; few, medium, black bodies, moderately alkaline (pH 8.1); gradual boundary.

B3 ----- 71-185 cm -- dark reddish brown (5 YR 3/4); silty clay loam; moderate, medium prismatic structure; very firm to firm; few pores; fine salt crystals; few fine calcium carbonate mycelia; few, moderate, black and white bodies; clay films on ped surfaces; very slight effervescence; moderately alkaline (pH 8.2); clear boundary.

C ------ 185-197 cm -- dark red (2.5 YR 3/6); silt loam; unconsolidated siltstone; moderately alkaline (pH 8.4).

PEDON 8

Classification: Unnamed series, Fine-silty, mixed, thermic, Udic Haplustalfs.

Location: 105 m west and 309 m north of southeast corner of section 36, T. 27 N., R. 3 W.

Physiographic position: nearly level upland grading to stream terrace, 1-2 % linear slope, west aspect, elevation 311 m.

Drainage: Well-drained, floods rare.

Vegetation: Wheat.

Parent Material: Wellington Unit of Permian "Redbeds" overburdened with alluvial deposits.

Remarks: None.

(Colors are for moist soils)

Ap ----- 0-15 cm -- Very dark brown (10 YR 2/3); silt loam; weak, medium, subangular blocky breaking to granular structure; very friable; many roots; many pores; strongly acid (pH 5.2); abrupt boundary.

B1 ----- 15-53 cm -- dark brown (7.5 YR 3/2); silt loam; weak, medium, subangular blocky structure; friable; many roots; many pores; medium acid (pH 6.0); clear boundary.

B21t --- 53-84 cm -- dark brown (7.5 YR 3/3); silt loam: moderate, coarse, prismatic structure; friable; common pores; clay films on ped surfaces; fine manganese oxide mycelia; slightly acid (pH 6.5); gradual boundary.

IIB22t - 84-112 cm -- dark reddish brown (5 YR 2/4), silt loam; moderate, coarse, prismatic structure; firm; common pores; clay films on ped surfaces; few, fine, black bodies; few calcium carbonate mycelia; mildly alkaline (pH 7.7); gradual boundary.

IIB31 -- 112-165 cm -- dark, reddish-brown (5 YR 3/4); silty clay loam; moderate, coarse, prismatic structure; firm; few pores; few calcium carbonate mycelia; moderately alkaline (pH 8.1); gradual boundary.

IIB32 -- 165-216 cm -- dark, reddish-brown (5 YR 3/4); silty clay loam; moderate, coarse, prismatic structure; very firm, few pores; few, fine calcium carbonate mycelia; moderately alkaline (pH 7.9).

PEDON 9

Classification: Oscar series; Fine-silty, mixed, thermic, Typic Natrustalfs.

Location: 427 m south and 110 m west of the northeast corner of section 22, T. 27 N., R. 8 W.

Physiographic position: Stream terrace, 0-1 % concave slope; elevation 343 m.

Drainage: Somewhat poorly drained.

Vegetation: Mixed grasses.

Parent Material: High terrace of Quarternary alluvium.

Remarks: Water ponds in this area after rainstorms.

(Colors are for moist soils)

A1 ----- 0-6 cm -- very dark brown (10 YR 2/2); silt loam; weak, medium, granular structure; friable, common, fine roots and pores; mildly alkaline (pH 7.7); clear boundary.

B21t --- 6-41 cm -- dark grayish-brown (10 YR 4/2); clay loam; moderate, coarse, blocky structure; extremely firm; few, fine roots and pores; few, fine and medium-soft calcium carbonate concretions; strong effervescence; strongly alkaline (pH 8.5); gradual boundary.

B22t --- 41-64 cm -- very dark grayish-brown (10 YR 3/2); clay loam; moderate, coarse, blocky; extremely firm; few, fine roots and pores; common, fine and medium-soft bodies of calcium carbonate concretions; strong effervescence; strongly alkaline (pH 8.8); gradual boundary.

IIB23t - 64-86 cm -- very dark grayish-brown (10 YR 3/2); silty clay loam; weak, coarse, blocky structure; very firm; few, fine pores; common fine to coarse, soft and hard calcium carbonate concretions; strong effervescence; strongly alkaline (pH 8.7); gradual boundary.

IIB24t - 86-117 cm -- dark olive-gray (5 Y 3/2); silty clay; weak, coarse, blocky structure; very firm; few fine pores; medium, common olive (5 Y 4/3) mottles; common, fine to coarse, soft and hard calcium carbonate concretions; strong effervescence; strongly alkaline (pH 8.7); diffuse boundary.

IIC ---- 117-183 cm -- very dark grayish-brown (10 YR 3/2); silty clay loam; massive; extremely firm; fine, many olive (5 Y 4/3) mottles; few, fine, black (5 Y 2/1) mottles; common, fine to coarse, soft and hard calcium carbonate concretions; strong effervescence; strongly alkaline (pH 8.6).

TABLE VII

CHEMICAL ANALYSES - PEDON 1

Horizon	Depth (cm)	pH (1:1) H_2O	pH (1:1) KCl	CEC meq/100g	Exchangeable cations meq/100g Na^+	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+	%OM
Ap	0-12	5.8	5.4	9.2	2.3	.3	1.5	3.1	.1	1.9	.8
B21t	12-34	7.6	6.8	14.9	3.3	.4	2.9	2.5	.1	1.4	.9
B22t	34-54	7.7	7.1	22.8	5.3	.6	25.0	6.4	.4	1.2	.8
B3	54-82	8.2	7.8	12.3	2.0	.3	31.8	3.9	.2	0.3	.3
C	82-93	8.4	7.5	6.6	1.9	.2	28.9	2.3	.2	0.3	.1

Horizon	Depth (cm)	EC(1:1) mmho/cm	Soluble salts (1:1) meq/100g Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	CO_3^{2-}	HCO_3^-	SO_4^{2-}
Ap	0-12	14.1	16.1	.1	1.2	3.6	12.6	<.1	.2	1.3
B21t	12-34	6.2	7.1	<.1	0.3	0.8	4.2	<.1	.2	0.6
B22t	34-54	10.4	11.3	<.1	2.5	2.7	4.8	<.1	.2	2.4
B3	54-82	8.4	8.8	<.1	2.1	1.8	4.3	<.1	.2	1.1
C	82-93	4.5	5.2	<.1	0.2	0.3	3.0	<.1	.2	0.4

TABLE VIII

CHEMICAL ANALYSES - PEDON 2

Horizon	Depth (cm)	pH (1:1)		CEC meq/100g	Exchangeable cations meq/100g						%OM
		H_2O	KCl		Na^+	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+	
Ap	0-11	6.0	5.4	13.8	0.9	.5	4.9	3.9	.1	3.4	1.7
B21t	11-31	7.3	6.8	23.5	4.1	.9	6.5	9.9	.1	1.6	1.3
B22t	31-51	8.0	7.3	24.0	5.7	.9	28.4	15.5	.2	0.1	0.7
B3	51-76	8.7	8.2	10.5	2.9	.3	20.9	11.0	.2	<0.1	0.2
C	76-88	8.2	7.8	8.1	1.9	.3	30.2	7.5	.2	<0.4	0.1

Horizon	Depth (cm)	EC(1:1) mmho/cm	Soluble salts (1:1) meq/100g							
			Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	CO_3^{2-}	HCO_3^-	SO_4^{2-}
Ap	0-11	1.1	0.9	.2	.2	0.2	0.5	<.1	.2	.1
B21t	11-31	4.2	4.6	<.1	.4	0.8	2.0	<.1	.3	.6
B22t	31-51	5.7	6.7	<.1	.4	1.2	1.8	<.1	.4	.8
B3	51-76	5.0	5.5	<.1	.4	0.7	2.4	<.1	.3	.6
C	76-88	4.1	4.4	<.1	.3	0.5	2.2	<.1	.2	.5

TABLE IX

CHEMICAL ANALYSES - PEDON 3

Horizon	Depth (cm)	pH (1:1) H_2O	pH (1:1) KCl	CEC meq/100g	Exchangeable cations meq/100g Na^+	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+	%OM
Ap	0-8	6.1	5.9	14.2	0.1	.8	6.8	4.1	.2	6.3	1.9
A12	8-23	6.3	5.7	15.4	0.2	.5	6.4	5.4	.2	6.0	1.8
B21t	23-38	7.5	6.7	20.8	0.9	.5	6.3	10.7	.2	3.0	1.1
B22t	38-65	8.5	7.7	20.4	2.0	.5	28.0	16.5	.3	0.8	0.5
B3	65-102	8.7	8.0	11.6	1.6	.3	29.5	12.3	.2	1.4	0.2
C	102-113	8.7	8.0	8.4	1.5	.3	28.7	7.5		1.0	0.2

Horizon	Depth (cm)	EC(1:1) mmho/cm	Soluble salts (1:1) meq/100g Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	CO_3^{2-}	HCO_3^-	SO_4^{2-}
Ap	0-8	1.6	0.1	.1	.4	.4	.2	<.1	.6	.1
A12	8-23	0.3	0.1	<.1	.1	<.1	.3	<.1	.1	.1
B21t	23-38	0.4	0.3	<.1	.1	<.1	.4	<.1	.2	.1
B22t	38-65	1.6	1.3	<.1	.1	.2	.6	<.1	.3	.2
B3	65-102	2.1	1.8	<.1	.1	.2	.8	<.1	.3	.2
C	102-113	1.5	1.3	<.1	.1	.1	.6	<.1	.3	.2

TABLE X

CHEMICAL ANALYSES - PEDON 4

Horizon	Depth (cm)	pH (1:1)		CEC meq/100g	Exchangeable cations meq/100g						%OM
		H_2O	KCl		Na^+	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+	
Ap	0-11	6.3	5.7	11.1	1.3	.5	4.8	3.7	.1	3.8	1.4
B21t	11-26	7.6	6.7	26.0	5.8	.7	8.1	11.1	.3	3.0	1.3
B22t	26-48	7.8	7.2	26.7	4.1	.6	32.7	10.8	.6	<0.1	0.7
B31	48-112	8.0	7.6	12.1	3.0	.3	33.7	7.1	.4	0.4	0.4
B32	112-133	8.3	7.6	8.8	2.6	.3	30.0	6.7	.2	0.8	0.2
C	133-148	8.4	7.4	10.5	3.4	.3	29.7	7.0	.2	1.0	0.3

Horizon	Depth (cm)	EC(1:1) mmho/cm	Soluble salts (1:1) meq/100g							
			Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	CO_3^{2-}	HCO_3^-	SO_4^{2-}
Ap	0-11	5.0	4.4	<.1	0.8	1.1	3.4	<.1	.2	0.3
B21t	11-26	5.0	5.1	<.1	0.4	0.7	3.1	<.1	.1	0.5
B22t	26-48	8.4	8.5	<.1	1.5	2.5	4.8	<.1	.2	1.8
B31	48-112	6.8	7.2	<.1	0.7	1.1	3.9	<.1	.2	0.6
B32	112-133	2.7	4.4	<.1	0.5	0.1	2.2	<.1	.2	0.4
C	133-148	3.1	3.3	<.1	0.3	0.2	1.6	<.1	.3	0.3

TABLE XI

CHEMICAL ANALYSES - PEDON 5

Horizon	Depth (cm)	pH (1:1)		CEC meq/100g	Exchangeable cations meq/100g						%OM
		H_2O	KCl		Na^+	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+	
Ap	0-13	7.8	7.2	18.8	3.8	.9	21.4	4.1	.2	1.5	1.4
B21t	13-38	7.9	7.2	22.0	6.5	.9	20.4	9.8	.2	1.9	1.1
B22t	38-66	8.0	7.2	32.8	7.8	.8	32.9	12.4	.4	1.1	0.6
B23t	66-112	7.9	7.1	35.7	6.1	.7	23.8	4.3	.6	1.4	0.3
B3	112-165	3.2	7.3	30.4	8.1	.7	14.4	12.9	.4	1.4	0.2
IIC	165-175	8.2	7.3	22.7	6.3	.6	15.3	16.6	-	1.9	0.2

Horizon	Depth (cm)	EC(1:1) mmho/cm	Soluble salts (1:1) meq/100g							
			Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	CO_3^{2-}	HCO_3^-	SO_4^{2-}
Ap	0-13	13.0	13.7	<.1	3.3	2.5	9.3	<.1	.2	1.6
B21t	13-38	9.0	10.0	<.1	0.9	1.2	7.8	<.1	.4	0.6
B22t	38-66	7.9	8.3	<.1	0.7	1.1	6.1	<.1	.4	0.6
B23t	66-112	9.9	10.3	<.1	2.3	2.2	4.8	<.1	.3	0.7
B3	112-165	4.0	4.2	<.1	0.2	0.3	2.6	<.1	.6	0.4
IIC	165-175	3.9	4.1	<.1	0.3	0.2	2.2	<.1	.4	0.4

TABLE XII

CHEMICAL ANALYSES - PEDON 6

Horizon	Depth (cm)	pH (1:1)		CEC meq/100g	Exchangeable cations meq/100g						%OM
		H_2O	KCl		Na^+	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+	
Ap	0-23	7.9	7.1	30.5	0.2	.9	35.5	5.0	.2	1.5	5.0
B22t	23-51	8.2	7.2	29.1	0.4	.4	30.0	14.0	.4	0.4	2.6
B23t	51-84	8.6	7.5	25.9	3.0	.4	28.8	15.9	.5	0.5	1.1
B24t	84-137	8.7	7.6	23.1	3.9	.4	30.7	5.6	.5	0.4	0.5
B3	137-193	8.7	7.6	15.8	3.2	.3	6.4	14.4	.4	0.6	0.3
C	193-205	not sampled									

Horizon	Depth (cm)	EC(1:1) mmho/cm	Soluble salts (1:1) meq/100g							
			Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	CO_3^{2-}	HCO_3^-	SO_4^{2-}
Ap	0-23	0.3	0.1	<.1	.2	.1	0.3	<.1	0.5	0.6
B22t	23-51	0.3	0.2	<.1	.1	<.1	0.3	<.1	0.5	0.4
B23t	51-84	0.5	0.6	<.1	.1	.1	0.4	<.1	0.5	0.8
B24t	84-137	1.2	0.9	<.1	.1	.1	2.3	<.1	1.0	2.7
B3	137-193	1.4	1.0	<.1	.3	.2	3.8	<.1	2.6	6.0
C	193-205	not sampled								

TABLE XIII

CHEMICAL ANALYSES - PEDON 7

Horizon	Depth (cm)	pH (1:1)		CEC meq/100g	Exchangeable cations meq/100g						%OM
		H_2O	KCl		Na^+	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+	
Ap	0-13	7.6	6.3	14.4	3.1	.4	6.6	6.5	.1	2.2	.9
B21t	13-33	8.0	7.2	18.3	7.9	.5	60.0	5.7	.2	1.4	.8
B22t	33-71	8.1	7.5	17.0	3.3	.4	36.2	7.4	.2	0.6	.4
B3	71-186	8.2	7.2	15.6	4.4	.5	9.5	9.0	.2	1.2	.2
C	186-197	8.4	7.1	12.4	10.7	.5	28.1	11.1	.2	1.4	.2

Horizon	Depth (cm)	EC(1:1) mmho/cm	Soluble salts (1:1) meq/100g							
			Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	CO_3^{2-}	HCO_3^-	SO_4^{2-}
Ap	0-13	1.4	1.4	<.1	0.1	0.1	0.4	<.1	.4	5.6
B21t	13-33	4.2	4.1	<.1	0.5	0.9	0.4	<.1	.4	8.0
B22t	33-71	9.1	8.9	.1	2.2	3.5	1.1	<.1	.2	26.7
B3	71-186	2.6	2.8	<.1	0.1	0.1	0.9	<.1	.4	10.2
C	186-197	1.0	1.0	.1	0.1	0.1	0.8	<.1	.6	5.4

TABLE XIV

CHEMICAL ANALYSES - PEDON 8

Horizon	Depth (cm)	pH (1:1)		CEC meq/100g	Exchangeable cations meq/100g						%OM
		H_2O	KCl		Na^+	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+	
Ap	0-15	5.2	4.6	14.4	.1	.5	6.5	4.7	.3	6.7	1.7
B1	15-53	6.0	4.9	10.8	.2	.3	5.0	3.7	.2	3.7	0.7
B21t	53-84	6.5	5.1	11.4	.2	.4	7.8	5.0	.3	3.3	0.5
IIB22t	84-112	7.7	6.8	14.9	.3	.5	16.2	6.9	.2	1.9	0.4
IIB31	112-165	8.1	6.9	16.4	.3	.6	21.5	10.2	.3	1.1	0.3
IIB32	165-216	7.9	7.1	16.1	.2	.6	21.4	11.4	.3	1.1	0.3

Horizon	Depth (cm)	EC(1:1) mmho/cm	Soluble salts (1:1) meq/100g							
			Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	CO_3^{2-}	HCO_3^-	SO_4^{2-}
Ap	0-15	.7	.1	<.1	.1	.1	.1	<.1	.1	2.6
B1	15-53	.2	<.1	<.1	.1	<.1	.1	<.1	.1	0.3
B21t	53-84	.9	<.1	<.1	<.1	<.1	.1	<.1	.1	3.0
IIB22t	84-112	.3	<.1	<.1	.1	<.1	.1	<.1	.3	0.8
IIB31	112-165	.2	.1	<.1	.1	.1	<.1	<.1	.3	0.4
IIB32	165-216	.3	.1	<.1	.1	.1	.2	<.1	.3	0.7

TABLE XV

CHEMICAL ANALYSES - PEDON 9

Horizon	Depth (cm)	pH (1:1)		CEC meq/100g	Exchangeable cations meq/100g						%OM
		H_2O	KCl		Na^+	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+	
A1	0-6	7.7	6.9	20.4	1.5	1.8	15.2	11.9	.1	2.1	4.2
B21t	6-41	8.5	8.0	17.5	10.6	0.7	25.8	13.3	.3	0.8	0.8
B22t	41-64	8.8	8.0	15.9	17.2	0.6	13.5	13.6	.5	0.6	0.3
IIB23t	64-86	8.7	8.0	20.3	11.4	0.7	19.0	13.5	.5	1.8	0.3
IIB24t	86-117	8.7	7.9	21.3	20.2	0.8	23.7	10.9	.5	1.9	0.4
IIC	117-183	8.6	7.9	21.4	18.6	0.7	18.2	13.9	.6	1.9	0.3

Horizon	Depth (cm)	EC(1:1) mmho/cm	Soluble salts (1:1) meq/100g							
			Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	CO_3^{2-}	HCO_3^-	SO_4^{2-}
A1	0-6	1.1	0.9	.1	.1	.1	0.3	.1	1.2	3.9
B21t	6-41	9.4	11.8	.1	.2	.5	5.9	.1	1.2	13.9
B22t	41-64	7.8	9.8	.1	.2	.3	4.8	.1	0.6	14.9
IIB23t	64-86	5.1	5.4	.1	.1	.1	3.1	.1	0.6	13.6
IIB24t	86-117	5.2	5.6	.1	.1	.2	3.1	.1	0.6	6.8
IIC	117-183	3.8	4.5	.1	.1	.1	2.3	.1	1.0	6.8

TABLE XVI

MECHANICAL ANALYSES - PEDON 1

Particle size distribution for Pedon 1.

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm	Clay <0.002mm	Texture Class
		%							
A1	0-12	<.1	.1	.2	.5	12.4	73.8	13.0	Silt loam
B21t	12-34	<.1	.1	.2	.4	7.2	65.9	26.1	Silt loam
B22t	34-54	<.1	.1	.2	.4	2.3	57.8	39.1	Silty clay loam
B3	54-82	<.1	<.1	<.1	.1	.7	78.7	20.5	Silt loam
C	82-93	<.1	<.1	<.1	.2	.7	84.8	14.3	Silt loam

Particle size distribution - recalculated to a clay-free basis

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm
		%					
A1	0-12	<.1	.1	.2	.6	14.3	84.8
B21t	12-34	<.1	.1	.3	.5	9.7	89.4
B22t	34-54	<.1	.1	.3	.7	3.8	95.1
B3	54-82	<.1	<.1	<.1	.1	0.9	99.0
C	82-88	<.1	<.1	<.1	.2	0.8	99.0

TABLE XVII

MECHANICAL ANALYSES - PEDON 2

Particle size distribution for Pedon 2.

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm	Clay < 0.002mm	Texture Class
		%							
Ap	0-11	<.1	.3	.7	1.1	6.3	73.3	18.3	Silt loam
B21t	11-31	<.1	.1	.3	0.6	2.8	59.2	37.0	Silty clay loam
B22t	31-51	.1	.3	.8	1.7	2.5	55.7	38.9	Silty clay loam
B3	51-76	<.1	<.1	<.1	0.3	0.9	73.0	25.8	Silt loam
C	76-88	<.1	<.1	<.1	0.6	2.4	81.2	15.8	Silt loam

Particle size distribution - recalculated to a clay-free basis

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm
		%					
Ap	0-11	<.1	.4	0.9	1.3	7.7	89.7
B21t	11-31	<.1	.2	0.5	1.0	4.4	94.0
B22t	31-51	.2	.5	1.3	2.8	4.1	91.1
B3	51-76	<.1	<.1	<0.1	0.4	1.2	98.4
C	76-88	<.1	<.1	<0.1	0.7	2.9	96.4

TABLE XVIII

MECHANICAL ANALYSES - PEDON 3

Particle size distribution for Pedon 3.

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm	Clay <0.002mm	Texture Class
		%							
Ap	0-8	<.1	.2	.4	.6	5.4	74.0	19.4	Silt loam
A12	8-23	<.1	.1	.3	.5	5.8	70.8	22.5	Silt loam
B21t	23-38	<.1	.1	.2	.5	5.3	60.8	33.2	Silty clay loam
B22t	38-65	.1	.1	.3	.5	2.4	59.7	36.9	Silty clay loam
B3	65-102	<.1	<.1	.1	.3	0.8	70.0	28.8	Silty clay loam
C	102-113	.5	.2	.1	.2	1.1	77.2	20.7	Silt loam

Particle size distribution - recalculated to a clay-free basis

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm
		%					
Ap	0-8	<.1	.2	.5	.7	6.7	91.9
A12	8-23	<.1	.1	.4	.6	7.5	91.4
B21t	23-38	<.1	.1	.3	.7	7.9	91.0
B22t	38-65	.2	.2	.5	.8	3.8	94.5
B3	65-102	<.1	<.1	.1	.4	1.1	98.4
C	102-113	.6	.3	.1	.3	1.4	97.3

TABLE XIX

MECHANICAL ANALYSES - PEDON 4

Particle size distribution for Pedon 4.

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm	Clay <0.002mm	Texture Class
		%							
Ap	0-11	.1	.2	.6	.9	6.9	74.3	17.0	Silt loam
B21t	11-26	.1	.1	.3	.4	3.3	50.2	45.7	Silty clay
B22t	26-48	.1	.1	.2	.4	2.7	55.3	41.3	Silty clay
B31	48-112	.2	.1	.1	.3	1.3	70.8	27.2	Silty clay loam
B32	112-133	.2	.7	.8	.8	1.1	71.3	25.1	Silt loam
C	133-148	.1	.1	.1	.1	0.6	78.9	20.2	Silt loam

Particle size distribution - recalculated to a clay-free basis

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm
		%					
Ap	0-11	.1	.2	0.7	1.1	8.3	89.6
B21t	11-26	<.1	.2	0.6	0.7	6.1	92.4
B22t	26-48	<.1	.2	0.3	0.7	4.6	94.2
B31	48-112	.3	.1	0.1	0.4	3.7	97.4
B32	112-133	.3	.9	1.1	1.1	1.5	95.1
C	133-148	.1	.1	<0.1	0.1	0.8	98.9

TABLE XX

MECHANICAL ANALYSES - PEDON 5

Particle size distribution for Pedon 5.

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm	Clay <0.002mm	Texture Class
		%							
Ap	0-13	<.1	0.3	3.0	2.1	2.6	54.5	37.5	Silty clay loam
B21t	13-38	<.1	0.3	3.0	2.0	2.7	44.5	47.5	Silty clay
B22t	38-66	.1	1.6	2.7	1.9	2.2	42.4	49.1	Silty clay
B23t	66-112	.1	0.2	1.4	1.4	1.9	38.7	56.3	Clay
B3	112-165	<.1	0.1	0.6	1.0	2.3	46.5	49.5	Silty clay
IIC	165-175	<.1	0.5	2.3	8.5	4.8	53.3	30.6	Silty clay loam

Particle size distribution - recalculated to a clay-free basis

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm
		%					
Ap	0-13	.1	0.5	4.8	3.4	4.2	87.1
B21t	13-38	.1	0.6	5.7	3.8	5.1	84.8
B22t	38-66	.2	3.1	5.3	3.7	4.3	83.4
B23t	66-112	.2	0.5	3.2	3.2	4.3	88.6
B3	112-165	.1	0.2	1.2	2.0	4.6	92.0
IIC	165-175	.1	0.7	3.3	12.2	6.9	76.9

TABLE XXI

MECHANICAL ANALYSES - PEDON 6

Particle size distribution for Pedon 6.

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm	Clay <0.002mm	Texture Class
		%							
Ap	0-23	<.1	.3	3.3	2.0	1.7	47.1	45.6	Silty clay
B22t	23-51	.5	.4	2.7	1.8	2.0	45.8	46.8	Silty clay
B23t	51-84	.3	.2	1.3	1.1	2.2	46.6	48.3	Silty clay
B24t	84-137	<.1	.1	0.8	0.7	3.1	46.5	48.8	Silty clay
B3	137-193	<.1	.1	0.1	0.1	2.2	62.5	35.0	Silty clay loam
C	193-205	not sampled							

Particle size distribution - recalculated to a clay-free basis

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm
		%					
Ap	0-23	<.1	.6	6.1	3.7	3.3	86.3
B22t	23-51	.9	.8	5.1	3.4	3.8	86.0
B23t	51-84	.6	.4	2.5	2.1	4.2	90.2
B24t	84-137	<.1	.2	1.6	1.4	6.0	90.8
B3	137-193	<.1	.1	0.2	0.2	3.4	96.0
C	193-205	not sampled					

TABLE XXII

MECHANICAL ANALYSES - PEDON 7

Particle size distribution for Pedon 7.

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm	Clay < 0.002mm	Texture Class
		%							
Ap	0-13	<.1	.2	.7	0.5	1.9	69.8	26.9	Silt loam
B21t	13-33	<.1	.1	.2	0.2	1.6	63.5	34.4	Silty clay loam
B22t	33-71	<.1	<.1	.1	0.2	2.6	66.5	30.6	Silty clay loam
B3	71-186	<.1	<.1	.1	0.7	4.6	65.2	29.4	Silty clay loam
C	186-197	<.1	<.1	.2	1.0	5.8	66.1	26.9	Silt loam

Particle size distribution - recalculated to a clay-free basis

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05	Silt 0.05-0.002mm
		%					
Ap	0-13	<.1	.3	1.0	0.7	2.6	95.4
B21t	13-33	<.1	.2	0.3	0.3	2.4	96.8
B22t	33-71	<.1	<.1	0.1	0.3	3.7	95.9
B3	71-186	<.1	<.1	0.1	1.0	6.5	92.4
C	186-197	<.1	<.1	0.3	1.4	7.9	90.4

TABLE XXIII

MECHANICAL ANALYSES - PEDON 8

Particle size distribution for Pedon 8.

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm	Clay < 0.002mm	Texture Class
		%							
Ap	0-15	.1	.1	0.4	0.7	5.0	74.2	19.6	Silt loam
B1	15-53	.1	.1	1.0	1.4	9.3	75.1	13.1	Silt loam
B21t	53-84	.1	.4	4.2	2.1	8.2	63.2	21.9	Silt loam
IIB22t	84-112	.1	.1	1.1	0.8	4.6	69.1	24.4	Silt loam
IIB31	112-165	.1	.1	0.1	0.4	3.2	68.8	27.5	Silty clay loam
IIB32	165-216	.1	.1	0.1	0.6	3.3	67.9	28.1	Silty clay loam

Particle size distribution - recalculated to a clay-free basis

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm
		%					
Ap	0-15	<.1	.1	0.5	0.9	6.2	92.3
B1	15-53	<.1	.1	1.2	1.6	10.7	86.4
B21t	53-84	<.1	.5	5.4	2.7	10.5	80.9
IIB22t	84-112	<.1	<.1	1.5	1.1	6.1	91.4
IIB31	112-165	<.1	<.1	0.1	0.6	4.4	94.9
IIB32	165-216	<.1	<.1	0.1	0.8	4.6	94.4

TABLE XXIV

MECHANICAL ANALYSES - PEDON 9

Particle size distribution for Pedon 9.

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm	Clay <0.002mm	Texture Class
		%							
A1	0-6	.1	1.5	9.7	9.0	8.3	53.3	18.1	Silt loam
B21t	6-41	.3	2.1	9.5	10.2	7.6	39.1	31.2	Clay loam
B22t	41-64	.1	2.0	9.5	7.7	6.2	41.1	33.4	Clay loam
IIB23t	64-86	.1	1.3	7.6	5.8	3.3	45.1	36.8	Silty clay loam
IIB24t	86-117	.1	0.6	5.9	4.7	2.5	46.2	40.0	Silty clay
IIC	117-183	.1	0.9	7.5	5.4	2.9	45.4	37.8	Silty clay loam

Particle size distribution - recalculated to a clay-free basis

Horizon	Depth (cm)	Very Coarse Sand 2-1mm	Coarse Sand 1-0.5mm	Medium Sand 0.5-0.25mm	Fine Sand 0.25-0.1mm	Very Fine Sand 0.1-0.05mm	Silt 0.05-0.002mm
		%					
Ap	0-6	.1	1.8	11.9	11.0	10.1	65.1
B21t	6-41	.4	3.1	13.8	14.8	11.0	56.9
B22t	41-64	.2	3.0	14.3	11.6	9.3	61.6
IIB23t	64-86	.2	2.1	12.0	9.2	5.2	71.3
IIB24t	86-117	.2	1.0	9.8	7.8	4.2	77.0
IIC	117-183	.2	1.4	12.1	8.7	4.7	72.9

VITA 2

Thomas Glynn Reinsch

Candidate for the Degree of

Master of Science

Thesis: COMPARATIVE STUDY OF SLICKSPOTS IN GRANT COUNTY, OKLAHOMA

Major Field: Agronomy

Biographical:

Personal Data: Born in Gilroy, California, June 28, 1955, the son of Mr. and Mrs. Cecil A. Reinsch.

Education: Graduated from Gilroy High School, Gilroy, California, in June, 1973; received Bachelor of Science degree in Agronomy from Brigham Young University, Provo, Utah, in August, 1978; completed requirements for Master of Science in Agronomy at Oklahoma State University, Stillwater, Oklahoma, in December, 1979.

Professional Experience: Spanish teacher, Language Training Mission, Brigham Young University, 1976-78; lab instructor, Agronomy Department, Brigham Young University, 1977-78; lab technician, Agronomy Department, Brigham Young University, 1978; graduate research assistant, Agronomy Department, Oklahoma State University, 1978-1979.