December 18, 1969

To the Graduate Council:

I am submitting herewith a thesis written by Charern Oonmuang entitled "Some Chemical and Morphological Characteristics of Twelve Tennessee Soils." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:

Vice Chancellor for
Graduate Studies and Research

SOME CHEMICAL AND MORPHOLOGICAL CHARACTERISTICS OF TWELVE TENNESSEE SOILS

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Charern Oonmuang

March 1970

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ABSTRACT

Tennessee soils are many and varied. They vary widely in both texture and fertility. Therefore, each soil needs to be characterized in detail for crop suitability. Some chemical properties of twelve soil profiles were investigated. The chemical properties selected for study were those that were believed to most strongly influence the classification and fertility status of the soils.

The main objective of this study was to determine some selected chemical characteristics of several representative soils in Tennessee. A second objective was to compare the chemical characteristics within and among the soils studied.

Twelve soil series located on six Agricultural Experiment Stations of The University of Tennessee in East, Middle, and West Tennessee were investigated. The following properties were studied: pH by five different methods, cation exchange capacity by two different methods, exchangeable bases, percent base saturation, exchange acidity, available P and K, and particlesize distribution.

Most soils studied were low in pH, percent base saturation, Ca/Mg ratios and available P and K in the subsoils, but these values were relatively high in the surface horizons. Cation exchange capacity of most soils was rather low except in Sequoia and Maury soils. Exchangeable Ca was rather high, while exchangeable Mg was relatively low in most of the soil profiles. Exchangeable K and Na were very low throughout the soil profiles. Exchange acidity showed considerable fluctuation, as did the soil reaction among horizons of each soil profile.

In all soil profiles, cation exchange capacity varied with exchange acidity and with clay content. Exchange acidity also varied with clay content, with the exception of the Dickson and Sequatchie profiles. The pH values varied with the sum of exchangeable bases and percent base saturation in all soils studied.

Two cycles of profile development were noted in the Dickson, Huntington, Sequoia, Collins, Grenada, Emory, Tilsit, Loring, and Dexter profiles, but there was only one developmental sequence in the Sequatchie, Maury, and Hartsells profiles. The laboratory data appeared to support the field observations in this regard.

The ammonium acetate and the sum of cations methods were used in determining cation exchange capacity and in calculating percent base saturation. In certain soils, great differences between the two cation exchange capacity methods were noted as regards the magnitude of the cation exchange capacity and the percent base saturation, whereas, with other soils, little difference between the two cation exchange capacity methods was noted in the magnitude of these two properties.

The younger soils appeared to have greater differences in percent base saturation, calculated by the ammonium acetate-cation exchange capacity method versus by the sum of cations-cation exchange capacity method, than did the older soils. Emory and Collins profiles showed the greatest differences in percent base saturation, due to cation exchange capacity method, whereas Sequoia and Tilsit both had the smallest differences in this value between the cation exchange capacity methods. In the cases of the other eight soils, the effect of the cation exchange capacity method

on the magnitude of the percent base saturation was variable. The cation exchange capacity values determined by the two methods showed similar trends.

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CHAPTER I

INTRODUCTION

In recent years recognition of the soil as a natural body and as a basis of natural wealth has given it and the science of Pedology a high degree of importance (51). The background of observations upon which the generalization of this young science rests is as yet comparatively limited, and the final universal statement of many basic and fundamental principles has not been agreed upon by scientists. Therefore, each addition to the existing body of knowledge or each restatement of observations from different points of view is considered to be of some value at this particular time in the development of the science. Many soils are recognized in Tennessee and each needs to be characterized in detail.

Tennessee soils are many and varied. They vary widely in both texture and fertility. In texture, they range from the heavy clays in the East Tennessee Valley to the sandy soils of the Cumberland Plateau; in fertility, they range from the low fertility, gravelly and slate hill soils to the very fertile, loamy valley and river botton soils. These soil differences are due to differences in parent material, climate, relief, time, and vegetation. The topography of the state also has been strongly influenced by the characteristics of the original rock formations and by the stratigraphic positions in the landscape.

Some Tennessee soils are adapted to a wide range of crop plants, whereas others have notable limitations. Soil suitability for any purpose is directly related to its morphological, chemical, physical, and mineralogical characteristics. Research in soil science has been aimed primarily toward better methods of soil management and increased crop production, without much effort to relate yields to the fundamental properties of soil profiles.

Recommendations for use of lime and fertilizer in Tennessee are based on soil tests made on samples of the surface soil. There is some information on the nutrient levels of subsoils. The surface soil determinations might have limited values for estimating the soil fertility status of the profile where use of lime and fertilizer has been appreciable. The nutrient levels of the soil profile to rooting depth should be investigated for fertilizer and lime recommendations.

The objectives of this study were:

1. To determine some selected chemical characteristics of some selected representative soil series.
2. To compare the chemical characteristics within and among these soils.

CHAPTER II

REVIEW OF LITERATURE

I. SOIL REACTION AND ITS IMPORTANCE

The pH and nutrient levels of a soil from the surface through the subsurface layers to rooting depth play significant roles in plant growth. pH often can be a symptom of some disorder in the nutrient status in the soil.

Several workers have stated that the use of pH determination would be of greatest value if evaluated in connection with some other soil properties such as texture, cation exchange capacity, organic matter and exchangeable calcium (11, 47, 53).

Shaw (47) described difficulties of soil pH measurements which could lead to differences in lime requirements of from a few hundred to several thousand pounds of calcium carbonate per acre. Variations in pH values caused by dilution, presence of electrolytes, carbon dioxide concentration, and clay mineral type have been pointed out (11). McGeorge (27) mentioned that the principal variables affecting the soil pH measurements are: drying of the soil sample, the soil water content, the content of soluble salts, the content of carbon dioxide as influenced by season or drying, the amount of grinding given the soils, and the field variation from core to core.

In general, the more dilute the soil suspension, the higher the soil pH value found, whether the soil is acid or alkaline (28). Jackson

(25) stated that the use of 1:1 soil:water ratio is common. The determination of pH at various other moisture contents has been made. Soil:water ratios from the sticky point to a 1:10 soil:water ratio are used in different laboratories. The rise in soil pH with dilution, from the sticky point to a 1:10 ratio of soil:water, is usually between 0.2 and 0.5 of a pH unit, but may be 1.0 or more pH units in certain neutral and alkaline soils (9). McGeorge (28) suggested the adoption of the practice of determining the pH value in a mixture of 1:10 of soil: water, because at this dilution the potentially alkaline compounds reach an approximate maximum hydrolysis.

The presence of soluble salts should have a more pronounced effect on pH in soils with a low buffer capacity than on those of higher buffer capacity. Carolus and Lucas (8) stated that in most cases where soil samples were leached with distilled water the pH increased; in a few cases it was depressed. The rise of pH was probably due to the removal of soluble salts of strong acids, since the addition of small quantities of such salts will depress the soil pH. Reed and Cummings (42) and Whitney and Gardner (56) pointed out that leaching also may have removed some carbon dioxide which would have a depressing influence on the pH values above pH 6.0.

Coleman and Mehlich (11) stated that seasonal changes of salt content could change the pH as much as 0.5 unit. For precise soil studies involving pH measurements, Bell (1) suggests that it is desirable that pH values be reproducible after various periods and at different seasons of sampling. For such studies, it would be important to remove the

soluble salts by leaching (with carbon dioxide free-water) before making the pH determinations on the soil samples.

pH may be measured in dilute salt solutions of definite concentrations to eliminate some of these variations. Dunn (16) stated that the pH values were 1.0 to 1.5 units lower in salt solutions than in water. Schofield and Taylor (44) have proposed a method for determination of soil pH in 0.01M $CaCl_2$. Measurement of pH in 0.01M $CaCl_2$ solution has several advantages which are: the masking of the variability in salt content of soils, the maintaining of the soil in a flocculated condition, and the decreasing of the junction potential effect. Coleman and Mehlich (11) considered this method a more reliable index to soil reaction than pH measurements in water because pH in 0.01M $CaCl_2$ does not vary with seasonal salt content or soil:solution ratio. Graham (19) suggested an interpretation of pH values of mineral soils measured in 0.01M $CaCl_2$ in terms of percent base saturation and crop suitability. Peech (39) also stated that pH values determined in 0.01M $CaCl_2$ is a better index of base saturation than is the pH of the soil measured in water. Under similar conditions he found that the pH values obtained by this method are lower than those obtained in water.

II. EXCHANGE ACIDITY AND ITS DETERMINATION

Shaw (47) expressed the idea that the term "exchangeable hydrogen" was similar in connotation to "soil acidity." Coleman and others (11, 12) preferred the use of the term "exchange acidity" to "exchangeable hydrogen." They suggested that part of the permanent charge which was not

neutralized by basic metal cations was saturated by aluminum, and that the only exchangeable hydrogen in most mineral soils is that which is neutralized between pH 6.0 and pH 8.2.

A great deal of attention has been given to the determination of exchange acidity as an estimate of the lime requirement of soils (35, 47, 48). Several methods have been developed for these purposes. It is important to understand the respective principles of the method used in the determination of exchange acidity, and also to evaluate the effect of the other soil properties in order to make an accurate estimation of fertilizer and lime recommendation (35, 36).

The $BaCl_2$-triethanolamine (TEA) and ammonium acetate methods appear to be those most commonly used for the determination of exchange acidity. The ammonium acetate method described by Peech et al. (36) involves extraction with neutral normal ammonium acetate for the simultaneous determination of exchangeable bases and cation exchange capacity (35, 36, 45). Exchange acidity is then calculated as the difference between the cation exchange capacity and the sum of bases. Peech et al. (36) stated that the NH_4OAC method gave high results on soils high in organic matter because of decomposition of organic matter. However, in a subsequent study of the ammonium acetate method by Peech et al. (37) it was suggested that the low results for exchange acidity, as determined by differences, are presumably due to losses of some ammoniated organic constituent upon washing out the excess of ammonium acetate from the soil with 95 percent ethyl alcohol.

The $BaCl_2$-TEA method as described by Peech (38) involves extraction with barium chloride buffered at pH 8.0 ($\pm$ 0.02) with triethanolamine.

Several researchers have reported lower values with the ammonium acetate method than with the $BaCl_2$-TEA method for exchange acidity on 1:1 clay minerals and also on organic soils (36, 40, 49). Mehlich (30) also pointed out the more complete neutralization of 1:1 clay type and organic soils by the $BaCl_2$-TEA method as compared to the ammonium acetate method.

III. CATION EXCHANGE PROPERTIES OF ACID SOILS

The property of ion-exchange and the exchange reaction are of very great basic and practical significance in all fields in which clay minerals are studied and used. In the field of soils, plant nutrients are primarily held in the soil as exchangeable ions; consequently, their persistence in the soil and their availability for plant growth depend on exchange reactions.

Jackson (25) stated that the two most reliable definitions of CEC are the quantities of cations absorbed from salt solutions buffered at either pH 7.0 or from those buffered at pH 8.2. The former has the rationale of neutrality. The latter corresponds to Bradfield's (5) definition of a calcium-saturated soil and has more pertinence in calcareous than in acid conditions. Coleman and Thomas (14) stated that a pH of 8.0 or a little higher empirically appears to correspond with complete neutralization of sorbed Fe^{3+} or Al ions. Thus, CEC determined by salt solutions buffered at pH 8.2 as $BaCl_2$-TEA may give a reasonably close estimate

of the lattice charge of layer silicates, including contributions from organic matter which may be present. In most cases, the cation exchange capacity is determined at pH of 7.0 or above because it includes most of those charges dependent on pH as well as the more or less permanent ones. The cation exchange capacity of the colloidal fraction of soils exhibits a wide range, because of the variable amount of humus and of the kinds and propertions of the clay minerals present. The cation exchange capacity of humus, vermiculite, montmorillonite, hydrous mica and chlorides, kaolinite and hydrous oxides, are more or less in the order of 200, 150, 100, 30, 8 and 4 m.e./100 g soil, respectively (6).

Coleman and Thomas (15) stated that cation exchange capacity varied with soil particle sizes and that most of the cation exchange properites of the inorganic portion of soils are characteristically concentrated in the clay fraction. The percent clay content is therefore a major factor influencing the magnitude of the cation exchange capacity of a soil. Jackson (26) reported that the decrease of cation exchange capacity and base saturation of the soils studied correspond to the decrease of clay content.

Grim (20) stated that the cation exchange capacity of clay minerals per se varied over a wide range, due to such factors as particle size, crystallinity, and time of treatment with the extractant.

IV. RELATIONSHIPS OF SOIL REACTION TO OTHER SOIL PROPERTIES

Coleman and others (11, 12) related pH and exchangeable cations to two sources of cation exchange capacity. The permanent charge of clay

minerals results from their crystal structure. The pH-dependent charge results chiefly from ionization of hydrogen ions from Si-OH groups and does not contribute to the effective cation exchange capacity of the soils. Organic matter has only pH-dependent charge resulting from ionization of hydrogen from carboxyl and phenol groups of the organic matter. In this concept, the pH at which exchangeable cations and cation exchange capacity are determined and the amount of clay and the kind of clay and of organic matter influence the magnitude of cation exchange capacity values.

Pratt and Bair (41) studied CEC of 15 acid California surface soils at pH between three and eight. They concluded that the pH-dependent CEC was due both to organic matter and to clay. Apparently 60 Wisconsin soils studied by Helling *et al.* (22) were only slightly interlayered with hydrous sesquioxide, and thus retained appreciable pH permanent charge at low pH. They measured CEC of soils at pH values between two and eight, and by multiple correlation analysis determined the contributions of organic matter and of clay at each pH level. CEC of the clay was nearly constant in the pH range of five to seven; organic matter was the major contributor to the pH-dependent CEC. Similar results of CEC-pH relationship for Michigan soils were obtained by Rose *et al.* (43).

Bhumbla and Mclean (3) studied the CEC measured for several limed and unlimed surface soils from Ohio, using $BaCl_2$-TEA at pH 8.2 and NH_4OAc at pH 7.0. Their results showed that generally CEC at pH 8.2 was larger than CEC at pH 7.0, and that the difference between the two methods was correlated directly with organic matter content. Subsoil samples

of the Red Yellow Podzolic soils studied by Coleman et al. (13) had an average CEC of 5.7 m.e., with a range from 3.2 to 8.3 m.e. Their acid soils derived from shale and sandstone had an average of 6.4 m.e. Much larger differences of CEC are observed among some soils containing heavily interlayered vermiculite or allophane. They also stated that in the Southeastern soils with pH near 5.0, neutral salt CEC is very small.

pH-percent base saturation relationships differ greatly from soil to soil. pH is a measure of hydrogen ion concentration, and it usually has a direct relationship to degree of base saturation. On the basis of calculations on percent base saturation versus CEC at pH 8.2, as determined with $BaCl_2$-TEA, Mehlich and Colwell (29) concluded that montmorillonite and illite, and those soils containing these minerals, required some 80 percent base saturation to reach pH 7.0, while soils dominated by kaolinite and/or organic matter reached pH 7.0 when they were 30 percent to 50 percent base saturated. Dunn (16) and Webster and Harward (54) reported better correlation of pH with base saturation when pH was determined in salt solution than when pH was determined in water. For the relation of percent base saturation to clay types, several researchers (12, 29, 31) reported that a lower degree of base saturation was required on 1:1 clay mineral types to produce responses of certain plants than for 2:1 types. Coleman, Kamprath, and Weed (12) related this to whether the charge was pH-dependent or pH-independent.

V. RELATIONSHIPS OF SURFACE AND SUBSOIL TO PLANT GROWTH

It is generally agreed that both the characteristics and nature of the profile within the plow layer and of that below this layer influence the growth of plants and the yields obtained. Winters and Simonson (57), summarizing the information on the kinds, characteristics, and behavior of subsoils by soil groups, stated that there is a growing interest in that part of the soil profile which lies beneath the surface soil, and also in the effect of subsoil on plant growth response. The quantity of mineral plant nutrients in the subsoil of many soils is suggested as a fruitful question for study. Fitts and Nelson (17) discussed the usefulness of information about the lower profile characteristics relative to plant nutrient availability and to acidity. They pointed out that under most farming conditions the fertility characteristics of the soil profile below the surface soil do not change materially in a short time.

Murdock and Engelbert (32), studying the importance of subsoil phosphorus to corn, concluded that the subsoil as well as topsoil levels of phosphorus should be considered when fertilizer recommendations are made.

Winters and Simonson (57), discussing the difference between fertility levels of the A and B horizons, mentioned that the movement of amendments into the deeper horizons is slow except for nitrates and sulfates. Thus, the original relationship of nutrient levels between these horizons may be obscured under cultivation because of fertility changes in the A horizon due to soil management. Wells and Parks (55)

reported the vertical distribution of soil phosphorus and potassium on established alfalfa stands on Maury, Dickson, Dunmore, and Dewey silt loams in Tennessee. The conclusion was that in these soils, except Maury, added phosphorus was retained in a 0-3 inch soil layer and added potassium was retained predominantly in the 0-6 inch layer. A more significant movement of potassium was found where the higher rates of fertilization were applied.

CHAPTER III

METHODS AND PROCEDURES

I. FIELD METHODS

The twelve soil series selected represent a wide range of parent materials, textures, and physiographic positions in East, Middle, and West Tennessee. Soils studied were located on six Agricultural Experiment Stations of The University of Tennessee as shown below:

1. The University of Tennessee, Knoxville
    1.1. Sequoia series
    1.2. Sequatchie series
2. Plateau Experiment Station, Crossville
    2.1. Hartsells series
    2.2. Tilsit series
3. Highland Rim Experiment Station, Springfield
    3.1. Huntington series
    3.2. Dickson series
4. Middle Tennessee Experiment Station, Spring Hill
    4.1. Emory series
    4.2. Maury series
5. The University of Tennessee, Martin
    5.1. Collins series
    5.2. Grenada series

6. West Tennessee Experiment Station, Jackson

6.1. Loring series

6.2. Dexter series

Pits were excavated at each location to an approximate depth of 60 inches except at the Hartsells site, which was underlain by bedrock at a relatively shallow depth. The profiles were described and sampled by genetic horizons. A vertical slice of approximately eight inches by six inches in cross section was removed from the profile, and the morphological characteristics of the soil were described using observational standards developed by Buntley (7). Natural peds were selected from each horizon for color characterization. Munsell color notations of moist and dry soil were recorded.

Samples were collected from each described horizon to the depth of the pit as outlined by the Soil Conservation Service, United States Department of Agriculture Soil Characterization Laboratories (50). Contamination of horizons was avoided by sampling upward from the bottom of the profile. Soil samples were collected and labeled by horizon and depth; then each horizon sample was stored in a plastic bag inside a gallon cardboard carton.

II. LABORATORY METHODS

Soil samples were air-dried, rolled with a bottle as a rolling pin to break up aggregates, and passed through a 2 mm. seive. Samples were then mixed thoroughly by rolling on a large sheet of paper, and stored in gallon cardboard cartons. A sub-sample of approximately one

pint of each well-mixed sample was taken for determination of chemical properties in the laboratory.

Cation exchange capacity and exchangeable base determinations were made in duplicate on samples from six profiles, and single determinations were made on the samples from the remaining six profiles.

pH was determined on air-dried samples using five different methods as follows: water paste; 1:1 of soil:0.01 M $CaCl_2$ ratio; 1:1 of soil:water ratio; 1:10 of soil:water ratio; and after leaching out salts with distilled water. The suspension was allowed to stand about 30 minutes; the suspension was again stirred and pH determined with a Fisher Model 210 glass electrode pH meter.

Exchangeable bases were extracted with one normal ammonium acetate, (NH_4OAc), pH 7.0 (50). Exchangeable calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) were determined directly on the leachate using an Hitachi Perkin-Elmer Model 139-0400 flame spectrophotometer (24).

Cation exchange capacity (CEC) was determined by two procedures. First, by direct distillation of absorbed NH_4^+ ions from NH_4OAc-leached soil, after removal of excess NH_4OAc with 95 percent ethanol (50). Second, by sum of cations, i.e., Ca, Mg, K, Na, and exchange acidity.

Exchange acidity (EA) was determined by the barium chloride-triethanolamine ($BaCl_2$-TEA) method, pH 8.0 ($\pm$ 0.02) by titration of the $BaCl_2$-TEA leachate with 0.2 normal hydrochloric acid (HCl), as described by Peech (38).

Available phosphorus (P) and potassium (K)[1], were extracted with 0.05 normal sulfuric acid (H_2SO_4) containing 1 percent ammonium sulfate [$(NH_4)_2SO_4$], with a soil:solution ratio of 1:4. Phosphorus and potassium were determined colorimetrically and spectrophotometrically, respectively, as outlined by Page (33).

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[1]Appreciation is expressed to the State Soil Testing Laboratory, Nashville, for analysis for available P and K.

CHAPTER IV

RESULTS AND DISCUSSION

I. CHEMICAL PROPERTIES OF SOILS STUDIED

pH Values

pH values of twelve soil series determined by five different methods are given in Table V, Appendix A. In comparing the five methods, the pH values determined in 0.01M $CaCl_2$ were lower than in the other four methods, with all soils studied. The comparisons of the average pH differences of all soils are shown in Table I and in Figure 1. pH values determined in 0.01M $CaCl_2$ were 0.4, 0.6, 0.9, and 0.9 units lower, respectively, than in water paste, in 1:1 soil-water, in 1:10 soil-water, and in leached soil. These results agreed with the study by Schofield and Taylor (44) working on salt pH by 0.01M $CaCl_2$. They report the pH measured in this solution is about 0.5 pH unit lower than that measured in a 1:2 soil-water ratio.

The pH values of each soil sample varied with the methods used. The pH increased progressively from the 1:1 soil:0.01M $CaCl_2$ mixture, water paste, a 1:1 soil-water mixture, a 1:10 soil-water mixture, and leached soil, with the exception of the last two methods. This result was attributed to a corresponding decrease in the salt concentration of the soil:water mixture used for making the pH measurements. pH values of the Sequatchie soil, for example, increased as the concentration of soluble salts decreased as caused by increases in water:soil ratio (Figure 2). Similar results were found in all soils studied.

TABLE I

COMPARISONS OF THE AVERAGE pH DIFFERENCES AMONG FIVE pH PROCEDURES

Soil Series	Number of Samples*	0.01M $CaCl_2$ soil pH versus Water Paste	0.01M $CaCl_2$ soil pH versus Soil:Water 1:1	0.01M $CaCl_2$ soil pH versus Soil:Water 1:10	0.01M $CaCl_2$ soil pH versus Water Leached	Water Paste Soil pH versus Soil:Water 1:1	Water Paste Soil pH versus Soil:Water 1:10	Water Paste Soil pH versus Water Leached	Soil:Water pH 1:1 versus Soil:Water 1:10	Soil:Water pH 1:1 versus Water Leached	Water Leached Soil pH versus Soil:Water 1:10
Dickson	6	0.6	0.7	0.9	0.9	0.1	0.3	0.3	0.2	0.3	0.01
Huntington	9	0.5	0.5	0.8	0.7	0.1	0.3	0.3	0.2	0.2	-0.04
Sequoia	8	0.5	0.8	0.7	1.0	0.2	0.3	0.6	0.1	0.4	0.3
Sequatchie	7	0.3	0.6	1.0	0.9	0.3	0.8	0.6	0.4	0.3	-0.1
Collins	8	0.2	0.5	0.8	0.8	0.3	0.5	0.7	0.3	0.3	-0.01
Grenada	7	0.4	0.6	0.9	0.8	0.2	0.5	0.4	0.3	0.3	-0.1
Emory	8	0.5	0.7	0.9	0.8	0.1	0.4	0.2	0.2	0.1	-0.1
Maury	6	0.6	0.7	0.8	0.9	0.03	0.2	0.2	0.1	0.2	0.2
Hartsells	4	0.7	0.8	1.0	0.8	0.1	0.3	0.2	0.3	0.1	0.2

TABLE I (continued)

Soil Series	Number of Samples*	0.01M $CaCl_2$ soil pH versus Water Paste	Soil:Water 1:1	Soil:Water 1:10	Water Leached	Water Paste Soil pH versus Soil:Water 1:1	Soil:Water 1:10	Water Leached	Soil:Water pH 1:1 versus Soil:Water 1:10	Water Leached	Water Leached Soil pH versus Soil:Water 1:10
Tilsit	7	0.6	0.6	0.8	0.9	0.01	0.2	0.3	0.2	0.3	0.1
Loring	9	0.2	0.9	0.8	1.0	0.3	0.6	0.8	0.3	0.5	0.2
Dexter	7	0.3	0.7	1.0	0.9	0.4	0.7	0.6	0.3	0.2	-0.01
Average pH Difference		0.4	0.6	0.9	0.9	0.2	0.4	0.4	0.3	0.3	0.02

*Number of the samples corresponding to the number of horizons in each soil profile.

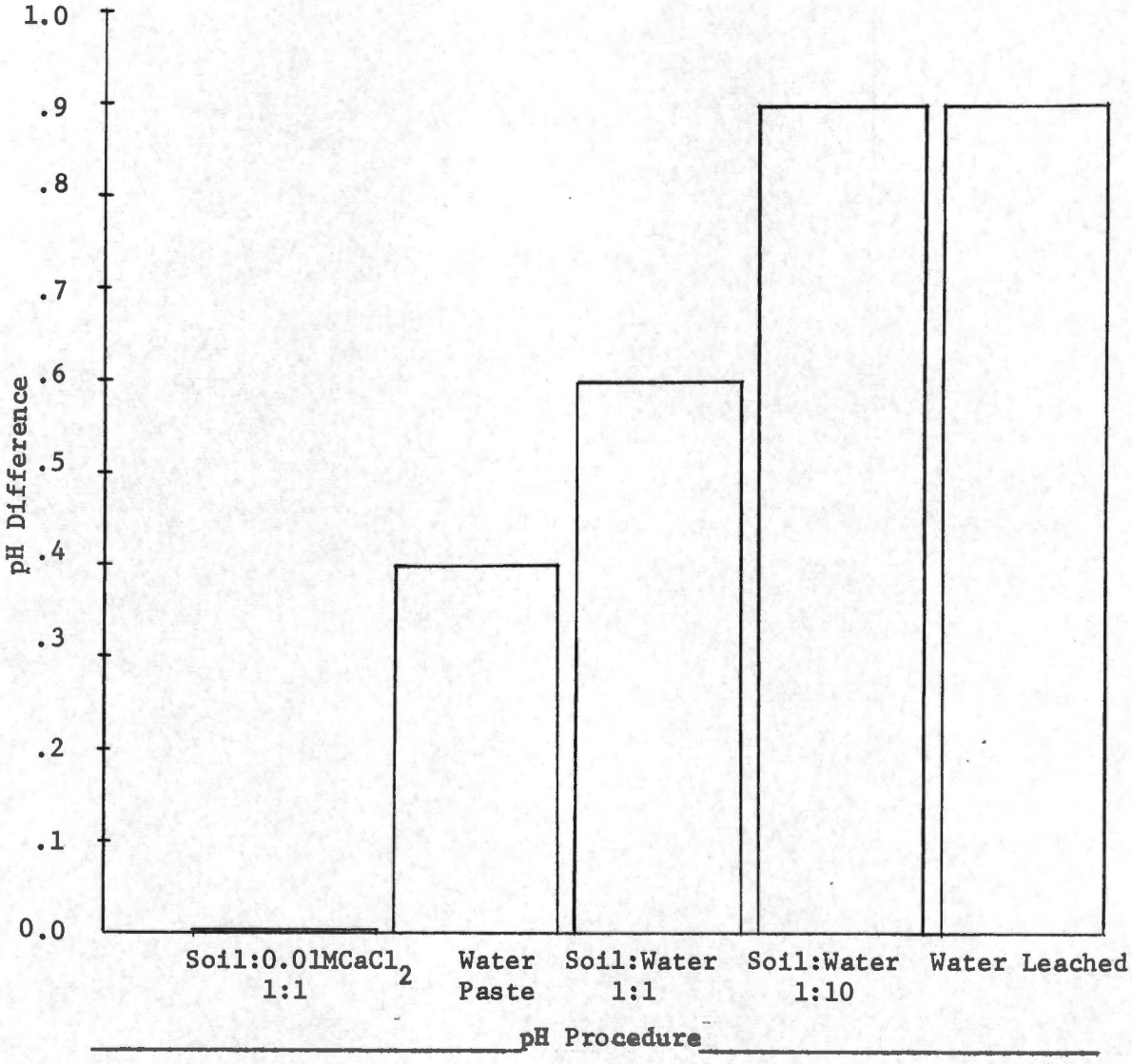


Figure 1. Comparisons of pH differences among five pH procedures of twelve soils (each bar represents 86 samples).

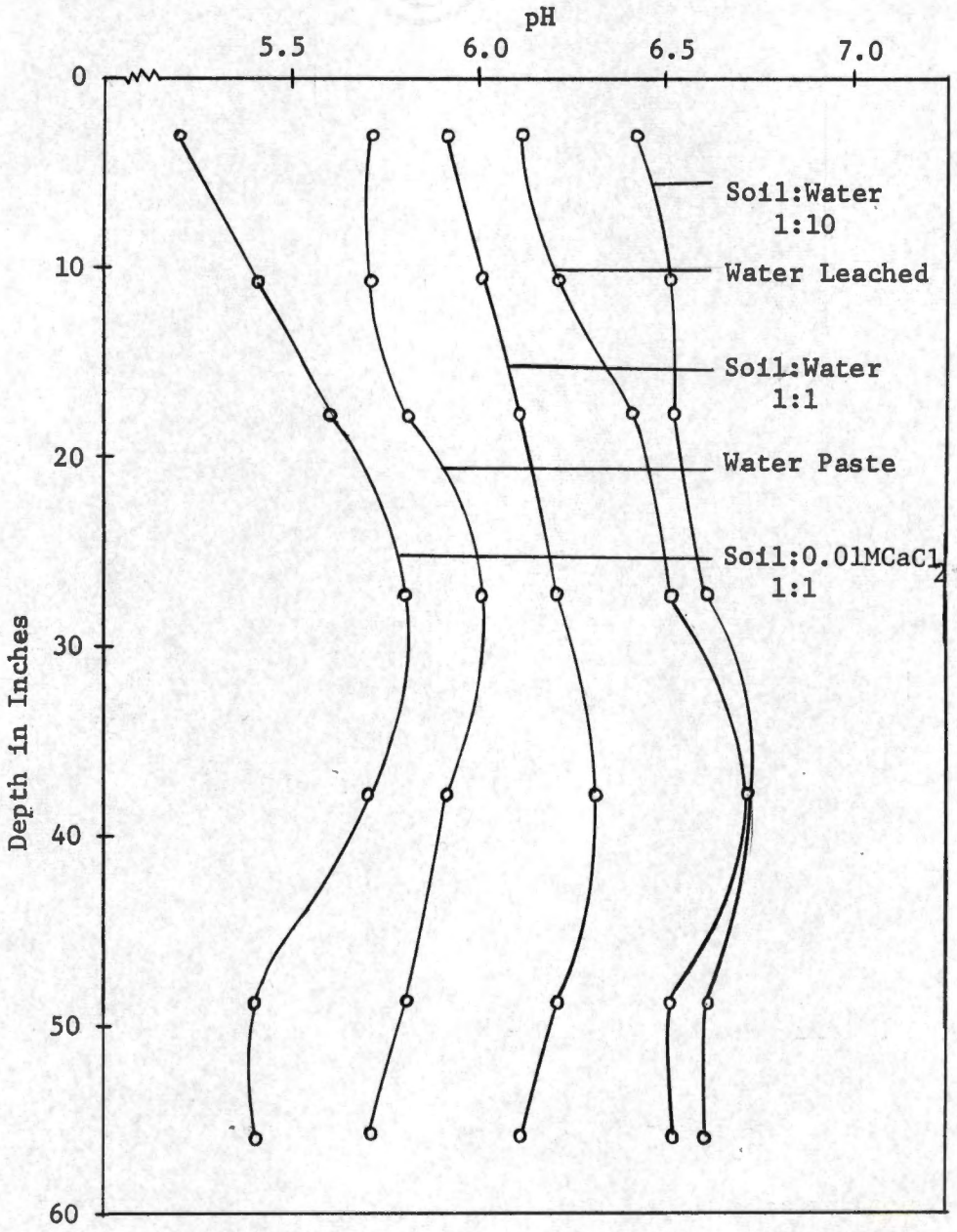


Figure 2. pH Values of the Sequatchie soil by five procedures.

In 0.01M $CaCl_2$, all surface soils were strongly acid to slightly acid with pH ranging from 4.7 in the surface of Loring to 6.7 in the surface of Grenada. Comparatively, all subsurface horizons of all soils were strongly acid to moderately acid, except Sequatchie.

pH values in water paste were 0.2, 0.4 and 0.4 units lower, respectively, than in 1:1 soil-water, in 1:10 soil-water, and in leached soil. This observation agreed with Chapman's (9) findings.

The average pH differences determined in a 1:1 soil-water were 0.3 unit lower than those obtained in 1:10 soil-water or water leached pH. According to Shaw (49), leaching could result in a pH rise of as much as 0.5 to 1.0 pH unit. Bell (1) also reported an increase of 0.3 pH unit in Tennessee soil samples by leaching with water; this he attributed to removal of soluble salts. His findings agreed with the results of this study.

It appeared that, with all soils studied, there were few differences of pH values determined between the 1:10 soil-water method and the pH determined after leaching out salts with water. Among soils, pH determined in water paste and in 1:1 soil-water also showed small differences of values.

Cation Exchange Capacity

CEC determined by the NH_4OAc and by the sum of cations methods is presented in Table II. In all soils and all horizons, CEC determined by the NH_4OAc method was less than by the sum of cations method. CEC by the sum of cations method included exchange acidity determined by $BaCl_2$-TEA which gave higher results than that obtained by the NH_4OAc method.

TABLE II

CATION EXCHANGE CAPACITY AND TEXTURAL CLASSES OF TWELVE SOILS

Soil Series	Horizon	Depth (inches)	CEC NH_4OAc Sum of Cations m.e./100 g soil		Textural Class*
Dickson	Ap	0 -12	7.6	9.9	sil
	B21t	12 -22	10.2	13.7	sil
	B'21tx	22 -30	9.1	11.9	sil
	B'22tx	30 -40	12.3	15.5	sicl
	IIB'23tx	40 -51	11.7	15.5	sicl
	IIB'3t	51 -60	10.1	13.4	sicl
Huntington	Ap	0 -11	7.5	10.6	sil
	B21	11 -17	6.0	9.1	sil
	B22	17 -25	5.0	7.9	sil
	C1	25 -31	7.1	8.2	sil
	IIC2	31 -40	8.1	9.9	sil
	IIIA11b	40 -48	7.2	10.9	sil
	IIIA12b	48 -55	6.1	11.1	sil
	IIIA13b	55 -59	5.6	11.6	sil
	IIIB2b	59 -64	3.9	9.5	sil
Sequoia	Ap	0 - 6	9.4	12.6	sil
	A1-B1	6 - 9.5	8.3	12.3	sicl
	IIB2t-A1	9.5-15	15.3	19.0	sicl
	IIB21t	15 -20.5	22.7	22.8	c
	IIB22t	20.5-30	23.6	26.5	c
	IIIB3t	30 -38	24.6	27.1	c
	IIIC1	38 -50	29.0	30.2	c
	IIIR	50 -60	27.7	28.6	sicl/sic
Sequatchie	Ap	0 -11	5.4	8.4	sal
	B1	11 -15	5.5	7.9	l
	B21t	15 -25	6.5	9.4	l
	B22t	25 -34	7.4	10.3	l
	B23t	34 -46	5.8	10.0	sal
	B3t	46 -56	5.0	7.6	sal
	I-IIB3 or C	56 -60	5.2	7.4	sal

TABLE II (continued)

Soil Series	Horizon	Depth (inches)	CEC NH_4OAc Sum of Cations m.e./100 g Soil		Textural Class*
Collins	Ap	0- 6	10.2	11.9	sil
	IIA1	6-12	10.5	13.7	sil
	IIB1	12-20	9.3	13.2	sil
	IIB2	20-29	11.0	15.1	sil
	IIIA2'b	29-36	11.3	15.9	sil
	IIIA2'b-B'2xb	36-45	8.0	11.0	si/sil
	IIIB'2gxb	45-53	7.3	10.0	si/sil
	IIIB2'gxb	53-60	6.6	8.8	sil
Grenada	Ap1	0- 6	8.9	11.6	sil
	Ap2	6-12	8.7	10.8	si/sil
	B21	12-22	10.3	13.3	sil
	B22	22-31	10.7	13.0	sil
	IIA2'	31-38	13.5	16.1	sil
	IIB2'x-A2'	38-51	15.8	20.7	sil
	IIB2'x-A'2	51-60	13.5	13.8	sil
Emory	Ap	0- 7	12.1	16.6	sicl
	B21t	7-17	11.3	15.4	sicl
	B22t	17-24	10.4	14.9	sil/sicl
	IIA1b	24-30	10.1	15.5	sil
	IIB1tb	30-39	8.5	11.9	sil
	IIB21tb	39-51	7.9	13.7	sil
	IIB22tb	51-59	9.9	13.8	sil
	IIB3tb	59-65	7.8	18.1	sicl
Maury	Ap	0-10	12.3	16.9	sicl
	B21t	10-21	10.5	16.8	sicl
	B22t	21-34	12.1	18.4	sic
	B23t	34-42	14.1	19.0	sic
	B24t	42-57	14.8	20.1	c
	B25t	57-60	16.0	21.8	c
Hartsells	Ap	0-10	7.8	11.1	l
	B21	10-18	7.8	10.3	l
	B22	18-28	7.9	10.5	l
	B23	28-33	8.8	11.9	l
	IIR	33+	----	-----	----

TABLE II (continued)

Soil Series	Horizon	Depth (Inches)	CEC NH_4OAc Sum of Cations m.e./100 g soil		Textural Class*
Tilsit	Ap	0 - 5	10.6	13.8	sil
	A3	5 -10	9.0	11.7	sil
	B1	10 -16	9.6	11.8	sil
	B21	16 -23	9.2	11.8	si/cl
	IIB'22tx	23 -35	10.2	12.3	cl
	IIB'23tx	35 -45	13.3	16.2	sic
	IIB'24tx	45 -57	12.1	14.3	cl
Loring	Ap1	0 - 6	9.2	12.9	sil
	Ap2	6 - 9.5	9.3	12.6	sil
	B21t	9.5-18	15.1	19.5	sicl
	B22t	18 -25	13.5	19.0	sil
	B23t	25 -36	11.9	16.3	sil
	I-IIA2'x-B2'x	36 -41	10.2	14.3	sil
	I-IIB2'x-A2'x	41 -50	8.5	11.8	sil
	I-IIB3'x-A2'x	50 -56	7.1	9.4	l
	IIB3'x-A2'x	56 -60	5.6	6.4	l
	IIC	60+	----	----	----
Dexter	Ap	0 - 6	8.4	11.3	sil
	B21t	6 -14	10.1	14.3	sicl
	B22t	14 -24	13.0	18.8	sicl
	B23t	24 -32	15.7	19.8	sicl
	B24t	32 -43	13.5	17.4	sil
	I-IIB31t	43 -48	10.4	15.0	sil
	IIB32	48 -60	6.4	6.4	l

*Textural class is based on laboratory determination of particle size distribution.

This finding agreed with those of Mehlich (30), who found that soils of high organic matter content, and soils containing appreciable kaolin, halloysite or other 1:1 type clay minerals, will often give somewhat lower values for exchange capacity by the NH_4OAc method than by the $BaCl_2$-TEA method. This may be due to a less complete replacement of absorbed hydrogen and aluminum ions by ammonium ions. With both CEC methods, the widest range of CEC among horizons within the soil profile was in Sequoia. The CEC values ranged from 8.3 milliequivalents (m.e.)/100 g soil in the A1-B1 horizon to 29.0 m.e. in the C1 horizon by the NH_4OAc method and 12.3 to 30.2 m.e. by the sum of cations method in the A1-B1 and C1 horizons, respectively. The narrowest range of CEC among horizons, in the case of all the soils, was within the Hartsells profile. The values ranged from 7.8 m.e. in the Ap and B21 horizon to 8.8 m.e. in the B23 horizon by the NH_4OAc method, and from 10.3 m.e. in the B21 horizon to 11.9 m.e. in the B23 horizon by the sum of cations method.

The NH_4OAc method. In all soils studied except Sequoia, CEC was rather low. In general, the clays in Southern soils are likely to be dominated by kaolinitic minerals and have a low exchange capacity, ranging perhaps between 5 and 20 m.e./100 g of soil (6). Sequoia showed a rather high CEC in the B and C horizons in comparison to that in these horizons of other soil profiles, ranging from 15.3 m.e. in the II B2t-A1 horizon to 20.9 m.e. in the C1 horizon. CEC of Huntington, Sequatchie, and Hartsells was rather low and there was little change in values throughout the profiles. Dickson, Grenada, Sequoia, Maury, and Tilsit had some

increase in CEC with depth. On the other hand, Collins and Emory decreased in CEC with depth. Loring had a greater CEC in B21t, B22t, and B23t horizons than in other horizons in the profile. Similar results were found in the Dexter profile.

The sum of cations method. CEC of all soil profiles by the sum of cations method was greater than CEC by the NH_4OAc method in all horizons. CEC by the sum of cations method, which is used on acid soils, includes both exchangeable bases and exchange acidity (10). In all horizons of soils studied, CEC by the sum of cations method gave similar trends to CEC by the NH_4OAc method. However, the widest variation between the two methods was found in the Emory and Maury soils. In the Emory soil, the average difference between the CEC values determined by the two methods was 5 m.e., while the difference was 6 m.e. in the Maury soil. Sequatchie and Hartsells showed the lowest variation of CEC by the two methods.

CEC of Dickson by the NH_4OAc method ranged from 7.6 m.e. in the Ap horizon to 12.3 m.e. in the B'22tx horizon; CEC generally increased with depth, but CEC by the sum of cations method ranged from 9.9 m.e. in the Ap horizon to 15.5 m.e. in the B22tx and B23tx horizons. CEC of Dickson by both methods gave greater values in the B horizon than in the Ap horizon. Sequoia, Grenada, Maury, and Tilsit showed similar trends in CEC as in the Dickson profile. This was probably due to the greater amount of clay content of the lower horizons. Hartsells, Tilsit, and Sequatchie, siliceous coarser-textured soils, are low in colloidal

clay and are very likely to be deficient in humus. Thus, CEC of these soils is rather low. Finer textured soils, such as Sequoia, Dickson, and Maury, in marked contrast, have a greater clay content than the other soils. Therefore, their CEC is usually high. Sutton (52) stated that in horizons below B1, CEC increased with depth and was directly correlated to clay content. Collins and Emory, which are young soils with minimal profile development, decreased in CEC with depth by both methods. The variation of CEC of these soil profiles may be due to some variation in particle size distribution. In Loring, CEC by both methods was greater in the B21t, B22t, B23t, and I-II A2'x-B2'x horizons than the other horizons. Dexter also had a greater CEC by both methods in the B22t, B23t, B24t, and I-II B31t horizons than in other horizons. This observation may be indicative of eluviation and weathering, resulting in an accumulation of more clay in these specified horizons of these two soils.

Percent Base Saturation

In all soils studied, percent base saturation calculated from the NH_4OAc CEC was higher than that calculated from the sum of cations CEC, the latter method including EA determined by the $BaCl_2$-TEA extraction (Table III). The indicated values of percent base saturation were much lower where CEC was measured at pH 8.0 than at pH 7.0, because CEC at pH 8.0 includes EA between pH 7.0 and pH 8.0, thus resulting in a large denominator in the ratio used to calculate the percent base saturation. This observation has been noted by Pratt and Bair (41). Percent base saturation

TABLE III

EXCHANGEABLE BASES, EXCHANGE ACIDITY, PERCENT BASE SATURATION AND Ca/Mg RATIO OF TWELVE SOILS

Soil Series	Horizon	Depth (inches)	Exchangeable Bases				Sum of Exchangeable Bases	Exchange Acidity	Base Saturation (Percent)		
			Ca	Mg	K	Na			NH_4OAc	Sum of Cations	Ca/Mg
			m.e./100 g Soil								
Dickson	Ap	0 -12	6.6	0.3	0.4	0.2	7.5	2.4	99	76	20.5
	B21t	12 -22	6.3	0.6	0.2	0.2	7.3	6.4	72	53	10.6
	B'21tx	22 -30	0.9	1.1	0.1	0.2	2.3	9.6	25	19	0.9
	B'22tx	30 -40	0.8	1.8	0.2	0.2	3.0	12.5	24	19	0.4
	IIB'23tx	40 -51	0.6	2.0	0.1	0.2	2.9	12.6	25	19	0.2
	IIB'3t	51 -60	0.4	1.7	0.1	0.2	2.4	11.0	24	18	0.3
Hunting-ton	Ap	0 -11	5.7	0.3	0.4	0.2	6.6	4.0	88	62	16.6
	B21	11 -17	2.7	0.2	0.2	0.2	3.3	5.8	55	36	12.1
	B22	17 -25	2.1	0.2	0.2	0.2	2.7	5.2	24	34	9.9
	C1	25 -31	2.9	0.4	0.2	0.2	3.7	4.5	52	45	7.6
	IIC2	31 -40	3.3	0.4	0.2	0.2	4.1	5.8	51	41	8.1
	IIIA11b	40 -48	3.5	0.3	0.2	0.2	4.2	6.7	58	39	11.8
	IIIA12b	48 -55	2.4	0.3	0.2	0.2	3.1	8.0	51	28	8.1
	IIIA13b	55 -59	2.3	0.3	0.2	0.2	3.0	8.6	54	26	7.8
	IIIB2b	59 -64	1.8	0.2	0.1	0.2	2.3	7.2	59	24	10.5
Sequoia	Ap	0 - 6	5.8	2.7	0.2	0.1	8.8	3.8	94	70	2.2
	A1-B1	6 -9.5	4.1	2.8	0.2	0.1	7.2	5.1	87	59	1.5
	IIB2t-A1	9.5-15	2.9	1.9	0.2	0.1	5.1	13.9	33	27	1.5
	IIB21t	15 -20.5	2.4	2.0	0.2	0.1	4.7	18.1	21	21	1.2
	IIB22t	20.5-30	1.3	1.5	0.2	0.1	3.1	23.4	13	12	0.8
	IIIB3t	30 -38	0.6	1.0	0.2	0.1	1.9	25.2	8	7	0.6
	IIIC1	38 -50	0.2	0.8	0.2	0.1	1.3	28.9	5	4	0.3
	IIIR	50 -60	0.2	0.8	0.2	0.1	1.3	27.3	5	5	0.3

TABLE III (continued)

Soil Series	Horizon	Depth (inches)	Exchangeable Bases				Sum of Exchangeable Bases	Exchange Acidity	Base Saturation (Percent)		
			Ca	Mg	K	Na			NH_4OAc	Sum of Cations	Ca/Mg
			m.e./100 g Soil								
Sequat-chie	Ap	0-11	2.3	0.6	0.3	0.1	3.3	5.1	61	39	3.5
	B1	11-15	2.2	0.8	0.2	0.1	3.3	4.6	60	42	2.6
	B21t	15-25	3.3	0.7	0.2	0.1	4.3	5.1	66	46	4.3
	B22t	25-34	4.3	0.9	0.2	0.1	5.5	4.8	74	53	4.5
	B23t	34-46	3.1	1.0	0.2	0.1	4.5	4.5	78	45	2.8
	B3t	46-56	2.4	0.9	0.1	0.1	3.5	4.1	70	46	2.7
	I-IIB3 or C	56-60	2.2	0.9	0.2	0.1	3.4	4.0	65	46	2.3
Collins	Ap	0- 6	7.6	2.1	0.4	0.1	10.2	1.7	100	86	3.7
	IIA1	6-12	7.6	2.1	0.5	0.1	10.3	3.4	98	75	3.7
	IIB1	12-20	5.1	2.1	0.2	0.2	7.6	5.6	82	58	2.5
	IIB2	20-29	5.0	2.7	0.2	0.2	8.1	7.0	74	54	1.9
	IIIA2'b	29-36	6.1	2.7	0.2	0.2	9.2	6.7	81	58	2.3
	I_IA2'b-B'2xb	36-45	2.8	1.3	0.2	0.1	4.4	6.6	55	40	2.2
	IIIB'2gxb	45-53	2.0	0.9	0.2	0.1	3.2	6.8	44	32	2.2
	IIIB2'gxb	53-60	1.3	0.8	0.2	0.1	2.4	6.4	36	27	1.6
Grenada	Ap1	0- 6	7.6	0.9	0.3	0.1	8.9	2.7	100	77	8.3
	Ap2	6-12	6.8	0.9	0.5	0.1	8.3	2.5	95	77	7.3
	B21	12-22	3.8	2.3	0.2	0.2	6.5	6.8	63	49	1.2
	B22	22-31	2.8	2.8	0.2	0.2	6.0	7.0	56	46	1.0
	IIA2'	31-38	2.8	2.8	0.3	0.3	6.2	9.9	46	39	1.0
	IIB2'x-A2'	38-51	3.1	3.1	0.3	0.3	6.8	13.9	43	33	1.0
	IIB2'x-A2'	51-60	2.7	2.9	0.3	0.3	6.2	7.6	46	45	0.9

TABLE III (continued)

Soil Series	Horizon	Depth (inches)	Exchangeable Bases				Sum of Exchangeable Bases	Exchange Acidity	Base Saturation (Percent)		
			Ca	Mg	K	Na			NH_4OAc	Sum of Cations	Ca/Mg
			m.e./100 g Soil								
Emory	Ap	0- 7	7.0	1.1	0.5	0.2	8.8	7.8	73	53	6.4
	B21t	7-17	6.6	1.1	0.3	0.2	8.2	7.2	73	53	6.0
	B22t	17-24	5.6	1.2	0.2	0.2	7.2	7.7	69	48	4.6
	IIA1b	24-30	4.8	1.1	0.2	0.2	6.3	9.2	62	41	4.5
	IIB1tb	30-39	4.1	1.0	0.2	0.2	5.5	6.4	65	46	4.0
	IIB21tb	39-51	4.0	1.1	0.2	0.2	5.5	8.2	70	40	3.8
	IIB22tb	51-59	4.7	1.4	0.2	0.1	6.4	7.4	65	46	3.4
	IIB3tb	59-65	4.1	1.8	0.2	0.1	6.2	11.9	79	34	2.2
Maury	Ap	0-10	7.6	1.3	0.6	0.2	9.7	7.2	79	57	6.0
	B21t	10-21	4.2	1.8	0.2	0.2	6.4	10.4	61	38	2.4
	B22t	21-34	1.8	1.4	0.4	0.2	3.8	14.6	31	21	1.3
	B23t	34-42	1.2	0.9	0.4	0.2	2.7	16.3	19	14	1.4
	B24t	42-57	0.9	0.9	0.4	0.2	2.4	17.7	16	12	1.1
	B25t	57-60	0.9	1.1	0.3	0.2	2.5	19.3	16	11	0.8
Hart-sells	Ap	0-10	3.5	0.5	0.2	0.1	4.3	6.8	55	39	7.0
	B21	10-18	2.3	0.6	0.1	0.2	3.2	7.1	41	31	4.0
	B22	18-28	1.0	0.3	0.2	0.2	1.7	8.8	22	16	2.9
	B23	28-33	1.2	0.3	0.2	0.2	1.9	10.0	22	16	3.9
	R	33+	---	---	---	---	---	----	--	--	----

TABLE III (continued)

Soil Series	Horizon	Depth (inches)	Exchangeable Bases CA	Mg	K	Na	Sum of Exchangeable Bases	Exchange Acidity	Base Saturation (Percent) NH_4OAc	Sum of Cations	Ca/Mg
			m.e./100 g Soil								
Tilsit	Ap	0 - 5	9.6	0.3	0.5	0.2	10.6	3.2	100	77	34.3
	A3	5 -10	6.7	0.2	0.2	0.2	7.3	4.4	81	62	44.9
	B1	10 -16	5.0	0.2	0.2	0.2	5.6	6.2	58	47	27.8
	B21	16 -23	2.8	0.1	0.2	0.1	3.2	8.6	35	27	20.0
	IIB'22tx	23 -35	0.8	0.1	0.1	0.1	1 1	11.2	11	9	6.2
	IIB'23tx	35 -45	0.2	0.2	0.1	0.1	0.6	15.6	5	4	1.3
	IIB'24tx	45 -57	0.2	0.1	0.1	0.1	0.5	13.8	4	3	1.1
Loring	Ap1	0 - 6	4.3	1.1	0.5	0.2	6.1	6.8	66	47	4.0
	Ap2	6 - 9.5	5.2	0.9	0.3	0.2	6.6	6.0	71	52	5.7
	B21t	9.5-18	9.1	2.6	0.4	0.2	12.3	7.2	81	63	3.5
	B22t	18 -25	4.4	3.2	0.4	0.2	8.2	10.8	61	43	1.4
	B23t	25 -36	2.2	2.6	0.3	0.2	5.3	11.0	45	33	0.8
	I-IIA2'x-B2'x	36 -41	1.5	2.6	0.2	0.2	4.5	9.8	44	31	0.6
	I-IIB2'x-A2'x	41 -50	0.9	2.5	0.2	0.2	3.8	8.0	45	32	0.4
	I-IIB3'x-A2'x	50 -56	0.6	2.2	0.2	0.2	3.2	6.2	45	34	0.3
	IIB3'x-A2'x	56 -60	0.4	1.5	0.1	0.2	2.2	4.2	39	34	0.3
	IIC	60+	---	---	---	---	----	----	--	--	---
Dexter	Ap	0 - 6	5.5	2.3	0.5	0.1	8.4	2.9	100	74	2.4
	B21t	6 -14	5.0	3.4	0.3	0.1	8.8	5.5	87	62	1.4
	B22t	14 -24	5.7	1.9	0.3	0.1	8.0	10.8	62	43	3.0
	B23t	20 -32	3.7	2.8	0.4	0.2	7.1	12.7	45	36	1.3
	B24t	32 -43	2.3	2.4	0.4	0.2	5.3	12.1	39	30	1.0
	I-IIB31t	43 -48	1.5	3.3	0.3	0.2	5.3	9.7	51	35	0.5
	IIB32	48 -60	0.7	1.3	0.2	0.1	2.3	4.1	36	36	0.6

by both methods was relatively high in the surface horizons of all soils except those of Sequatchie, Hartsells, and Loring.

Percent base saturation by exchangeable bases and CEC by the NH_4OAc method. Sequoia and Tilsit gave a wide range of percent base saturation in the profiles. Percent base saturation of Sequoia ranged from 94 percent in the surface to 5 percent in the C1 horizon, while Tilsit ranged from 100 percent in the surface to 4 percent in the IIB'24tx. Huntington, Collins, and Emory did not show a decreased percent base saturation with depth. Similar results were found in the Sequatchie profile. Percent base saturation of these soils probably is high becuase most of the material deposited was originally from A horizons of other soils. Hartsells had a rather low percent base saturation in comparison to the other soils studied, ranging from 55 percent in Ap to 22 percent in B23 horizon. This may be due to a high rate of leaching and weathering in the profile. The other five soils had rather high percent base saturation values in the lower parts of the profiles.

Percent base saturation by exchangeable bases and CEC by the sum of cations method. Percent base saturation of all soils studied showed similar trends to percent base saturation calculated by the NH_4OAc method. There was a narrow range in percent base saturation in the Hartsells profile. It ranged from 39 percent in the Ap horizon to 16 percent in the B22 and B23 horizons. There were also small differences in values of percent base saturation by both methods in the B horizon of the Sequoia and Tilsit soils.

Percent base saturation decreased with depth, except in the Sequatchie, Huntington, Collins, and Emory profiles. There were generally greater values of percent base saturation by both methods in Huntington, Collins, and Emory horizons, where higher exchangeable Ca was found. Collins had 100 percent base saturation by the NH_4OAc method in the Ap horizon which then decreased with depth to 29 inches. Percent base saturation again increased at about 30 inches and then again decreased with depth. Probably Collins has different parent material which was buried at that depth. Emory gave rather high percent base saturation throughout the profile, in comparison to the other soils studied.

Exchangeable Bases

Exchangeable Ca and Mg. In surface horizons of all soils, except Sequatchie, exchangeable Ca was rather high (Table III, page 29). Probably lime had been added to these soils. Dickson, Sequoia, Maury, Hartsells, and Tilsit showed a great decrease in exchangeable Ca with depth. There was a general decrease in exchangeable Ca with depth in Grenada, Emory, Loring, and Dexter. In Huntington, Sequatchie, and Collins, exchangeable Ca generally decreased with depth.

Exchangeable Mg in all soil profiles was lower than exchangeable Ca (Table III, page 29). Exchangeable Mg in Huntington, Sequatchie, Emory, Maury, Hartsells, and Tilsit was rather low. Huntington had a range of exchangeable Mg from 0.2 to 0.4 m.e. in the profile and Tilsit from 0.1 to 0.3 m.e. Loring and Dexter had relatively high exchangeable Mg throughout the profiles. The exchangeable Mg values ranged from 3.2

in the B22t to 1.1 m.e. in the Ap1 horizon of the Loring profile and from 3.4 in the B21t to 1.3 m.e. in the II B32 horizon of the Dexter profile.

Dickson, Grenada, and Loring profiles containing fragipans and having intense weathering and severe leaching showed a decrease in exchangeable Ca with depth, but an increase in exchangeable Mg with depth. The reason why exchangeable Mg increased in concentration while exchangeable Ca generally decreased with depth is not altogether clear. Hutcheson (23), who studied fragipan soils in Kentucky, indicated that other cations would be released through mineral weathering more readily than Mg^{2+} ions and would therefore be subject to more rapid leaching. Thus, Mg^{2+} ions from primary minerals would be moving through the profiles somewhat behind Ca^{2+} ions. In addition, certain of the clay minerals containing Mg^{2+} ions in dioctahedral positions might be expected to release these ions very slowly, allowing them to accumulate in or near the pan horizons. Black (4) also stated that this evidence is particularly pronounced in highly weathered soils. Thus, the content of exchangeable Mg may exceed that of Ca in the B and C horizons. Both exchangeable Ca and Mg of Sequoia decreased with depth. This might be caused by the long periods of leaching of the Sequoia soil. Huntington, Collins, and Sequatchie were variable in exchangeable Ca probably because of variability in the original alluvial deposits. It should be noted that the Huntington, Sequatchie, Emory, Hartsells and Tilsit profiles had very small difference in exchangeable Mg.

Exchangeable K and Na. For all soil profiles, exchangeable K and Na were very low, averaging less than 0.5 m.e. (Table III, page 29). Exchangeable Na was rather similar in the profiles, while exchangeable K varied slightly with depth. Exchangeable Na which averaged about 0.2 m.e. of all soils showed the lowest values of any of the cations.

Calcium/Magnesium Ratios

In most of the soil surface horizons studied, there were rather high Ca/Mg ratios, probably because of the past treatment by liming. The kinds of lime and amount of Ca and Mg contained in lime applied to the soil is unknown. Therefore, the differences in the Ca/Mg ratios in the surface of the soils is difficult to interpret.

Ca/Mg ratios of all soil profiles generally decreased with depth except in the Sequatchie and Huntington profiles (Table III, page 29). The greatest Ca/Mg ratio of Sequatchie was 4.5 in the B22t horizon while the lowest ratio was 2.3 in the I-II B3 or C horizon. Huntington had variations in Ca/Mg ratios with depth; the values of Ca/Mg ratios were 16.6 in the Ap horizon and 7.6 in the C1 horizon. The Ca/Mg ratios in the profiles of Huntington, Collins, Emory and Sequatchie were higher than those in the other soil profiles, probably because these soils are younger and less weathered than the other soils. Dickson, Sequoia, Grenada, Maury, Tilsit, Loring, and Dexter drastically decreased in Ca/Mg ratios with depth. Low Ca/Mg ratios, resulting from differential rate of leaching of basic cations, indicated rather advanced stages of weathering in these soils. According to Grossman et al. (21) such decreases of Ca/Mg ratios are indicative of relative amount of weathering that soils

have undergone, with small ratios representing greater amounts of weathering. Low Ca/Mg ratios in Dickson, Grenada and Loring might be explained by the fact that the exchangeable Ca was higher in the upper layer horizons and decreased with depth, whereas exchangeable Mg increased with depth resulting in low Ca/Mg ratios with depth.

Exchange Acidity

EA determined by the $BaCl_2$-TEA method showed considerable fluctuation, as did the soil reaction among horizons of each profile (Table III, page 29). EA of Huntington, Sequatchie and Emory varied very little with depth. EA in B horizons of Sequoia, Maury and Tilsit was found to be rather high as compared to EA in the B horizons of the other soils. The highest EA of Sequoia was 28.9 m.e. in the IIIC1 horizon, of Maury was 19.3 m.e. in the B25t horizon, and of Tilsit was 15.6 m.e. in the IIB23tx horizon. EA of some horizons of certain soils exceeded CEC by the NH_4OAc method. For example, EA of Maury was 14.6, 16.3, 17.7, and 19.3 m.e., respectively in the B22t, B23t, B24t, and B25t horizons, whereas the corresponding CEC by the NH_4OAc method (Table II, page 23) was 12.1, 14.1, 14.8, and 16.0 m.e. This was probably due to the disassociation of H^+ ions of pH-dependent charges from hydroxyl layer of kaolinite clay and the disassociation of H^+ ions from certain organic groups in the organic matter. In many cases, EA determined by the $BaCl_2$-TEA method at pH 8.0 was greater than CEC by the NH_4OAc method at pH 7.0. If CEC would have been determined at pH 8.0, it would be expected that the CEC values would be greater and that the difference between EA and CEC would have been

less. Assuming that kaolinite is the dominant type of clay mineral in these soils, the deviation may be accounted for by the greater dissociation of H^+ ions from the hydroxyl layers of the kaolinite at a pH of 8.0 than at a pH of 7.0 (34).

EA was rather high in the surface horizons of all soils, even though in most cases their pH values were near to neutral. This could be partially explained by the disassociation of pH-dependent charges from organic matter in the soils and pH-dependent charges on the clay surface.

Available Phosphorus and Potassium

Available P. In all soils studied, available P was relatively low (Table IV). As compared to the other soils studied, Dickson, Huntington, Sequoia, Hartsells, and Tilsit had very low amounts of available P throughout the profiles and P concentrations decreased with depth. Sequoia showed very low available P of only three ppm in the surface horizon. Godfrey and Riecken (18) recognized a decrease in P content with the depth of the profile as the degree of profile development increased. It was assumed that the major soil formation variable in the soils studied by Godfrey and Riecken was the time of weathering. Collins had a greater available P content in the A horizon than any of the other soils; there were 72.5 ppm in the Ap and 75+ ppm of available P in the II A1 horizon. Perhaps large quantities of P fertilizer have been applied periodically to this soil. Available P of Grenada, Loring, and Dexter showed considerable variation within the profiles. As pointed out by Godfrey and Riecken, slow internal drainage and poor aeration

TABLE IV

AVAILABLE P AND K OF TWELVE SOILS

Soil Series	Horizon	Depth (Inches)	Available (ppm) P	K
Dickson	Ap	0 -12	17.5	110
	B21t	12 -22	1.0	45
	B'21tx	22 -30	2.0	30
	B'22tx	30 -40	3.0	35
	IIB'23tx	40 -51	1.0	35
	IIB'3t	51 -60	1.0	25
Huntington	Ap	0 -11	14.0	95
	B21	11 -17	1.0	60
	B22	17 -25	1.5	40
	C1	25 -31	1.5	30
	IIC2	31 -40	1.0	45
	IIIA11b	40 -48	2.0	40
	IIIA12b	48 -55	4.0	35
	IIIA13b	55 -59	2.5	35
	IIIB2b	59 -64	2.0	35
Sequoia	Ap	0 - 6	3.0	45
	A1-B1	6 - 9.5	1.0	30
	IIB2t-A1	9.5-15	1.5	45
	IIB21t	15 -20.5	4.5	55
	IIB22t	20.5-30	1.5	50
	IIIB3t	30 -38	1.0	45
	IIIC1	38 -50	1.0	45
	IIIR	50 -60	3.0	35
Sequatchie	Ap	0 -11	13.5	100
	B1	11 -15	11.5	40
	B21t	15 -25	6.5	40
	B22t	25 -34	15.0	40
	B23t	34 -46	6.5	40
	B3t	46 -56	13.0	35
	I-IIB3 or C	56 -60	6.5	35
Collins	Ap	0 - 6	72.5	115
	IIA1	6 -12	75.0+	145
	IIB1	12 -20	8.5	55
	IIB2	20 -29	4.5	55
	IIIA2'b	29 -36	3.5	35
	IIIA2'b-B'2xb	36 -45	7.0	35
	IIIB'2gxb	45 -53	8.5	40
	IIIB2'gxb	53 -60	7.0	35

TABLE IV (continued)

Soil Series	Horizon	Depth (Inches)	Available (ppm) P	K
Grenada	Ap1	0- 6	15.0	65
	Ap2	6-12	17.5	140
	B21	12-22	9.5	45
	B22	22-31	10.5	45
	IIA2'	31-38	6.0	70
	IIB2'x-A2'	38-57	8.5	75
	IIB2'x-A'2	57-60	14.5	55
Emory	Ap	0- 7	13.0	110
	B21t	7-17	10.5	50
	B22t	17-24	11.0	45
	IIA1b	24-30	15.0	30
	IIB1tb	30-39	25.0	30
	IIB21tb	39-51	30.0	30
	IIB22tb	51-59	30.0	30
	IIB3tb	59-65	32.5	45
Maury	Ap	0-10	13.5	150
	B21t	10-21	15.0	60
	B22t	21-34	22.5	100
	B23t	34-42	30.0	105
	B24t	42-57	35.0	100
	B25t	57-60	42.5	100
Hartsells	Ap	0-10	15.0	45
	B21	10-18	1.5	40
	B22	18-28	1.0	50
	B23	28-33	1.0	45
	IIR	33+	----	---
Tilsit	Ap	0- 5	14.5	120
	A3	5-10	3.5	45
	B1	10-16	1.5	45
	B21	16-23	1.0	40
	IIB'22tx	23-35	1.0	30
	IIB'23tx	35-45	1.0	30
	IIB'24tx	45-57	3.0	30

TABLE IV (continued)

Soil Series	Horizon	Depth (Inches)	Available (ppm) P	K
Loring	Ap1	0 - 6	20.0	105
	Ap2	6 - 9.5	14.0	70
	B21t	9.5-18	13.0	85
	B22t	18 -25	17.5	85
	B23t	25 -36	17.5	70
	I-IIA2'x-B2'x	36 -41	15.0	60
	I-IIB2'x-A2'x	41 -50	11.5	55
	I-IIB3'x-A2'x	50 -56	10.0	45
	IIB3'x-A2'x	56 -60	10.5	40
	IIC	60+	----	---
Dexter	Ap	0 - 6	35.0	180
	B21t	6 -14	15.0	85
	B22t	14 -24	14.5	90
	B23t	24 -32	27.5	100
	B24t	32 -43	15.0	95
	I-IIB31t	43 -48	12.5	80
	IIB32t	48 -60	10.5	45

are associated with low P values in loess. Variability of alluvium in available P in Sequatchie might account for differences of available P in the profile. Emory and Maury had an increase in available P with depth. Characterization data for Maury indicate that the upper solum was developed in loess over phosphatic limestone (46). Maury is often used as an example of a soil which is high in phosphate. The intermediate P levels of the subsoil could have resulted through mixing of the loess and phosphatic limestone residuum. Emory occurs adjacent to Maury and has developed from local alluvium. Thus, available P of Emory profile showed similarity to that of the Maury profile.

Available K. Available K of all soils was rather low (Table IV). Apparently as a result of fertilizer additions, the A horizon of each soil, except that of Sequoia and Hartsells, showed appreciably higher available K than was found in lower horizons of each soil profile. The narrowest range of available K was found in Hartsells; it ranged from 50 ppm in the B22 horizon to 40 ppm in the B21 horizon. The widest range of available K was found in Dexter; it ranged from 180 ppm in the Ap horizon to 45 ppm in the II B32t horizon. The low available K of Sequoia and Hartsells might be due to sources of parent material containing low levels of K. Dexter and Maury profiles contained higher available K in the profiles than other soil profiles. The relatively higher available K in Dexter and Maury could be explained by release of K from clay and/or weathering of K minerals which would thus replenish the K lost through leaching.

Huntington, Sequatchie, and Collins had higher available K in the surface than in the lower layers. The small amount of available K of these three soils may have been due to factors other than source of parent material. Bell (2), noting the low amounts of K in the bottom soils in comparison to the upland soils, stated that the bottom soils had a lower illite clay content and that, therefore, smaller amounts of K would be released from the clay present. A low available K test in the soils studied could result from more frequent cropping which reduced the level of K in subsurfaces. Available K in Dexter and Maury could be higher because these soils contain more clay or parent material with high K content. Other possible causes are that the crop growing on these soils did not penetrate the layers deeply, or that the roots which did penetrate did not extract the K. However, the higher available K in all surface soils could be due to the translocation of K by roots from the lower layers and/or to the application of K fertilizer.

II. RELATIONSHIPS OF CERTAIN CHEMICAL PROPERTIES WITHIN THE SOIL PROFILES

Dickson

Field observations and laboratory determinations appear to indicate that two distinct parent materials and two sequences of soil development occur in this soil.

Percent base saturation, the sum of exchangeable bases, Ca/Mg ratio, and pH were all higher in the loess-like material than in the old residuum (Figure 3). There are two possible explanations for these

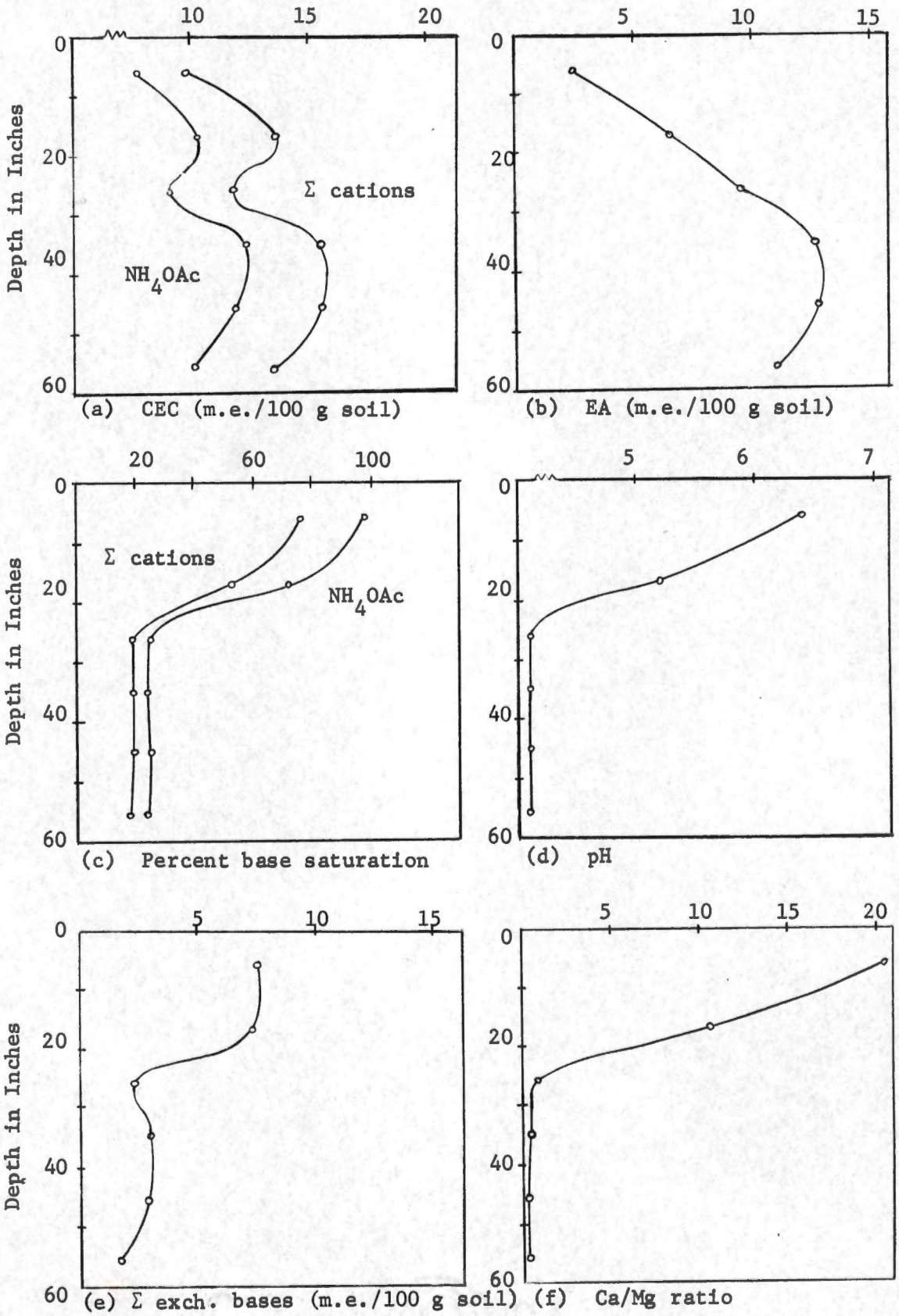


Figure 3. Some chemical properties of the Dickson soil.

differences. The overlying loess-like material is younger and possibly higher in weatherable minerals which are releasing bases. Since the loess is probably younger, it has not been subjected to weathering and leaching as long as has the older underlying residuum. The addition of fertilizers and lime also may have increased the percent base saturation of the overlying loess-like materials. There were few variations in the percent base saturation, the sum of exchangeable bases, Ca/Mg ratios, and pH in the older, underlying residuum.

The CEC varied with the clay content (Table VI, Appendix B) in loess-like material. There was a higher clay content and correspondingly higher CEC in the old residuum than in the overlying loess-like material.

In the lower part of the profile, the CEC also varied with the clay content, as would be expected. In the total profile, there appeared to be a similar pattern of CEC, EA, and clay content in the solum developed in the loess-like material and in the older weathered underlying residuum.

Huntington

The Huntington soil is a young alluvial soil developed in stratified medium textured alluvium overlying an older profile that appears to have been developed in loess.

The CEC and EA (Figure 4) generally varied with the clay content.

Percent base saturation in the profile varied with the sum of exchangeable bases pH and Ca/Mg ratio followed similar trends in the upper 35 inches of the profile as did the percent base saturation.

There appeared to be two different sequences of profile development in Huntington. The buried soil below 40 inches showed evidence of some

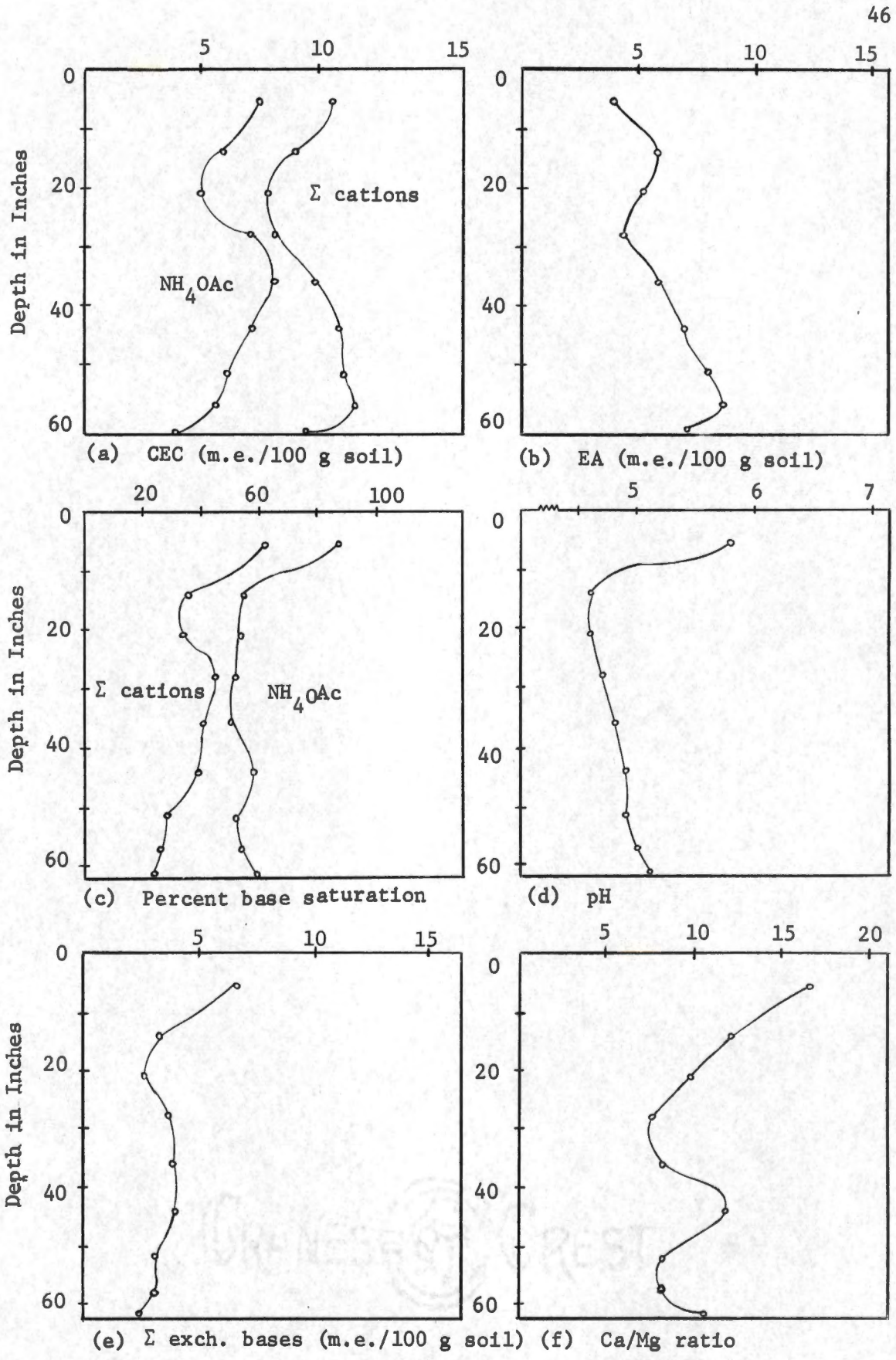


Figure 4. Some chemical properties of the Huntington soil.

clay movement. There appeared to be little clay movement in the overlying stratified alluvium.

Sequoia

The profile description of this soil indicates that Sequoia may have developed from terrace-alluvium over clay-shale residuum.

Generally, CEC and EA varied with the clay content in the soil profile (Figure 5).

Percent base saturation and the sum of exchangeable bases were relatively high in the younger overlying alluvium, but were lower in the older underlying shale material.

pH and Ca/Mg ratio showed patterns similar to those of percent base saturation and sum of exchangeable bases. These very low values of percent base saturation and pH appear to indicate greater weathering and leaching of the lower layers.

Sequatchie

The profile description of the Sequatchie profile seems to indicate that only one developmental cycle is present, although a discontinuity in material was found at about 56 inches.

The CEC in the Sequatchie soil appears to be correlated with clay content. EA did not appear to vary in relation to clay content.

The percent base saturation, Ca/Mg ratio, the sum of exchangeable bases and pH appeared to follow a pattern similar to that shown by the clay content.

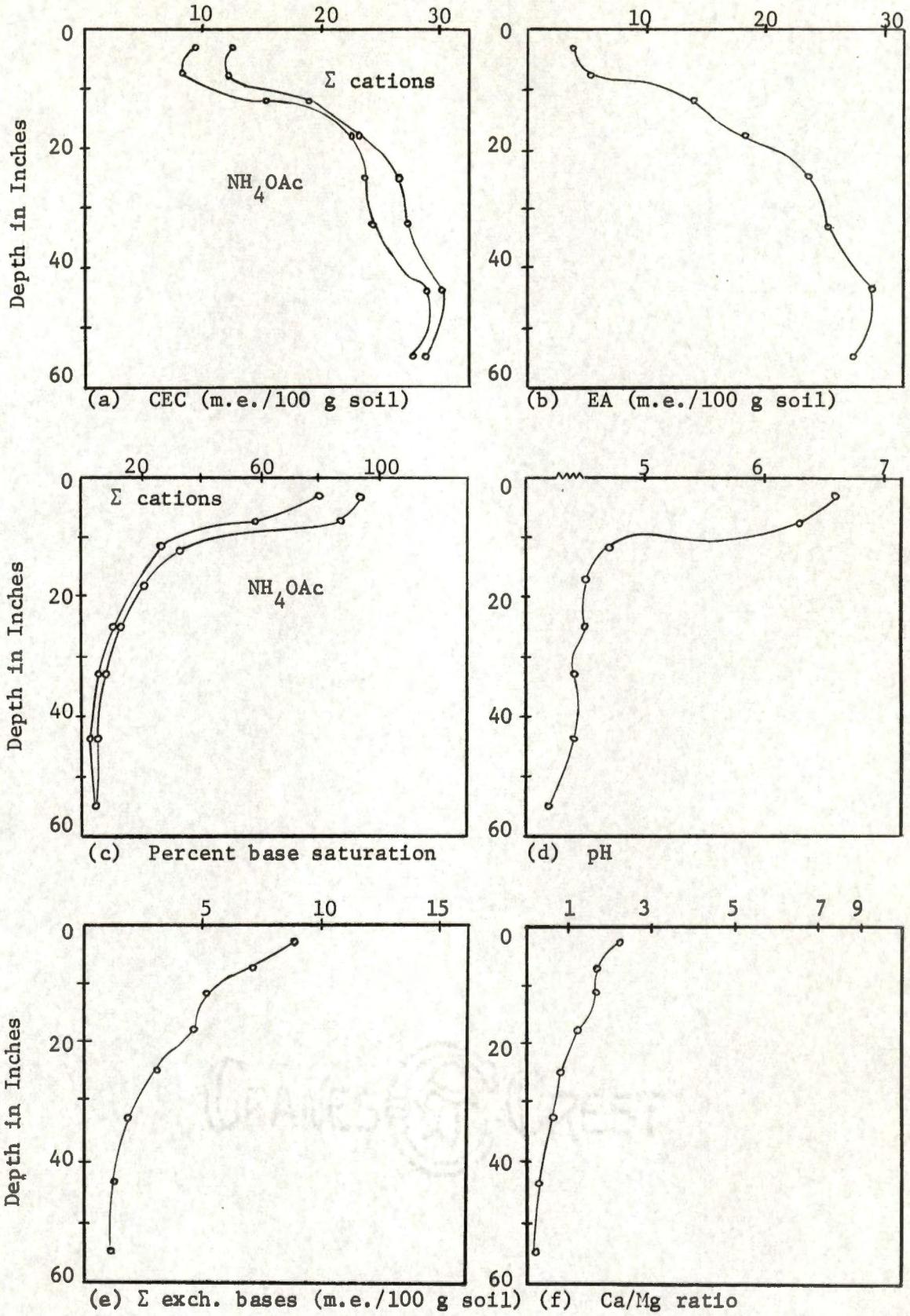


Figure 5. Some chemical properties of the Sequoia soil.

The maximum values for EA, CEC, pH and percent base saturation (Figure 6) and clay content occurred at the approximate depth of 30 inches. This is probably due to leaching of bases and clay movement from the surface to that depth.

Collins

Collins, a bottom land soil, appears to have developed from silty local alluvium from loess, over loess in situ. The buried soil developed in the underlying loess in places appears to have morphological characteristics similar to those associated with Henry soils.

Percent base saturation, the sum of exchangeable bases, and pH were all higher in the local alluvium overburden than in the buried soil (Figure 7). These values showed similar trends, and generally decreased with depth. The values for these properties were lower in the buried soil than in the younger overlying alluvium.

CEC and EA showed similar patterns in the overlying alluvium, but the CEC appeared to decrease to a greater degree in the buried soil than did the EA in the same zone of the profile. CEC and EA roughly varied with the clay content in the profile.

The laboratory data appeared to support the field observations related to the polygenesis of the soil profile at this site.

Grenada

From the field description it appears that the Grenada soil was developed in loess, and that possibly the parent-loess represented more than one depositional period.

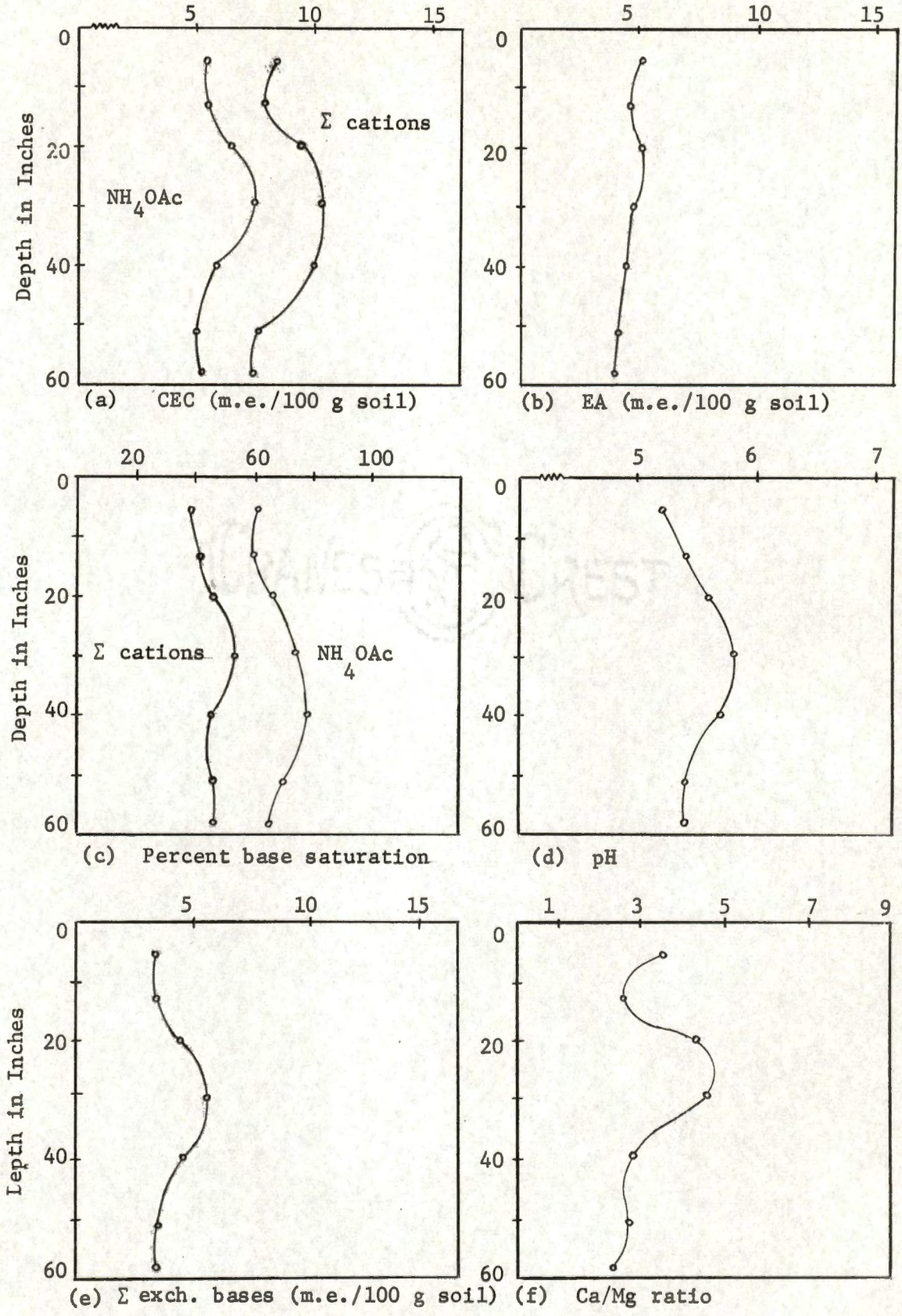


Figure 6. Some chemical properties of the Sequatchie soil.

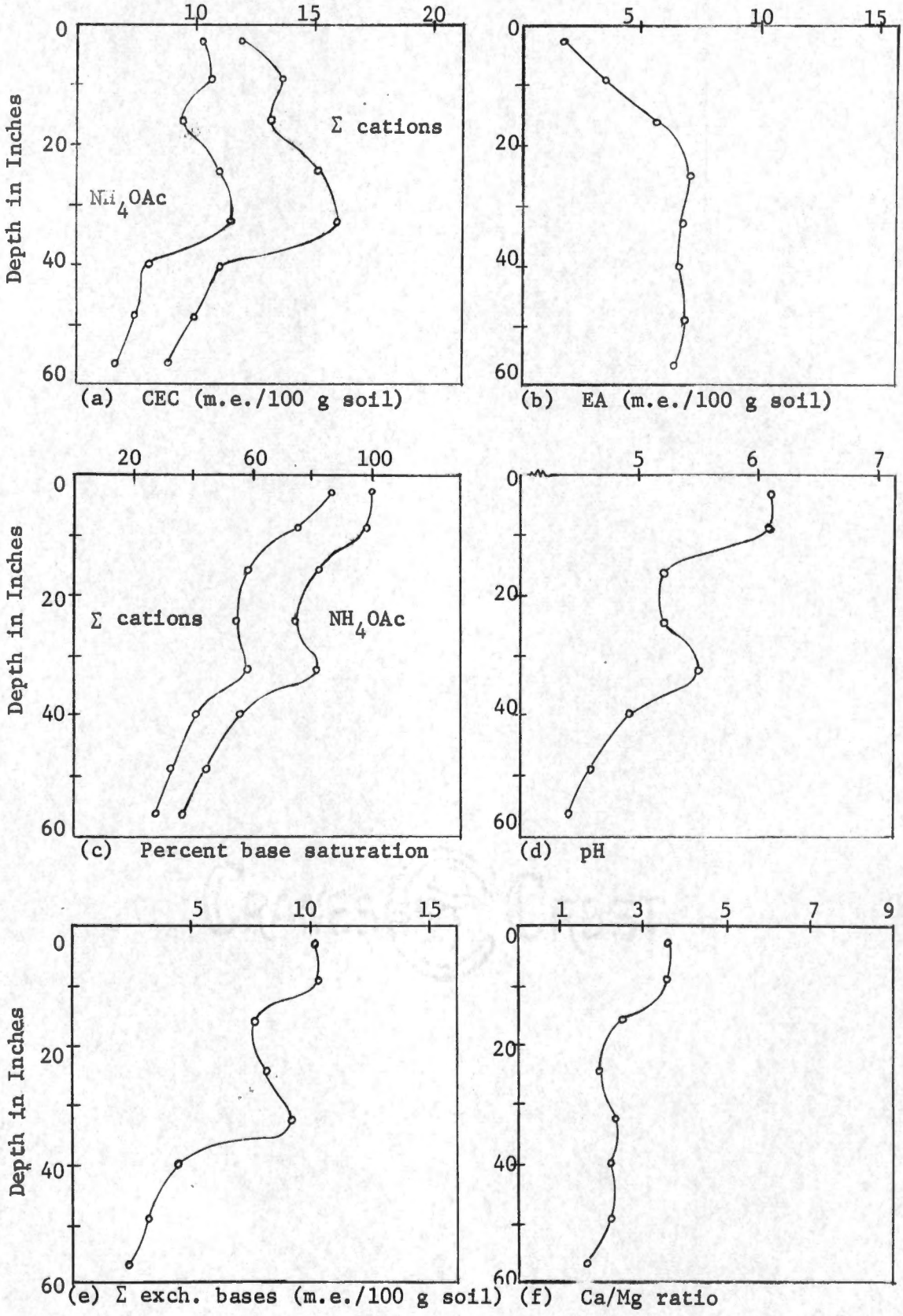


Figure 7. Some chemical properties of the Collins soil.

The CEC and EA varied with the clay content in the profile. These properties showed higher values in the buried soil than in the overlying younger loess deposit (Figure 8).

Percent base saturation, the sum of exchangeable bases and pH all showed similar patterns. These values decreased with depth.

In the Grenada soil profile, soil development in the underlying loess material appeared to be more advanced than did the development in overlying loess material. There appeared to be greater illuviation of clay in the lower sequm than in the upper sequm. The greater CEC, EA, and clay content in the underlying sequm probably resulted from longer periods of weathering, leaching, and soil development prior to the deposition of the upper loess.

The laboratory data appeared to support the field observations as to the bisequal nature of this profile.

Emory

From the field observations it appears that the Emory soil has been developed in local alluvium over limestone residuum or old alluvium and is bisequal.

EA and CEC showed similar patterns in the profile. The EA and CEC generally varied with the clay content (Figure 9). In the buried soil, the correlation of CEC, EA, and clay content was better than in the overlying local alluvium.

Percent base saturation, the sum of exchangeable bases, Ca/Mg ratio and pH generally followed similar patterns.

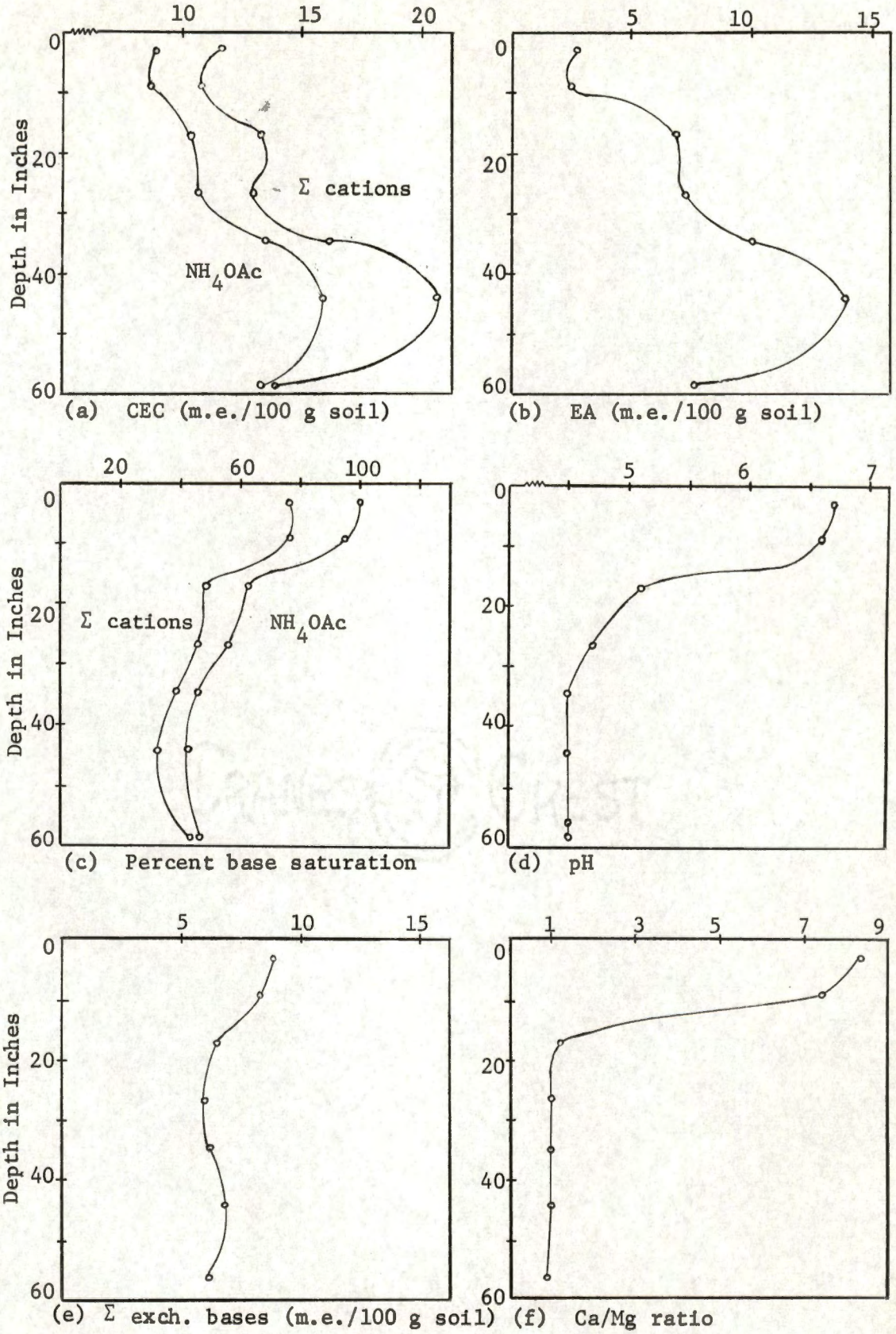


Figure 8. Some chemical properties of the Grenada soil.

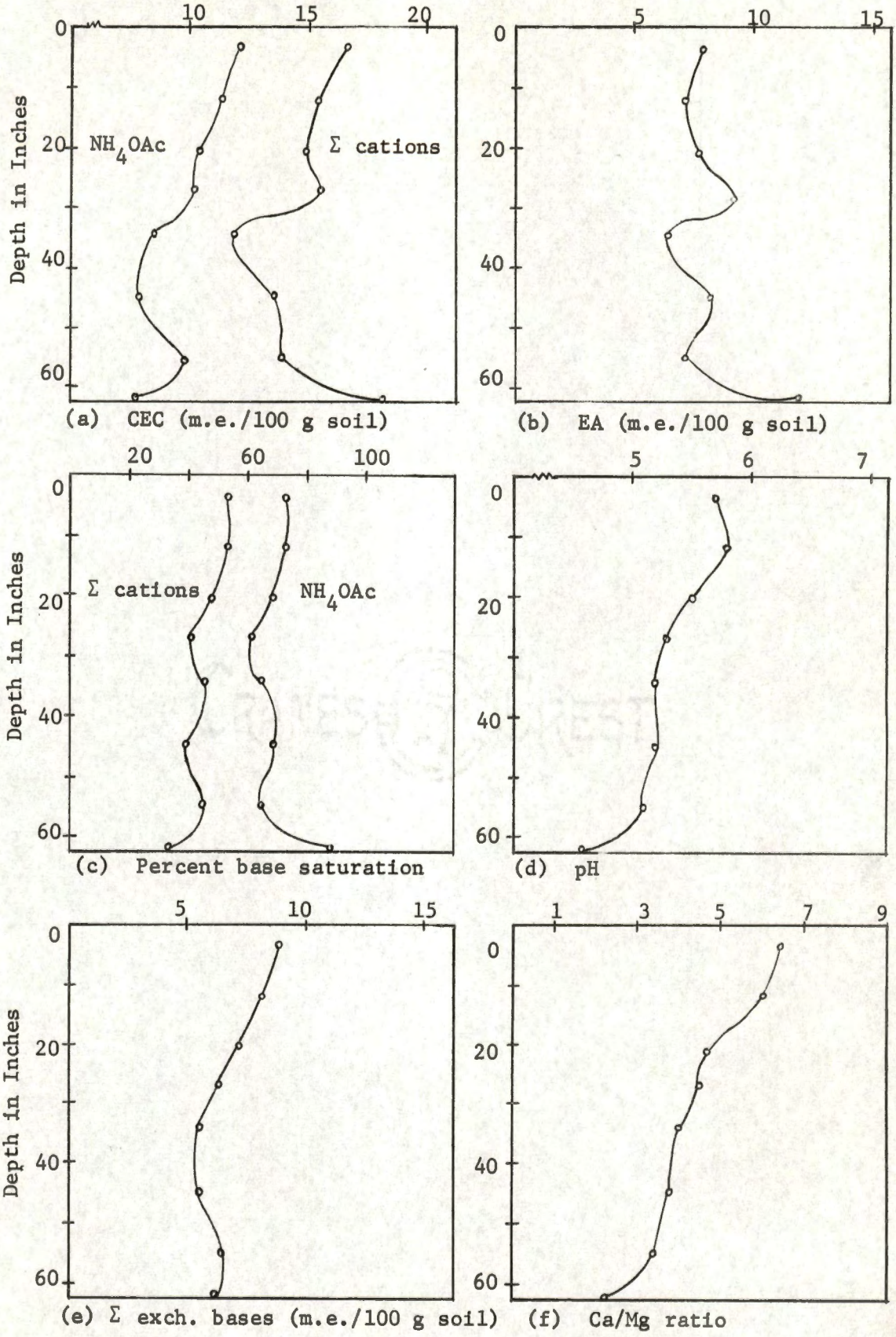


Figure 9. Some chemical properties of the Emory soil.

The clay curve indicates that the eluviation or illuviation sequence is more pronounced in the buried soil than in the overlying alluvium.

Maury

On the basis of the field observations and the laboratory data, it appears that the Maury soil is monosequal and was developed in phosphatic limestone residuum.

EA, CEC (Figure 10), and clay content followed similar patterns and these values increased with depth.

Percent base saturation, the sum of exchangeable bases, pH, and Ca/Mg ratio decreased considerably with depth.

Hartsells

On the basis of the field observations and laboratory data the Hartsells profile seems to be developed from loess-contaminated sandstone residuum.

CEC and EA generally showed rather little variation with depth (Figure 11). These values tended to increase with depth, as did clay content.

The percent base saturation, the sum of exchangeable bases, pH and Ca/Mg ratio generally decreased with depth. They all followed in a similar pattern in the profile.

Tilsit

From the field observations the Tilsit soil appears to have developed in loess or alluvium over residuum from interbedded siltstone and sandstone.

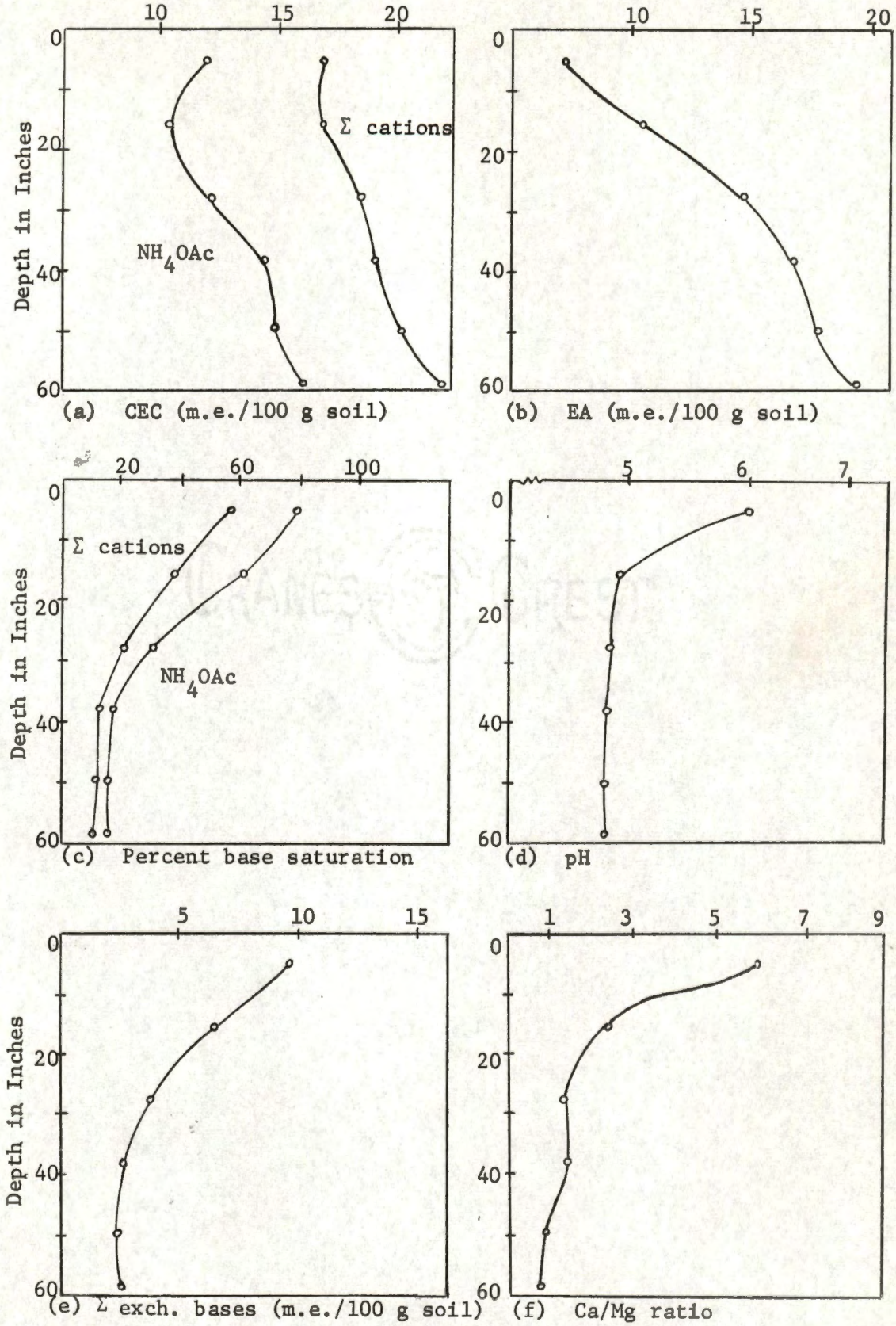


Figure 10. Some chemical properties of the Maury soil.

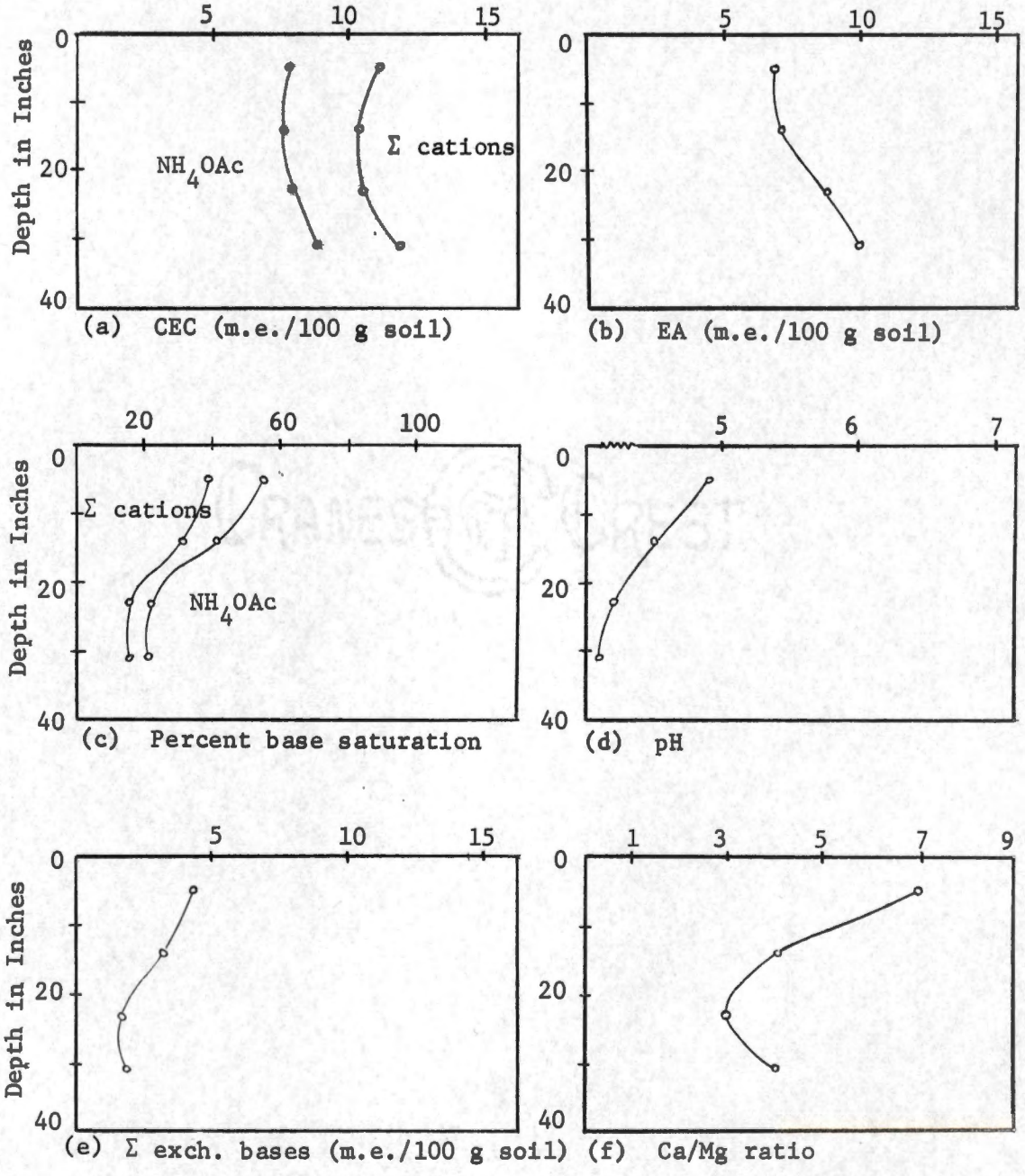


Figure 11. Some chemical properties of the Hartsells soil.

The CEC and EA of the profile (Figure 12) were correlated with the clay content.

The percent base saturation, the sum of exchangeable bases, pH and Ca/Mg ratio all followed a similar pattern and these values decreased with depth.

Very low percent base saturation and pH values in the lower horizons of the Tilsit soil indicate greater weathering and leaching of the sequm material.

The laboratory data appear to support the bisequal nature of the soil profile as described.

Loring

From the field description it seems that the Loring soil developed in loess of possibly more than one depositional period over sandy alluvium. The field observation also appears to indicate a bisequal profile development, although the laboratory data did not strengthen this observation.

The CEC varied with clay content in the profile. The sharp increase in CEC from the surface to 13 inches in depth and also a correspondingly sharp increase in clay content occurred. Then, CEC generally decreased as the clay content decreased from the depth of 13 to 60 inches.

The variation in the EA was very similar to variation in clay content with depth. The decrease in EA, CEC (Figure 13), and clay content is undoubtedly due to the coarse texture of the overlying alluvial sandy material.

Percent base saturation, the sum of exchangeable bases, and pH values all followed similar patterns in the profile. The maximum values

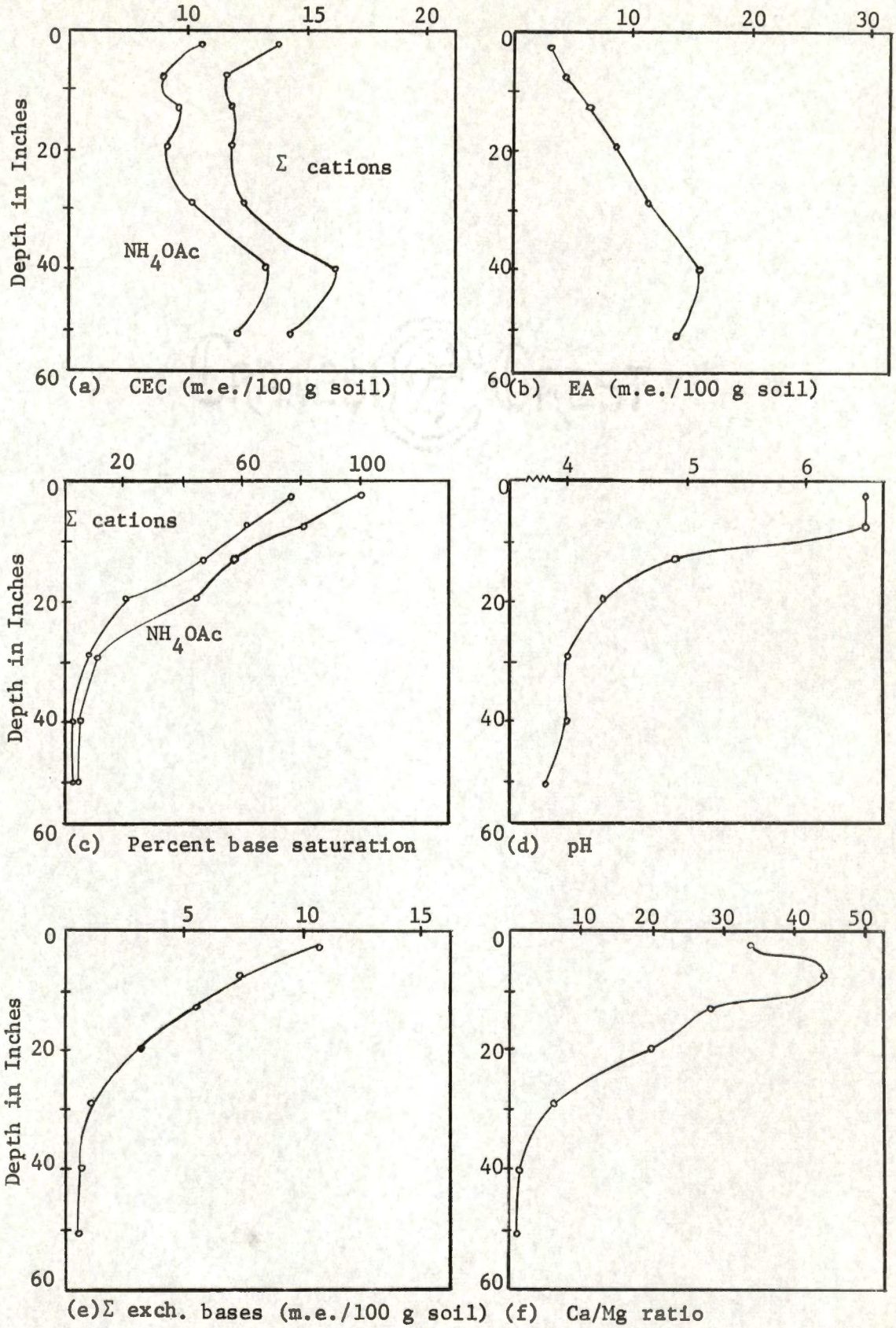


Figure 12. Some chemical properties of the Tilsit soil.

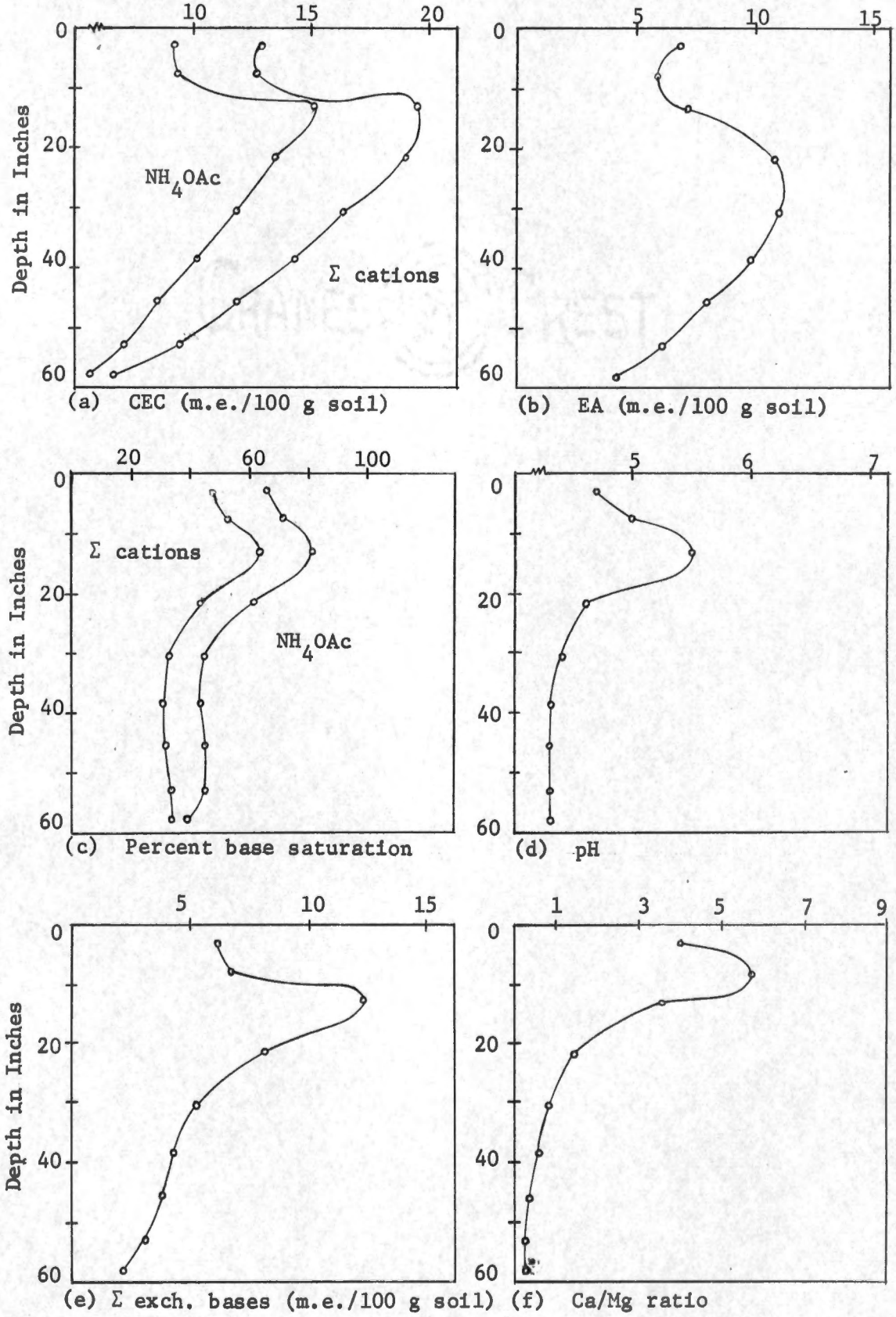


Figure 13. Some chemical properties of the Loring soil.

of these properties occurred at the depth of 18 inches. This may be due to the high rate of fertilization in the surface and a subsequent loss of bases from the surface to 18 inches in depth.

In the alluvial sandy material, there were smaller changes in the percent base saturation, pH, and the sum of exchangeable bases than in the upper loess-like material.

Dexter

According to the field observations, the Dexter soil has been developed from loess over alluvial sand and is a monosequal profile.

CEC and EA increased to a maximum at a depth of 25 inches and then decreased to 60 inches. Clay content followed a similar pattern, as did CEC and EA (Figure 14).

Percent base saturation, pH, and the sum of exchangeable bases all showed similar patterns with decreasing values with depth.

Available Phosphorus and Potassium

Available P and K of each soil are shown in Figures 15 and 16, respectively. Two soils at each location were grouped together for study of available P and K.

In most of the soil profiles studied, the values of available P and K were much higher in the surfaces than in the subsoils. There were exceptions with the higher quantities of available P in the subsoils of Maury and Emory with increasing depth.

The higher available P in the sub-surfaces of Emory and Maury (Figure 15) was probably due to the soils having been developed

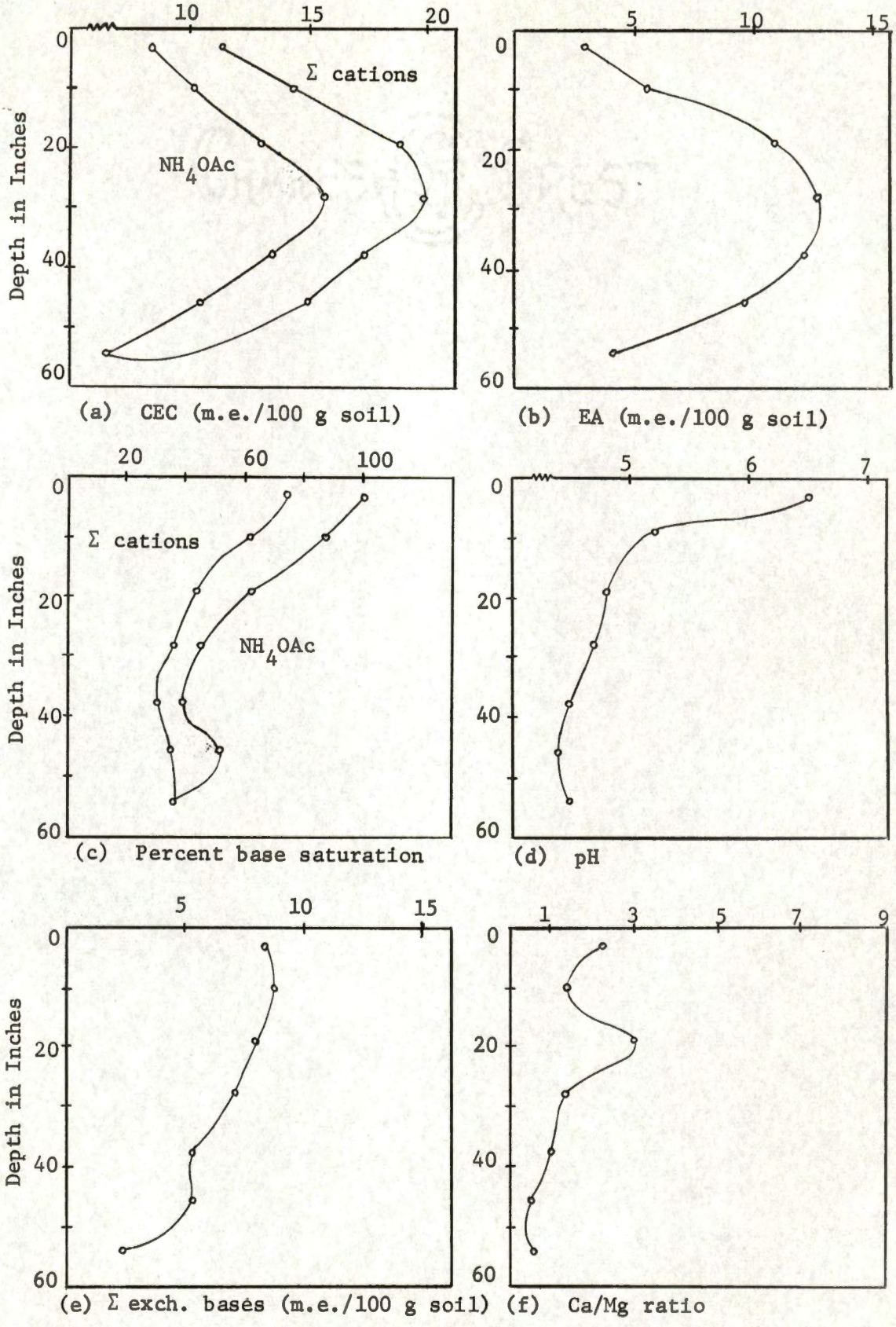


Figure 14. Some chemical properties of the Dexter soil.

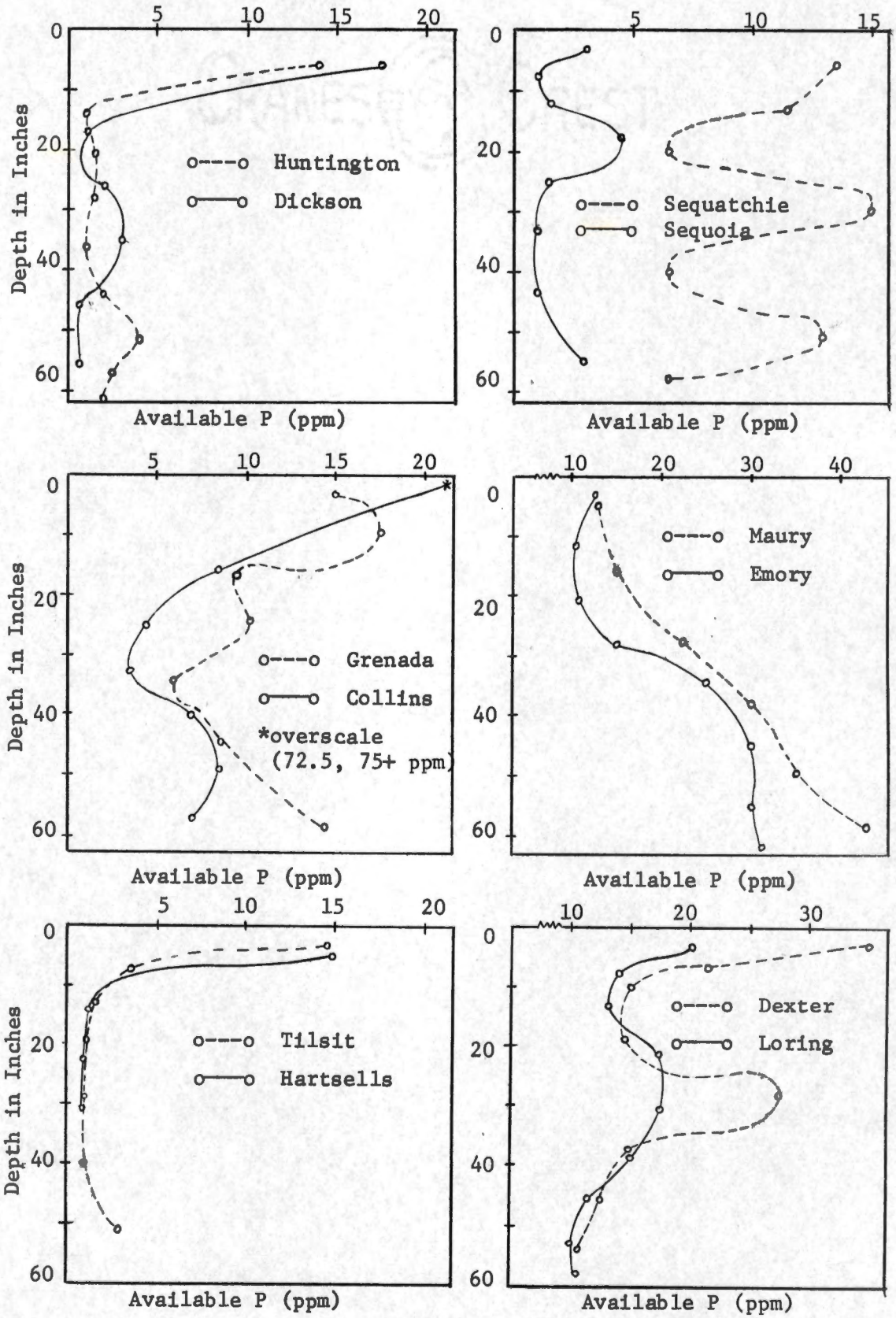


Figure 15. Available phosphorus of twelve soils.

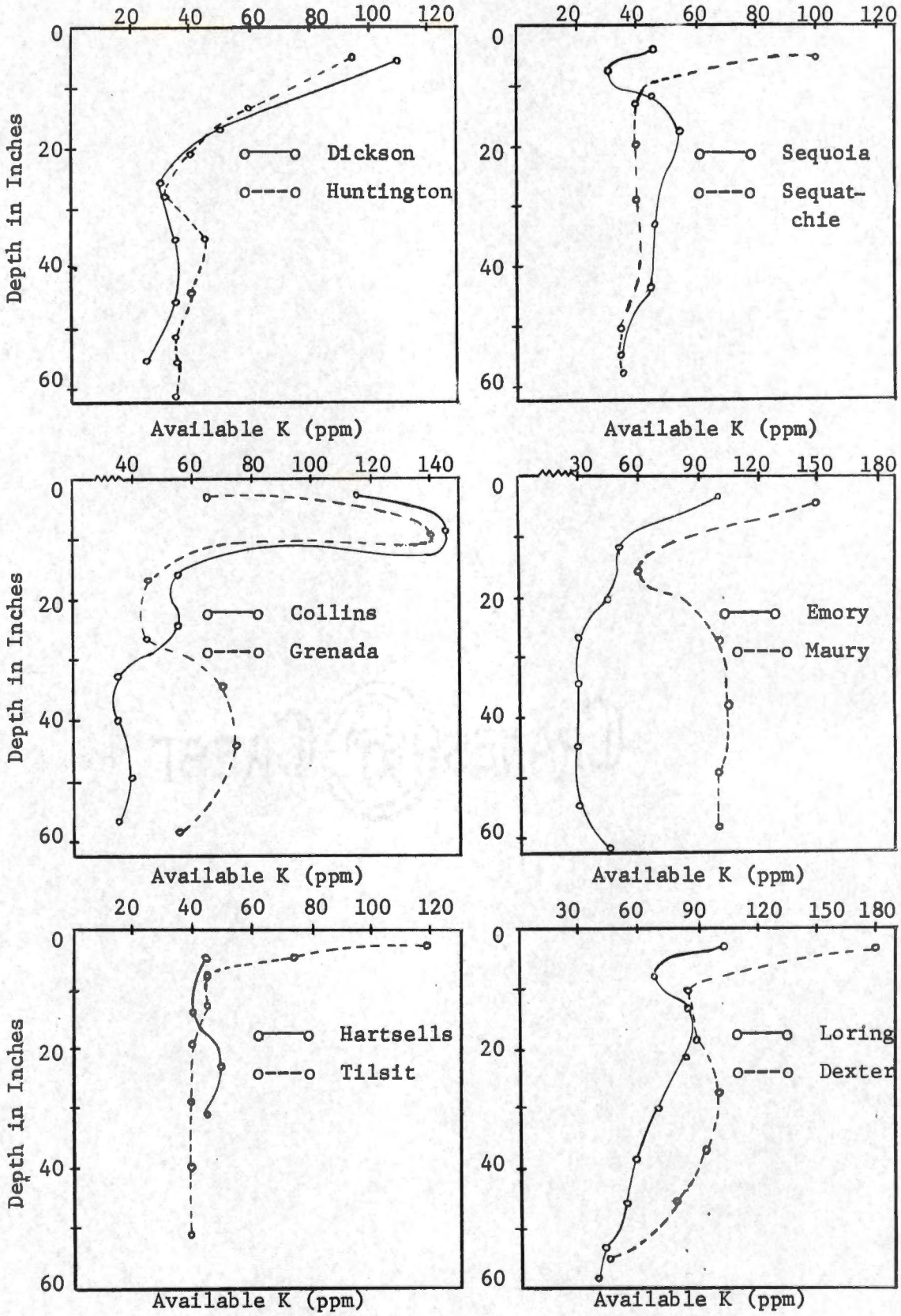


Figure 16. Available potassium of twelve soils.

from limestone rock with very high P content. The high level of available P in the surfaces of most soils studied probably was due to the additions of fertilizer phosphorus to the surfaces. Dickson and Huntington (Figure 15), Sequoia (Figure 15), and Hartsells and Tilsit (Figure 15) had very low available P in the subsurfaces as compared with their surfaces.

Available K generally decreased with depth in the soil profiles studied (Figure 16). In most soils, available K generally showed a similar pattern, as did available P. The high quantities of available K in most soils was probably caused by the addition of fertilizer potassium.

Maury also had greater available K in the subsurfaces and the values remained rather constant with depth from 27 to 60 inches in depth. This might be due to parent material rather than to the other factors.

Some more details of available P and K of the soils have already been discussed (pages 38-43).

The small amount of available P and K in the soils studied might be due to frequent cropping over a long period of time, because all the soils studied were located on the Agricultural Experiment Stations. Therefore, all surfaces of these soils undoubtedly have been changed in soil properties by practical management.

III. COMPARISONS OF CHEMICAL PROPERTIES AMONG SOILS

From the result of the laboratory study, the values of the chemical properties varied somewhat with the methods used. For instance, different results between methods occurred in CEC of Emory and

Maury and in percent base saturation of Tilsit and Sequoia. The values of the chemical properties were influenced by the characteristics of soil and by the laboratory methods used. Comparisons were made between the chemical properties and the morphological properties of each soil profile. Comparisons also were made of the chemical properties among soil profiles.

Cation Exchange Capacity

CEC determined by the NH_4OAc and $BaCl_2$-TEA methods varies considerably within and among the soils. Soils with the greatest differences in CEC between these two methods were Collins, Emory, Maury, Loring, and Dexter (Figures 7a, page 51; 9a, page 54; 10a, page 56; 13a, page 60; and 14a, page 62). There were some exceptions in the underlying loess-like material of Collins and the underlying alluvial sands in Loring; these materials seemed to show smaller differences in CEC between methods in the underlying parts as compared to their upper parts of the profiles.

Intermediate differences in CEC values between the two methods used were noted in Dickson, Sequatchie and Hartsells profiles (Figures 3a, page 44; 6a, page 50; and 11a, page 57). It appeared that the sizes of the differences in CEC as measured by the two methods were uniform in the different horizons of these soils profiles.

The smallest differences in values of CEC values found by the two methods used were noted in Huntington, Sequoia, Grenada, and Tilsit profiles (Figures 4a, page 46; 5a, page 48; 8a, page 53; and 12a, page 59).

Comparisons also were made on the basis of the degree of correlation of CEC and clay content in all soils studied.

CEC values of Dickson, Sequatchie, Collins, Grenada, Loring, and Dexter (Figures 3a, page 44; 6a, page 50; 7a, page 51; 8a, page 53; 13a, page 60; and 14a, page 62) appeared to be well correlated with their clay content (Table VI, Appendix B). As clay content increased, CEC increased.

Huntington, Sequoia, and Maury were grouped because their CEC values, as shown in Figures 4a, page 46; 5a, page 48; and 10a, page 56, were somewhat less well correlated with the clay content (Table VI, Appendix B) in the profiles than in the case of the soils in the above mentioned group.

The Emory, Hartsells, and Tilsit soils appeared to show the poorest correlations between CEC values and clay content (Figures 9a, page 54; 11a, page 57; and 12a, page 59). Factors other than clay content, such as organic matter content and type of clay minerals present, may have been responsible for the poorer correlation between CEC and clay content in this group of soils.

Percent Base Saturation and the Sum of Exchangeable Bases

The twelve soil profiles also were divided into three groups on the basis of the similarity of the profile patterns and degrees of difference of percent base saturation values determined with the two methods.

Dickson, Sequoia, Maury, Hartsells, and Tilsit (Figures 3c, page 44; 5c, page 48; 10c, page 56; 11c, page 57; and 12c, page 59) were

placed in a group (group 1) because they all showed similar profile patterns and the smallest differences in percent base saturation between the two methods. In these soils, the percent base saturation gradually decreased from the surface to about 25 inches; thereafter, i.e., below about 25 inches, the values remained essentially constant with greater profile depth. There were greater differences in percent base saturation by the two methods in the upper horizons than in the lower horizons. These differences may be due to less weathering of the younger materials in the overlying horizons and to greater weathering of the possibly older materials in the underlying horizons and/or to past fertilization and liming of the surface horizons.

Grenada, Loring, and Dexter (Figures 8c, page 53; 13c, page 60; and 14c, page 62) were placed in another group (group 2) because they seemed to show intermediate differences in percent base saturation values between the two methods as compared to the soils of group 1. They also tended to have uniform changes in values from horizon to horizon in the profiles.

The greatest differences in percent base saturation between the two methods were found in group 3 soils, Huntington, Sequatchie, Collins, and Emory (Figures 4c, page 46; 6c, page 50; 7c, page 51; and 9c, page 54). Huntington showed variations in percent base saturation with depth, but still seemed to fall into this group. In the Sequatchie, Emory, and Huntington profiles, there were smaller differences in percent base saturation in the lower horizons than in the upper parts of the profiles. The Collins profile was an exception to this trend. All soils in group 3 have

been formed from alluvium and appear to have high percent base saturation values throughout the profile. This magnitude of percent base saturation might be an explanation for the greater differences in percent base saturation between the two methods. The younger, high percent base saturation soils appear to have greater differences in percent base saturation by the two methods than do the older, lower percent base saturation soils.

Although the actual differences in percent base saturation by the two methods are greater in high percent base saturation soils than in the lower percent base saturation soils, the proportionate differences between the two methods remain relatively uniform.

Since percent base saturation is one of the major criteria for differentiating soils among orders in the New Classification System, it would appear that the choice of the CEC method used in the analysis would be more critical in high base saturation soils than in the low base saturation soils.

Another grouping of the soils was made on the basis of the sum of exchangeable bases. Dickson, Sequoia, Collins, Maury, Hartsells, Tilsit, Dexter, and Loring (Figures 3e, page 44; 5e, page 48; 7e, page 51; 10e, page 56, 11e, page 57; 12e, page 59; 13e, page 60; and 14e, page 62) were placed in group 1a. In each soil of this group, the sum of exchangeable bases paralleled the percent base saturation.

Huntington, Sequatchie and Grenada, group 2a,(Figures 4e, page 46; 6e, page 50; and 8e, page 53), were separated from group 1a because

they showed different patterns in the sum of exchangeable bases. These soils also showed a close relationship between the sum of exchangeable bases and percent base saturation.

Only Emory (Figure 9e, page 54) was placed in group 3a. The sum of exchangeable bases in Emory did not relate well with percent base saturation as determined by either method.

Calcium/Magnesium Ratio

Dickson, Sequoia, Maury, Hartsells, Tilsit, and Loring showed a rather similar pattern in Ca/Mg ratio (Figures 3f, page 44; 5f, page 48; 10f, page 56; 11f, page 57; 12f, page 59; and 13f, page 60). In all soils with the exception of Hartsells, there were very low Ca/Mg ratios in the lower layers. Ca/Mg ratios were high in the upper parts of most of the twelve profiles.

The Ca/Mg ratio pattern of Grenada (Figure 8f, page 53) was similar to that of the other soils, but there was a poorer relationship of Ca/Mg ratio to percent base saturation and/or to pH in this profile than in that of the other profiles.

There were great variations of Ca/Mg ratios in the Huntington, Sequatchie, Collins, Emory, and Dexter profiles (Figures 4f, page 46; 6f, page 50; 7f, page 51; 9f, page 54; and 14f, page 62). In these soils, Ca/Mg ratios were generally related to percent base saturation values.

Exchange Acidity

The relationships between EA and CEC and clay content were the criteria for grouping the soils relative to EA.

Dickson, Sequoia, Maury, Hartsells and Tilsit (Figures 3b, page 44; 5b, page 48; 10b, page 56; 11b, page 57; and 12b, page 59) showed rather similar profile EA patterns. EA appeared to vary with CEC and clay content. The EA values of these soils appeared to have an inverse relationship to base saturation.

EA of Loring and Dexter (Figures 13b, page 60 and 14b, page 62) was well correlated with CEC and clay content. EA of Loring and Dexter decreased with depth, as did percent base saturation, pH, and CEC.

Huntington, Grenada and Emory were grouped together because they showed small variations of values in EA in the upper parts rather than in the lower parts of the profiles (Figures 4b, page 46; 8b, page 53; and 9b, page 54). EA in these soils was well correlated with clay content. EA of Grenada was inversely related to pH and to percent base saturation as based on both methods of determining CEC.

Sequatchie showed a unique pattern (Figures 6b, page 50), since it exhibited small variation in EA values throughout the profile.

pH Determined by 0.01M $CaCl_2$ Method

pH values for Dickson, Sequoia, Sequatchie, Collins, Grenada, Emory, Maury, Hartsells, Tilsit, Loring and Dexter were grouped together (Figures 3d, page 44; 5d, page 48; 6d, page 50; 7d, page 51; 8d, page 53; 9d, page 54; 10d, page 56, 11d, page 57; 12d, page 59; 13d, page 60; and 14d, page 62) because their pH values were generally similar throughout their profiles. pH values of these soils decreased with depth.

The pH pattern of the Huntington was not similar to those of the other soils (Figures 4d, page 46 and 9d, page 54), since below 15 inches its pH values increased with depth rather than decreased with depth.

CHAPTER V

SUMMARY AND CONCLUSIONS

Field and laboratory studies were conducted on twelve selected soil series representing a wide range of parent material, texture, and physiographic positions in East, Middle, and West Tennessee. Each soil profile was excavated to about 60 inches in depth in order to describe its morphological characteristics. Samples were collected from each described horizon to the depth of the pit. These chemical properties were studied: pH, CEC, exchangeable bases, percent base saturation, the sum of exchangeable bases, EA, Ca/Mg ratio, and available P and K. Particle size distribution also was determined. Differences in some chemical properties within and among soils studied were compared and related.

In the twelve soil profiles, pH values were relatively high in the surface horizons, but pH values were relatively low in the subsoils. Rather high pH values in the surface were probably due to the addition of lime. The pH values of the soil profiles varied with the methods used. The 1:1 soil-0.01M $CaCl_2$ method resulted in the lowest pH values in comparison with those values that were obtained in water.

CEC of most soils studied was relatively low. Sequoia and Maury showed a greater exchange capacity and correspondingly higher clay content than the other soils. In all soils and all horizons cation exchange capacity by the NH_4OAc method was lower than cation exchange

capacity by the sum of cations method. This was because cation exchange capacity determined by the sum of cations method included hydrogen and aluminum ions extracted by the $BaCl_2$-TEA method.

Percent base saturation, determined by both methods, was rather high in the surface horizons of all soils except Sequatchie, Hartsells, and Loring, probably because of the additions of lime. The lower percent base saturation in the subsoils could have been due to a long period of weathering and leaching of bases. Percent base saturation calculated from NH_4OAc-CEC was greater than that calculated from sum-of-cations-CEC.

In all surfaces of all soils except Sequatchie, exchangeable Ca was rather high, while exchangeable Mg was relatively low in the profiles. Exchangeable K and Na were very low throughout the profiles.

EA was rather high in the surface horizons of all soils, although in most cases pH values were near to neutral. EA varied with the clay content of most soil profiles.

In most of the soil profiles studied, available P and K were much higher in the surface horizons than in the subsoils, with the exception of higher quantities of available P in the subsoils of Maury and Emory. Rather high available P and K in the surfaces of most soils were probably due to the additions of fertilizer phosphorus and potassium. The small quantities of available P and K in some soils might have been due to frequent cropping over a long period of time and/or to other factors.

In studying the relationships of some chemical properties of each soil profile, CEC of all soil profiles varied with EA and clay content; EA also varied with clay content in all soil profiles except in the

Dickson and Sequatchie profiles. In all soils, pH values varied with the sum of bases as well as with percent base saturation.

Two cycles of profile development were found in Dickson, Huntington, Sequoia, Collins, Grenada, Emory, Tilsit, Loring, and Dexter profiles, but only one cycle of profile development was found in the Sequatchie, Maury, and Hartsells profiles.

CEC determined by the NH_4OAc and by the sum of cations methods showed considerable variations in values within and among the soils. Soils with great differences in CEC between the two methods were Collins, Emory, Maury, Loring, and Dexter. Dickson, Sequatchie, and Hartsells showed intermediate differences in CEC values between the two methods. The smallest differences in CEC values found by the two methods used were noted in the Huntington, Sequoia, Grenada, and Tilsit profiles.

The degree of correlation between CEC and clay content was studied. CEC of Dickson, Sequatchie, Collins, Grenada, Loring, and Dexter were well correlated with the clay content in the profiles. Huntington, Sequoia and Maury were somewhat less well correlated with CEC to clay content in the profiles. The poorest correlation between CEC and clay content was in the Emory, Hartsells, and Tilsit profiles.

Dickson, Sequoia, Maury, Hartsells and Tilsit, the older soils, showed the smallest differences in percent base saturation between the two CEC methods. Grenada, Loring and Dexter were intermediate in percent base saturation values between the two CEC methods. Huntington, Sequatchie, Collins, and Emory, the younger soils, had the greatest differences in percent base saturation values between the two CEC methods used.

Since percent base saturation is one of the major criteria for differentiating soils among orders in the New Classification System, the choice of the CEC methods used is more critical in the high percent base saturation soils than in the low percent base saturation soils.

Most of the twelve soil series had rather low pH values, low CEC, low percent base saturation, and were low in available P and K. However, there were some substantial differences in chemical properties within and among the soil profiles. These differences may be large enough to justify more or less lime and fertilizer applications than are presently recommended on the basis of the surface soil test results only. Because of differences in the chemical properties of the subsoils, the adjustments in recommendations should be determined from studies of crop yield responses to additions of fertilizer and lime.

LITERATURE CITED

LITERATURE CITED

1. Bell, F. F. A lime requirement study of some Tennessee soils. Unpublished Master's thesis, The University of Tennessee, 1949.

2. _____. Characteristics and production capacity of Grenada and related soils in West Tennessee. Unpublished Doctoral dissertation, Iowa State College, 1956.

3. Bhumbla, D. R., and Mclean, E. O. Aluminum in soils: VI Changes in pH-dependent acidity, cation exchange capacity and extractable aluminum with additions of lime to acid surface soils. Soil Sci. Soc. Amer. Proc., 29:370-374. 1965.

4. Black, C. A. Soil-plant relationships. New York: John Wiley and Sons, Inc., 1968.

5. Bradfield, R. Calcium in the soil: I Physico-chemical relations. Soil Sci. Soc. Amer. Proc., 6:8-15. 1942.

6. Buckman, H. O., and Brady, N. C. The nature and properties of soils. New York: MacMillan Company, 1969.

7. Buntley, C. J. A more quantitative approach to soil morphology. Unpublished Doctoral dissertation, South Dakota State University, 1963.

8. Carolus, R. L., and Lucas, R. E. Some factors influencing fluctuation in acidity during periods of extreme change in moisture content of soil. Proc. Amer. Soc. Hort. Sci., 42:507-510. 1945.

9. Chapman, H. D., Axley, J. H., and Curtis, D. C. The determination of pH at soil moisture contents approximating field condition. Soil Sci. Soc. Amer. Proc., 5:191-200. 1940.

10. _____. Cation exchange capacity. Agronomy, 9:891-901. 1965.

11. Coleman, N. T., and Melich, A. The chemistry of soil pH. U.S.D.A. Yearbook Agr., pp. 72-77. 1957.

12. _____, Kamprath, E. J., and Weed, S. B. Liming. Advances in Agron. X. New York: Academic Press, 1958.

13. _____, Weed, S. B., and McCracken, R. J. Cation exchange capacity and exchangeable cations in Piedmont soils of North Carolina. Soil Sci. Soc. Amer. Proc., 23:146-149. 1959.

14. _____, and Thomas, G. W. Buffer curves of acid clays as affected by the presence of ferric iron and aluminum. Soil Sci. Soc. Amer. Proc., 28:187-190. 1964.

15. _____, and _____. The basic chemistry of soil acidity. Agronomy, 12:1-34. 1967.

16. Dunn, L. E. Lime requirement determination of soils by means of titration curves. Soil Sci., 56:341-351. 1943.

17. Fitts, J. W., and Nelson, W. L. The determination of lime and fertilizer requirement of soils through chemical tests. In A. G. Norman, ed., Advances in Agron. New York: Academic Press, 1956.

18. Godfrey, C. L., and Riecken, F. F. Distribution of phosphorus in some genetically related loess-derived soils. Soil Sci. Soc. Amer. Proc., 18:80-84. 1954.

19. Graham, E. R. An explanation of theory and methods of soil testing. Missouri Agr. Exp. Sta. Bul. 734. 1959.

20. Grim, R. E. Clay mineralogy. New York: McGraw-Hill Book Company, 1968.

21. Grossman, R. B., Fehrenbacher, J. B., and Beavers, A. H. Fragipan soils of Illinois: I. General characteristics and field relationships of Hosmer silt loam. Soil Sci. Soc. Amer. Proc., 23:55-59. 1959.

22. Helling, C. S., Chester, G., and Corey, R. B. Contributions of organic matter and clay to soil cation exchange capacity as affected by the pH of the saturating solution. Soil Sci. Soc. Amer. Proc., 28:517-520. 1964.

23. Hutcheson, Jr., J. B., and Bailey, H. H. Fragipan soils: certain genetic implications. Soil Sci. Soc. Amer. Proc., 28:684-685. 1964.

24. Instruction Manual for Hitachi-Perkin-Elmer Flame Photometry Attachment (139-0400) for Model 139 UV-VIS Spectrophotometer. Printed. Madison, Illinois: Coleman Instruments Corporation, 1965.

25. Jackson, M. L. Soil chemical analysis. Englewood Cliffs, New Jersey: Prentice-Hall, 1958.

26. Jackson, G. T., et al. Soil survey of Putnam County, Tennessee. Washington: U. S. Government Printing Office, 1963.

27. McGeorge, W. T. The measurement and significance of hydroxyl-ion concentration alkaline calcareous soils. Ariz. Agr. Exp. Sta. Tech. Bul. 57, 1935.

28. _____. Factors contributing to the reaction of soils and their pH measurement. Ariz. Agr. Exp. Sta. Tech. Bul., 78, 1938.

29. Mehlich, A., and Colwell, W. E. Influence of nature of soil colloids and degree of base saturation on growth and nutrient uptake by cotton and soybeans. Soil Sci. Soc. Amer. Proc., 11:148-179. 1943.

30. _____. Effect of soil colloid on cation-absorption capacity and on exchangeable hydrogen and calcium as measured by different methods. Soil Sci., 60:289-304. 1945.

31. _____, and Reed, J. E. Influence of type of colloid and degree calcium saturation on fruit characteristics of peanuts. Soil Sci. Soc. Amer. Proc., 11:201-205. 1946.

32. Murdock, J. T., and Engelbert, L. E. The importance of subsoil phosphorus to corn. Soil Sci. Soc. Amer. Proc., 22:53-57. 1958.

33. Page, N. R. Procedures used by State soil-testing laboratories in the Southern Region of the United States. Southern Cooperative Series. Bul. No. 102, 1965.

34. Parsons, R. S. Characterization of Dewey and Fullerton soils. Unpublished Master's thesis, The University of Tennessee, 1957.

35. Peech, M. Chemical methods for assessing soil fertility. In H. B. Kitchen, ed. Diagnostic Techniques for Soils and Crops. Washington: American Potash Institute, 1948.

36. _____, Alexander, L. T., Dean, L. A., and Reed, J. F. Methods of soil analysis for soil fertility investigations. U.S.D.A. Circular 757, 1947.

37. _____, Cowan, R. L., and Parker, J. H. A critical study of the $BaCl_2$-triethanolamine and the ammonium acetate methods for determining the exchangeable hydrogen content of soils. Soil Sci. Soc. Amer. Proc., 26:37-40. 1962.

38. _____. Exchange acidity. Agronomy, 9:906-913. 1965.

39. _____. Hydrogen-ion activity. Agronomy, 9:914-926. 1965.

40. Pratt, P. F., and Holowaychuk, N. A. A comparison of ammonium acetate, barium acetate and buffered barium chloride methods of determining cation exchange capacity. Soil Sci. Soc. Amer. Proc., 18:365-368. 1954.

41. _____, and Bair, B. F. Cation exchange capacities of some acid soils of California. Hilgardia, 33:689-706. 1962.

42. Reed, J. F., and Cummings, R. W. Soil reaction-glass electrode and colorimetric methods for determining pH values of soils. Soil Sci., 59:97-104. 1945.

43. Rose, C. J., Lawton, K., and Ellis, B. G. Lime requirement related to physical and chemical properties of nine Michigan soils. Soil Sci. Soc. Amer. Proc., 28:190-212. 1964.

44. Schofield, R. K., and Taylor, A. W. The measurement of soil pH. Soil Sci. Soc. Amer. Proc., 19:164-167. 1955.

45. Schollenberger, C. J., and Simon, R. H. Determination of exchange capacity and exchangeable bases in soil-ammonium acetate method. Soil Sci., 50:13-25. 1945.

46. Seventh Congress of the International Society of Soil Science, Tour II guide booklet, Unpublished, 1960.

47. Shaw, W. M. Determination of exchangeable hydrogen and lime requirement of soils. J. Assoc. Off. Agr. Chem., 32:595-597. 1949.

48. _____. Report of liming materials and exchangeable hydrogen in soils. J. Assoc. Off. Agr. Chem., 34:595-597. 1951.

49. _____, and MacIntire, W. H. Exchangeable hydrogen as determined by various procedures in relation to the soil's capacity for calcite decomposition. J. Assoc. Off. Agr. Chem., 34:471-492. 1951.

50. Soil Survey Laboratory methods and procedures for collecting soil samples. Soil survey investigation report No. 1. S.C.S., U.S.D.A., 1967.

51. Soil Survey manual, U.S.D.A. Handbook No. 18, 1951.

52. Sutton, Jr., J. P. The influence of loess on the formation and morphology of Mountview and Dickson soils in Robertson County, Tennessee. Unpublished Master's thesis, The University of Tennessee, 1964.

53. Thorne, D. W., and Seatz, L. F. Factors controlling soil pH. In F. E. Bear, ed. Chemistry of the soil. New York: Reinhold, pp. 220-227. 1955.

54. Webster, G. R., and Harward, M. E. Hydrogen and calcium ion ratios in dilute equilibrium solutions as related to cation saturation. Soil Sci. Soc. Amer. Proc., 23:446-451. 1959.

55. Wells, K. L., and Parks, W. L. Vertical distribution of soil phosphorus and potassium on several established alfalfa stands that received various rates of annual fertilization. Soil Sci. Soc. Amer. Proc., 25:117-120. 1961.

56. Whitney, R. S., and Gardner, R. The effect of carbon dioxide on soil reaction. Soil Sci., 55:127-141. 1943.

57. Winters, E., and Simonson, R. W. The subsoil. In A. G. Norman, ed. Advances in Agron. New York: Academic Press, Inc., 1951.

APPENDIXES

APPENDIX A

TABLE V

pH VALUES DETERMINED BY FIVE DIFFERENT METHODS

Soil Series	Horizon	Depth (inches)	pH Value				
			0.01M $CaCl_2$	Water Paste	Soil:Water 1:1	Soil:Water 1:10	Water Leached
Dickson	Ap	0 -12	6.4	6.6	6.9	7.1	7.2
	B21t	12 -22	5.2	5.7	5.8	6.0	5.9
	B'21tx	22 -30	4.1	4.8	4.8	5.0	5.1
	B'22tx	30 -40	4.1	4.8	4.8	5.0	5.2
	IIB'23tx	40 -51	4.1	4.8	4.9	5.0	5.1
	IIB'3t	57 -60	4.1	4.9	4.9	5.0	5.1
Huntington	Ap	0 -11	5.8	6.2	6.3	6.6	6.5
	B21	11 -17	4.6	5.1	5.2	5.4	5.4
	B22	17 -25	4.6	5.1	5.2	5.4	5.4
	C1	25 -31	4.7	5.2	5.3	5.5	5.4
	IIC2	31 -40	4.8	5.3	5.3	5.6	5.6
	IIIA11b	40 -48	4.9	5.3	5.4	5.7	5.7
	IIIA12b	48 -55	4.9	5.4	5.5	5.7	5.7
	IIIA13b	55 -59	5.0	5.5	5.5	5.8	5.7
	IIIB2b	59 -64	5.1	5.5	5.6	5.8	5.7
Sequoia	Ap	0 - 6	6.6	6.9	7.1	7.3	7.2
	A1-B1	6 - 9.5	6.3	6.7	6.9	7.1	7.0
	IIB2t-A1	9.5-15	4.7	5.0	5.2	5.2	5.7
	IIB21t	15 -20.5	4.5	5.0	5.1	5.1	5.6
	IIB22t	20.5-30	4.5	5.1	5.3	5.3	5.7
	IIIB3t	30 -38	4.4	5.0	5.1	5.2	5.6
	IIIC1	38 -50	4.4	5.8	5.0	5.1	5.5
	IIIR	50 -60	4.2	4.8	4.8	5.1	5.4
Sequatchie	Ap	0 -11	5.2	5.7	5.9	6.4	6.1
	B1	11 -15	5.4	5.7	6.0	6.5	6.3
	B21t	15 -25	5.6	5.8	6.1	6.5	6.4
	B22t	25 -34	5.8	6.0	6.2	6.6	6.5
	B23t	34 -46	5.7	5.9	6.3	6.7	6.7
	B3t	46 -56	5.4	5.8	6.2	6.6	6.5
	I-IIB3 or C	56 -60	5.4	5.7	6.1	6.6	6.5

TABLE V (continued)

Soil Series	Horizon	Depth (inches)	pH Value 0.01M $CaCl_2$	Water Paste	Soil:Water 1:1	Soil:Water 1:10	Water Leached
Collins	Ap	0- 6	6.1	6.5	6.5	7.1	6.9
	IIA1	6-12	6.1	6.5	6.6	7.0	6.8
	IIB1	12-20	5.2	5.4	5.8	5.9	6.0
	IIB2	20-29	5.2	5.3	5.7	5.9	5.9
	IIIA2'b	29-36	5.5	5.7	6.0	6.2	6.2
	IIIA2'b-B'2xb	36-45	4.9	5.1	5.4	5.6	5.7
	IIIB'2gxb	45-53	4.6	4.8	5.1	5.4	5.5
	IIIB2'gxb	53-60	4.4	4.6	4.9	5.2	5.4
Grenada	Ap1	0- 6	6.7	7.4	7.4	7.5	7.6
	Ap2	6-12	6.6	7.0	7.0	7.2	7.4
	B21	12-22	5.1	5.3	5.5	5.6	5.8
	B22	22-31	4.7	4.9	5.2	5.4	5.6
	IIA2'	31-38	4.5	4.7	5.0	5.4	5.2
	IIB2'x-A2'	38-57	4.3	4.6	4.9	5.4	5.1
	IIB2'x-A'2	57-60	4.3	4.8	5.2	5.9	5.1
Emory	Ap	0- 7	5.7	6.0	6.3	6.6	6.3
	B21t	7-17	5.8	6.3	6.4	6.7	6.4
	B22t	17-24	5.5	6.0	6.1	6.3	6.2
	IIA1b	24-30	5.3	5.9	6.0	6.2	6.1
	IIB1tb	30-39	5.2	5.9	5.9	6.1	6.0
	IIB21tb	39-51	5.2	5.6	5.9	6.1	6.0
	IIB22tb	51-59	5.1	5.7	5.8	6.0	5.9
	IIB3tb	59-65	4.6	5.4	5.5	5.6	5.6
Maury	Ap	0-10	6.0	6.4	6.6	6.9	6.7
	B21t	10-21	4.7	5.4	5.5	5.7	5.6
	B22t	21-34	4.2	4.9	4.9	5.0	5.1
	B23t	34-42	4.1	4.7	4.7	4.8	5.1
	B24t	42-57	4.0	4.8	4.7	4.8	5.0
	B25t	57-60	4.0	4.8	4.8	4.8	5.0
Hartsells	Ap	0-10	4.9	5.6	5.7	6.1	5.8
	B21	10-18	4.5	5.3	5.4	5.6	5.5
	B22	18-28	4.2	4.8	4.8	5.1	4.9
	B23	28-33	4.1	4.7	4.7	4.9	4.8
	IIR	33+	---	---	---	---	---

TABLE V (continued)

Soil Series	Horizon	Depth (inches)	pH Value 0.01M $CaCl_2$	Water Paste	Soil:Water 1:1	Soil:Water 1:10	Water Leached
Tilsit	Ap	0- 5	6.5	6.7	6.7	7.0	7.3
	A3	5-10	6.5	6.8	6.8	7.0	7.1
	B1	10-16	4.9	5.4	5.5	5.8	5.6
	B21	16-23	4.3	4.9	5.0	5.2	5.4
	IIB'22tx	23-35	4.0	4.9	4.9	5.0	5.0
	IIB'23tx	35-45	4.0	4.8	4.7	4.8	4.9
	IIB'24tx	45-57	3.8	5.6	4.6	4.8	4.8
Loring	Ap1	0- 6	4.7	4.8	5.1	5.5	5.7
	Ap2	6- 9.5	5.0	5.2	5.4	5.8	5.9
	B21t	9.5-18	5.5	5.7	5.9	6.3	6.2
	B22t	18-25	4.6	4.8	5.1	5.4	5.5
	B23t	25-36	4.4	4.6	4.9	5.2	5.4
	I-IIA2'x-B2'x	36-41	4.3	4.5	4.8	5.1	5.4
	I-IIB2'x-A2'x	41-50	4.3	4.5	4.8	5.1	5.4
	I-IIB3'x-A2'x	50-56	4.3	4.6	4.9	5.2	5.5
	IIB3'x-A2'x	56-60	4.3	4.7	5.1	5.4	5.7
	IIC	60+	---	---	---	---	---
Dexter	Ap	0- 6	6.5	6.9	7.0	7.4	7.3
	B21t	6-14	5.2	5.3	5.7	6.0	5.9
	B22t	14-24	4.8	4.9	5.4	5.6	5.5
	B23t	24-32	4.7	4.9	5.2	5.5	5.3
	B24t	32-43	4.5	4.9	5.3	5.6	5.5
	I-IIB31t	43-48	4.4	4.8	5.2	5.4	5.5
	IIB32	48-60	4.5	4.9	5.6	5.9	5.7

APPENDIX B

TABLE VI

PARTICLE SIZE DISTRIBUTION AND TEXTURAL CLASSES

Soil Series	Horizon	Depth (inches)	Particle size distribution (mm) Percent Sand 2.0-0.05	Percent Silt 0.05-0.02	Percent Silt 0.02-0.002	Percent Clay <0.002	Textural Class
Dickson	Ap	0 -12	8.5	22.1	47.3	22.1	sil
	B21t	12 -22	5.5	20.2	48.9	25.4	sil
	B'21tx	22 -30	7.4	21.2	47.9	23.5	sil
	B'22tx	30 -40	6.8	17.3	40.3	35.6	sicl
	IIB'23tx	40 -51	7.9	17.0	38.4	36.7	sicl
	IIB'3t	51 -60	9.8	15 3	42.3	32.6	sicl
Huntington	Ap	0 -11	6.4	25.9	51.6	16.1	sil
	B21	11 -17	6.8	24.5	53.3	15.4	sil
	B22	17 -25	5.9	29.7	51.6	12.8	sil
	C1	25 -31	1.5	30.3	57.3	10.9	si
	IIC2	31 -40	12.3	25.6	44.2	17.9	sil
	IIIA11b	40 -48	5.4	22.9	51.4	20.3	sil
	IIIA12b	48 -55	4.2	20.1	57.0	18.7	sil
	IIIA13b	55 -59	3.6	15.0	60.5	20.9	sil
	IIIB2b	59 -64	2.6	16.4	58.6	22.4	sil
Sequoia	Ap	0 - 6	18.6	16.5	46.8	18.1	sil
	A1-B1	6 - 9.5	12.0	3.9	54.4	29.7	sicl
	IIB2t-A1	9.5-15	5.3	8.9	35.8	50.0	sicl
	IIB21t	15 -20.5	2.4	5.0	30.2	62.4	c
	IIB22t	20.5-30	2.1	5.1	30.2	62.6	c
	IIIB3t	30 -38	3.4	6.3	32.2	58.1	c
	IIIC1	38 -50	2.6	6.4	38.7	52.0	c
	IIIR	50 -60	4.9	8.1	47.0	40.0	sicl/sic
Sequatchie	Ap	0 -11	52.8	9.9	19.4	17.9	sal
	B1	11 -15	53.3	13.4	15.3	18.0	l
	B21t	15 -25	48.4	8.1	18.4	25.1	l
	B22t	25 -34	49.9	8.1	16.1	25.9	l
	B23t	34 -46	58.1	9.4	15.5	17.0	sal
	B3t	46 -56	66.7	5.8	11.7	15.8	sal
	I-IIB3 or C	56 -60	70.2	5.4	11.1	13.3	sal

TABLE VI (continued)

Soil Series	Horizon	Depth (inches)	Particle Size Distribution (mm) Percent Sand 2.0-0.05	Percent Silt 0.05-0.02	Percent Silt 0.02-0.002	Percent Clay <0.002	Textural Class
Collins	Ap	0- 6	0.8	37.7	46.2	15.3	sil
	IIA1	6-12	0.8	40.5	44.8	13.9	sil
	IIB1	12-20	0.9	43.5	40.4	15.2	sil
	IIB2	20-29	0.4	35.2	47.1	17.3	sil
	IIIA2'b	29-36	1.0	26.2	54.3	18.5	sil
	IIIA2'b-B'2xb	36-45	3.7	39.9	43.8	12.6	si/sil
	IIIB'2gxb	45-53	4.2	37.4	45.8	12.6	si/sil
	IIIB2'gxb	53-60	5.7	35.8	46.1	12.4	sil
Grenada	Ap1	0- 6	3.1	46.9	36.0	14.0	sil
	Ap2	6-12	2.9	46.2	38.5	12.4	si/sil
	B21	12-22	3.1	37.9	40.2	18.8	sil
	B22	22-31	3.6	35.6	43.9	16.9	sil
	IIA2'	31-38	3.7	36.5	40.2	19.6	sil
	IIB2'x-A2'	38-51	1.7	39.3	35.6	23.4	sil
	IIB2'x-A'2	51-60	1.3	40.4	40.3	18.0	sil
Emory	Ap	0- 7	15.4	19.7	36.7	28.2	sicl
	B21t	7-17	15.6	17.8	36.4	30.2	sicl
	B22t	17-24	15.9	19.2	37.7	27.2	sil/sicl
	IIA1b	24-30	13.8	18.4	42.8	25.0	sil
	IIB1tb	30-39	13.6	28.1	34.9	23.4	sil
	IIB21tb	39-51	14.1	20.0	43.1	22.8	sil
	IIB22tb	51-59	15.4	19.2	40.2	25.2	sil
	IIB3tb	59-65	20.4	15.3	33.0	31.3	sicl
Maury	Ap	0-10	16.0	17.5	36.4	30.1	sicl
	B21t	10-21	16.0	13.8	33.6	36.6	sicl
	B22t	21-34	16.9	14.2	28.4	40.5	sic
	B23t	34-42	16.9	14.2	26.0	42.9	sic
	B24t	42-57	16.6	14.4	22.1	46.9	c
	B25t	57-60	17.4	12.0	19.5	51.1	c
Hartsells	Ap	0-10	38.1	14.4	32.3	15.2	l
	B21	10-18	40.3	5.5	33.6	20.6	l
	B22	18-28	41.5	13.1	26.0	19.4	l
	B23	28-33	47.0	10.2	19.4	23.4	l
	IIR	33+	----	----	----	----	----

TABLE VI (continued)

Soil Series	Horizon	Depth (inches)	Particle Size Distribution (mm) Percent Sand 2.0-0.05	Percent Silt 0.05-0.02	Percent Silt 0.02-0.002	Percent Clay <0.002	Textural Class
Tilsit	Ap	0- 5	27.7	15.3	37.2	19.8	sil
	A3	5-10	26.4	19.0	34.5	20.1	sil
	B1	10-16	21.2	12.3	39.4	27.1	sil
	B21	16-23	22.3	13.1	37.1	27.5	sil/cl
	IIB'22tx	23-35	23.9	13.3	30.7	32.1	cl
	IIB'23tx	35-45	15.9	12.7	29.2	42.2	sic
	IIB'24tx	45-57	20.4	14.7	29.6	35.3	cl
Loring	Ap1	0- 6	12.5	33.3	37.1	17.1	sil
	Ap2	6- 9	12.7	32.4	37.8	17.1	sil
	B21t	9-18	2.9	26.4	40.1	30.6	sicl
	B22t	18-25	2.0	30.7	40.8	26.5	sil
	B23t	25-36	3.6	29.9	43.0	23.5	sil
	I-IIA2'x-B2'x	36-41	7.5	30.8	41.4	20.3	sil
	I-IIB2'x-A2'x	41-50	20.6	26.1	36.2	17.1	sil
	I-IIB3'x-A2'x	50-56	43.9	13.0	28.4	14.7	l
	IIB3'x-A2'x	56-60	62.2	10.8	17.1	9.9	l
	IIC	60+	----	----	----	----	----
Dexter	Ap	0- 6	9.2	30.3	45.3	15.2	sil
	B21t	6-14	4.1	31.3	35.9	28.7	sicl
	B22t	14-24	3.8	24.2	40.0	32.0	sicl
	B23t	24-32	4.6	18.4	47.2	29.8	sicl
	B24t	32-43	7.8	30.9	35.4	25.9	sil
	I-IIB31t	43-48	26.2	23.6	29.9	20.3	sil
	IIB32	48-60	34.2	21.1	25.1	19.6	l

c = clay; cl = clay loam; sic = silty clay; sicl = silty clay loam; sil = silt loam; si = silt; l = loam; sal = sandy loam.

VITA

Charern Oonmuang, a native Thai, was born in Kampaengpet Province, Thailand, on May 18, 1941. He attended elementary school there and secondary school in Pothisarn Sueksa School in Nakornsawarn Province. He was graduated from Amnuaysilpa High School, Bangkok, Thailand, in 1958. He then attended Kasetsart University, and, in April 1964, received his Bachelor of Science degree in Agronomy. From May, 1964, to December, 1967, he was employed as an Agronomist by the Department of Land Development, the Ministry of National Development in Thailand. He was acting superintendent of the Acid Soil Improvement Center, which is located in the middle part of Thailand, in September, 1967.

In January of 1968, he entered graduate school at The University of Tennessee, under a THAI-AID Program working towards his Master of Science degree with a major in Agronomy.