

PHYSICAL AND CHEMICAL ANALYSES
OF SOME GRANITIC SOILS

By

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PHYSICAL AND CHEMICAL ANALYSES
OF SOME GRANITIC SOILS

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CHAPTER I

INTRODUCTION

The scientific study of soils is fundamental to the growth of crops. A study of the physical and chemical properties of soils is a component part of soil genesis, soil morphology, and soil classification.

Smith, Gray and Galloway (41) stated that the effect of parent material is dominant in soil series developed from granitic rocks in South Central Oklahoma. Granitic rocks are formed essentially from an assemblage of crystalline grains of feldspars and quartz with a small proportion of mica flakes and occasionally hornblende (33). Gray and Galloway (15) reported that granitic soils are formed from granitic hills mostly in the Precambrian period. The elevation variability is from 700 to 1,300 feet. Average annual precipitation is about 38 inches (moist subhumid region) with cross timber and tall grass as the natural vegetation. The main use of the granitic soils and mountains is for wildlife protection and some grazing.

The objective of this study was to determine the physical and chemical properties of four selected soils from Johnston County, Oklahoma. These soils are from the Belton, Tishomingo, Ravia, and Agan series. Physical determinations were mechanical analyses. The chemical properties measured were soil reaction (pH), exchangeable

cations, cation exchange capacity, base saturation, total phosphorus, and organic matter content. In addition, the clay minerals of these granitic soils were determined by X-ray diffraction.

CHAPTER II

LITERATURE REVIEW

Physical Analyses

Physical analyses of soils, especially mechanical analyses, are basic requirements for a knowledge of the soil's physical properties. Mechanical analyses yield fundamental data which are indispensable in the study of classification, morphology, and genesis of soils (21). The major soil separates: coarse fragments (> 2 mm), sand (2-0.05 mm), silt (0.5-0.002 mm), and clay (< 0.002 mm); constitute one of many possible classification schemes (42). In the determination of soil textural class, assuming no gravel present, it is often desirable to separate the soil into three size fractions: sand, diameter larger than 50 μ ; silt, diameter between 50 and 24 μ ; and clay, diameter smaller than 24 μ (31). The common physical characteristics of soils that can be determined through field observations are color, texture, structure, consistence, porosity, nature of the ped surfaces, and content of the smaller coarse fragments.

For mechanical analyses of soils, Youngberg (45) suggested that soil samples should be pretreated with hydrogen peroxide to destroy the organic matter. Furthermore, the soil should be treated with five per cent calgon solution as the dispersing agent if the hydrometer method is used. Day (10) reported that the hydrometer method of particle size analyses is a popular procedure in soil laboratories.

Although it is less accurate than the pipette method, it is sufficiently accurate for many practical purposes. Its chief advantages are speed and convenience. Bouyoucos (5) stated that the hydrometer method seems to be especially accurate with the fraction 0.005 mm diameter. In the clay fraction (0.002 mm) it may not be so accurate in some soils that have a large amount of finer material just slightly above the 0.002 mm size. In such soils, the hydrometer method measures a larger content of the 0.002 mm fraction than the pipette method, but the difference may not be more than 10 per cent.

Mineralogical Analyses

Mineralogical analyses by X-ray diffraction are used to determine the clay minerals of soils. In X-ray analysis the humidity of the atmosphere surrounding the soil sample in the X-ray diffractometer should be controlled because clay minerals lose or gain water to attain equilibrium with resultant changes in basal spacings (1). Clay minerals vary in their cation exchange capacities and specific surfaces. The particle size affected the cation exchange capacity of the kaolinite and illite types of clay minerals, but did not appear to affect the cation exchange capacity of the montmorillonite clay minerals to any great extent (27). The cation affinity of Na-saturated materials increased in the order $K > Mg > Ca > Sr > Ba$ for montmorillonite clays, $Mg > K > Ca > Sr > Ba$ for biotite, $Mg > Ca > Sr > K > Ba$ for muscovite, and $K > Ba > Sr > Ca > Mg$ for vermiculite (12). All Li-saturated montmorillonites expanded linearly with water contents greater than 35 per cent. Na-saturated hectorite also exhibited similar expansion characteristics. Na-saturated Otay and Wyoming bentonite and

nontronite showed step-wise expansion to about 110 per cent water content, and linear expansion at higher moisture contents. All Ca-saturated montmorillonites expanded in a step-wise manner, reaching a maximum spacing of about 20 Å (14).

Dowdy and Hutcheson (13) reported that illite appears to be the source of potassium released by drying. Potassium fixation at moisture levels higher than four per cent is associated with vermiculite and fixation at lower moisture levels, with montmorillonite. The magnitude of release and fixation appears to be directly related to the type of clay minerals. Mortland, Lawton and Uehara (29) studied the release of potassium from fixed forms of illite, montmorillonite plus vermiculite, and from native forms of illite, biotite plus muscovite. They found the potassium fixed by vermiculite and montmorillonite was available for plant growth. The native potassium of biotite was much more available for plant growth than that of an illite or muscovite. Stanford (43) reported that montmorillonite fixed a very small amount of potassium in the moist state, while illite fixed greater quantities. Mortland, et al. (29) observed that biotite could be altered to vermiculite by plant action and they further noted that increased cation exchange capacity decreased the potassium content and diminished the charge as time and plant action continued. Scott et al. (40) stated that in preliminary experiments with sodium teraphenylboron (NaBPh_4) extracting solution, the non-exchangeable interlayer potassium in illite, muscovite and vermiculite can be extracted.

Chemical Analyses

Chemical analyses of soils measure the chemical properties such as exchangeable cations, cation exchange capacity, percentage base saturation, organic matter content, and soil reaction (pH).

Russell (38) noted that the pH of a soil determined electrometrically on a paste or solution of the soil made up with water depends not only on the salt concentration in the solution, but also on the amount of water added to make the suspension. The higher the ratio of water to soil, the higher was the apparent pH of the soil. The pH of a soil measured in a salt solution is more constant and lower than the pH measured in a water suspension. It was typically lower by 0.5 to 0.9 units, the difference tending to be greater in near neutral than in acid soils. The pH was usually higher in cool, moist weather or in winter than in warm, dry weather or in summer. It was also usually higher under crops in summer than under fallow.

Reeve et al. (34) investigated the effects of exchangeable sodium and exchangeable potassium on the physical properties of soils. Permeability ratio of air to water and modulus of rupture determinations were used. The permeability ratio and modulus of rupture increased markedly with increasing exchangeable sodium percentage. However, increases in the exchangeable potassium percentage had little effect. The percentages of exchangeable calcium and magnesium increased while those of potassium and sodium decreased as the soil moisture increased (7). Soils in which the colloids retain large amounts of calcium are usually in a high state of aggregation, are porous and in good tilth (26). Mazurak (24) stated that the amount of sodium in a soil influences the dispersion of aggregates, thereby affecting the

movement of water. The associated cation with sodium on the clay fraction was hydrogen. The variation in exchangeable hydrogen was from zero to 85 per cent and in calcium from five per cent to excess, exerted very little influence on aggregation, bulk density, hydraulic conductivity, and moisture retention (23). Increasing exchangeable potassium or ammonium only slightly reduced soil aggregation, but greatly reduced water conductivity. Increasing exchangeable hydrogen increased the dispersing action of sodium, potassium and ammonium.

De Villiers and Jackson (21) found that the cation exchange capacity can be markedly increased by pretreatment of chloritic soil clays with alkaline solution. Coleman et al. (9) suggested that the sum of cations, including hydrogen, extracted with 1.0N KCl provides a measure of the so-called permanent charge component of the cation exchange capacity. The cation exchange capacity of clay and organic matter increased linearly with pH (8).

Rhoades and Krueger (35) stated that the amounts of calcium and magnesium extracted by sodium acetate (NaOAc) were, in general, less than those extracted by ammonium acetate (NH₄OAc). Extraction with ammonium acetate reduced the exchangeable potassium and sodium contents of orthosilicates and chain silicates to negligible amounts and of the framework silicates to small amounts except for albite and nepheline. The proportions of extractable cations were in decreasing order of: Ca and Mg > Na > K for all silicate minerals except for the two feldspars microcline and anorthoclase.

Bates and Scott (3) showed that the NH₄OAc-extractable potassium of Marshall subsoil samples dried in an oven at 110C for 48 hours increased from 27 to 210 ppm. This release of potassium was reduced to

varying degrees by adding a variety of organic compounds to the soil samples before they were dried. Available potassium in soils frequently is estimated from the potassium extractable with neutral N NH_4OAc (39). Milford and Jackson (25) stated that exchangeable potassium in soils originated, by weathering process, from the potassium-bearing minerals, mainly mica and feldspars. Potassium levels in soils are also affected by other factors such as the soil environment, cation exchange capacity of the soil, species of cations on the exchange sites, and cropping systems. Exchangeable soil potassium is markedly reduced during the growing season and additions of potassium in corn residues greatly enhanced the exchangeable potassium of soils (17). Krause (22) observed that potassium losses from a strongly acid (pH 4.3) soil were 1.7 to 2.4 times higher than losses from a moderately acid (pH 5.1) soil, and 2.5 to 3.5 times higher than losses from a weakly acid (pH 6.4) soil. Seasons of the greatest potassium leaching were late fall, early spring, and wet period during summer. Exchangeable potassium was lost through leaching more readily than either calcium or magnesium (41).

Cheng and Bray (8) suggested that the use of ethylenediaminetetraacetate (EDTA) as titrant in the volumetric determination of calcium and magnesium in soils is acceptable. There are several variations in the procedures used, but most procedures are designed to determine calcium in one aliquot and calcium plus magnesium in a second aliquot, obtaining the magnesium by difference.

Runge and Riecken (37) showed that the amount of total phosphorus was higher near the surface, had minimum values from one to three feet deep, had maximum values from three to six feet, and had nearly uniform

values below six to seven feet deep. The larger amounts near the surface was attributed to organic phosphorus. Most of the total phosphorus is in the inorganic form, but substantial amounts of organic phosphorus are removed from some soils (2). Okruszko et al. (30) noted that phosphorus in muck soils may be fixed as a calcium phosphate. They also showed that an increase in calcium decreased the availability of native and applied phosphorus. In the pH range from 7.5 to about 8.5, calcium combines with HPO_4^{--} and precipitates. This dicalcium phosphate is relatively insoluble in water and consequently, not readily available for plant growth (41). Bray and Kurtz (6) suggested the procedure of using perchloric acid as an extracting reagent for determination of total, organic and available forms of phosphorus in soils.

CHAPTER III

LABORATORY METHODS AND PROCEDURES

All soil samples for this experiment were collected from each horizon of four granitic soil profiles of the Belton, Tishomingo, Ravia, and Agan series. These soil profiles are located in Johnston County, Oklahoma. (Profile descriptions are found in the Appendix.) The soil samples were air-dried in the laboratory and then divided into two portions: unground soils for physical analyses (mechanical analyses) and ground soils, passed through a 60-mesh sieve, for chemical analyses.

Physical Analyses

Particle size distribution analyses (mechanical analyses) were determined by the method described by Kilmer and Alexander (21). Organic matter was removed by treating with hydrogen peroxide. One hundred ml of 10 per cent H_2O_2 were added to a 1,000 ml beaker which contained 40 g of unground soil. The beaker was covered with a watch glass, and allowed to stand overnight. The sample was evaporated on a hot plate to a thin paste. One hundred ml of 30 per cent H_2O_2 were then added and allowed to set for an hour before evaporating again to a thin paste in order to destroy H_2O_2 . The soil paste in the 1,000 ml beaker was washed through a number 10 (2 mm) sieve into a 1,000 ml hydrometer cylinder. The material remaining on the sieve was gravel (more than

2 mm diameter). This material was oven-dried and weighed on an analytical balance. One hundred ml of five per cent calgon (sodium hexametaphosphate) were added to the hydrometer cylinder and the suspension was made up to 1,000 ml with distilled water. A blank of 100 ml of five per cent calgon diluted to 1,000 ml with distilled water was used. The hydrometer cylinder was placed in a constant temperature room at 23C until it reached a constant temperature. Then the suspension and blank hydrometer cylinders were shaken and hydrometer readings were taken after eight hours to determine the per cent clay. The corrected hydrometer reading is the reading after eight hours minus the blank reading, or

$$\% \text{ clay} = \frac{\text{hydrometer reading after eight hours} - \text{blank}}{40 \text{ g} - \text{g of gravel}} \times 100.$$

After the reading, the suspension was washed through a 300-mesh sieve. Sand remained on the sieve and this was washed thoroughly so that all silt and clay particles passed through the sieve. The sand left on the sieve was washed into a beaker, dried in an oven (110C) overnight, and weighed. The amount of sand in the subfractions was then determined. After weighing, the dried sand was placed in a nest of sieves (No. 20, 40, 60, 140, and 300), and shaken for 10 minutes in order to obtain the sand subfractions (very coarse sand, coarse sand, medium sand, fine sand, and very fine sand on the No. 20, 40, 60, 140, and 300 sieves, respectively). Each fraction was weighed to determine the percentages of sand subfractions. Sand and silt percentages were determined as follows:

$$\% \text{ sand} = \frac{\text{weight of oven-dry sand (g)}}{40 \text{ g} - \text{g of gravel}} \times 100 \text{ and}$$

$$\% \text{ silt} = 100\% - (\% \text{ clay} + \% \text{ sand}).$$

Mineralogical Analyses

The total clay suspension was saved for X-ray diffraction analyses. After 24 hours the clay suspension (at depth of 30 cm) was siphoned off and saved. The hydrometer cylinder was refilled to 1,000 ml with distilled water, shaken, allowed to stand for 24 hours, and then siphoned off again. Siphoning was repeated until the suspension (after setting 24 hours) was essentially clear (about six resiphonings). Certain horizons were selected from each profile for X-ray analyses. In these analyses, total clay was the only fraction analyzed.

The preparation and X-ray examination of samples are described in the succeeding paragraphs (4). A dilute suspension of clay, containing approximately 25 mg clay, was added to the surface of a porous ceramic plate after Mg-saturation, glycerol solvation, and K-saturation. The samples were air-dried and X-rayed. Then the samples were heated to 550C for four hours and then X-rayed again.

Mg-saturation of air-dried sample may help identify montmorillonite, vermiculite, chlorite, or a mixture of these species. Solvation with glycerol allows separation and positive identification of montmorillonite. Saturation with potassium similarly allows separation of vermiculite from chlorite which does not collapse. Heating of a sample to 550C serves two important functions: (1) causes the collapse of vermiculite which contains non-exchangeable interlayer aluminum hydroxy complexes, and (2) it destroys the kaolin minerals.

Chemical Analyses

The chemical analyses consisted of the determination of pH, cation exchange capacity, extractable cations, base saturation, total phosphorus, and organic matter content.

The pH of the soil samples from each horizon was determined by the two methods: 1:1 soil:water ratio and 1:1 soil:1N KCl ratio as outlined in the U.S.D.A. Handbook No. 60 (36). Readings were made using a model H2 Beckman (glass electrode) pH meter.

The cation exchange capacity for each horizon was determined by saturating the soil samples with sodium acetate (36). Five g of soil were leached four times with 30 ml of 1N sodium acetate (pH 8.2). The excess sodium was removed by washing three times with 30 ml of 95 per cent ethanol. Washing consisted of shaking the samples for five minutes on a reciprocating shaker and centrifuging until the soil particles were thrown out of suspension. The sodium acetate and ethanol washings were decanted as completely as possible and discarded. Sodium was then completely replaced with ammonium by leaching three times with 30 ml of 1N NH_4OAc (pH 7.0). The leachate was diluted to 250 ml and saved. Sodium was determined with a model 303 Perkin-Elmer atomic absorption spectrophotometer and the cation exchange capacity was calculated.

Extractable calcium, magnesium, sodium and potassium for each soil horizon were obtained by leaching five g of soil samples four times with 20 ml of 1N NH_4OAc (pH 7.0). The leachate was saved and diluted to 100 ml with distilled water. The extractable sodium and potassium were determined with the atomic absorption spectrophotometer as described in U.S.D.A. Handbook No. 60 (36). The extractable calcium

and magnesium were determined by EDTA titration (8).

The extractable hydrogen for each soil horizon was determined by the method of Peech et al. (32). Ten g of soil were mixed with 100 ml of BaCl_2 -Triethanolamine solution, then allowed to stand overnight. The soil suspension was then filtered and the soil on the filter paper was leached with small portions of BaCl_2 -Triethanolamine until about 225 ml had been collected. Then the leachate was diluted to 250 ml with BaCl_2 -Triethanolamine solution, and titrated with 0.25N HCl.

The per cent base saturation for each soil horizon was calculated as follows:

$$\% \text{ base saturation} = \frac{\text{meq}/100 \text{ g of Ca} + \text{Mg} + \text{Na} + \text{K}}{\text{meq}/100 \text{ g Ca} + \text{Mg} + \text{Na} + \text{K} + \text{H}} \times 100.$$

The total phosphorus for each soil horizon was determined by perchloric acid digestion method (44). Two g of soil were boiled slowly with 15 ml of 60 per cent perchloric acid until the soil turned light in color. The extract was brought up to a volume of 250 ml with distilled water. The residue was allowed to settle overnight in a 250 ml erlenmeyer flask. Then, eight ml of reagent A and B (ammonium molybdate + antimony potassium tartrate in H_2SO_4 and ascorbic acid) were added to a 15 ml aliquot. The volume was brought up to 50 ml with distilled water and allowed to stand for 10 minutes. The samples were read in a colorimeter.

The organic matter for each soil horizon was determined by the potassium dichromate wet oxidation method (36). Ten ml of 0.4N potassium dichromate and 15 ml of concentrated H_2SO_4 , respectively, were added to 0.5 g soil samples. The samples were heated slowly to 165°C and allowed to cool. After cooling, 100 ml of distilled water were

added. Three drops of ortho-phenanthroline ferrous sulfate indicator were added prior to the titration with 0.2N ferrous ammonium sulfate.

CHAPTER IV

RESULTS AND DISCUSSION

Physical Analyses

The particle size distributions in the profiles of the four granitic soils studied are shown in Figures 1-4 and in Table I. In the Belton, Agan and Ravia soils, the percentage of sand generally decreased in the B horizon and then increased in the C horizon. In the Tishomingo series, the percentage of sand remained constant from A1 to B2t and then increased at lower depths. The percentage of silt generally decreased with depth in the Belton and Agan soils. Tishomingo loam showed an increase in silt from B to the C horizon. The percentage of clay of the four granitic soils increased substantially in the B2t horizon and then decreased in the C horizon. The dominance of clay in the B2t horizon may be due to illuviation caused by high precipitation. The clay may have been leached from the A horizon and deposited in the B2t horizon.

The sand subfraction percentages of the four granitic soils are presented in Table II. In the Belton series, all sand subfractions generally decreased from the A2 horizon down to B22t and B23t, and then increased at the C horizon. In the Tishomingo soil, very coarse and coarse sands generally increased from the A1 to the B2t and B3 and then decreased in the C horizon. Medium sand, fine sand, and very fine sand generally decreased from the A1 down to B2t and then increased in

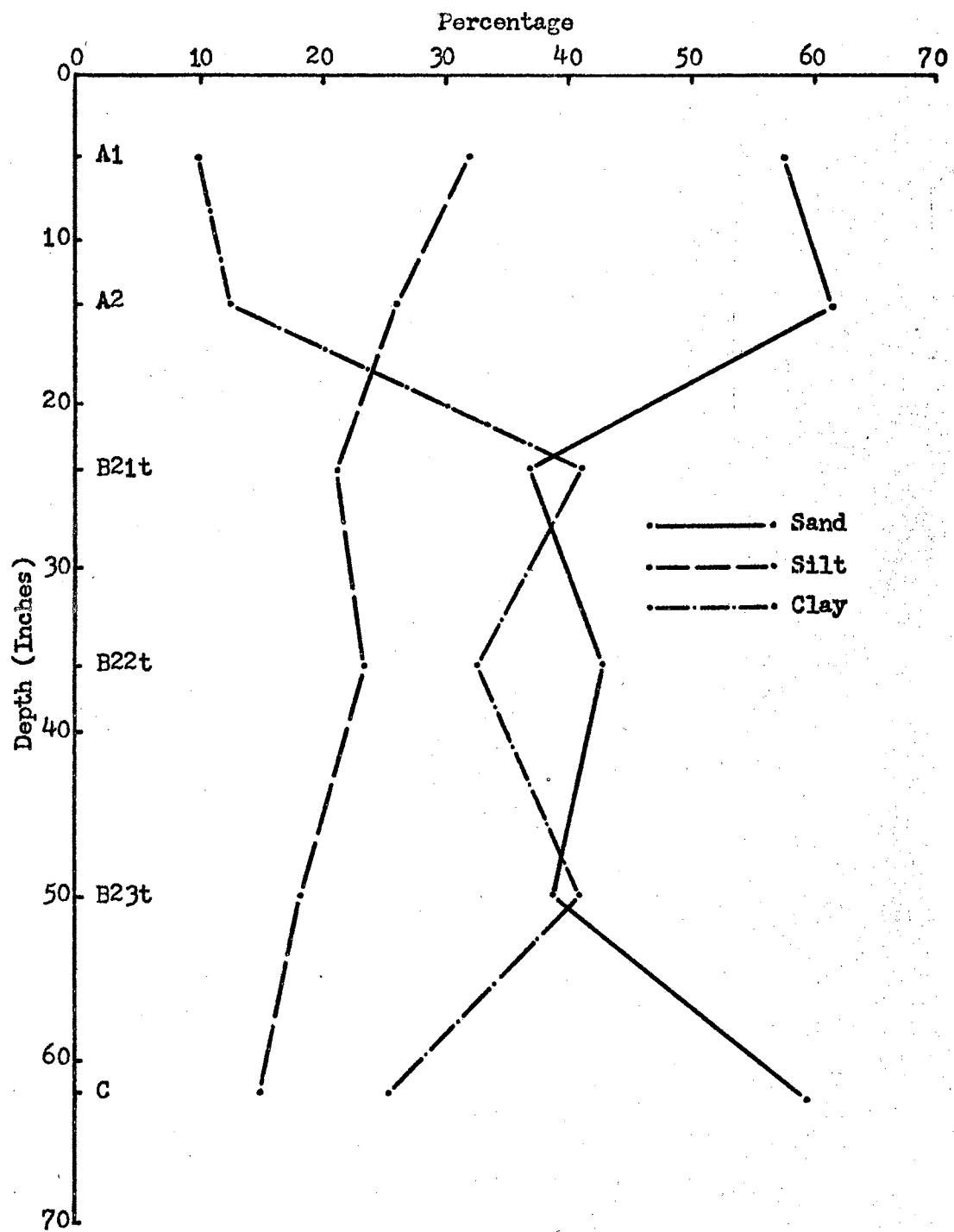


Figure 1. Particle Size Distribution in the Profile of Belton Sandy Loam

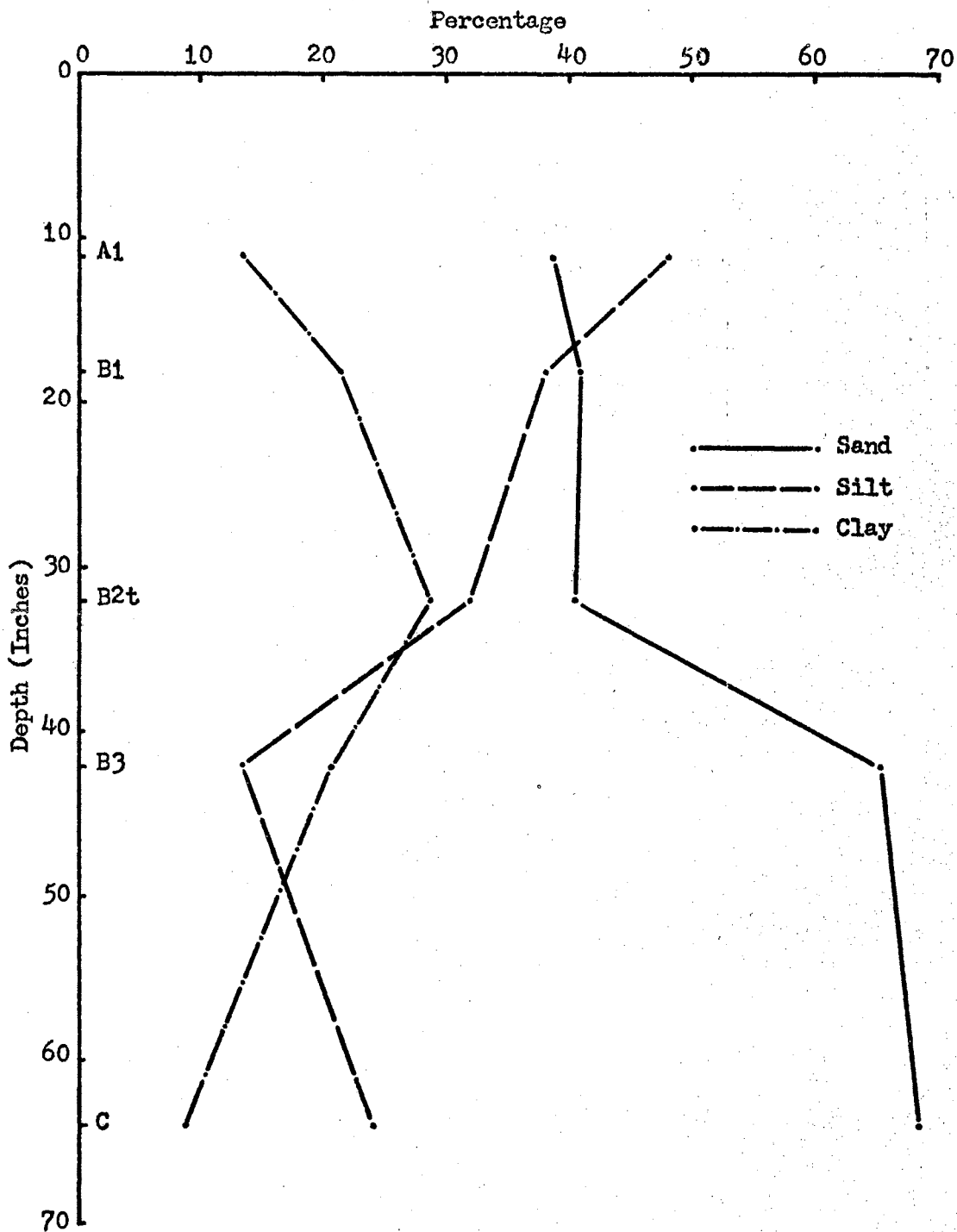


Figure 2. Particle Size Distribution in the Profile of Tishomingo Loam

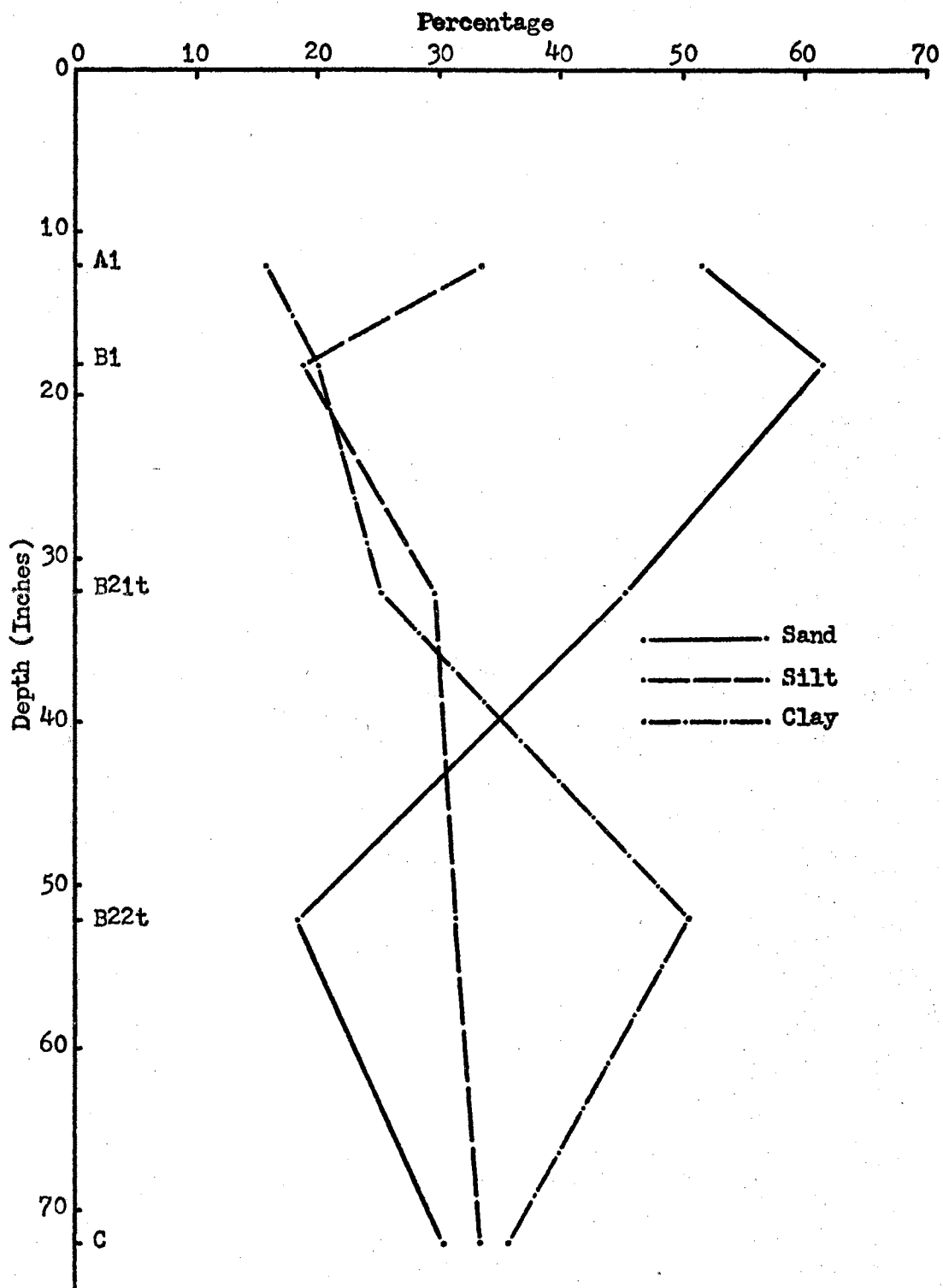


Figure 3. Particle Size Distribution in the Profile of Ravia Loam

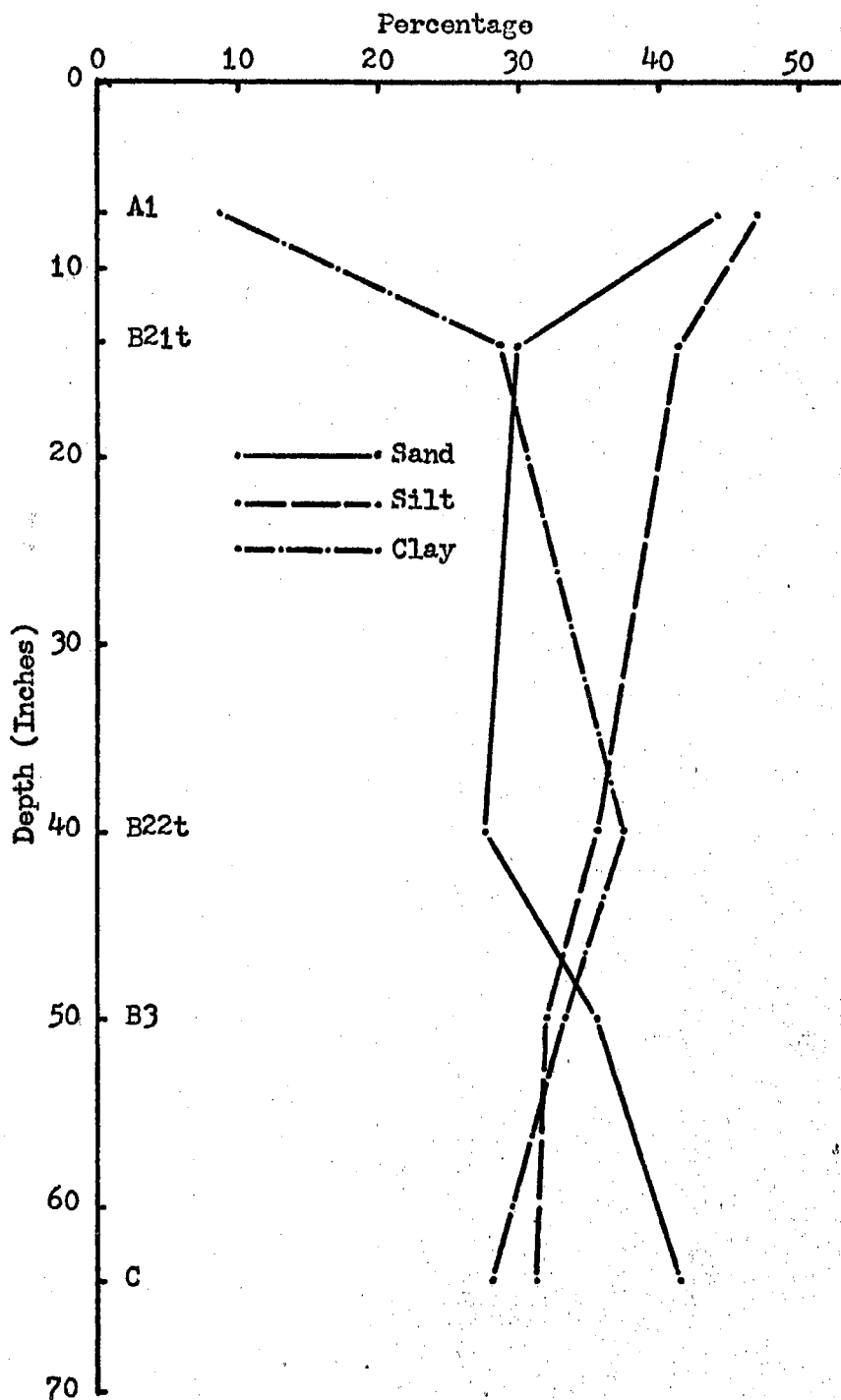


Figure 4. Particle Size Distribution in the Profile of Agan Loam

TABLE I
PARTICLE SIZE DISTRIBUTION IN THE PROFILES OF FOUR
GRANITIC SOILS

Horizon	Depth (in.)	Sand %	Silt %	Clay %	Textural class
<u>Belton sandy loam</u>					
A1	0-5	57.39	32.44	10.17	Sandy loam
A2	5-14	61.42	26.37	12.21	Sandy loam
B21t	14-24	37.29	21.40	41.31	Clay
B22t	24-36	42.65	24.32	33.03	Clay loam
B23t	36-50	39.36	19.17	41.47	Clay
C	50-62	59.17	15.09	25.74	Sandy clay loam
<u>Tishomingo loam</u>					
A1	0-11	38.04	48.05	13.91	Loam
B1	11-18	41.09	36.92	21.99	Loam
B2t	18-32	40.61	31.72	27.67	Clay loam
B3	32-42	65.44	14.04	20.52	Sandy clay loam
C	42-64	68.18	23.81	8.01	Sandy loam

TABLE I (Continued)

Horizon	Depth (in.)	Sand %	Silt %	Clay %	Textural class
<u>Ravia loam</u>					
A1	0-12	51.58	32.61	15.81	Loam
B1	12-18	60.92	19.33	19.75	Sandy clay loam
B21t	18-32	45.40	29.64	24.96	Loam
B22t	32-52	18.78	31.09	50.13	Clay
B3	52-72	30.83	33.66	35.51	Clay loam
<u>Agan loam</u>					
A1	0-7	44.27	46.48	9.25	Loam
B21t	7-14	30.03	41.93	28.04	Clay loam
B22t	14-40	27.40	35.36	37.24	Clay loam
B3	40-50	34.91	32.18	32.91	Clay loam
C	50-64	41.50	30.85	27.65	Clay loam

TABLE II
SAND SUBFRACTION PERCENTAGES OF FOUR
GRANITIC SOILS

Horizon	Depth (in.)	Very coarse sand 2.0-1.0 (mm)	Coarse sand 1.0-0.5 (mm)	Medium sand 0.5-0.25 (mm)	Fine sand 0.25-0.10 (mm)	Very fine sand 0.10-0.05 (mm)
<u>Belton sandy loam</u>						
A1	0-5	13.93	12.95	8.51	11.08	10.92
A2	5-14	17.20	13.60	8.55	11.06	11.01
B21t	14-24	10.60	9.17	4.70	6.35	6.47
B22t	24-36	11.83	9.61	5.65	7.66	7.90
B23t	36-50	14.16	9.12	5.49	7.37	3.22
C	50-62	19.26	14.25	9.56	8.96	7.14
<u>Tishomingo loam</u>						
A1	0-11	6.45	8.93	7.42	7.73	7.51
B1	11-18	17.71	10.59	4.14	4.40	4.25
B2t	18-32	20.05	9.92	3.36	3.87	3.41
B3	32-42	27.69	19.74	6.17	6.54	5.30
C	42-64	20.74	16.89	11.69	11.85	7.01

TABLE II (Continued)

Hori- zon	Depth (in.)	Very coarse sand 2.0-1.0 (mm)	Coarse sand 1.0-0.5 (mm)	Medium sand 0.5-0.25 (mm)	Fine sand 0.25-0.10 (mm)	Very fine sand 0.10-0.05 (mm)
<u>Ravia loam</u>						
A1	0-12	10.87	13.08	9.43	9.95	8.25
B1	12-18	22.51	16.52	7.44	7.83	6.62
B21t	18-32	13.39	12.36	6.43	7.05	6.17
B22t	32-52	5.27	4.09	2.16	4.09	3.17
B3	52-72	1.65	3.88	5.83	10.73	8.74
<u>Agan loam</u>						
A1	0-7	6.24	7.80	5.55	6.48	8.20
B21t	7-14	8.17	8.01	4.35	5.07	4.33
B22t	14-40	4.07	4.84	4.07	6.65	7.77
B3	40-50	4.84	6.66	6.06	9.14	8.21
C	50-64	5.64	7.22	6.58	11.47	10.59

horizon C. In the Ravia loam, very coarse and coarse sands increased in B1 and then decreased downward. The trend for medium sand, fine sand, and very fine sand was a decrease from A1 down to B22t and then an increase downward in the B3. In the Agan loam, very coarse and coarse sands increased in the B21t, decreased in the B22t, and then increased again down to the C horizon. Medium sand, fine sand, and very fine sand decreased from the surface down to the B21t horizon and then increased at lower depths.

Mineralogical Analyses

The four granitic soils were studied in the following manner for identification and differentiation of clay minerals (4).

Mg-saturated Air-dried Samples

A diffraction spacing of approximately 14Å obtained from Mg-saturated preparation indicated the following clay minerals: montmorillonite, vermiculite, chlorite, or a mixture of these species. Obviously, further treatments of the sample were necessary to identify the individual species.

Mg-saturated and Glycerol-solvated Samples

From slides prepared with these treatments, a diffraction spacing of 17-18Å indicated montmorillonite which expanded from 14 to 17 or 18Å upon glycerol solvation of Mg-saturated samples.

K-saturated Air-dried Samples

This treatment allowed the separation of vermiculite from illite. With this treatment, illite collapsed to 10A, but vermiculite did not,

K-saturation and then Heating of Samples to 550C

This treatment, as mentioned earlier, served two important functions which led to the identity of clay minerals. First, it caused the collapse of vermiculite which contained non-exchangeable interlayer aluminum hydroxy complexes. Second, it destroyed the kaolin minerals. When chlorite was present in the sample, it normally yielded a second-order peak maximum at nearly the same position as the first-order maximum of kaolinite (7.15A). If 7.15A spacing was obtained from an unheated sample, or disappeared or decreased in intensity after heating to 550C, the presence of kaolinite was confirmed.

The results of mineralogical analyses are presented in Table III. Kaolinite and illite were dominant in the A1 horizon of most of the granitic soil profiles. Only a small quantity of interstratified vermiculite was present in the A1 horizon of Agan loam. The total clay of the A1 horizon may be the coarse fraction (2.0-0.2 μ). Jackson (19) noted that the coarse clay (< 2 μ) is abundant in illite and that the large amounts of hydrous micas of poorly resolved basal spacings may not be detected in large amounts of montmorillonite or kaolinite. Quartz, kaolinite, and mica give strong diffraction patterns and mask the diffraction of the interstratified layer silicates. Montmorillonite series minerals often occur abundantly in the fraction less than 0.08 μ in diameter. Jackson, et al. (20) found that randomly interstratified material has no indicative spacing, but is represented by a

TABLE III
MINERALOGICAL DATA OF FOUR GRANITIC SOILS

Hori- zon	Depth (in.)	Clay minerals
<u>Belton sandy loam</u>		
A1	0-5	Kaolinite and illite
B21t	14-24	Kaolinite, illite, and chlorite
C	50-62	Illite, montmorillonite, and vermiculite
<u>Tishomingo loam</u>		
A1	0-11	Kaolinite and illite
B2t	18-32	Kaolinite, illite, and interstratified montmorillonite
C	42-64	Illite and interstratified vermiculite
<u>Ravia loam</u>		
A1	0-12	Kaolinite and illite
B21t	18-32	Kaolinite and interstratified vermiculite
B3	52-72	Interstratified montmorillonite
<u>Agan loam</u>		
A1	0-7	Kaolinite, illite and interstratified vermiculite
B21t	7-14	Kaolinite, illite, and chlorite
C	50-64	Illite and interstratified montmorillonite

broad diffraction band at low angles. Illite and kaolinite were both present and were indicated by the same reflections as in the coarse clay. The size of the illite and kaolinite peaks suggested that illite was present in relatively small quantities and kaolinite was present in very minute quantities. Increased amounts of interstratified material with increasing depth suggested increased aggregate size of the interstratified material.

The B_{2t} and B_{21t} horizons of the granitic soils studied contained an abundance of kaolinite, illite, some chlorites and a small amount of interstratified montmorillonite.

Generally, in the C horizon of the four soils, illite was the dominant clay mineral, plus some interstratified montmorillonite and vermiculite.

The mineralogical analyses showed that kaolinite (1:1 type clay) decreased with depth in the profile. On the other hand, illite and montmorillonite (2:1 type clay) increased with depth. This pattern may be due to environment, especially temperature and rainfall, which broke down the large particles of the 1:1 type clay to small particles of 2:1 type clay.

Chemical Analyses

The soil reactions (pH) of the four granitic soils are presented in Figure 5, while certain chemical data including pH are shown in Table IV. Generally, the pH increased in the B horizons of the profiles, then increased in the C horizon except in the Agan loam where the pH increased gradually with depth. This trend in pH of Agan loam may be caused by exchangeable sodium in the profile which was much

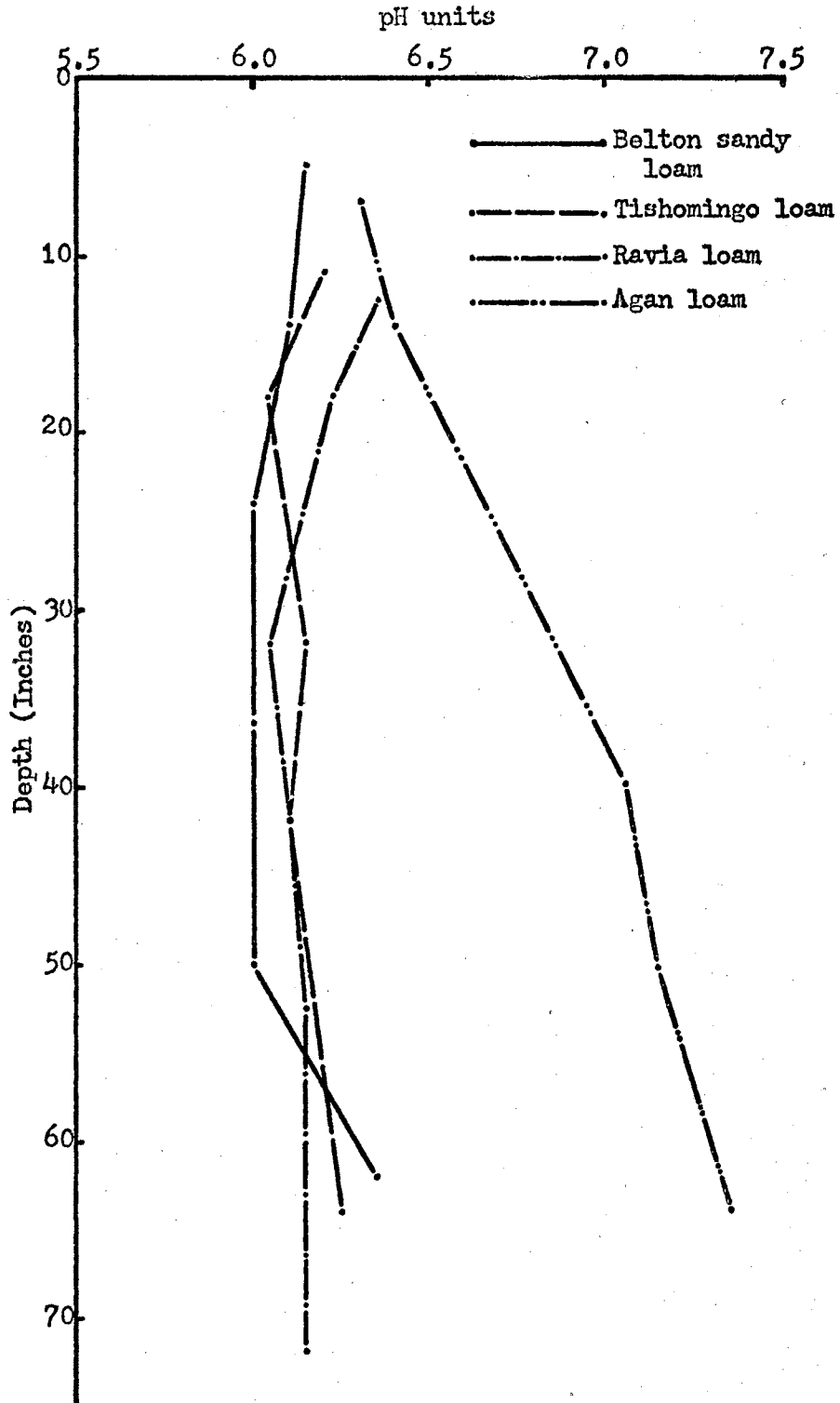


Figure 5. pH Distribution in the Profiles of Four Granitic Soils

TABLE IV
CERTAIN CHEMICAL ANALYSES OF FOUR GRANITIC SOILS

Horizon	Depth (in.)	pH		Organic matter %	Total phosphorus lb/A
		1:1 soil: water ratio	1:1 soil: 1N KCl ratio		
<u>Belton sandy loam</u>					
A1	0-5	6.3	5.5	2.04	826
A2	5-14	6.2	5.2	1.34	468
B21t	14-24	6.0	5.0	0.65	520
B22t	24-36	6.0	5.0	0.44	621
B23t	36-50	6.0	4.7	0.44	96
C	50-62	6.7	4.9	0.31	213
<u>Tishomingo loam</u>					
A1	0-11	6.4	5.4	2.49	1524
B1	11-18	6.1	5.0	1.31	1375
B2t	18-32	6.3	4.9	0.52	1056
B3	32-42	6.2	4.9	0.59	912
C	42-64	6.5	4.9	0.31	967

TABLE IV (Continued)

Hori- zon	Depth (in.)	pH		Organic matter %	Total phosphorus lb/A
		1:1 soil: water ratio	1:1 soil: 1N KCl ratio		
<u>Ravia loam</u>					
A1	0-12	6.7	5.7	3.51	921
B1	12-18	6.3	4.9	1.31	704
B21t	18-32	6.1	4.9	0.89	529
B22t	32-52	6.3	5.0	0.89	416
B3	52-72	6.3	5.0	0.69	396
<u>Agan loam</u>					
A1	0-7	6.6	5.4	2.03	583
B21t	7-14	6.9	5.4	1.39	337
B22t	14-40	7.1	6.0	1.10	320
B3	40-50	7.3	6.5	0.41	229
C	50-64	7.7	6.6	0.21	171

greater than in the other profiles, and it also increased with depth. The pH in the A horizon for all soils was approximately 6.5. In the B horizons, the pH ranged from 6.0 for Belton, 6.2 for Tishomingo and Ravia, to 7.1 for Agan series.

Total phosphorus decreased with the depth in the profiles of these granitic soils (Table IV). The data also indicated that total phosphorus was dominant in the A1 horizon. The larger amounts near the surface was due to organic phosphorus (37) and phosphorus fertilization since these soils have been cultivated.

The organic matter percentages of the four soils are graphed in Figure 6, while the chemical data are given in Table IV. The graph in Figure 6 showed that the per cent of organic matter decreased rapidly with increasing depth in the profiles. Organic matter was dominant in the A1 horizon in all four soils. This pattern was caused by native grasses which have grown on these soils for a long period of time. The organic matter was gradually increased by this vegetation over a period of time.

The data for cation exchange capacities in the profiles of the four granitic soils are found in Table V. The cation exchange capacities in the profiles of these soils generally increased with depth. The results of the cation exchange capacity determination seem reasonable in relation to the kind of clay minerals identified. Grim (16) stated that illite has a cation exchange capacity of 10-40 meq/100 g; kaolinite, 3-15 meq/100 g; and montmorillonite, 90-120 meq/100 g. The cation exchange capacity of interstratified montmorillonite-illite clay would vary with the amount of each component present.

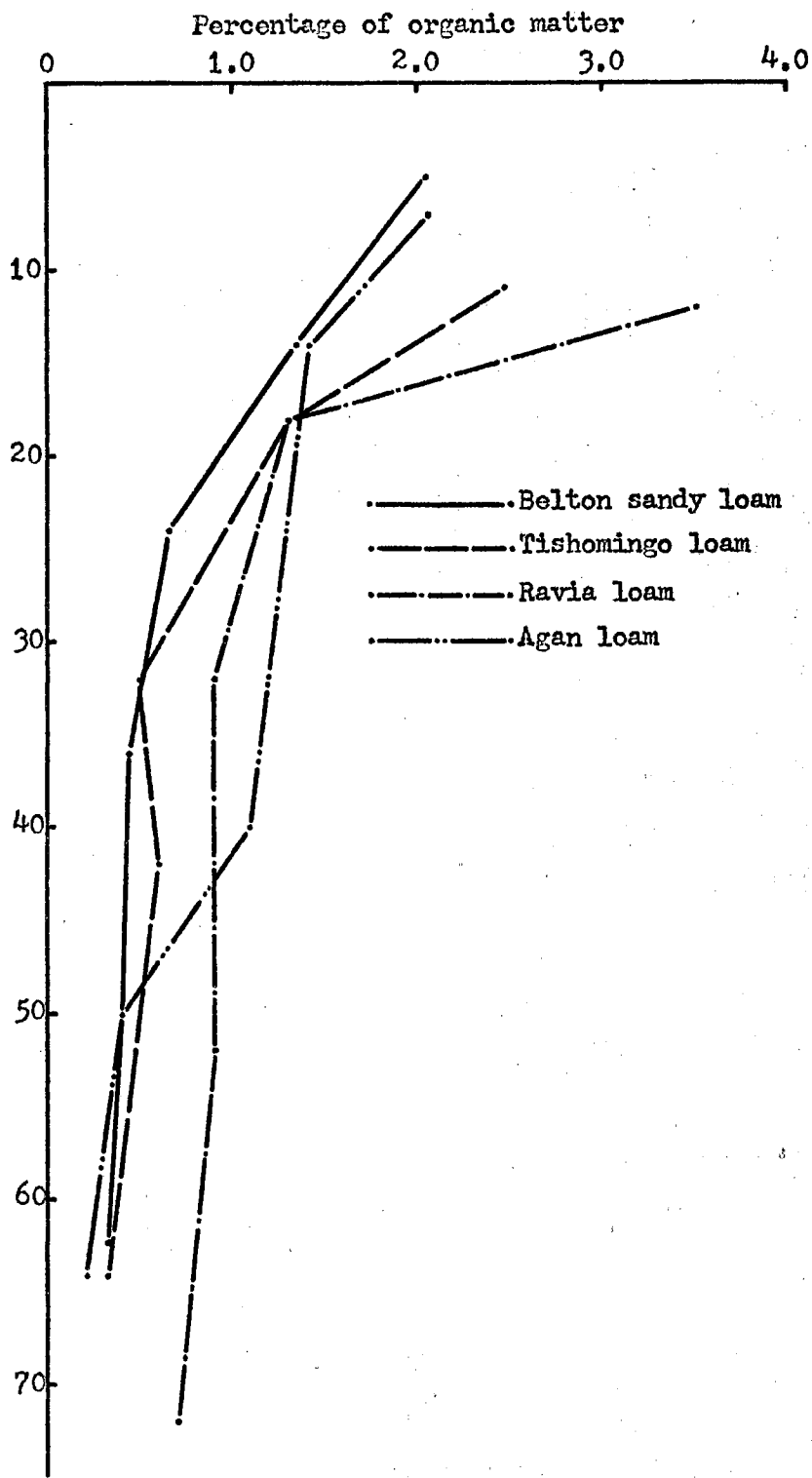


Figure 6. Organic Matter Distribution in the Profiles of Four Granitic Soils

TABLE V
 CATION EXCHANGE CAPACITIES AND EXCHANGEABLE CATIONS
 OF FOUR GRANITIC SOILS

Horizon	Depth (in.)	CEC, meq/100 g	Exchangeable cations (meq/100 g)					% base saturation
			Ca	Mg	K	Na	H	
<u>Belton sandy loam</u>								
A1	0-5	7.60	3.85	1.14	0.14	0.14	3.97	57.03
A2	5-14	3.79	2.08	0.62	0.06	0.17	1.81	61.81
B21t	14-24	14.59	6.70	2.66	0.29	0.16	4.33	69.66
B22t	24-36	10.85	5.51	1.04	0.19	0.17	5.54	56.60
B23t	36-50	25.66	14.46	6.76	0.21	0.86	6.38	77.75
C	50-62	31.23	18.72	8.94	0.16	1.37	5.30	84.63
<u>Tishomingo loam</u>								
A1	0-11	11.44	5.30	0.94	0.15	0.20	4.33	60.35
B1	11-18	10.68	3.95	1.46	0.12	0.21	4.81	54.41
B2t	18-32	12.00	4.06	2.18	0.15	0.18	5.18	55.91
B3	32-42	11.79	3.95	2.60	0.14	0.17	5.05	57.60
C	42-64	17.11	7.80	5.93	0.08	0.25	4.90	74.68

TABLE V (Continued)

Horizon	Depth (in.)	CEC, meq/100 g	Exchangeable cations (meq/100 g)					% base saturation
			Ca	Mg	K	Na	H	
<u>Ravia loam</u>								
A1	0-12	13.62	7.60	1.56	0.10	0.14	5.53	62.96
B1	12-18	11.37	4.06	2.29	0.11	0.14	4.90	57.39
B21t	18-32	12.32	4.78	3.54	0.14	0.16	5.78	59.86
B22t	32-52	27.13	11.23	9.36	0.31	0.26	8.55	71.22
B3	52-72	44.25	22.46	15.50	0.35	0.35	11.19	77.55
<u>Agan loam</u>								
A1	0-7	8.68	4.67	1.78	0.10	0.21	3.61	65.19
B21t	7-14	24.36	11.96	5.41	0.18	2.73	6.02	77.11
B22t	14-40	28.36	14.04	4.89	0.20	5.03	4.69	83.74
B3	40-50	24.20	11.44	5.82	0.19	5.98	3.13	88.22
C	50-64	20.94	9.88	5.10	0.19	5.16	2.65	88.51

The quantities of exchangeable cations were also shown in Table V. Exchangeable calcium was usually dominant in the B and C horizons and only small quantities were detected in the A horizon. Exchangeable magnesium in these granitic soils generally increased with depth in the profile. Exchangeable potassium had a similar trend except in the Tishomingo series, but the increase was not as substantial as that of calcium and magnesium. Brown (7) reported that the percentages of exchangeable calcium and magnesium increase while those of potassium and sodium decrease as the soil moisture increases. In the four granitic soils studied, exchangeable sodium increased with depth in the profiles, but only small amounts of this element were usually detected except in Agan loam where exchangeable sodium was much greater than in the other profiles. The pattern of distribution of exchangeable hydrogen in the profiles showed that it was dominant in the B horizon. The A horizons of the Belton and Tishomingo series generally had nearly as much exchangeable hydrogen as the C horizon.

The base saturation percentages are presented in Table V. This table showed that the percentage base saturation was usually higher in the B and C horizons. This trend may be attributed to exchangeable calcium and magnesium.

CHAPTER V

SUMMARY AND CONCLUSIONS

Four selected granitic soils from the Belton, Tishomingo, Ravia, and Agan series were sampled from Johnston County, Oklahoma. Physical, mineralogical and chemical analyses were made on these soils.

The percentage of sand generally decreased in the B2t horizons and was dominant in the C and A1 horizons. The percentage of silt decreased with depth in the Belton and Agan soils. The percentage of clay was abundant in the B2t horizons and then decreased gradually in the C horizons. Coarse and very coarse sands were dominant in the C horizons of the Belton and Tishomingo series. Medium sand, fine sand, and very fine sand fractions usually had similar patterns of distribution in the profiles. They were high in the A horizon, decreased in the B horizon, and increased in the C horizon.

Mineralogical determinations of these soils showed that kaolinite and illite were the dominant clay minerals in the A horizon. In the B horizons there was an abundance of kaolinite and illite, plus some chlorite and a small amount of interstratified clay minerals. Illite was the dominant clay mineral in the C horizon. This horizon also contained some interstratified montmorillonite and vermiculite.

The soil reaction or pH in these soils generally decreased in the B horizon and then increased in the C horizon. Cation exchange capacity increased with depth. Exchangeable calcium, magnesium,

potassium, and sodium had usually the same distribution patterns in the profile as cation exchange capacity. Exchangeable hydrogen was dominant in the B horizon. Base saturation percentage was generally the highest in the B and C horizons of these soils.

Total phosphorus decreased with depth in the four soil profiles. Organic matter was the highest in the A₁ horizons and then decreased rapidly with increasing depth in the profile.

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APPENDIX

LOCATION AND PROFILE DESCRIPTIONS OF FOUR GRANITIC
SOILS

Belton Sandy Loam

Location: One-half mile north and 1,110 feet west of SE corner Section 20-35-6E of Johnston County, Oklahoma.

<u>Horizon</u>	<u>Depth (in.)</u>	<u>Description</u>
A1	0-5	Grayish brown (10YR 5/2) sandy loam, very dark grayish brown (10YR 3/2) when moist; moderate to medium granular structure; slightly hard dry, very friable moist; pH 6.3; clear wavy boundary.
A2	5-14	Light brown (7.5YR 6/4) coarse sandy loam, brown (7.5YR 5/4) when moist; moderate to medium granular structure; slightly hard dry, very friable moist; pH 6.2; clear wavy boundary.
B21t	14-24	Brown (7.5YR 5/4) clay; dark brown (7.5YR 4/4) when moist; moderate to medium blocky structure, continuous clay film on ped faces; common quartz and feldspar particles larger than 2 mm; very hard dry, firm when moist; pH 6.0; gradual wavy boundary.
B22t	24-36	Yellowish brown (10YR 5/6) clay loam, dark yellowish brown (10YR 4/4) when moist; common fine distinct yellowish brown mottles; strong medium blocky structure; very hard dry, very firm when moist; roots and pores common; pH 6.0; gradual wavy boundary.
B23t	36-50	Reddish yellow (10YR 6/6) gravelly clay, strong brown (7.5YR 5/6) when moist; common medium distinct grayish brown mottles (10YR 5/2) weak coarse blocky structure, patchy clay film on peds; extremely hard dry, very firm moist; roots common; pH 6.0; clear wavy boundary.
C	50-62	Brownish yellow (10YR 6/6) gravelly sandy clay loam; yellowish brown (10YR 5/4) when moist; splotched with red and light gray; rock structure, 60-75 per cent feldspar and quartz gravel; very hard dry, friable moist; pH 6.7; rests on slightly weathered granite.

Note: Sampled from pit 50 feet north of Devil's Den road. Northeast facing convex slope of approximately one per cent gradient, open stand of Post Oak-Blackjack timber. Colors are for dry soil unless otherwise stated.

Tishomingo Loam

Location: 500 feet south and 500 feet east of the NW corner of Section 2-35-6E of Johnston County, Oklahoma.

<u>Horizon</u>	<u>Depth (inc.)</u>	<u>Description</u>
A1	0-11	Brown (7.5YR 4/2) loam, moderate and strong medium granular structure; slightly hard dry, very friable moist; pH 6.4; gradual wavy boundary.
B1	11-18	Reddish brown (10YR 5/4) loam, dark reddish brown (5YR 3/4) when moist; strong medium and coarse granular structure; slightly hard dry, very friable moist; many quartz and feldspar particles larger than 2 mm; pH 6.1; gradual wavy boundary.
B2t	18-32	Strong brown (5YR 5/6) clay loam, reddish brown (5YR 4/4) when moist; weak fine subangular blocky and coarse granular structure; few clay films on peds; about 40 per cent particles larger than 2 mm; hard when dry, firm when moist; pH 6.3; gradual wavy boundary.
B3	32-42	Reddish yellow (5YR 6/6) gravelly sandy clay loam, yellowish red (5YR 5/6) when moist; coarse granular and rock structure; hard when dry, firm when moist; roots common; about 70 per cent quartz and feldspar larger than 2 mm; pH 6.2; clear wavy boundary.
C	42-64	Reddish yellow (7.5YR 6/6) gravelly sandy loam, strong brown (7.5YR 5/6) when moist; rock structure; very hard dry, very firm moist; about 85 per cent sand and gravel larger than 2 mm; pH 6.5; rests on partially weathered granite.

Note: Sampled from pit on NE facing convex slope of about three per cent gradient.

Ravia Loam

Location: Six hundred feet south and 300 feet east of the center of Section 33-25-6E of Johnston County, Oklahoma.

<u>Horizon</u>	<u>Depth (in.)</u>	<u>Description</u>
A1	0-12	Very dark grayish brown (10YR 3/2) loam, very dark brown (10YR 2/2) when moist; moderate and strong medium granular structure; slightly hard dry, very friable moist; pH 6.7; gradual wavy boundary.
B1	12-18	Brown (7.5YR 4/4) light sandy clay loam, dark brown (7.5YR 3/2) when moist; strong coarse granular structure; hard when dry, friable when moist; gravel larger than 2 mm common; pH 6.3; gradual wavy boundary.
B21t	18-32	Brown (10YR 5/3) heavy loam, brown (10YR 4/3) when moist; weak medium blocky structure; then clay films on peds; few faint fine strong brown mottles, few iron and manganese concretions, very hard when dry, very firm moist; pH 6.1; gradual wavy boundary.
B22t	32-52	Grayish brown (10YR 5/2) clay, dark grayish brown (10YR 4/2) when moist, common fine distinct reddish brown mottles; strong medium blocky structure with clay films on ped surfaces; few iron and manganese concretions; very hard dry, very firm moist; pH 6.3; gradual wavy boundary.
B3	52-72	Grayish brown (10YR 5/2) clay loam, dark grayish brown (10YR 4/2) when moist; splotted with dark yellowish brown, contains many iron and manganese concretions; very hard when dry, very firm moist; pH 6.3.

Note: Sampled from pit on NE facing plane slope of about one per cent in native grass meadow.

Agan Loam

Location: Eight hundred feet west and 350 feet north of center of Section 33-15-6E of Johnston County, Oklahoma.

<u>Horizon</u>	<u>Depth (in.)</u>	<u>Description</u>
A1	0-7	Dark grayish brown (10YR 4/2) loam, very dark brown (10YR 2/2) when moist; weak fine granular structure; slightly hard dry, very friable moist; pH 6.6; abrupt boundary.
B21t	7-14	Very dark grayish brown (10YR 3/2) clay loam, very dark brown (10YR 2/2) when moist; weak coarse blocky to massive structure; extremely hard dry, extremely firm moist; sticky when wet; quartz grains larger than 2 mm common; pH 6.9; gradual wavy boundary.
B22t	14-40	Dark brown (10YR 4/3) clay loam, dark brown (10YR 3/3) when moist; massive structure showing only few pressure planes; extremely hard dry, extremely firm moist; common coarse sand size quartz particles; roots concentrated along natural faces; pH 7.1; gradual wavy boundary.
B3	40-50	Grayish brown (10YR 5/2) clay loam, dark grayish brown (10YR 4/2) when moist; massive structure; extremely hard when dry, extremely firm when moist; few pressure planes evident; pH 7.3; gradual wavy boundary.
C	50-64	Light brownish gray (10YR 6/2) gravelly clay loam, grayish brown (10YR 5/2) when moist; common distinct medium yellowish brown mottles; massive structure; extremely hard dry, extremely firm moist; appreciable amount of chert, feldspar and quartz particles; pH 7.7.

Note: Sampled from pit on SW facing slightly concave slope less than one per cent. This is land that has been farmed some 30-40 years ago and is now in pasture of low order annuals and perennials.

VITA

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Candidate for the Degree of

Master of Science

Thesis: PHYSICAL AND CHEMICAL ANALYSES OF SOME GRANITIC SOILS

Major Field: Agronomy

Biographical:

Personal Data: Born in Roi-Ed, Thailand, August 31, 1938, son of Sathit and Tongbai Kongpiroon. Married Sunee Wongratana, March 12, 1967.

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