THE BASE-EXCHANGE CAPACITY OF THE ORGANIC AND INORGANIC FRACTIONS OF SEVERAL PODZOLIC SOIL PROFILES

THESIS FOR DEGREE OF
MASTER OF SCIENCE

MICHIGAN STATE COLLEGE
J. C. F. TEDROW
1940

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by

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A THESIS

Submitted to the Graduate School of Michigan State College of Agriculture and Applied Science in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

Department of Soils

1940

ACKNOWLEDGEMENT

For the many helpful suggestions and criticisms received during the progress of this investigation the writer is very grateful to Dr. W. S. Gillam, under whose general supervision the work was done. The writer also wishes to thank Dr. C. H. Spurway for his kind advice during the progress of this study.

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INTRODUCTION

It is a well known fact that both the organic and inorganic portions of the soil play an important part in the base-exchange reaction. Considerable work of the past dealt either with the inorganic and organic portion of the soil as a whole, or just the mineral fraction.

The effect of different fertilizer treatments and various farming practices upon the exchangeable bases has been studied extensively. The ability of a soil to release certain ions readily and to retain other ions firmly, has been investigated rather thoroughly.

The total analysis and base-exchange capacity of a number of soils at different depths have been reported. But until recent years little work has been done on the base-exchange capacity of the organic matter of the soil, and the importance of this fraction in the base-exchange reaction has not been thoroughly investigated. The study of various types of decomposing organic materials and their base-exchange capacities has been an expanding study the last number of years.

However, as far as the writer is aware, no one has attempted to determine the base-exchange capacity of the organic matter in the different soil horizons. Therefore, in this paper, an attempt was made to gain some further knowledge regarding the base-exchange capacity of the organic matter in the different soil horizons.

It was the object of this investigation to determine the base-exchange capacity of the organic matter in the A_1, A_2, B_1,

B_2, and C horizons of six soil profiles collected in Michigan. The profiles were also analyzed for exchangeable calcium and magnesium. The effect of pH upon the base-exchange capacity of each soil was also studied, by using ammonium acetate adjusted to a pH of 7.0 on one set of samples, and ammonium acetate adjusted to the pH of the soil, on a second set of samples.

REVIEW OF LITERATURE

Way, (16)[1] in the year 1852 first discovered that soils had the power to exchange bases. Gedroiz (5) in some of his earlier writings conveyed the idea that although the organic portion of the soil did have some power to exchange bases, it was practically negligable in comparison to the inorganic portion. However, in later years, Gedroiz (4) revised his ideas and suggested that the organic portion of the soil may have an important part in base-exchange and that the base-exchange capacity of the organic matter may even exceed that of the mineral portion.

Baver (2) found that 30 to 60 per cent of the total base-exchange capacity of a soil could be attributed to the organic portion. Mitchell (10), found that the organic portion of the soil constitutes 41 to 65 per cent of the total base-exchange capacity. Olson and Bray (12), in their study of Illinois soils, found that the base-exchange capacity of the organic portion varied from 0.6 to 16.3 milliequivalents constituting from 6.8 to 43.4 per cent of the total base-exchange capacity of the soils. In their investigation the destruction of the

[1]Indicates literature cited.

base-exchange capacity of the organic portion was accomplished by using a single 40 ml. treatment of 15% H_2O_2. Although there are many conflicting opinions as to methods of destroying organic matter, Alexander and Byers (1), after a critical laboratory study of methods of determining organic matter, came to the conclusion that H_2O_2 may be used to determine the amount of readily oxidizable organic portion of the soil, but it should not be used in determining the total amount of organic matter present.

McGeorge (7) concluded from his data that there was a wide variation in the base-exchange capacity of lignin-like bodies in different soils, and also that it was by no means a constant quantity, for in all cases these exchange compounds were able to undergo further alteration, probably a hydrolysis, which increased, or built up their base-exchange capacities. He found that lignin from different soils had a base-exchange capacity that ranged from 38 to 178 milliequivalents per 100 grams. Ligno-humate material showed a much higher and more constant capacity, ranging from 381 to 431 milliequivalents per 100 grams. He also found a close correlation between the total base-exchange capacity and the carbon content of the soil, there being an increase of 35 milliequivalents base-exchange capacity for each 10 grams of carbon in the soil.

Mitchell (11) pointed out that the presence of organic matter increases the base-exchange capacities in the surface horizons. Millar, Smith, and Brown (9) showed that mature plants vary greatly in their base-exchange capacity. It was also shown that the increase in base-exchange capacity can be

attributed, at least partially, to the increase in the lignin content of the decomposed materials. However, the increase in base-exchange capacity was so much larger than the increase in lignin, it would seem that the absorptive capacity of lignin has been increased during the decomposition.

Turner (14) found that the humus of the soil has a base-exchange capacity of 151 milliequivalents per 100 grams, while the clay fraction has only 24 milliequivalents per 100 grams or about one-sixth that of humus.

Mitchell (11) found that the base-exchange capacity in general showed no marked difference throughout the different horizons of the same profile. In most cases it follows the clay content fairly closely.

Mattson (8) found that clay had a base-exchange capacity of 16.4 to 110.2 milliequivalents per 100 grams of clay.

Kerr (6), in his review of the literature, points out that it is evident that there is a lack of unanimity concerning the true nature of the mechanism involved in the base-exchange reaction. One school favors the theory that the phenomenon is one of adsorption attributable to the highly dispersed condition of the soil colloids. Another group believes in the chemical idea, because it has been demonstrated that many of the characteristics of the reaction, point to true chemical forces as being the controlling agencies of the process. The great speed of the base-exchange reaction led Gedroiz to believe that it was a non-chemical reaction.

A review of the literature has yielded only fragments of data as to the base-exchange capacity of the soil in different

horizons, and the percentage that is due to inorganic and the organic matter. The lack of concrete data of this nature led to the study of this problem.

DESCRIPTION OF THE SOILS STUDIED[1]

This study was confined to the podzolic soils of the lower peninsula of Michigan. Representative samples of six different profiles developed under the prevailing humid climate from various parent materials, and under various drainage conditions were obtained from the locations indicated in figure 1. The numbers refer to the profiles described below.

1. Isabella loam. This is a well drained soil developed from calcareous, morainic drift under a hardwood forest in which beech, maple, hemlock, ash, and basswood were the dominant species together with a few scattered white pine. The forest floor is covered with a 2 to 4 inch litter of decomposing and decaying leaves which overlie a relatively homogenous layer of black granular, neutral to slightly alkaline, organic material ranging from ½ to 1 inch in thickness. Underlying this is a 2 to 6 inch layer of harsh, platy, ashy-gray loamy sand to sandy loam which is sometimes acid in reaction, and somewhat stained at the top by infiltering organic matter. Below the podzolized layer, 10 to 14 inches of transitional sandy loam or loam grade into reddish-brown, acid, highly structured sandy clay. This layer is characterized by a nut or block-like structure, the surfaces of the block-like structure,

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[1] Acknowledgement is made to Mr. A. H. Mick for his description of the soil profiles used in this study.

MICHIGAN

Figure 1. Distribution of the soil sites sampled in this study.

the surfaces of the blocks being covered with a dark brown coating and many minute roots. In the lower part free carbonates are not infrequently observed. Massive, calcareous, pinkish or reddish-brown till clay is encountered at depths ranging between 2 and 6 feet below the surface.

2. Selkirk loam. This is a well-drained heavy textured soil which developed on the clayey calcareous lake plains under a mixed forest of pine and hardwoods. From the surface downward Selkirk loam consists of a dark colored humus layer from 1 to 3 inches in thickness; 4 to 8 inches of ashy-gray fine sandy or silty loam; pale yellowish-brown often slightly mottled sandy loam to clay loam, 3 to 8 inches thick; and finally impervious pale reddish-brown clay. The first three layers may sometimes be acid but the heavy subsoil is alkaline and the sub-stratum contains a high percentage of carbonates.

3. Rubicon sand. This is a well-drained, pervious soil of the dry pine plains. 1 to 3 inches of litter accumulates under a virgin cover of red and white pine. A one-fourth inch humus layer is underlain by the chacteristic ashy-gray podzolized sand which ranges between 2 and 8 inches in thickness. This layer in turn overlies and grades into a pale yellowish brown loamy sand from 4 to 6 inches in thickness, slightly indurated in places. The substrate consists of pale yellow, loose, previous sand which extends more than 7 or 8 feet below the surface.

4. Ogemaw sandy loam. Ogemaw sandy loam is a ground water podzol of the poorly drained pine plains. The surface is characteristically rather mucky under a relatively deep

accumulation of litter; this soggy humus layer, 2 or 3 inches thick overlies 4 to 8 inches of conspicuously white sand or loamy sand. Abruptly underlying the leached layer is a dark coffee-brown heavily indurated, sandy "hard pan" which in places may be as much as 12 inches thick. Through a thin transition layer the brown color rapidly changes to the drab, dingy gray of waterlogged sand. At a depth varying between 3 and 5 feet, heavy impervious locustrine clay is encountered. The sub soil contains a small percentage of carbonates.

5. Kalkaska loamy sand. This soil developed under a hardwood forest of beech, maple, and hemlock on the dry sand plains. The surface litter decomposes rapidly to produce a thin, dark-brown, neutral, humus layer which overlies 2 to 4 inches of a dark gray, loamy sand. This layer grades downward into 2 to 5 inches of ashy-gray loamy sand which may be acid in reaction. Underlying this podozolized horizon are 4 to 10 inches of dark coffee-brown loamy sand which often is slightly indurated. This brown color rapidly fades so that between 18 to 24 inches the pale yellow, pervious, sandy substratum is encountered.

6. Emmet loamy sand. This is a light textered soil which is developed beneath a hardwood cover in the alkaline, sandy, morainic drift. Under a moderate accumulation of litter and a thin, neutral to slightly acid grayish-brown humus layer, are 2 to 3 inches of dark-gray stained loamy sand to sandy loam which grades into the harsh, platy, compact ashy-gray leached horizon. This podzol horizon is acid in reaction and ranges between 2 and 6 inches in thickness. It is under-

lain by 6 to 10 inches of brownish-yellow, acid, loamy sand which in turn grades downward into the sandy and gravelly parent drift material.

ANALYTICAL PROCEDURES

The soil samples were collected by horizons and allowed to air dry. They were then screened and ground to pass through a seive containing 0.84 mm. openings. The soils were thoroughly mixed, the percentage moisture was determined and the remaining portion of the sample was reserved for other determinations.

Organic matter was calculated by heating the equivalent of a two gram sample of water-free soil and weighing the amount of carbon dioxide liberated. The method employed consisted of heating the sample, after it had been treated with small quantities of manganese dioxide and crystaline alumina, in an electric furnace at 950°C. and passing a stream of oxygen through the soil. The organic matter was completely destroyed in less than 10 minutes of heating. The carbon dioxide was collected in a tube of ascarite which was weighed before and after it absorbed the gas. The increase in weight was found and the organic matter was calculated by multiplying the weight of the carbon dioxide liberated, by the factor 0.471. This factor is derived by the following method:

Soil organic matter is approximately 58 per cent carbon. Therefore per cent C x 1.728 = per cent organic matter.

$$\frac{\text{Mol. Wt. C}}{\text{Mol. Wt. } CO_2} = \frac{12}{44} \times 1.728 = 0.471$$

$$\frac{\text{Wt. } CO_2 \times .471 \times 100}{g} = \text{per cent organic matter}$$

Of the 29 samples studied, seven contained free calcium carbonate. When organic matter was determined in the presence of calcium carbonate by the method just described, the sample was heated above the decomposition point of this substance. Therefore the following reaction took place

$$CaCO_3 \xrightarrow{898.6^\circ} CaO + CO_2$$

and the carbon dioxide from the calcium carbonate collected in the ascarite tube with the carbon dioxide from the organic matter.

In order to correct for the percentage of carbonate present, the amount of carbonates[1] were determined by the Scheibler method. A two to five gram sample of soil, depending on the carbonate content, was treated with 20 per cent HCl and the volume of carbon dioxide liberated was determined with Scheibler's apparatus. The volume of carbon dioxide was then corrected to standard conditions and the weight calculated from the volume. When the weight of carbon dioxide from the calcium carbonate was determined, and that weight subtracted from the weight of carbon dioxide liberated by using the combustion furnace, the resultant figure was due to the carbon dioxide from the decomposition of the soil organic matter.

The pH of the soil was determined electrometrically by means of the glass electrode. A small crucible was filled

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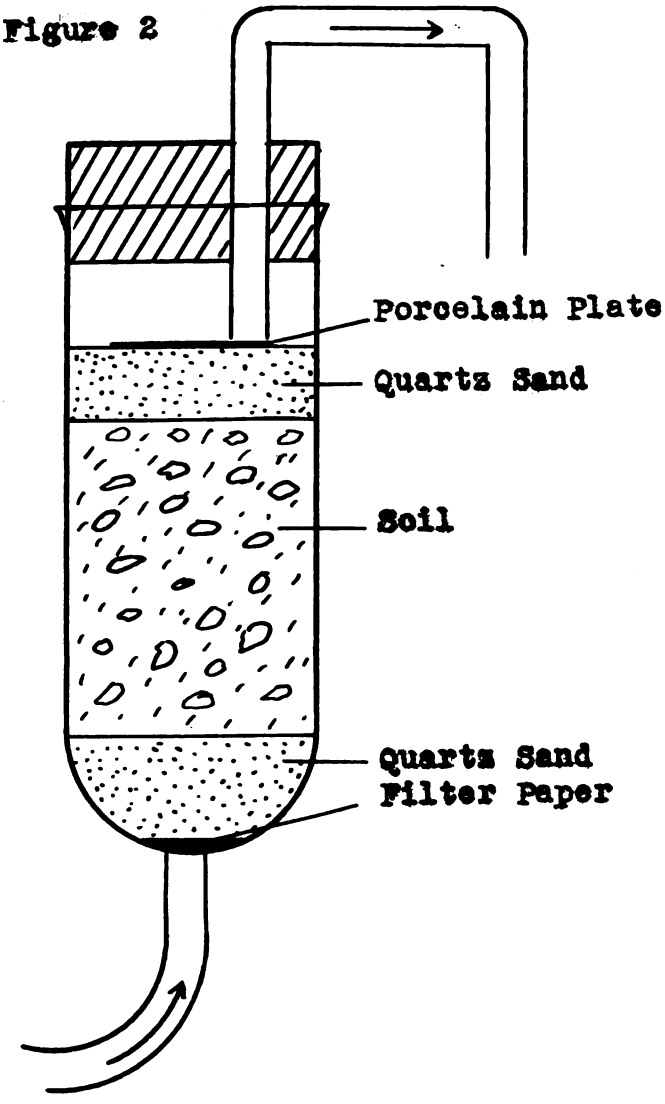
[1] It is realized that not all of the carbonates present in the soil are combined with calcium, however, since the relative percentages of calcium and magnesium carbonates present had no particular bearing on this problem, they were all reported as calcium carbonate.

with soil to within about one-fourth inch of the top and was saturated with distilled water. The samples were then left standing overnight to come to an equilibrium and the pH was determined the following day by using the Beckman pH meter.

Base-exchange Determinations

The apparatus used in the base-exchange studies was similar to that described by Russell (13). Twenty-five-gram samples of soil were used. The soil was packed firmly into the percolation tubes as shown in figure 2, so that the leaching solution came in contact with the entire sample of soil.

Figure 2



Normal ammonium acetate adjusted to a pH of 7.0 was used as the leaching solution. By using this extraction apparatus, it required about eight hours for the 500 ml. of ammonium acetate to pass through the soil. The leachate was then reserved for the determination of exchangeable calcium and magnesium.

Determination of the Base-exchange Capacity

After the soil was leached with the ammonium acetate, the excess ammonium acetate was removed from the soil by passing 300 ml. of 50 per cent methanol through the sample. The ammonia that remained in the soil after this treatment was in the exchangeable form.

The ammonia that saturated the soil complex was then removed by passing 250 ml. of normal calcium acetate solution through the soil. The solution of calcium acetate and ammonium acetate was collected in Kjeldahl flasks. The solution was then treated with 0.5 gm. of tannic acid, to prevent foaming, and 8 ml. of 40 per cent sodium hydroxide to make the solution alkaline. Two hundred ml. of the mixture was then distilled over into 25 ml. of a 4 per cent solution of boric acid. N/10 HCl was used to titrate the ammonium liberated, brom-phenol blue being used as the indicator. The results were then converted to milliequivalents per 100 grams of water-free soil.

Determination of Exchangeable Calcium

The ammonium acetate leachate was evaporated to dryness on the steam bath and the residue was then treated with 30 per cent hydrogen peroxide until all of the organic matter was

destroyed. The residue was then taken up in 200 ml. of distilled water, brought to a boil and 10 ml. of 10 per cent NH_4Cl was added. Then 20 ml. of N/2 $(NH_4)_2C_2O_4$ was added and the calcium was precipitated as CaC_2O_4. After the precipitate was covered and allowed to digest, a drop of $(NH_4)_2 C_2O_4$ was added to insure an excess of $(NH_4)_2C_2O_4$ in solution. When the CaC_2O_4 was digested it was filtered quickly and washed free of $(NH_4)_2C_2O_4$ with boiling water. The filtrate was reserved for the Mg determination. When the filtrate no longer gave a test for oxalates, the filter paper was broken and the CaC_2O_4 was washed into a clean beaker. The beaker now contained the CaC_2O_4 precipitate in about 200 ml. of water. The CaC_2O_4 was dissolved in 20 ml. of 18 N H_2SO_4 and brought to a boil. While the solution was still hot it was titrated with N/10 $KMnO_4$ solution. Next the filter paper was added to the beaker and the final end point determined. The calcium was calculated from the ml. of $KMnO_4$ reduced.

Determination of Exchangeable Magnesium

The filtrate from the calcium determination was adjusted to about 250 ml. The solution was then acidified with 4 ml. of con. HCl. Then 15 ml. of a freshly prepared 10 per cent solution of dibasic ammonium phosphate was added and the solution was cooled to 20°C. 30 ml. of con. NH_4OH was then slowly added with constant stirring. Phenolphthalein was used as an indicator and when a pH of 9.0 was reached, the solution was stirred vigorously until the magnesium precipitated, the remaining volume of the NH_4OH was then added. The beakers containing the precipitate were allowed to stand in a cool

place over night. The precipitate was filtered on No. 42 Whatman filter paper and washed with 10 per cent NH_4OH. The magnesium ammonium phosphate was then ignited at 900°C. to constant weight. During the ignition, the following reaction took place: $2\ MgNH_4PO_4.6\ H_2O \xrightarrow{900°C.} 2NH_3 + 13H_2O + Mg_2P_2O_7$ and the $Mg_2P_2O_7$ was determined gravimetrically.

Determination of the Base-exchange Capacity of the Mineral Portion of the Soil

The method used for determining the base-exchange capacity of the inorganic portion of the soil was that proposed by Mitchell (8), who found that ignition at 350° to 400° C. for seven or eight hours, produced a well oxidized sample, but did not destroy or change the base-exchange capacity of the inorganic material.

A 25 gram sample of soil was ignited at 400°C. for seven hours. When cool, the sample was placed in the percolation tube and the base-exchange capacity was determined.

Then the difference between the base-exchange capacity of the original soil and that of the sample in which the organic matter had been destroyed, represents the base-exchange capacity of the organic matter in 100 grams of soil.

The base-exchange capacity of the organic matter was then converted to the 100 gram equivalent basis by the formula.

$$\frac{100 \times \text{Exchange capacity due to organic matter expressed in M.E.}}{\text{per cent organic matter}} = \text{Base-exchange capacity per 100 grams of organic matter.}$$

The effect of Varying pH of the Ammonium Acetate Solution on the Base-exchange Capacity of the Soils

The object of this part of the problem was to extract the bases and determine the base-exchange capacity of a soil with the ammonium acetate adjusted to the same pH as that of the soil. The analyses were determined in the same manner as previously described.

DISCUSSION

The graphs in figure 3 show the variation in the base-exchange capacity in the different soil horizons; also the amount of the base-exchange capacity due to the organic fraction, and the amount due to the inorganic fraction of the soil. When the base-exchange capacity is relatively large as it is in the B and C horizons of the Isabella and Selkirk loams, and the C horizon of the Ogemaw sandy loam, it is due almost entirely to the inorganic fraction of the soil. The particular horizons mentioned are composed of a very fine textured clay, thus these horizons have a large specific surface. It is a well known fact that a large specific surface tends to increase the base-exchange capacity of a soil. Therefore, it is to be expected that in these heavy textured soils, a large base-exchange capacity should be found. In the sandy textured soils; Rubicon sand, Kalkaska loamy sand, and Emmet loamy sand, the inorganic fraction of the soil shows a very low base-exchange capacity, especially in the lower horizons. This can be attributed largely to the sandy texture of the soil which has a small specific surface as compared to clay

Base-exchange capacity of various horizons expressed in milliequivalents per 100 grams of oven-dry soil.

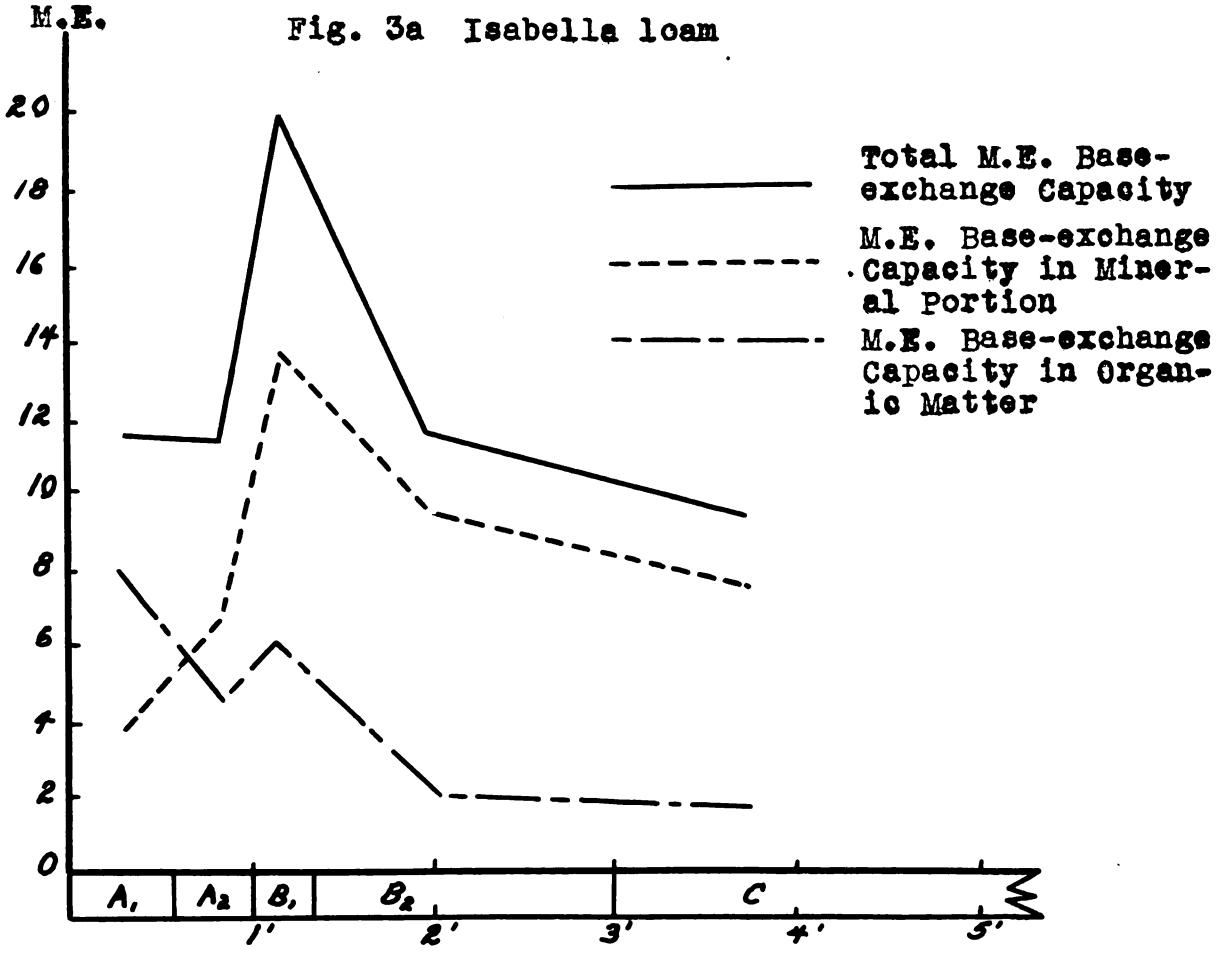


Fig. 3a Isabella loam

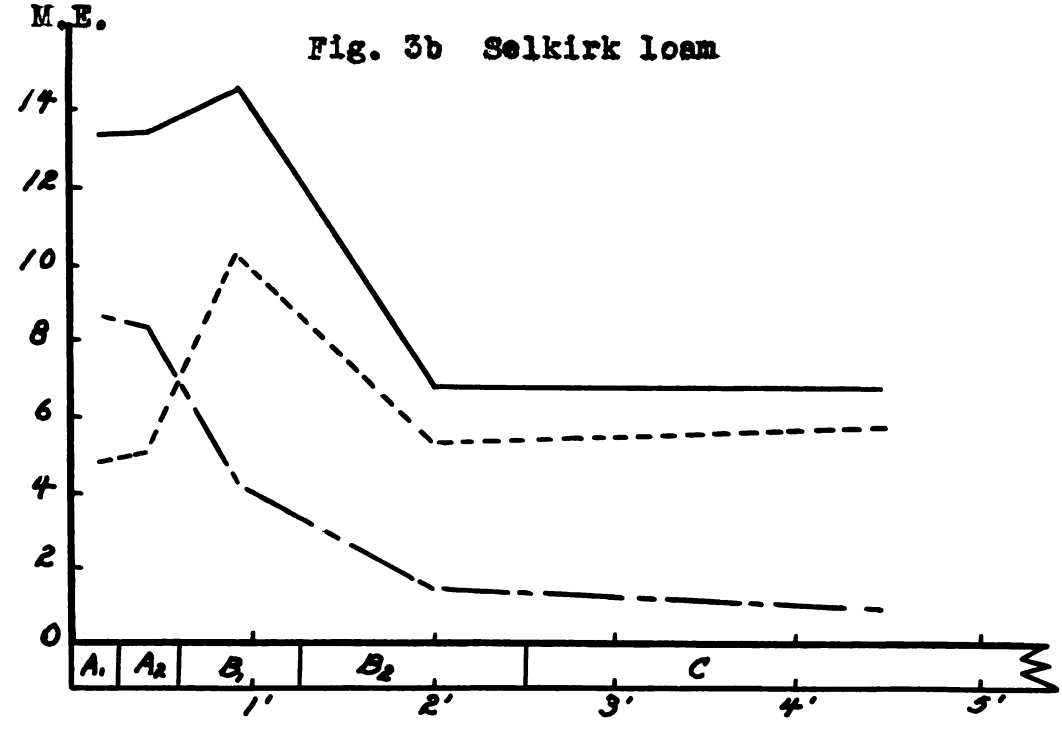


Fig. 3b Selkirk loam

Base-exchange capacity of various horizons expressed in milliequivalents per 100 grams of oven-dry soil.

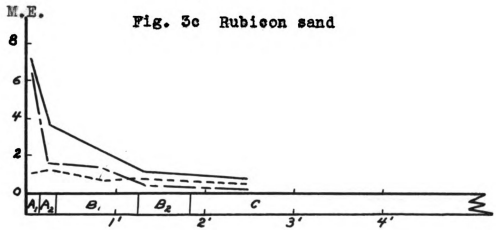


Fig. 3c Rubicon sand

Total M.E. Base-exchange Capacity

M.E. Base-exchange Capacity in Mineral Portion

M.E. Base-exchange Capacity in Organic Matter

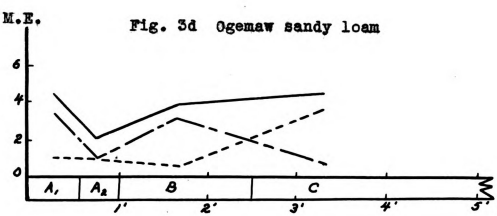


Fig. 3d Ogemaw sandy loam

Base-exchange capacity of various horizons expressed in milliequivalents per 100 grams of oven-dry soil.

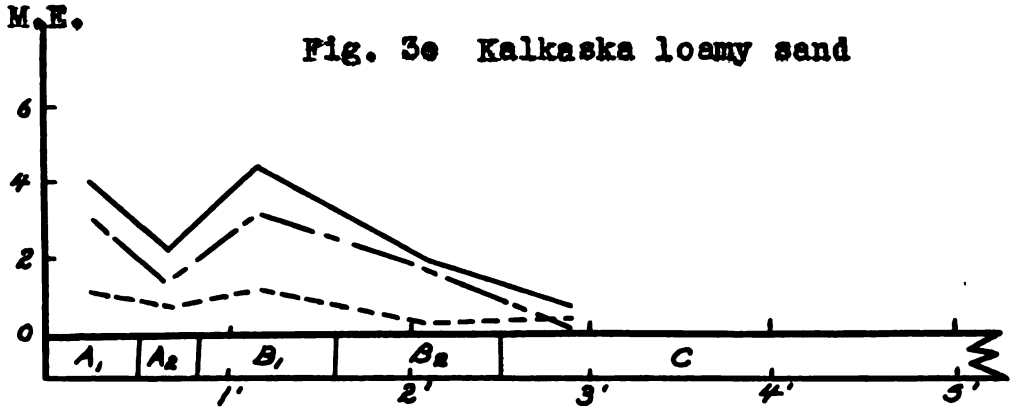


Fig. 3e Kalkaska loamy sand

———— Total M.E. Base-exchange Capacity
- - - - - - - M.E. Base-exchange Capacity in Mineral Portion
———·——— M.E. Base-exchange Capacity in Organic Matter

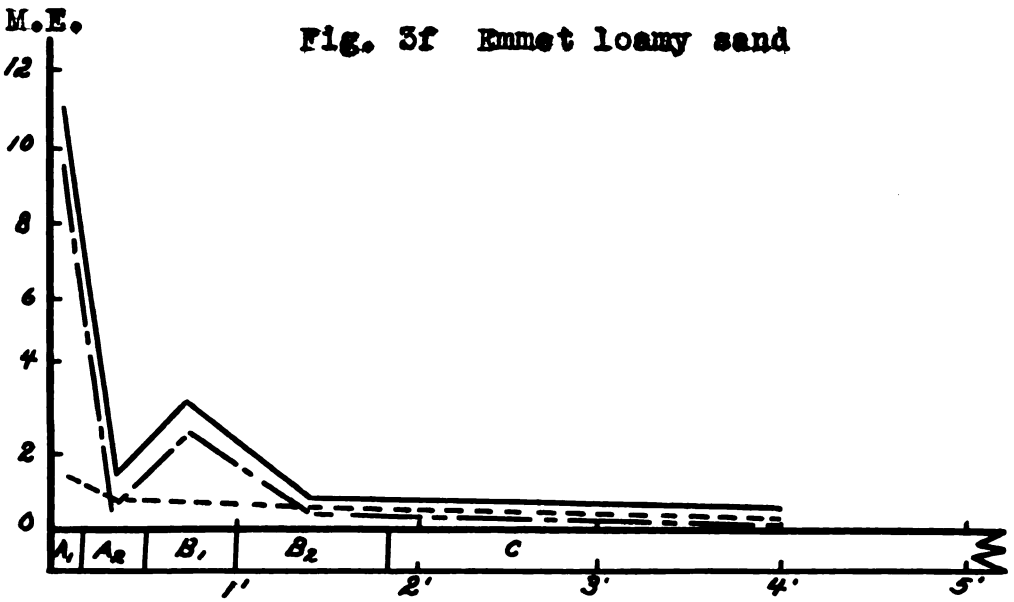


Fig. 3f Emmet loamy sand

soils. It can be seen in figures 3a and 3b that the organic matter in the calcareous soil[1] horizons, B_1, B_2, and C, usually show a greater base-exchange capacity than the organic matter in the non-calcareous soil horizons. This is also shown by horizon C, figure 3d. This is to be expected because of the fact that there is usually a larger percentage of organic matter present in the lower horizons that contain $CaCO_3$ than the corresponding horizons in other profiles that do not contain $CaCO_3$. This is accounted for by the fact that when colloidal humus moves downward through the profile, it is fixed when it comes into contact with $CaCO_3$. However, when the humus moves downward in a profile that does not contain $CaCO_3$, not as much of the humus will remain in the profile because there is no $CaCO_3$ nor $MgCO_3$ to fix the humus. Waksman (15) states that calcium is present in humus only in an adsorbed condition, but does not form any salts. Humus is fixed in the presence of calcium and when this base is removed, the humus is readily lost, hence the total base-exchange capacity of the soil organic matter decreases.

In most cases it is true, that the percentage of organic matter is higher and has a higher base-exchange capacity in the horizons that contain calcium carbonate than the corresponding horizons of other profiles that do not contain calcium carbonate. However, there may be other factors more powerful in influencing the movement of organic matter in the soil profile than calcium carbonate, such as water, soil tex-

[1]By a calcareous soil is meant one that shows effervescence when treated with a 20 per cent solution of HCl.

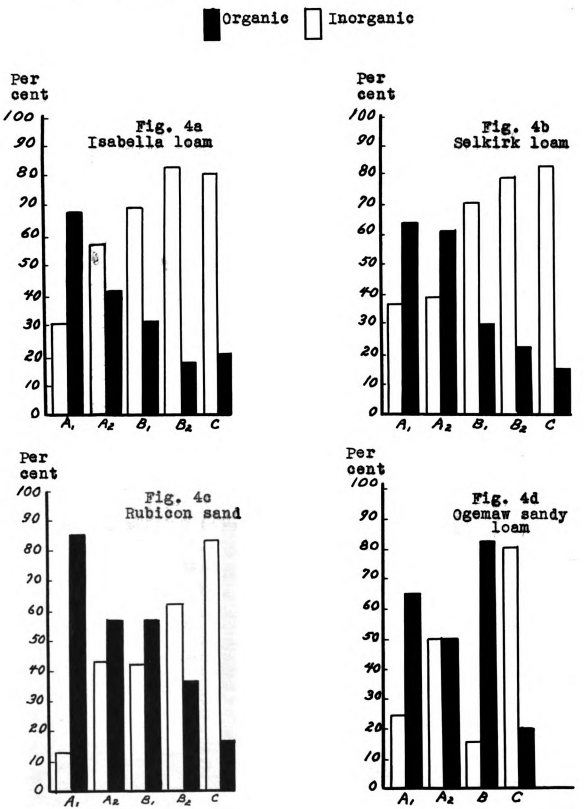
ture, and the quantity and nature of the organic matter in the top horizons.

Gedroiz (3) noted that the soil-adsorbing complex consists of both organic and inorganic soil constituents; the greater importance of one or the other in this process varies with different soils and with different horizons of the same soil.

The organic fraction of the surface horizon of all soils used in this investigation possessed a greater base-exchange capacity than the inorganic portion of that horizon. Except in the zone of accumulation, it is noted that the percentage of organic matter and the base-exchange capacity of the organic fraction decreases with increasing depth. All soils except the heavily leached Rubicon sand tend to show that there is a zone of accumulation in the B. horizon. It can be seen that the increase in the base-exchange capacity in the B horizon of the Ogemaw sandy loam, and the B_1 horizon of the Kalkaska loamy sand, and Emmet loamy sand is due mainly to the accumulation of organic matter in the horizon, figures 3d, 3e, and 3f. However, as previously explained, most of the base-exchange capacity of the heavy soils is due to the inorganic fraction.

As was pointed out in the review of literature, several workers reported that the percentage of the base-exchange capacity, due to the organic matter in the soil horizon, varied widely. The graphs given in figure 4 show the percentage of the base-exchange capacity due to the organic portion of the soil and the percentage due to the inorganic portion. In the Isabella (Fig. 4a), A_1 horizon, the organic matter is the pre-

Base-exchange capacity of the inorganic and organic soil fractions expressed as percentage of the total base-exchange capacity.



Base-exchange capacity of the inorganic and organic soil fractions expressed as percentage of the total base-exchange capacity.

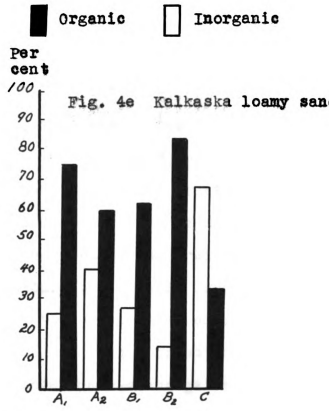


Fig. 4e Kalkaska loamy sand

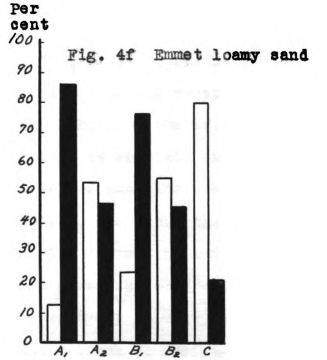


Fig. 4f Emmet loamy sand

dominant fraction, however, as we go deeper into the profile, the inorganic fraction possesses a greater capacity for exchanging bases relative to the organic fraction of the soil. This is to be expected since with increasing depth percentage organic matter decreases. The Selkirk (Fig. 4b), is somewhat similar to the Isabella; the organic matter in the A_1 and A_2 horizons constitutes over 50 per cent of total base-exchange capacity, whereas in the B_1, B_2, and C horizons, the inorganic portion is the dominant fraction in producing the base-exchange capacity. The organic matter is the predominant fraction in the A_1 horizon of the Rubicon sand, (Fig. 4c). In the A_2 and B_1 horizons, the organic fraction contributes about 56 per cent the total base-exchange capacity. However, in the B_2 and C horizon, the inorganic fraction contributes the greater portion of the total base-exchange capacity. In the Ogemaw sandy loam (Fig. 4d), the greater portion of the base-exchange capacity of the A_1 horizon is due to organic matter, while in the A_2 horizon about one-half of the base-exchange capacity is due to the organic matter and the other half due to the inorganic matter. In the B horizon the effect of the organic matter is very predominant, as we might expect, since this is the coffee-brown layer and contains a considerable amount of humus. In the C horizon, the inorganic matter is dominant, since the organic matter content is low and the parent material is sandy. In the Kalkaska loamy sand (Fig. 4e), the organic matter plays a dominant role in the base-exchange capacity of the A_1, A_2, B_1, and B_2 horizons while the inorganic fraction is dominant in the C horizon. In the Emmet sandy

loam (Fig. 4f), the organic matter in the A_1 horizon is the predominant fraction, however, in the A_2 horizon we find about one-half of the base-exchange capacity due to the inorganic matter and about one-half due to the organic matter. In the B_1 horizon there is a layer of accumulation of organic matter and, therefore, the greater portion of the base-exchange capacity is due to organic matter. However, in the B_2 and C horizons, the inorganic matter dominates.

All of the figures so far discussed clearly illustrate the greater effect of organic matter content on the base-exchange capacity of light-textured soils as compared to heavy textured soils.

Table 1. The percentage of the total base-exchange capacity that is due to the organic matter in the various soil horizons.

Horizon	Percentage of the total base-exchange capacity due to the organic matter
A_1	63.9 - 86.2
A_2	41.7 - 61.9
B_1	89.4 - 84.8
B_2	17.4 - 85.0
C	16.2 - 33.3

The base-exchange capacity of the soil organic matter was converted to milliequivalents per 100 grams of air dry organic matter. The results are shown in figure 5. It can be seen that there is a wide variation in the base-exchange capacity of the organic fraction in the different soil profiles, and also between horizons within the same profile.

It is apparent that the base-exchange capacity of the organic fraction of the Selkirk and Isabella soils is much

Base-exchange capacity of the soil organic matter at various depths expressed in milliequivalents per 100 grams of organic matter.

Fig. 5a Isabella loam

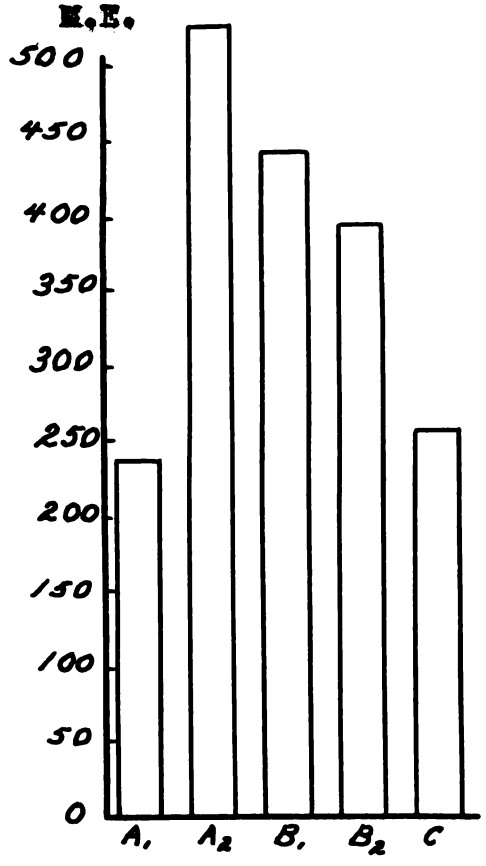


Fig. 5b Selkirk loam

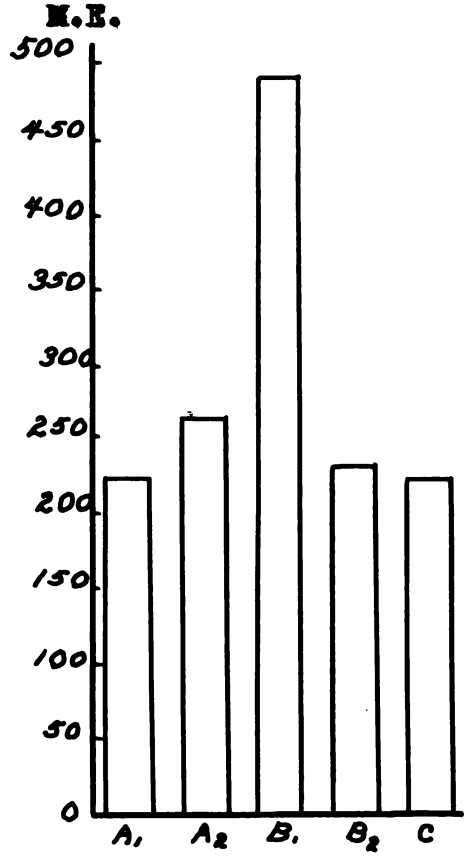


Fig. 5c Rubicon sand

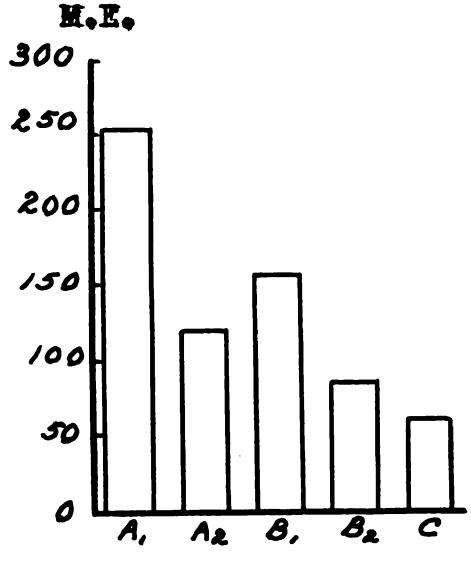
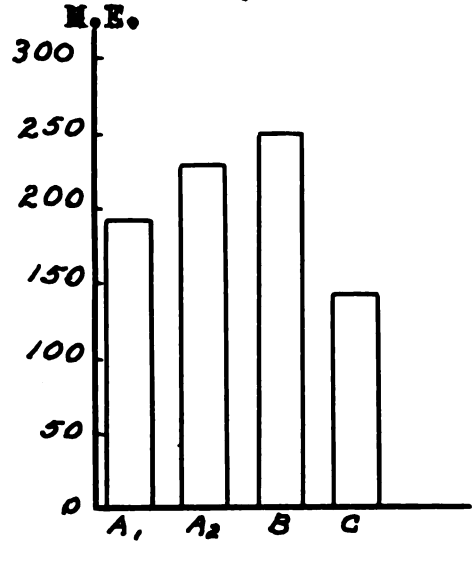


Fig. 5d Ogemaw sandy loam



Base-exchange capacity of the soil organic matter at various depths expressed in milliequivalents per 100 grams of organic matter.

Fig. 5e
Kalkaska loamy sand

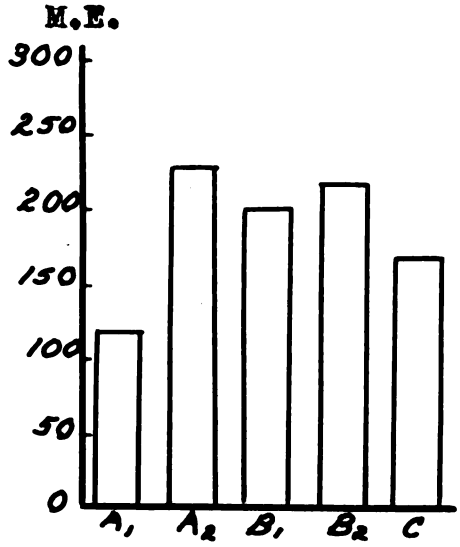
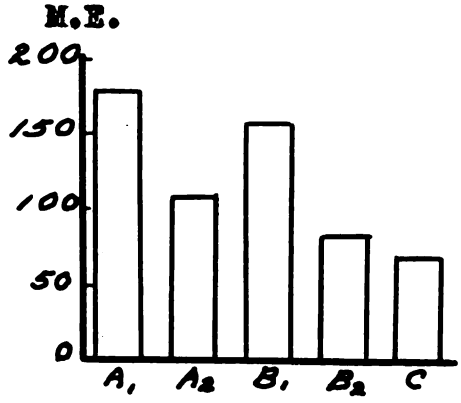


Fig. 5f
Emmet loamy sand



greater than for any of the other soil types studied. This possibly is due to a difference in the chemical constitution of the organic matter. Apparently the organic fraction in the Selkirk and Isabella soils has undergone hydrolysis capacity tremendously. The organic matter in the other soil types has undergone a slightly different degradation, due possibly to the influence of such factors as pH, increased drainage and biological activities; consequently, its base-exchange capacity is somewhat lower.

The writer is aware that the base-exchange capacity of the organic fraction in horizon A_2, figure 5a and horizon B_1, figure 5b is extremely high. When a soil sample contains less than one per cent organic matter, as some samples did, the results had to be multiplied by a factor that was larger than 100. Therefore, when such a large factor is used, the slightest error in the determination will result in a large final error.

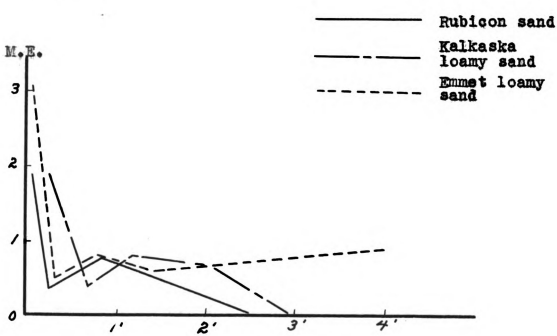
The graphs in figures 6a and 6 b show that there is a general decrease in exchangeable calcium and magnesium as we go deeper in the profile. However, it can be seen in figures 6a and 6 b that there is more exchangeable calcium and magnesium in the B_1 than A_2 horizon in the Kalkaska loamy sand.

In the horizons that contained carbonates, exchangeable calcium and magnesium were not determined.

Table 2 shows the base-exchange capacity of a soil with the ammonium acetate adjusted to a pH of 7.0 as compared to the extraction made with the ammonium acetate adjusted to the pH of the soil.

Milliequivalents of exchangeable magnesium per 100 grams of oven-dry soil at various depths.

Fig. 6a



Milliequivalents of exchangeable calcium per 100 grams of oven-dry soil at various depths.

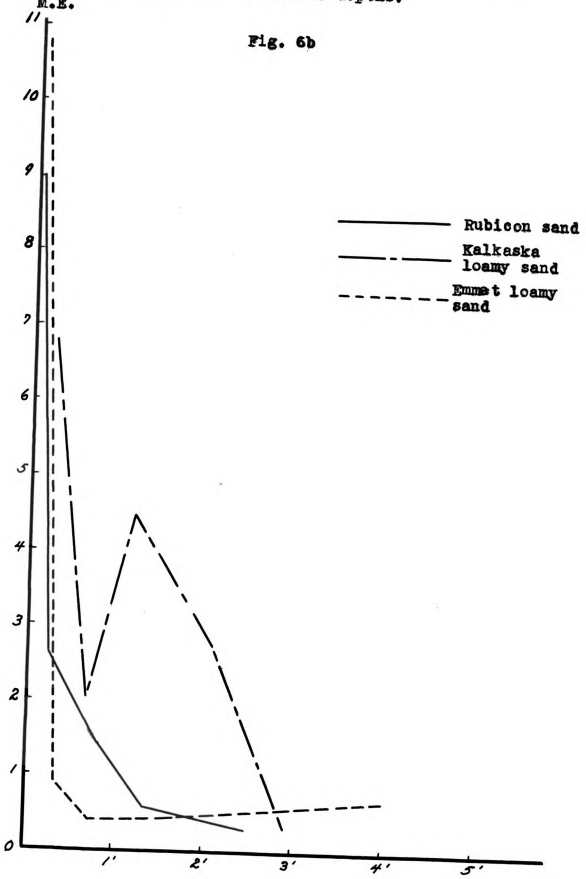


Fig. 6b

Table 2.

Base-exchange Capacity in M.E. per 100 grams of Oven-dry Soil

Soil Type		HORIZON A_1	A_2	B_1	B_2	C
1. Isabella Loam	pH of soil	8.0	7.0	7.7	7.8	8.8
	NH_4Ac adjusted to pH of the soil	11.9	11.3	19.5	11.8	10.0
	NH_4Ac adjusted to pH of 7.0	11.6	11.3	20.0	11.5	9.4
2. Selkirk Loam	pH of soil	7.8	7.6	7.7	8.0	8.1
	NH_4Ac adjusted to pH of the soil	14.0	13.4	14.5	7.1	6.9
	NH_4Ac adjusted to pH of 7.0	15.3	13.4	14.6	6.8	6.8
3. Rubicon Sand	pH of soil	7.6	7.2	7.0	6.5	6.2
	NH_4Ac adjusted to pH of the soil	7.0	2.9	3.0	1.1	0.6
	NH_4Ac adjusted to pH of 7.0	7.2	3.0	3.0	1.1	0.6
4. Ogemaw Sandy Loam	pH of soil	7.8	8.0	6.8		7.8
	NH_4Ac adjusted to pH of the soil	5.3	2.6	3.9		3.6
	NH_4Ac adjusted to pH of 7.0	4.4	2.0	3.8		4.3
5. Kaslkaska Loamy Sand	pH of soil	7.9	7.7	7.3	8.0	7.8
	NH_4Ac adjusted to pH of the soil	4.2	2.7	5.0	2.6	0.7
	NH_4Ac adjusted to pH of 7.0	3.8	2.2	4.4	2.0	0.6
6. Emmet Loamy Sand	pH of soil	7.4	6.6	5.6	5.9	7.5
	NH_4Ac adjusted to pH of the soil	10.8	1.6	2.6	1.2	0.7
	NH_4Ac adjusted to pH of 7.0	11.1	1.5	3.4	0.9	0.5

Of the 29 soils samples examined, twenty-one had a pH value greater than 7.0, six had a value below 7.0 and 2 were neutral. When the base-exchange capacity of the twenty-one basic soils were studied, it was found that when ammonium acetate was adjusted to the same pH as that of the soil, in fifteen of the cases the base-exchange capacity was greater than the value obtained with the ammonium acetate at a pH of 7.0. In four cases when the ammonium acetate was adjusted to the higher value, lower results were obtained, and in 2 cases the results were the same. Of the six acid horizons examined, three gave a lower base-exchange capacity when the ammonium acetate was adjusted to the pH of the soil as compared with the ammonium acetate adjusted to a pH of 7.0. The soils gave a higher result and one the same when ammonium acetate was adjusted to the pH of the soil.

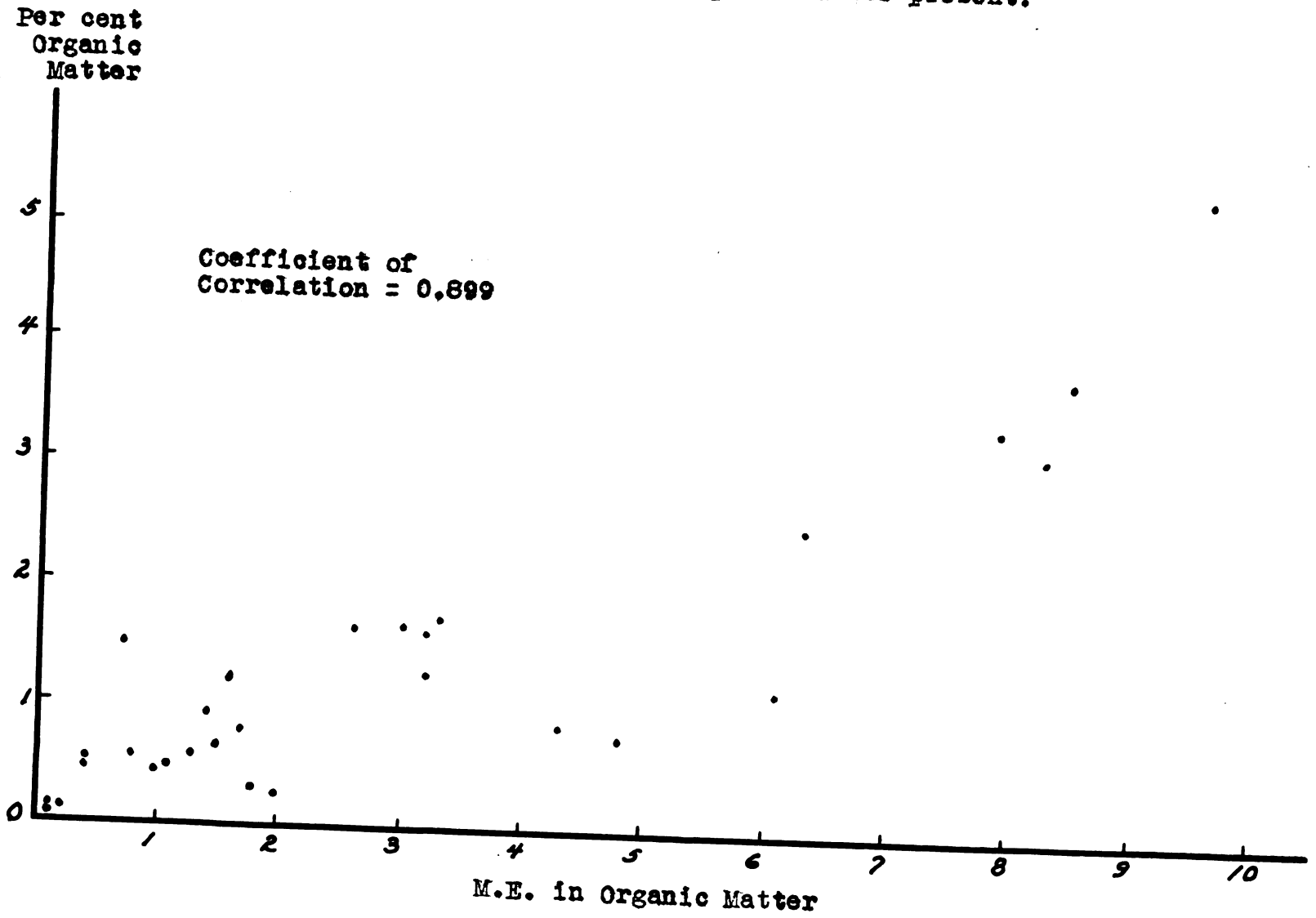
It can be seen from the data in table 2 that when the ammonium acetate was adjusted to the same pH as that of the soil, higher results were usually obtained, especially with the alkaline soils. This difference depended mainly upon the pH and the approximate base-exchange capacity of the soil. When the pH of the soil was high, usually greater differences were found.

There were not enough acid soils studied to draw any conclusions as to the effect of the base-exchange capacity when the ammonium acetate was adjusted to a pH of 7.0 as compared with the ammonium acetate to the same pH as that of the soil.

An attempt (Fig. 7), was made to determine whether the base-exchange capacity of the organic matter would show a

Fig. 7

The relationship of base-exchange capacity of the organic matter to the per cent of organic matter present.



direct correlation with the per cent of organic matter in the soil. It was found that there is a general increase of base-exchange capacity of the organic matter as the per cent of organic matter increases. The coefficient of correlation was found to be 0.899 which shows that there is a fairly close correlation between per cent organic matter and milliequivalents base-exchange capacity of the soil organic matter.

SUMMARY

1. Base-exchange studies were made of six soil profiles found in Michigan.

2. A wide variation in base-exchange capacity of the different soil profiles was noted. Similarly, a wide variation in base-exchange capacity at different depths of the same profile was noted.

3. Heavy textured soils have a far greater base-exchange capacity than light textured soils.

4. It was found that the organic matter contributed over one-half of the base-exchange capacity in the A_1 horizon of all the soils studied. Except for the zone of accumulation, it was found that with increasing depth the percentage of the organic matter becomes less and the percentage of the base-exchange capacity of the soil due to the organic matter also decreases.

5. The base-exchange capacity of the soil organic matter in various profiles within the different horizons of the same profile expressed in milliequivalents per 100 grams, was found to vary widely.

6. Exchangeable calcium and magnesium tend to decrease with increasing depths in the profile.

7. Comparing the base-exchange capacity, obtained with alkaline soils, when the ammonium acetate was adjusted to a pH of 7.0 with that obtained when it was adjusted to the pH of the soil, it was found that a higher base-exchange capacity was usually obtained in the latter case.

8. When per cent organic matter was plotted against milliequivalents of base-exchange capacity due to the organic matter in 100 grams of soil, the coefficient of correlation was found to be 0.899.

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APPENDIX

Analysis of the soil profile expressed on a basis of 100 grams of water-free soil.

ISABELLA LOAM

Horizon	A_1	A_2	B_1	B_2	C
Per cent moisture	3.05	6.03	10.38	1.51	3.50
pH	8.0	7.0	7.7	7.8	8.8
Per cent organic matter	3.38	0.76	1.16	0.25	0.31
Milliequivalents base-exchange capacity	11.6	11.5	20	11.5	9.4
Base-exchange capacity with organic matter destroyed	3.7	6.7	13.9	9.5	7.6
Base-exchange capacity of organic matter	7.9	4.8	6.1	2.0	1.8
Percentage of base-exchange capacity due to organic matter	68.1	41.7	30.5	17.4	19.2
Percentage of base-exchange capacity due to inorganic matter	31.9	58.3	69.5	82.6	80.8
Milliequivalents of exchangeable Ca	13.3	8.8	--	--	--
Milliequivalents of exchangeable Mg	0.8	1.6	--	--	--
Percentage of $CaCO_3$	--	--	8.00	31.49	33.05

Analysis of the soil profile expressed on a basis of 100 grams of water-free soil.

SELKIRK LOAM

Horizon	A_1	A_2	B_1	B_2	C
Per cent moisture	8.83	4.80	7.54	1.79	3.09
pH	7.8	7.6	7.7	8.0	8.1
Per cent organic matter	3.80	3.11	0.87	0.65	0.49
Milliequivalents base-exchange capacity	13.3	13.4	14.6	6.8	6.8
Base-exchange capacity with organic matter destroyed	4.8	5.1	10.3	5.3	5.7
Base-exchange capacity of organic matter	8.5	8.3	4.3	1.5	1.1
Percentage of base-exchange capacity due to organic matter	63.9	61.9	29.4	22.1	16.2
Percentage of base-exchange capacity due to inorganic matter	36.1	38.1	70.6	77.9	83.8
Milliequivalents of exchangeable Ca	12.7	12.4	--	--	--
Milliequivalents of exchangeable Mg	4.0	3.0	--	--	--
Percentage of $CaCO_3$	--	--	7.46	31.18	32.43

Analysis of the soil profile expressed on a basis of 100 grams of water-free soil.

RUBICON SAND

Horizon	A_1	A_3	B_1	B_2	C
Per cent moisture	0.98	0.55	1.07	0.83	0.47
pH	7.6	7.8	7.0	6.5	6.1
Per cent organic matter	2.50	1.21	0.91	0.49	0.16
Milliequivalents base-exchange capacity	7.3	2.8	2.1	1.1	0.6
Base-exchange capacity with organic matter destroyed	1.0	1.2	0.7	0.7	0.5
Base-exchange capacity due to organic matter	6.3	1.6	1.4	0.4	0.1
Percentage of base-exchange capacity due to organic matter	86.2	57.1	57.2	36.4	16.7
Percentage of base-exchange capacity due to inorganic matter	13.8	42.9	42.8	63.6	83.3
Milliequivalents of exchangeable Ca	9.0	2.6	1.4	0.6	0.3
Milliequivalents of exchangeable Mg	1.9	0.4	0.8	0.6	0.1
Percentage of $CaCO_3$	--	--	--	--	--

Analysis of the soil profile expressed on a basis of 100 grams of water-free soil.

OGEMAW SANDY LOAM

Horizon	A_1	A_2	B	C
Per cent moisture	0.83	2.45	1.51	1.12
pH	7.8	8.0	6.8	7.8
Per cent organic matter	1.70	0.45	1.27	0.55
Milliequivalents base-exchange capacity	4.4	2.0	3.8	4.3
Base-exchange capacity with organic matter destroyed	1.1	1.0	0.6	3.5
Base-exchange capacity of organic matter	3.3	1.0	3.2	0.8
Percentage of base-exchange capacity due to organic matter	75.0	50.0	84.2	19.0
Percentage of base-exchange capacity due to inorganic matter	25.0	50.0	15.8	81.0
Milliequivalents of exchangeable Ca	2.0	2.3	2.8	--
Milliequivalents of exchangeable Mg	2.7	0.4	0.6	--
Percentage of $CaCO_3$	--	--	--	10.98

Analysis of the soil profile expressed on a basis of 100 grams of water-free soil.

KALKASKA LOAMY SAND

Horizon	A_1	A_2	B_1	B_2	C
Per cent moisture	0.64	0.23	1.46	0.58	0.03
pH	7.9	7.7	7.3	8.0	7.8
Per cent organic matter	1.67	0.57	1.60	0.79	0.18
Milliequivalents base-exchange capacity	4.0	2.8	4.4	2.0	0.6
Base-exchange capacity with organic matter destroyed	1.0	0.9	1.2	0.3	0.4
Base-exchange capacity due to organic matter	3.0	1.3	3.2	1.7	0.2
Percentage of base-exchange capacity due to organic matter	75.0	59.1	68.7	85.0	33.3
Percentage of base-exchange capacity due to inorganic matter	25.0	40.9	27.3	15.0	67.7
Milliequivalents of exchangeable Ca	6.8	2.0	4.5	2.7	0.6
Milliequivalents of exchangeable Mg	1.9	0.4	0.8	0.6	0.1
Percentage of $CaCO_3$	--	--	--	--	--

Analysis of the soil profile expressed on a basis of 100 grams of water-free soil.

EMMET LOAMY SAND

Horizon	A_1	A_2	B_1	B_2	C
Per cent moisture	2.27	2.83	2.74	0.15	0.03
pH	7.4	6.6	5.6	5.9	7.5
Per cent organic matter	5.37	0.64	1.68	0.48	0.14
Milliequivalents base-exchange capacity	11.1	1.5	3.4	0.9	0.5
Base-exchange capacity with organic matter destroyed	1.5	0.8	0.8	0.5	0.4
Base-exchange capacity due to organic matter	9.6	0.7	2.6	0.4	0.1
Percentage of base-exchange capacity due to organic matter	86.5	46.7	76.5	44.5	80.0
Percentage of base-exchange capacity due to inorganic matter	13.5	53.3	23.5	55.5	80.0
Milliequivalents of exchangeable Ca	10.8	0.9	0.4	0.4	0.7
Milliequivalents of exchangeable Mg	3.1	0.5	0.8	0.6	0.9
Percentage of $CaCO_3$	--	--	--	--	--