A STUDY OF THE PROFILES OF THE SOILS
IN BAYFIELD COUNTY, WISCONSIN

THESIS FOR DEGREE OF PH. D.

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1929

A STUDY OF THE PROFILES OF THE SOILS IN BAYFIELD COUNTY, WISCONSIN

by

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A THESIS

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THESIS

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The field work was done during the season of 1928 and the other studies were completed during the winter of 1929 in the laboratories of the Department of Soils of the University of Wisconsin.

FOREWORD

Since the rise of Dokuchaev's school of soil science soil classification has been recognized as a separate branch of science. Its object of study is the soil, considered as a dynamic body, under the influence of natural forces. The action of climate, vegetation, and other agencies upon the surface of the earth has produced soil bodies with certain characteristics. On the basis of these characteristics the classification is made. The soil itself, as the product of soil-building forces acting upon the formations, is the object of classification.

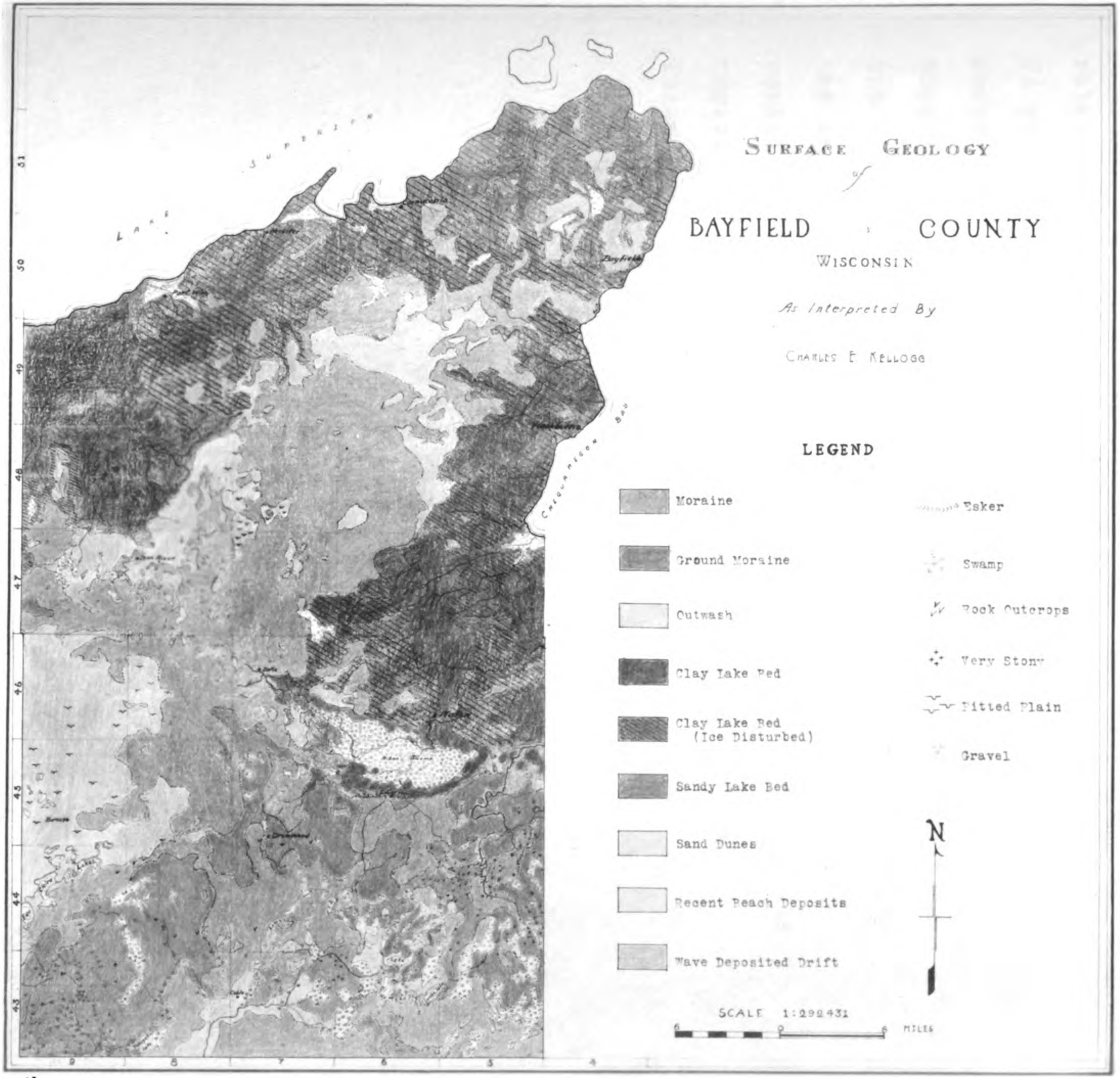
The soils of Bayfield County, Wisconsin, have been studied in order to determine something of their character and how they are to be classified.

Description of Bayfield County

Bayfield County is located in the northwestern part of Wisconsin on the south shore of Lake Superior. The county has an area of about 1497 square miles. The present drift is of the Wisconsin period of glaciation. The principle geological features are (Figure 1): (1) The Lake Superior Lowland occupying a continuous belt bordering Lake Superior. The body of the material is heavy lacustrine clay, covered in a few places with a thin layer of sand. (2) A large, sandy, interlobate moraine forms the centre of the peninsula. This is locally known as the Bayfield Ridge. (3) Terminal and grand moraines in the southern part of the county are composed of stony, clayey till. (4) Sandy outwash benches. The material forming the drift is largely of sandstone and acidic igneous rocks, high in iron.[1]

Climatic conditions are quite similar to those of Denmark, Sweden and central Finland except that there is more variation from the mean. The principle features of the climate are a mean temperature of about 40 $^{\circ}$F, an

1. For discussions of the geology of this area see (6) (10) (21) and (27).



SURFACE GEOLOGY
of
BAYFIELD COUNTY
WISCONSIN
As Interpreted By
CHARLES E KELLOGG
LAKE SUPERIOR
CHEQUAMEGON BAY
LEGEND
Moraine
Ground Moraine
Outwash
Clay Lake Bed
Clay Lake Bed (Ice Disturbed)
Sandy Lake Bed
Sand Dunes
Recent Beach Deposits
Wave Deposited Drift
Esker
Swamp
Rock Outcrops
Very Stony
Pitted Plain
Gravel
N
SCALE 1:292431
6 0 6 MILES

Figure I

average annual precipitation of about 28 inches, a snowfall of a little more than 50 inches, a mean relative humidity of between 70 and 85 percent, about 54 percent sunshine for the year, and a relatively low evaporation. The temperature of a belt near Lake Superior is lower in summer and higher in winter than the land more distant; but the mean annual temperature is the same. Compared to the remaining area the climatic conditions of this belt more nearly approach those of the region of highly developed Podsol soils in northern Europe. (3) (9) (29)

Soils

The region of the Podsol type of soil formation in the United States includes Bayfield County. Marbut(19) has outlined the geographic limits of the Podsol zone. That there is a broad transitional belt between this group and the Gray-Brown Forest soils has been emphasized by Veatch (30). The lower part of Bayfield County lies just north of the dividing line between the two great soil groups; consequently, the southern part of the county lies in the transitional zone, with the soils in the northern part exhibiting more definitely true Podsol character. In the discussion of climate the influence of Lake Superior was indicated. It will be seen that this influence will be reflected in the character of the soils.

In the regions of normally developed Podsol soils the surface is covered by a layer of undecomposed, 'raw' humus with only a narrow transition horizon of gray soil, stained with organic matter. This is underlain by a gray, often whitish, leached horizon or 'bleichered', varying considerably in thickness according to the texture and the stage of development of the soil. Beneath the gray layer is encountered a brown horizon, often indurated into a rock-like hardpan. Where indurated or cemented the name 'ortstein' has been given it; the softer formations are frequently designated as 'orterde'. Beneath the brown horizon of concentration there is generally a transitional layer, stained with brown, which grades into the unweathered parent material.

Gedroiz (11) has concluded that the podsolization process, under conditions of moderate humidity, is directly dependent upon the quantity of water passing through the soil and upon the quantity of carbonic acid present. Sufficient moisture must be supplied to ensure percolation downward through the soil. This also implies a low evaporation; but yet there must be sufficient evaporation to provide some upward movement of water.

A coniferous forest vegetation is peculiar to Posdol formation. Under the dense shade of the forest in cool climates, and especially where the organic matter is largely of coniferous origin, its decomposition and incorporation with the upper mineral soil is retarded. Thus the Podsol soil is characterised by a peaty layer of raw, dark brown, acid organic matter. Under these conditions the decomposition of mineral matter is comaratively slow so that descending waters can hurry downward much of that portion which is formed. As the bases, such as calcium and magnesium, are removed, they are replaced with hydrogen giving to the colloidal absorbing complex, both organic and inorganic, an increased mobility. It therefore becomes apparent that any vegetation which will furnish a leaf mold high in these bases will tend to retard the podsolization process. According to Ebermayer (7) the coniferous needles are lower in potassium, calcium and magnesium than are the deciduous leaves; further, the resinous nature of the coniferous forest accumulation retards its decomposition. Lundblad (18) has found that the coniferous vegetation has had an influence to accelerate podsol formation, other factors being equal. Similar results were obtained by Kvapil and Nemec (17) in comparing beech stands with spruce. These authors found the quality of the forest soil best with mixed spruce and beech stands; but the pure beech was superior to the pure spruce. It is well known that the ash content of leaves varies considerably within the same species, according to the site conditions; so that in one case a given forest cover may produce a mild humus, while in another a raw humus may be developed.(16) Müller(24) has given the name 'mull' to the forest humus free from acid while the acid, raw humus, characteristic of podsol formation, is designated as 'torf' or 'trockentorf'. Thus the first evidence of podsol formation is the development of the raw humus and conditions of acid weathering. Formations of a highly calcareous nature, even lying within the region of Podsol formation, will be delayed in the formation of the true podsol profile until the calcareous material has been removed from the surface. Excellent examples of the steps in the formation of the podsol profile under such conditions are furnished by J. Wityn from his studies of the soils of Latvia (34).

The bleicherde or gray horizon of the typical podsol has been impoverished of silica, alumina, iron, the sesquioxides and organic matter. Other constituents have also been removed to a lesser degree. O.Tamm has made a study of the chemical nature of the podsolization process. From a number of analyses of podsol profiles he has calculated the amounts of the different materials removed from the bleached horizon and also the percentages of the original amounts of each constituent in the parent material which have been removed. To make this calculation he has assumed that the quartz content would be constant. By averaging the results of seven of these analyses (28) the data in Table 1 were obtained. Much of this material has been deposited in the B, or lower horizon. A notable

Table I. Material Lost from the Bleached Horizon of Podsol Soils (After Tamm)

	Percentage of each constituent removed in terms of the parent material.	Loss of each constituent expressed in percentage of the amount of that constituent in the parent material
SiO_2	8.3	11
TiO_2	0.08	20
Al_2O_3	3.42	32
Sil. Fe_2O_3	1.41	55
CaO	0.56	33
MgO	0.49	51
K_2O	0.67	24
Na_2O	0.54	26
P_2O_5*	0.13	88

*The amounts were so small and the conditions between different soils so variable that these results can hardly be considered significant.

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exception is the silica; also the alkalis and alkali earths do not appear to be concentrated in this layer. In fact the calcium is invariably higher in the surface due to its continual renewal by decomposing vegetation. These statements are borne out by the analysis of a Podsol soil from north central Minnesota given by Baldwin(1) (Table 2)[1]. We notice that the silica is higher in the surface soil.

Table II. Analysis of a Podsol Soil from the North Central Part of Minnesota(Baldwin)*

Horizon	Leafmold	A_1	A_2	B	C
Thickness in In.	3	1	5	8	
SiO_2	21.60	58.99	73.00	65.02	53.14
TiO_2	0.20	0.75	0.41	0.76	0.66
Fe_2O_3	1.79	4.50	3.38	5.34	5.26
Al_2O_3	5.56	13.00	12.66	16.65	14.62
MnO	0.168	0.18	0.172	0.18	0.14
CaO	3.24	1.57	1.42	1.03	7.00
MgO	1.06	1.30	1.05	1.66	3.72
K_2O	0.87	2.15	2.71	2.48	2.19
Na_2O	0.48	1.18	1.67	1.20	1.01
P_2O_5	0.31	0.17	-	0.17	0.11
SO_3	0.45	0.12	0.08	0.05	0.06
Ignition loss	64.53	16.53	3.64	5.70	11.20
Total	100.26	100.44	100.20	100.20	99.11
N	1.862	0.44	0.074	0.12	0.05
Carbonate CO_2	None	None	None	None	7.59
H_2O at 110^{o}	10.76	4.96	1.25	4.55	-

* Analyses by R.S.Holmes and G. Edgington of the United States Bureau of Soils.

1. For other analyses of Podsol soils see:(2) (23) (28) (12).

This does not mean that none has been removed but only an amount less in proportion to the other constituents. The soil has been developed from calcareous glacial drift of heavy texture under a dense forest of mixed conifers and hardwoods. This analysis has been included as the sample was taken in a region of quite similar climatic conditions to those in Bayfield County.

All or part of the conditions necessary for the formation of a true Podsol may be present. Depending upon the climate, the vegetation, and the nature of the parent material as well as its age, a series of stages of maturity and of intensity of profile development will be found. Those soils which do not show a strong profile but yet which occur in a definite soil region and have clearly begun to express the characteristic profile are necessarily classed with the soils of that region. For that reason the soils of Bayfield County are all classed as Podsols, although some of them only weakly express the podsol profile at present.

In the following pages are presented the field descriptions of the profile and certain laboratory investigations conducted on the principal types. These latter investigations include the determination of the colloid content by the hydrometer method and the total base exchange capacity.

Description of Methods

The profile descriptions. The profiles of the main types are described in detail in the text as well as shown by diagram in Figures 2,3,4,5 and 6. The nomenclature of the horizons has been as follows:

A_0 Litter and forest mold.

A_1 Humus soil. This horizon is very thin in most of the soils considered. It has usually been included with the A_0 in the sketches.

A_2 Grayish or whitish, leached horizon. Region of greatest eluviation.*

A_3 In a few soils this horizon occurs as a transition to B.

B The region of illuviation. The various parts are designated as B_1, B_2, B_3 and so on, according to each soil. No definite scheme of subdivision was employed.*

C Parent material that has been unaltered by soil-building forces.

D Designating strata below the C horizon which have an influence upon the soil but cannot be considered as parent material.

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* In some cases, as we shall see, the A,B, and C are not differentiated primarily on the basis of textural differences, but rather upon the color and structure profile. The B horizon may not actually have a higher content of fine material than either A or C. The mineral portion is more brown in color than A and the soil more compact; also B will show the influence of weathering as compared to C which is unaltered by soil-building forces.

Samples were collected by horizon from typical locations for the laboratory investigations.

<u>The Colloid Content</u>. The colloid content was determined by the hydrometer method of Bouyoucos (4). That this method determines coarser material than that ordinarily considered as of colloidal size has been pointed out by Keen (14) and Joseph (13). As a rapid method for comparing the content of fine material in the soil the writer considers it very useful however, In using the term 'colloid content' it must be borne in mind that we are using the designation of Bouyoucos which includes the ultra-clay, clay, and probably a portion of the silt (5). Each value shown in the tables is the mean of two determinations. By calculating the standard of each set of determinations and then taking an average, the mean was found to be ± 0.226 in terms of percent colloids. The standard deviation of this mean is ± 0.178.

<u>The Base Exchange Capacity</u>. For this determination duplicate 25 gram samples of air dried soil were treated with 500 cc. of N/1 $CaCl_2$ and allowed to stand for 48 hours. In the case of very heavy clays 15 gram samples were used. The soil was then thrown on a filter and washed with an additional 500 cc. of N/1 $CaCl_2$. Subsequently the soil was washed free of chlorides with distilled water. The samples were then washed with one liter of N/1 NH_4Cl.

Calcium was determined in the filtrate in the usual manner as calcium oxalate. All of the soils used were acid except two; these were leached with an additional liter of N/1 NH_4Cl in order to determine the amount of soluble $CaCO_3$ present. This amount was subtracted from the amount of calcium obtained in the first liter in order to calculate the exchange capacity. Each value given is an average of two determinations. The mean standard deviation between duplicates is ± 0.069, expressed in milli-equivalents per 100 grams of soil. The standard deviation of this mean is $\pm$ 0.072.

Acidity Determinations

Soil acidity determinations were made with Soiltex by the method outlined by Spurway(26). The results are shown in the tables with the laboratory results. The degree of acidity given is based upon several field trials, the number varying according to the importance of the type. Spurway gives the following pH ranges for the several degrees given by the color:

Degree of Acidity	pH Range
Alkaline	7.0 - Up
Neutral	6.8 - 7.0
Slightly acid	6.2 - 6.7
Medium acid	5.7 - 6.1
Strongly acid	5.0 - 5.6
Very strongly acid	4.9 - Down

Kennan Series[1]

The Kennan Series is the principal one found in the regions of ground moraine formation. The series has three members: the Loam, Fine Sandy Loam and Silt Loam. Of these the Loam represents the usual condition. The profiles of these types are shown in Figure 2.

Profile of Kennan Loam

A_0 and A_1	Dark brown to nearly black leaf litter and forest mold. In nearly all areas this material contains at present large amounts of charcoal due to severe forest fires. A small amount of dark gray humus loam occurs as a transition to the lower horizon which is encountered at 1½ to 2½ inches.
A_2	Dull gray or gray very fine sandy loam containing considerable humus material. The soil has a more or less well defined laminated structure. This horizon extends down to 4 or 6 inches below the surface.
B_1	Yellowish-brown loam. The very fine sand separate forms a large part of the material. The soil has a fine crumb structure. At about 14 to 18 inches this

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1. Soil names used in this paper are those adopted by the Wisconsin Geological and Natural History Survey and local names for the series not heretofore recognized.

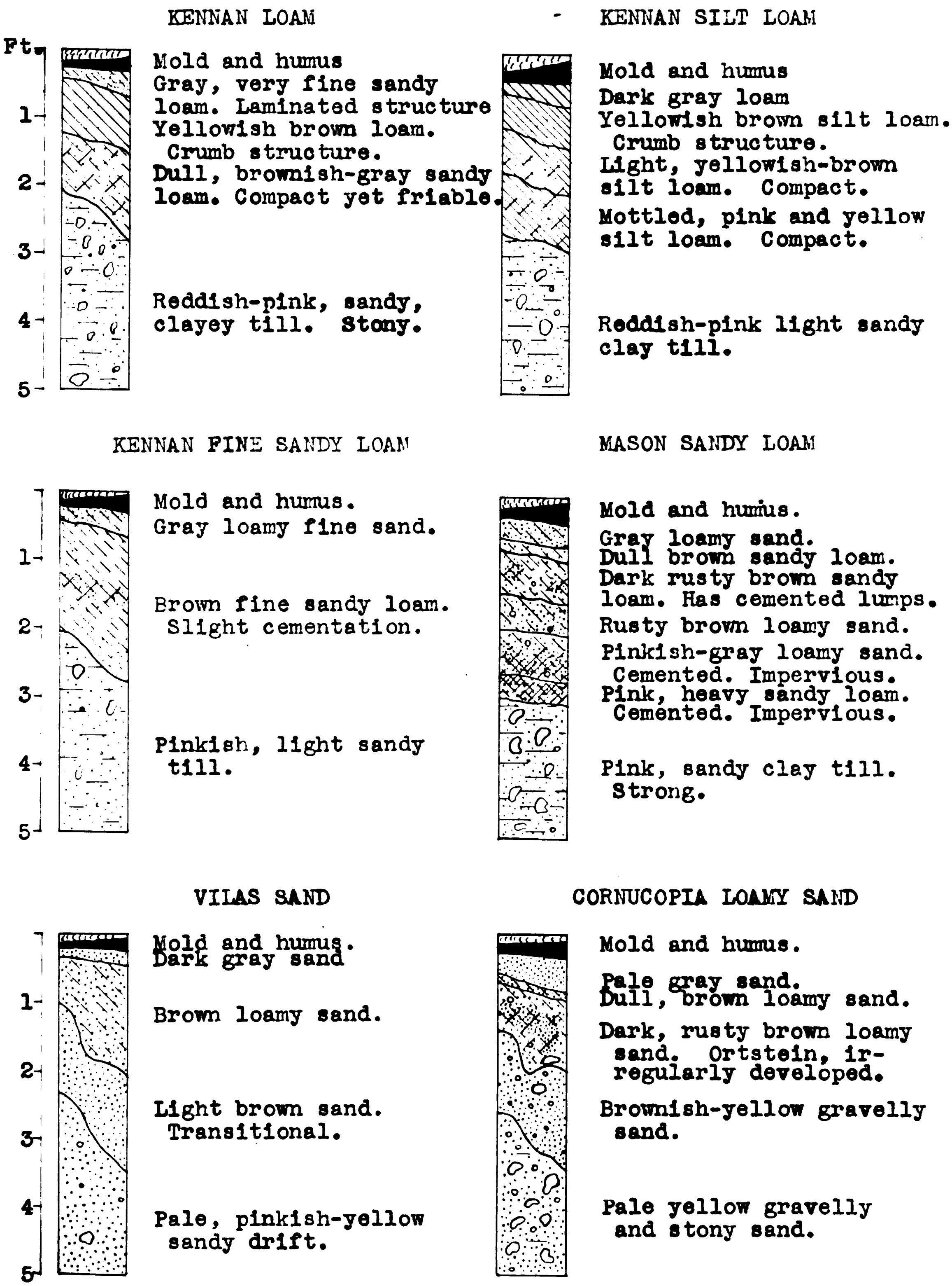
KENNAN LOAM
Ft.
1
2
3
4
5
Mold and humus
Gray, very fine sandy loam. Laminated structure
Yellowish brown loam. Crumb structure.
Dull, brownish-gray sandy loam. Compact yet friable.
Reddish-pink, sandy, clayey till. Stony.
KENNAN SILT LOAM
Mold and humus
Dark gray loam
Yellowish brown silt loam. Crumb structure.
Light, yellowish-brown silt loam. Compact.
Mottled, pink and yellow silt loam. Compact.
Reddish-pink light sandy clay till.
KENNAN FINE SANDY LOAM
1
2
3
4
5
Mold and humus.
Gray loamy fine sand.
Brown fine sandy loam. Slight cementation.
Pinkish, light sandy till.
MASON SANDY LOAM
Mold and humus.
Gray loamy sand.
Dull brown sandy loam.
Dark rusty brown sandy loam. Has cemented lumps.
Rusty brown loamy sand.
Pinkish-gray loamy sand. Cemented. Impervious.
Pink, heavy sandy loam. Cemented. Impervious.
Pink, sandy clay till. Strong.
VILAS SAND
1
2
3
4
5
Mold and humus.
Dark gray sand
Brown loamy sand.
Light brown sand. Transitional.
Pale, pinkish-yellow sandy drift.
CORNUCOPIA LOAMY SAND
Mold and humus.
Pale gray sand.
Dull, brown loamy sand.
Dark, rusty brown loamy sand. Ortstein, irregularly developed.
Brownish-yellow gravelly sand.
Pale yellow gravelly and stony sand.

Figure II

horizon gives way to:

B_2 Dull, brownish-gray fine sandy loam. A tinge of red of varying intensity is noticeable. The soil is compact, yet friable. At about 24 to 30 inches the soil grades into:

C Reddish-pink sandy, clayey till. This is generally very stony. Although there is considerable coarse material, very fine sand forms a large part of the mass. The till has a rather high water holding capacity, yet it is sufficiently pervious to allow drainage of excess water.

The gently rolling to rolling nature of the land affords good external drainage. Occasionally nearly level areas were sufficiently poorly drained to merit the indication of a separate phase. In these situations the only essential profile difference is a noticeable mottling.

The Kennan Loam probably represents the normal profile for the southern portion of the area. Table III gives the laboratory results. It is evident at once that this soil is only a weak Podsol. The development of a rather dry , acid surface organic covering, together with the gray A_2 horizon point to its podsol nature. The figures for the base exahange show that the A_2 horizon still contains a

Table III. Colloid Content, Base Exchange Capacity and Acidity of Kennan Loam

Horizon	A_2	B_1	B_2	C
Depth in Inches	2-4	4-16	16- 27	27- 48
Percent Colloids	24.29	24.38	20.64	17.35
Base exchange capacity as milliequivalents of Ca per 100 grams soil	10.55	5.86	5.01	5.80
Reaction toward Soiltex	Strongly acid	Very strongly acid	Very strongly acid	Strongly acid

larger quantity of the absorbing complex than the lower horizons. That nearly half of this exchange material is organic is shown by the figures in Table IV. There remains, however, a considerable amount due to inorganic material. It would seem that illuviation processes have not been greatly active in this soil, Here we have a case where the A, B, and C horizons are distinguished from each other on the basis of color and structure, rather than texture.

The profiles for the Silt Loam and Fine Sandy Loam members of the Kennan Series are shown in Figure 2. The general profile character of the Silt Loam is similar to the Loam with the exception of the mottling in the lower part of the B horizon and the finer texture. The Fine Sandy Loam has more evidence of Podsol nature. The gray horizon is somewhat better developed, particularly in the few areas occuring in the northern portion of the county. A slight cementation is evident in the B horizon.

Table IV. Influence of Ignition of the Base Exchange Capacity of the Kennan Loam A_2 Horizon.*

	Base exchange capacity as milli-equivalents per 100 grams of soil
Original soil	10.55
After Ignition at 550°C for 12 hours	5.92
Difference due to organic matter	4.63

*Unpublished date obtained by Prof. E. Truog of the Wisconsin Agricultural Experiment Station show that ignition in this manner does not injure the inorganic exchange material.

The forest cover of the Kennan Loam has been largely mixed hardwoods and white pine. A higher percentage of pine characterized the original cover of the Fine Sandy Loam type. Agriculture is limited by the topographic features and particularly by the degree of stoniness. Most of the land is suitable for farming, except for an often excessive amount of bowlders. The soil is sufficiently retentive of water to produce good crops and pasture and the less stony areas have made excellent farms.

Antigo Series

The Antigo Series, represented by the Fine Sandy Loam member, is largely confined to the more gravelly areas of outwash formation in the southern portion of the county.

In the course of the mapping a gravelly phase was indicated to isolate a few areas very gravelly, even in the surface. Figure 3 shows the profile which is described in more detail as follows:

Profile of Antigo Fine Sandy Loam

A_0 and A_1 Nearly black leaf litter and forest mold about 2 inches in thickness. In the lower part the light colored soil grains and humus material give it a 'salt and pepper' appearance.

A_2 Dull gray sandy loam or fine sandy loam containing considerable humus material. The soil has only a slight coherence. At about 4 to 8 inches this gives way to:

B_1 Brownish-yellow or dull brown fine sandy loam. The soil has a rather loose crumb structure. This horizon extends down to 10 or 12 inches below the surface.

B_2 Light brown heavy fine sandy loam or loam. The soil has a crumb structure, but is quite coherent. This horizon is pervious to water and easily penetrated by roots; however it has a good water holding capacity. Pebbles are quite numerous, especially in the lower part. At depths ranging from 18 to 26 inches this layer grades into:

B_3 A transitional horizon of loose loamy sand and gravel,

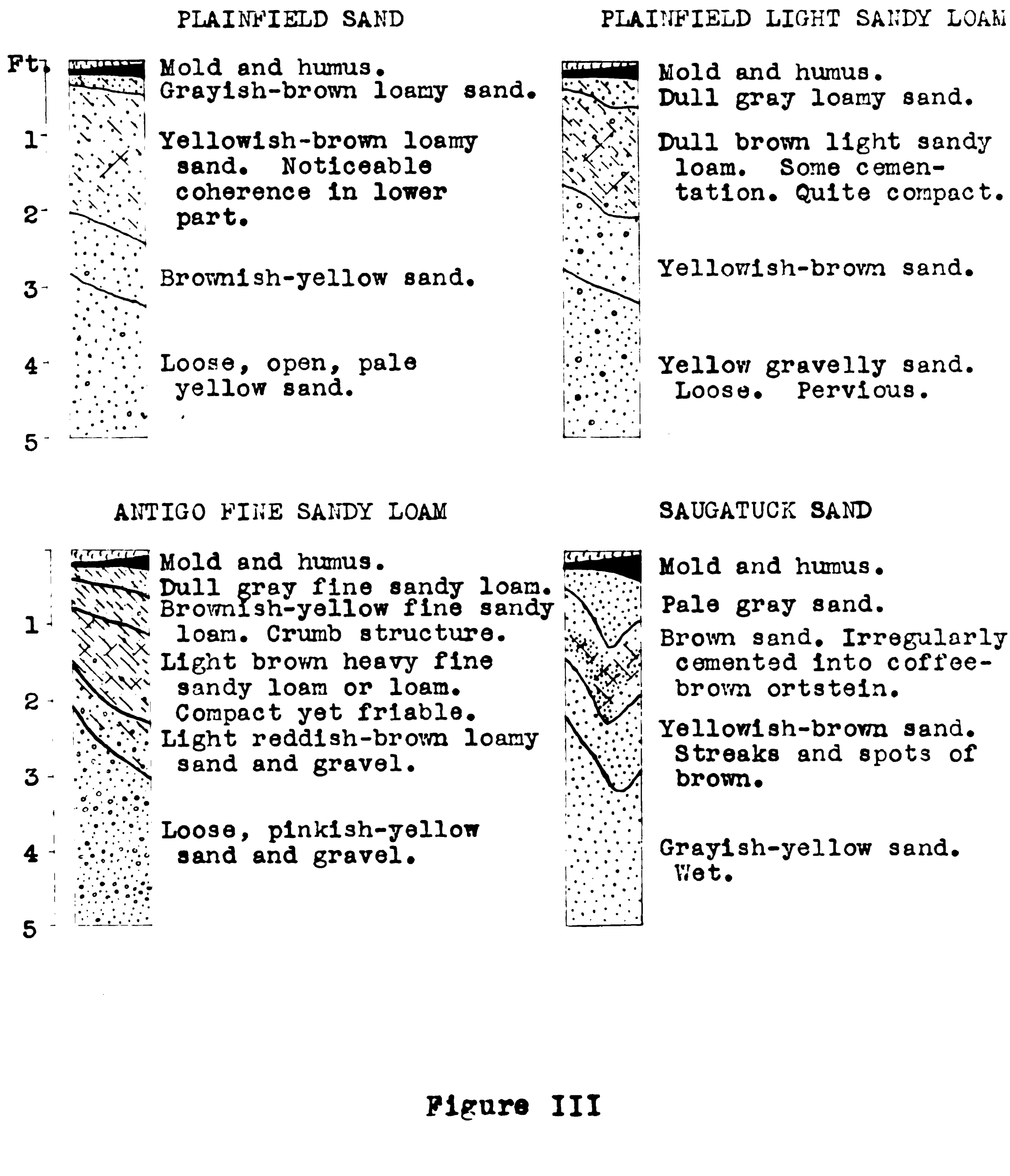
PLAINFIELD SAND
Ft.
1
2
3
4
5
Mold and humus.
Grayish-brown loamy sand.
Yellowish-brown loamy sand. Noticeable coherence in lower part.
Brownish-yellow sand.
Loose, open, pale yellow sand.
PLAINFIELD LIGHT SANDY LOAM
Mold and humus.
Dull gray loamy sand.
Dull brown light sandy loam. Some cementation. Quite compact.
Yellowish-brown sand.
Yellow gravelly sand. Loose. Pervious.
ANTIGO FINE SANDY LOAM
1
2
3
4
5
Mold and humus.
Dull gray fine sandy loam.
Brownish-yellow fine sandy loam. Crumb structure.
Light brown heavy fine sandy loam or loam. Compact yet friable.
Light reddish-brown loamy sand and gravel.
Loose, pinkish-yellow sand and gravel.
SAUGATUCK SAND
Mold and humus.
Pale gray sand.
Brown sand. Irregularly cemented into coffee-brown ortstein.
Yellowish-brown sand. Streaks and spots of brown.
Grayish-yellow sand. Wet.

Figure III

stained with light reddish-brown. At approximately 24 to 30 inches the soil passes abruptly into:

C Pinkish-yellow, loose stratified sand and gravel. A few well-rounded cobbles are not uncommon in the parent drift. The material appears to be largely derived from acidic igneous rocks.

As with the Kennan Series, the Antigo is rather weak Podsol. The results in Table V show, however, that podsolization has progressed to a considerable extent already. The A_2 horizon, as pointed out in the description, contains considerable organic matter to which its rather high base exchange capacity may be attributed.The fact that this soil is developed only in the southern part of the county probably accounts for its rather weak profile development as other conditions are apparently favorable for the podsolization process. The acid nature of the parent material, together with an original coniferous forest cover of Norway, white and jack pine would tend

Table V. Colloid Content, Base Exchange Capacity and Acidity of Antigo Fine Sandy Loam

Horizon	A_2	B_1	B_2	B_3	C
Depth in Inches	2- 5	5 - 10	10 - 18	18 - 28	28 - 48
Percent Colloids	15.33	14.75	14.13	5.65	4.75
Base exchange cap. as milliequivalents per 100 gm. soil	4.71	5.59	3.30	-	1.80
Reaction toward Soiltex	Strongly acid	Strongly acid	Very strongly acid	Strongly acid	Strongly acid

toward acid weathering. When we compare these figures to those for Kennan Loam (Table III) we see that the latter is not so far advanced as the Antigo. Both samples were collected within a distance of five miles and at nearly the same elevation so that the climatic conditions are similar. In both cases the soil reaction is acid, however the Kennan has a cover of mixed hardwoods with some white pine. The cover on the Antigo was almost entirely coniferous. By reason of the somewhat lower water holding capacity of the material, the Antigo soil is drier than Kennan. Both the vegetation and the drier surface would tend to produce the trockentorf more rapidly in Antigo and hasten the podsolization process.

Mason Series

The Mason Series is represented by only the Sandy Loam type. Its occurrence is limited as it is found almost exclusively on the less prominent islands of till within the Superior Lowland. These islands are very stony and appear to have been washed considerably by the waves during the stormy periods of the glacial lakes. Although the margins are often quite steep, their surfaces are nearly level. Much of the fine material had evidently been removed from the upper part of the drift before soil-building forces commenced to operate. While the Mason had some hardwoods in the original forest, it was chiefly white pine. On the more level areas balsam fir and white spruce are important constituents of the forest growth.

Even though the profile (Figure 2) is complex it was found to be quite uniform.

Profile of Mason Sandy Loam

A_0 and A_1 — Leaf litter, nearly black forest mold and sandy humus soil about 1½ to 3 inches in thickness.

A_2 — Dull gray light sandy loam. A relatively large amount of humus is present as compared to the A_2 horizons of other Podsol soils. The sand grains are rather coarse but the material has noticeable coherence. This horizon extends down to about 5 or 7 inches.

B_1 — A thin layer of dull brown sandy loam. The soil has a fine crumb structure. At 7 to 9 inches the next horizon is encountered.

B_2 — Dark rusty brown sandy loam containing coffee-brown cemented lumps. With the exception of the cemented lumps the soil has a fine crumb structure. This material is apparently very high in iron (qualitative test only). The lower limit of this layer is about 12 to 17 inches from the surface.

B_3 Light rusty brown loamy sand fading to a lighter shade in depth. The material is rather loose and resembles the transitional horizon between the B proper and the parent material in a sandy Podsol. At about 18 to 24 inches this grades into:

B_4 Dull pinkish-gray loamy sand or light loamy sand. The soil is very compact and is cemented in the lower part. When dry this layer is almost impenetrable with ordinary sampling tools. This hardpan is very brittle but pulverizes into rather loose sandy material. The entire thickness of this layer is about 5 to 7 inches and at depths ranging from 24 to 32 inches it grades into:

B_5 Pink, heavy sandy loam mottled with gray and yellow. Like the lower part of B_4 this layer is cemented, making it almost impenetrable. Its thickness is about 3 inches.

C Pinkish sandy clay till. This till is similar to that from which the Kennan Loam is developed except that it contains somewhat more clay. Stones and pebbles are plentiful.

On comparing this soil with the Kennan Loam, a close relative as far as parent material is concerned, we notice considerable difference. The data in Table IV show that the podsolization process has been more active. Although sufficient humus and other fine material persists in the A_2 horizon to give it a higher base exchange capacity than the B_2, yet we see that there has been much more movement downward than in the Kennan.

Table VI. Colloid Content, Base Exchange Capacity and Acidity of Mason Sandy Loam

Horizon	A_2	B_1	B_2	B_3	B_4	B_5	C
Depth in Inches	$2\frac{1}{2}$-6	6 -$8\frac{1}{2}$	$8\frac{1}{2}$-16	16-24	24-31	31-35	35-48
Percent Colloid	18.27	16.17	15.64	9.19	12.59	22.11	23.55
Base exchange capacity as milliequivalents per 100 gm. soil	7.74	-	6.05	2.79	2.49	-	4.92
Reaction toward Soiltex	Strongly acid throughout						

By reason of the comparatively heavy texture of the underlying till the drainage, particularly on the more level areas, is rather slow. The laboratory results also indicate the change in the parent material previous to the commencement of soil building forces. The more pervious nature of this upper material as compared to the heavy till beneath has produced a situation somewhat like that which obtains in the Orienta Series. In the Orienta Series, however, a gray hardpan in the lower part of the solum has not been observed. Frequently there is a somewhat compact, gray layer in the sand immediately above the clay but the writer has never observed appreciable cementation in it. No explanation can be offered for the cause of this indurated layer in the Mason, except that it is apparently associated with the rather abrupt change in the permeability of the soil at this depth.

Mr. Schoenmann[1] has observed approximately the same profile on Sugar Island in the St. Mary's River.[2] He describes the geological features to be the same as that of the Mason in Bayfield County.

Cornucopia Series

Only one type, the Loamy Sand, is included in this series. It is confined, almost entirely, to the northern part of the county where it is found on the sandy morainic knolls within the Superior Lowland and also on the northern end of the Bayfield Ridge. The profile is illustrated in Figure 2.

Profile of Cornucopia Loamy Sand

A_0 and A_1 — Leaf litter and dark brown, peaty organic matter together with a dark, sandy humus soil. This layer varies from 1½ to 3 inches in thickness.

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1. By personal communication of unpublished observations.
2. The St. Mary's River forms the boundary between the Upper Peninsula of Michigan and Canada.

A_2 Pale gray loose sand. Frequently the sand has a faint pinkish tinge. There is but very little organic matter in this material. At depths ranging from 5 to 11 inches this horizon gives way abruptly to:

B_1 Dull brown loamy sand horizon about 1½ inches in thickness.

B_2 Dark rusty brown or rusty brown loamy sand. Considerable fine sand and gravel are present. The sand is irregularly cemented into an ortstein. Sometimes this cementation is limited to lumps about the size of walnuts while in other places it is quite uniformly indurated into a sandy hardpan 4 to 10 inches in thickness. At about 27 inches the soil grades into:

B_3 A transitional horizon of dark yellowish or brownish-yellow gravelly sand extending down to about 36 inches.

C Pale yellowish-gray, gravelly and stony, sandy till. Most of the stones are sandstones. The material is very open and pervious.

From this description and the data set forth in Table VII it is evident that this soil is definitely a

Table VII. Colloid Content, Base Exchange Capacity and Acidity of Cornucopia Loamy Sand

Horizon	A_2	B_2	B_3	C
Depth in Inches	3 - 9	11 - 22	22 -36	36-48
Percent Colloids	4.89	8.20	3.40	2.90
Base exchange capacity as milliequivalents per 100 grams soil	1.26	4.16	-	1.22
Reaction toward Soiltex	Strongly acid	Very strongly acid	Medium acid	Slightly acid

Podsol. As in the case of the other strong Podsol soils, the figures for base exchange indicate a greater downward movement than do those for colloid content. The absorbing complex appears to be the more mobile portion of the fine material. In this case the B_2 horizon has not quite twice as much colloidal material as the A_2 but over three times as much base exchange material. Acid weathering has been active.

This soil has developed under a coniferous forest vegetation. There have been conditions of excessive drainage. The rolling to hilly surface insures rapid external drainage while the pervious nature of the substratum provides free internal drainage.

There is but very little real agricultural development on Cornucopia Loamy Sand. The extreme stoniness, coupled with its excessive drainage and unsuitable topographic feature has discouraged the use of the land for either crops or pasture.

Vilas Series

The Vilas Series is represented by one type, the Sand. In the course of the mapping two other unimportant types were differentiated, the Fine Sand and the Stony Sand. The last named type was confined to the few eskers that were found while areas of the Fine Sand were recognized within the Bayfield Ridge. Even though the Fine Sand may have a slightly higher water holding capacity, there is no real difference, either in the profile or in the relation to the native vegetation. Vilas Sand is developed on the sandy moraines; in addition other areas may be found in the till plain and in the regions of badly pitted outwash. The Vilas is not found in any important area nearer than six miles to the northern margin of the county. The profile is illustrated in Figure 2.

Profile of Vilas Sand

A_0 and A_1 — Leaf litter and nearly black sandy humus. This is very thin, ranging from scarcely one to two inches in thickness.

A_2 Dull gray or brownish-gray, loose loamy sand. Some humus material is mixed with the mineral soil. This gray horizon is very poorly developed and is frequently very thin. At about 3 to 4 inches is encountered:

B_1 Brown loamy sand. The sand is loose and open with very little evidence of structure. Occasionaly some slight cementation may be observed. This horizon is quite variable as to depth but may be said to extend down to between 12 and 24 inches.

B_2 A lighter brown transitional layer of loose, pervious sand. At 26 to 40 inches the soil grades into:

C Pale pinkish-yellow, loose, sandy drift. Occasionally this drift is stony, but usually it is nearly stone-free. Most of the pebbles and stones are acidic igneous rocks.

In the Fine Sand Type the A_2 horizon is also poorly developed but it is generally a little thicker than indicated by the above description. In the Stony Sand type there is no definite profile development.

From the data in Table VIII it is evident that we have quite a contrast as compared with the Cornucopia.

Table VIII. Colloid Content, Base Exchange Capacity and Acidity of Vilas Sand

Horizon	A_2	B_1	C
Depth in Inches	1.5 - 4	4 - 12	32 - 48
Percent Colloids	6.57	4.86	2.74
Base exchange capacity as milliequivalents per 100 gms. soil	3.15	2.66	1.61
Reasction toward Soiltex	Very strongly acid	Very strongly acid	Medium acid

The colloid content and the base exchange capacity are both higher in the surface. As pointed out in the description the A_2 horizon contains considerable organic matter. Very little illuviation has taken place as compared to Cornucopia.

The original cover of the Vilas Sand consisted largely of Norway pine, jack pine, and some white pine. The evidence in the fire devastated country is quite meagre but would seem to indicate that the original stand of timber was rather thin. Some areas within the Bayfield Ridge country have been free from timber growth since the region has been known to white men (27). The present cover is chiefly composed of a rather open stand of jack pine and scrub oak with other such species in spots as trembling aspen, cherry, etc. Many areas are open and devoid of vegetation except a ground cover consisting of sweet fern and a few scattered clumps of stunted jack pine and aspen.

The internal drainage is excessive, even more so than in Cornucopia. The surface configuration varies from gently rolling to very hilly. With only what appears to be minor differences in parent material, vegetative cover, elevation and drainage conditions we have represented by the Vilas and Cornucopia series two distinctly different profiles. While the Vilas has a rudimentary podsol profile it is only slightly advanced in the cycle of weathering which has produced the Cornucopia.

Plainfield Series

Two types of Plainfield, the Sand and the Light Sandy Loam, were recognized. From a study of their profiles there seems to be some doubt as to the justification of placing the two types in the same series, although from the point of view of their adaptability of growing plants it seems logical. Both soils are developed on the outwash plains discussed previously. Figure 3 shows the profiles by sketch.

Profile of Plainfield Sand

A_0 A thin layer of leaf litter and dark brown, dry, peaty organic matter about 1 or 1.5 inches in thickness.

A_1 A dark grayish loose mixture of sand and humus. The material has a 'salt and pepper' appearance. This layer has a thickness of only about one inch.

A2 Grayish-brown loamy sand. There is present noticeable humus material. At 3 to 5 inches from the surface this horizon gives way to:

B_1 Dull yellowish-brown loamy sand. The sand has some coherence and when wet has a crumb structure. At about 14 inches this grades into:

B_2 More compact dull yellowish-brown loamy sand. The soil has enough compactness to be noticeable. At 24 inches this horizon is underlain by:

B_3 A transitional layer of brownish-yellow loose sand. This extends to approximately 36 inches.

C Pale yellow loose sand. This material generally has more or less stratification.

The results of the laboratory investigations on this type are shown in Table IX. From the description of the profile and these results it becomes evident that this soil

Table IX. Colloid Content, Base Exchange Capacity, and Acidity of Plainfield Sand

Horizon	A2	B1	B2	B3	C
Depth in Inches	2 - 5	5 - 12	12 - 24	24 - 36	36 -48
Percent Colloids	8.03	8.33	7.49	4.23	3.75
Base exchange capacity as millie-quivalents per 100 grams soil	6.26	1.84	2.11	-	1.73
Reaction toward Soiltex	Strongly acid	Very strongly acid	Very strongly acid	Strongly acid	Medium acid

only very weakly expresses the podsol profile. Although the A2 horizon is high in base exchange material, the larger portion of which is undoubtedly organic matter, there has been a noticeable drift of this material to the lower horizons.

Now let us examine the Light Sandy Loam type.

Profile of Plainfield Light Sandy Loam

A_0 A thin layer of leaf litter and dark brown, or nearly black, dry, peaty organic matter ranging from 1 to 2 inches in thickness.

A_1 A very thin layer of dark gray loamy sand and humus with a 'salt and pepper' appearance. This horizon is only about one inch in thickness.

A_2 Dull gray loamy sand with a brownish tinge in the lower part. A small amount of organic matter is included. When wet the soil has appreciable coherence but when dry it is loose. At about 5 to 8 inches it grades into:

B1 Dull brownish loamy sand. A transitional layer only about one inch in thickness.

B_2 Dull, slightly yellowish, brown light sandy loam. The soil is quite compact and contains a few cemented lumps. When broken it has a rather poorly developed crumb structure. This material is apparently fairly retentive of water considering the large percentage of sand. At about 20 to 24 inches this horizon gives way to:

B_3 A transition horizon of sand or loamy sand, stained with yellowish-brown and rusty brown, extending down to about 34 inches from the surface.

C Yellow, loose gravelly sand grading into pale grayish yellow gravelly sand.

The results shown in table X indicate a much greater development of profile than in the case of the Plainfield Sand. In discussing the relationship existing between the Vilas Sand and the Cornucopia Loamy Sand it was pointed out that with very similar parent material and under almost identical forest growth, quite different profiles had been

Table X. Colloid Content, Base Exchange Capacity and Acidity of Plainfield Light Sandy Loam

Horizon	A_2	B_2	C
Depth in Inches	3 - 7	8 - 22	34 - 48
Percent Colloids	8.78	11.28	2.82
Base exchange capacity as milliequivalents per 100 grams soil	4.38	3.95	1.07
Reaction toward Soiltex	Very strongly acid	Strongly acid	Medium acid

produced. The same relationship exists between the two Plainfield types. Both of these soils have developed under a coniferous forest cover; the Plainfield Light Sandy Loam probably had more white and Norway pine in the original stand than did the Sand type. Jackpine and scrub oak are the predominating species of the present forest on both soils.

The Plainfield Series has been recognized over a considerable area in the region of the Great Lakes. The series, however, as recognized in this county has a somewhat different profile than that described in southern Michigan (22) and southern Wisconsin (33). This is particularly true of the Light Sandy Loam type. In profile character this type approaches the Rubicon Series as described by the Bureau of Soils (31).

Superior Series

The soils of the Superior Series are confined entirely to the Superior Lowland. Four types were included in the series on the basis of the texture of the surface soil. The normal development is the Clay Loam member; the others represent conditions produced by the deposition of sandy material on the surface of the lacustrine clay after its deposition by the glacial lake. Only those soils are included in the Superior Series that have at least a part of the solum derived from the clay. Profile sketches of these soils are shown in Figure 4.

Profile of Superior Clay Loam

A_0 and A_1 Nearly black granular peaty material with a small amount of silty humus soil. This layer is about 2 inches thick.

A_2 Faintly pinkish-gray, ashy silt loam to silty clay loam containing only a very small amount of organic matter. The surface structure is platy while the lower part has a blocky, nut structure. These lumps are more friable than those of the lower horizons. This layer extends down to 6 or 8 inches from the surface.

A_3 A transitional horizon of gray and pink clay loam with a blocky, nut structure. The surface of the soil blocks is gray while the matrix is pink. At 8 to 12 inches this layer is underlain by:

B_1 Pinkish-red, with some brownish-red, heavy clay.

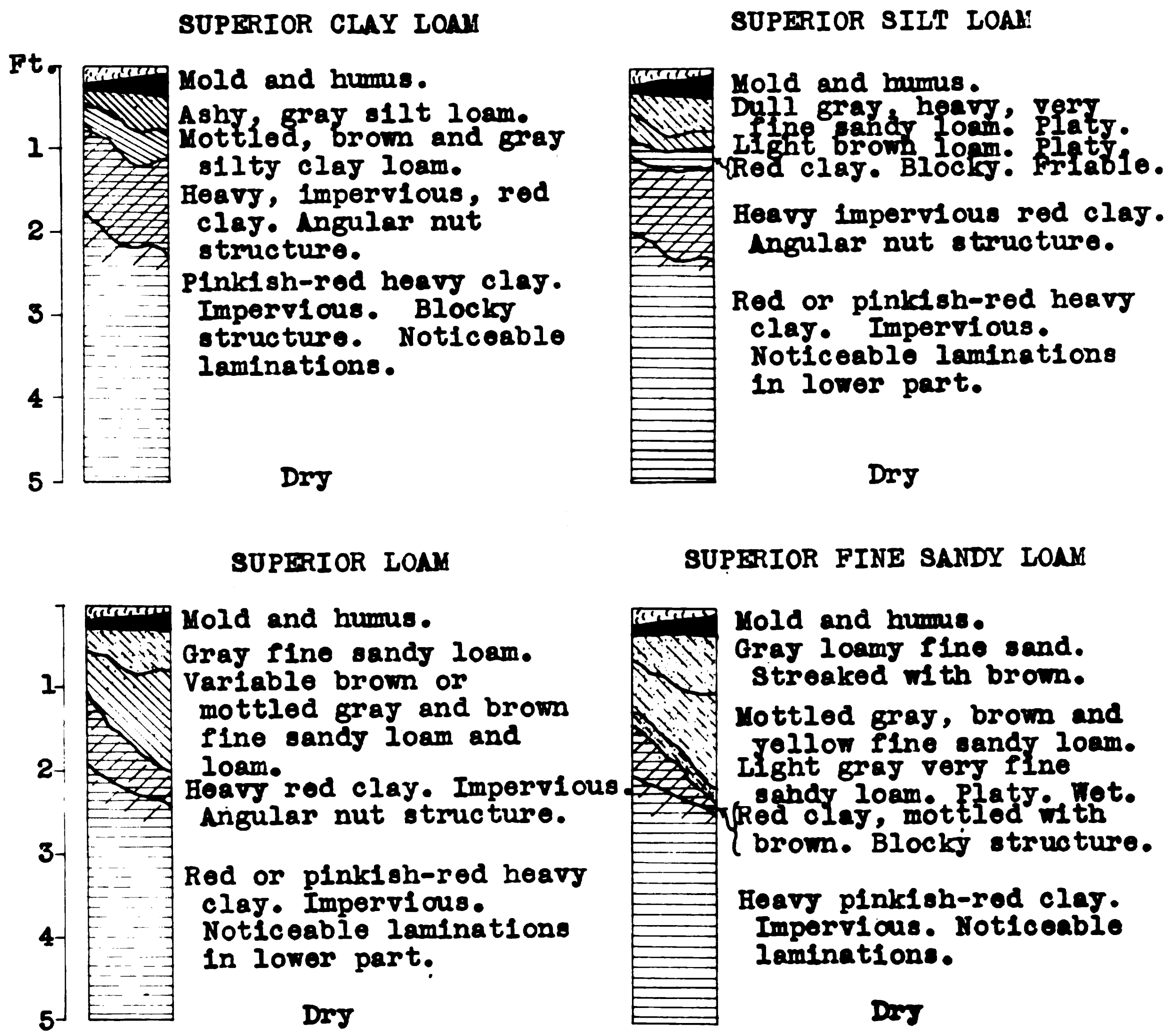

SUPERIOR CLAY LOAM
Ft.
1
2
3
4
5
Mold and humus.
Ashy, gray silt loam.
Mottled, brown and gray silty clay loam.
Heavy, impervious, red clay. Angular nut structure.
Pinkish-red heavy clay. Impervious. Blocky structure. Noticeable laminations.
Dry
SUPERIOR SILT LOAM
Mold and humus.
Dull gray, heavy, very fine sandy loam. Platy.
Light brown loam. Platy.
Red clay. Blocky. Friable.
Heavy impervious red clay. Angular nut structure.
Red or pinkish-red heavy clay. Impervious. Noticeable laminations in lower part.
Dry
SUPERIOR LOAM
1
2
3
4
5
Mold and humus.
Gray fine sandy loam.
Variable brown or mottled gray and brown fine sandy loam and loam.
Heavy red clay. Impervious. Angular nut structure.
Red or pinkish-red heavy clay. Impervious. Noticeable laminations in lower part.
Dry
SUPERIOR FINE SANDY LOAM
Mold and humus.
Gray loamy fine sand. Streaked with brown.
Mottled gray, brown and yellow fine sandy loam.
Light gray very fine sandy loam. Platy. Wet.
Red clay, mottled with brown. Blocky structure.
Heavy pinkish-red clay. Impervious. Noticeable laminations.
Dry

Figure IV

When dry the soil has an angular nut structure; when wet it is very sticky and plastic. The soil blocks have a thin covering of more brownish material. At about 24 inches this layer grades into:

C Pinkish-red, heavy, tough lacustrine clay. Gray and blue streaks are noticeable. When dry the material has an angular nut structure. The clay is quite impervious and apparently very little water percolates into the mass. In the lower part the clay often has a shale-like appearance. In places where the clay has not been disturbed by later ice movements, varving is very noticeable. Stones are absent except for a few areas that have suffered a re-advance of the ice. While the solum is entirely acid the parent material has sufficient calcium carbonate to effervescence with acids.

Even though the parent material is apparently very impervious to water considerable action by soil-building forces has taken place. As the heavy clay shrinks and swells, cracks are formed and it is largely through these cracks that the water passes downward. This is shown by the weathered surfaces of the soil blocks; these appear as gray coats in the A_2 horizon and as brown coats in the B horizon. From the results in Table XI it is evident that the portion of fine material which has moved downward into the B horizon has been largely the absorbing complex. The colloid content of the B horizon and of the parent material is higher than the A_2 horizon. It is very probable

Table XI. Colloid Content, Base Exchange Capacity and Acidity of Superior Clay Loam

Horizon	A_2	B	C
Depth in Inches	2 - 7	10 - 24	24 - 48
Percent Colloids	68.34	86.0	87.5
Base exchange capacity as milliequivalents per 100 grams soil	10.62	35.34	25.19
Reaction toward Soiltex	Very strongly acid	Strongly acid	Alkaline

that the original of the surface two feet was somewhat lower in clay content than the substratum. According to the values for the base exchange capacity a very large portion of the absorbing complex has moved from the A_2 horizon into the B horizon. Acid weathering has been active and the soil has the character of a true Podsol.

The Superior Clay Loam is probably the most important single type within the area; it occurs throughout the Superior Lowland region and is particularly well developed between Iron River and Port Wing and in the country between Mason and Ashland Junction. The topography varies from nearly level to gently rolling. Streams and drainways have cut many V-shaped valleys which are often very deep, especially near Lake Superior and the larger streams. Along these valleys and on the hills the whitish A_2 horizon has been completely, or nearly all, eroded away; leaving exposed the heavy red clay of the B horizon.

From the point of view of present agricultural development this soil is the leading type in the county. Despite its difficult cultivation and hardness of clearing, settlers have more commonly taken this soil in preference to others. Its high water holding capacity insures freedom from drought; and in this section where dairying is the chief agricultural pursuit, the ability of the soil to produce excellent pasture and forage crops explains its present development.

The next most important type in the Superior Series is the Fine Sandy Loam member.

Profile of Superior Fine Sandy Loam

A_o and A_1 Forest litter and nearly black, peaty organic matter. A thin layer of very dark gray fine sandy humus soil forms the transition to the lower horizon. The total thickness is about 1.5 to 2.5 inches.

A_2 Gray loamy fine sand, streaked with brown. A relatively small amount of organic matter is present. The soil has a very faint crumb structure. This horizon extends down to 8 or 12 inches.

B_1 Grayish-brown fine sandy loam mottled with gray, rusty brown and faint pink. The soil is quite compact and some cementation is noticeable, yet it is friable. At depths ranging from 15 to 25 inches this layer gives way to:

B_2 Light gray very fine sandy loam streaked with yellow and brown. The structure is platy. The soil is quite compact and is saturated with water much of the time. This horizon is quite variable as to thickness and development. It is usually 2 to 4 inches in thickness and overlies:

B_3 Pinkish-brown clay containing considerable sand, especially in the upper part. The soil has an angular nut structure. At about 25 to 32 inches this horizon gives way to:

C Heavy pinkish-red clay. Often noticeable gray lamenations are present. The dry material has a coarse blocky structure similar to the C horizon of the Clay Loam type. Under ordinary conditions not much water penetrates into this clay but when it is wetted it becomes very plastic and sticky.

The Superior Fine Sandy Loam has been developed from deposits consisting of heavy lacustrine clay overlain by fine sand. In many places this clay has been subjected to further ice movement by the ice so that it contains an admixture of sand and occasional bowlders. The slight change in the clay portion apparently has not influenced the resulting soil, except as more relief has been developed in the original lake bed. We would expect to find a somewhat variable profile in this soil because of variations in the depth of the original sand covering and of the drainage conditions as influenced by micro-relief. The profile description given is considered the average condition. In some instances the soil has developed under conditions of more rapid drainage with the result that horizon B_2 may be absent and horizon B_1 is yellowish-brown with very little mottling. On the other hand, under moist conditions the soil approaches a bog condition. The A_0 horizon becomes thicker and B_1 horizon begins to disappear.

From the results in Table XII we see that as in the case of the Clay Loam there has been considerable movement of the base exchange material from the surface into the B horizon. The B_3 horizon is developed at the surface of the clay but yet contains a considerable quantity of fine sand. Although the total content of colloid material as measured by the hydrometer is much greater in the parent material of the Clay Loam type as compared with the Fine Sandy Loam the base exchange capacity remains nearly the same. Throughout the investigation there is a noticeable lack of correlation between these two properties. Even though a field examination indicates some difference in the actual texture, the Fine Sandy Loam having a little more fine and very fine sand included in the clay of the C horizon, yet the parent material of both types are apparently

Table XII. Colloid Content, Base Exchange Capacity and Acidity of Superior Fine Sandy Loam

Horizon	A_2	B1	B_2	B_3	C
Depth in Inches	2 - 11	11 - 17	17 - 19	19 - 26	26 - 48
Percent Colloids	15.46	20.71	17.71	35.44	46.01
Base exchange capacity as milliequivalents per 100 grams soil	2.65	4.74	3.89	13.88	24.70
Reaction toward Soiltex	Strongly acid	Very strongly acid	Very strongly acid	Very strongly acid	Alkaline

about equally retentive of water. The type of acid weathering which characterized the development of the Clay Loam type has also influenced the Fine Sandy Loam, producing a definite podsol profile; but one somewhat different than the Clay Loam because of the stratigraphic nature of the parent material.

Two other types were recognized in the Superior Series, the Loam and Silt Loam. Their profiles are set forth in Figure 4 and will not be discussed in detail. These soils occur as transitional phases between the Clay Loam and Fine Sandy Loam types. They are found as small areas throughout the Superior Lowland but their total acerage is small.

The Superior Series is characterized by a coniferous forest vegetation. The original cover was largely white pine with some spruce and balsam fir. In the northern part of the peninsula a few hardwoods are to be found. Although these hardwood stands are generally found on the Loam and Fine Sandy Loam types they may be seen on the Clay Loam in a few places. The change in climatic conditions between the southern and northern portions of the Superior Lowland is probably quite important in bringing about these hardwood stands.

A soil very similar to the Superior was recognized in Ontonagon County, Michigan, as the Ontonogan Series(31). The Ontonagon Series as mapped in Chippewa County, Michigan, is a more uniformly level counterpart of the Superior Series as recognized in Bayfield County. Further south in Wisconsin, near Lake Michigan another large area of heavy clay soil has been classified as Superior by previous workers. This area, however, has not undergone podsolization to much extent according to the description of the series in Fond du Lac County(32).

Orienta Series

The Orienta Series is almost entirely confined to the Superior Lowland region. The soils have been developed from formations consisting of sandy material, usually fine sand, over heavy clay. Three types are recognized: the Fine Sand, Fine Sandy Loam, and Sandy Loam. The profile drawings illustrating these types are shown in Figure 5.

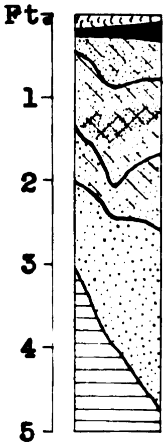
Profile of Orienta Fine Sand

A_0 and A_1 Surface litter and dark brown, dry, peaty organic matter with a 'salt and pepper' fine sandy humus soil. This layer is about 2 or 3 inches in thickness.

A_2 Pale whitish-gray, loose fine sand. Often the sand has a faint lavender tinge. The lower limit of this horizon is very irregular. Long tongues often penetrate to a depth of nearly 24 inches below the surface. The change to the lower horizon is very abrupt and generally is encountered at about 6 or 12 inches.

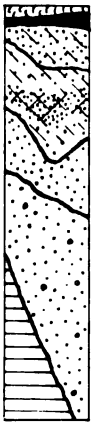
B_1 Brown loamy fine sand irregularly cemented into a

ORIENTA FINE SANDY LOAM



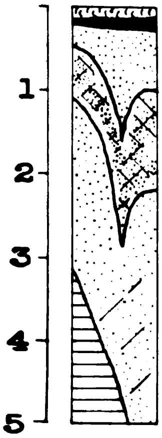
Mold and humus.
Gray loamy fine sand.
Rusty brown light fine sandy loam. Irregular coffee-brown Ortstein.
Light brown loamy fine sand.
Yellow, fine sand or sand, grading into gray in lower part. Moist.
Heavy, red clay. Mottled with gray in upper part. Impervious.

ORIENTA SANDY LOAM



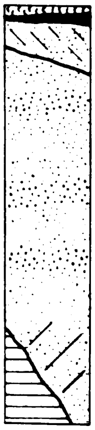
Mold and humus.
Gray sand or loamy sand.
Dark brown light sandy loam. Irregular Ortstein.
Light brown sand.
Yellowish sand grading into gray in lower part. Often gravelly. Generally moist.
over
heavy red clay. Impervious.

ORIENTA FINE SAND



Mold and humus.
Pale gray fine sand.
Brown loamy fine sand with irregular coffee-brown "hardpan", or Ortstein.
Yellowish fine sand. Somewhat compact. Lower part is generally gray and moist.
grading into
heavy, impervious clay.

BIBON FINE SAND



Mold and humus.
Dark yellow loamy fine sand.
Pale yellow sand, fine sand, and very fine sand. Often has noticeable stratification. Quite compact and moist in lower part,
over
heavy impervious clay at four to six feet.

Figure V

coffee-brown hardpan or ortstein. This layer is roughly parallel to the A2 horizon so that long tongues often extend downward a considerable distance below the average depth which varies from 14 to 24 inches below the surface.

C Yellowish fine sand. The upper part is often stained with brown while the lower part immediately above the clay may be whitish in color. The sand is generally quite compact, particularly in the lower part which is usually moist. This material extends to depths ranging from 40 to 72 inches.

D Heavy, impervious clay. The clay has a pink or reddish color with gray and yellow mottling.

From this description and the results given in Table XIII it is evident that this soil is a strong podsol. The presence of the clay beneath seems to have a tremendous influence on the profile development. For this reason it may be that the Orienta is related to the Saugatuck and has developed partly as a Ground Water Podsol.

Table XIII. Colloid Content, Base Exchange Capacity and Acidity of Orienta Fine Sand

Horizon	A_2	B	C	D
Depth in Inches	3 - 10	10 - 24	24 - 44	44 - 60
Percent Colloids	7.23	11.10	4.67	31.38
Base exchange capacity as milliequivalents per 100 grams soil	1.12	3.16	1.00	6.32
Reaction toward Soiltex	Very strongly acid	Very strongly acid	Strongly acid	Medium acid*

*This clay is frequently alkaline but not consistently so.

The Fine Sandy Loam and Sandy Loam members of the Orienta Series are very similar in profile development to the Fine Sand. The B horizon is not quite as completely cemented and, as indicated in the sketches shown in Figure 5 there is a more prominent transition zone between the B proper and the C horizon.

The predominating forest cover on these soils was white pine with a few hardwoods. A notable fact in regard to the Orienta soils is their adaptability to bush fruits. This is noticeable in Bayfield County as well as in Michigan where similar soils are mapped as members of the Ogemaw Series (22).

Saugatuck Sand

The Saugatuck Series is represented by only the Sand member. Marbut has identified the Saugatuck in Michigan as a Ground Water Podsol (20). The profile (Figure 3) of the Saugatuck as recognized in this area is identical with that in Michigan. The type is restricted in this county, there being only a few small areas. No laboratory investigations were conducted, but the profile character is nearly equivalent to the solum of the Orienta Fine Sand, the chief difference between the two being the heavy clay substratum of the latter. The profile is given in more detail below:

Profile of Saugatuck Sand

A_0 Nearly black, litter and peaty organic accumulation varying from 1 to 4 inches in thickness. In summer this appears as a dry turf or 'trockentorf'.

A_1 A very thin transition layer of sandy humus soil. It has a 'salt and pepper' appearance. This layer is about .5 to 1 inch in thickness.

A_2 Whitish-gray sand containing only a very small amount of organic matter. The soil is loose and incoherent. Often it has a 'fluffy' appearance. The lower limit of this horizon is very irregular but usually is encountered at 5 to 12 inches. The line of demarkation between this layer and the one beneath is very sharp.

B_1 Brown sand, irregularly cemented into a sandy hardpan or ortstein. The cemented portion is generally a coffee-brown color. At 18 to 24 inches the soil grades into:

B_2 Yellowish sand with spots and streaks of brown. The soil is quite loose and incoherent. At 24 to 36 inches this layer gives way to:

C Grayish-yellow, loose sand. The material is usually saturated or moist, except during the dry seasons of the year.

Saugatuck is developed on the lower lying, nearly level, sandy plains or benches. In drainage it is intermediate between Plainfield on the one hand and the marsh border soils on the other.

Skeleton Soils

Several young soils have been recognized in Bayfield County. These include the recent alluvial soils and also sandy beach deposits near the lake. The skeleton, or immature soils, have been placed in different series on the basis of their formation, texture of the lower part and the water relations of the substratum. None of the series are important but their recognition was necessary in order to preserve the classification.

The profile of Bibon Fine Sand is shown in Figure 5. This soil is essentially a deposit of sand, generally fine sand, over clay. Very little evidence of profile formation may be observed. The type occurs in small areas throughout the Superior Lowland. Geologically it appears to be the exact equivalent of Orienta Fine Sand, but instead of having developed a mature profile as the Orienta it has made very little advance in the weathering cycle. In some areas this difference appears to be due to youth in the sense of actual years; in other places the formation is probably as old in this sense as the Orienta but simply has not weathered at the same rate. Soil age is not determined by years alone. The Bibon Series is undoubtedly equivalent to the Ottawa Series of Michigan (22).

Port Wing Sand (Figure 6) has no profile development. It includes the recently deposited sand beaches along Lake Superior. These beaches are sometimes fairly well drained

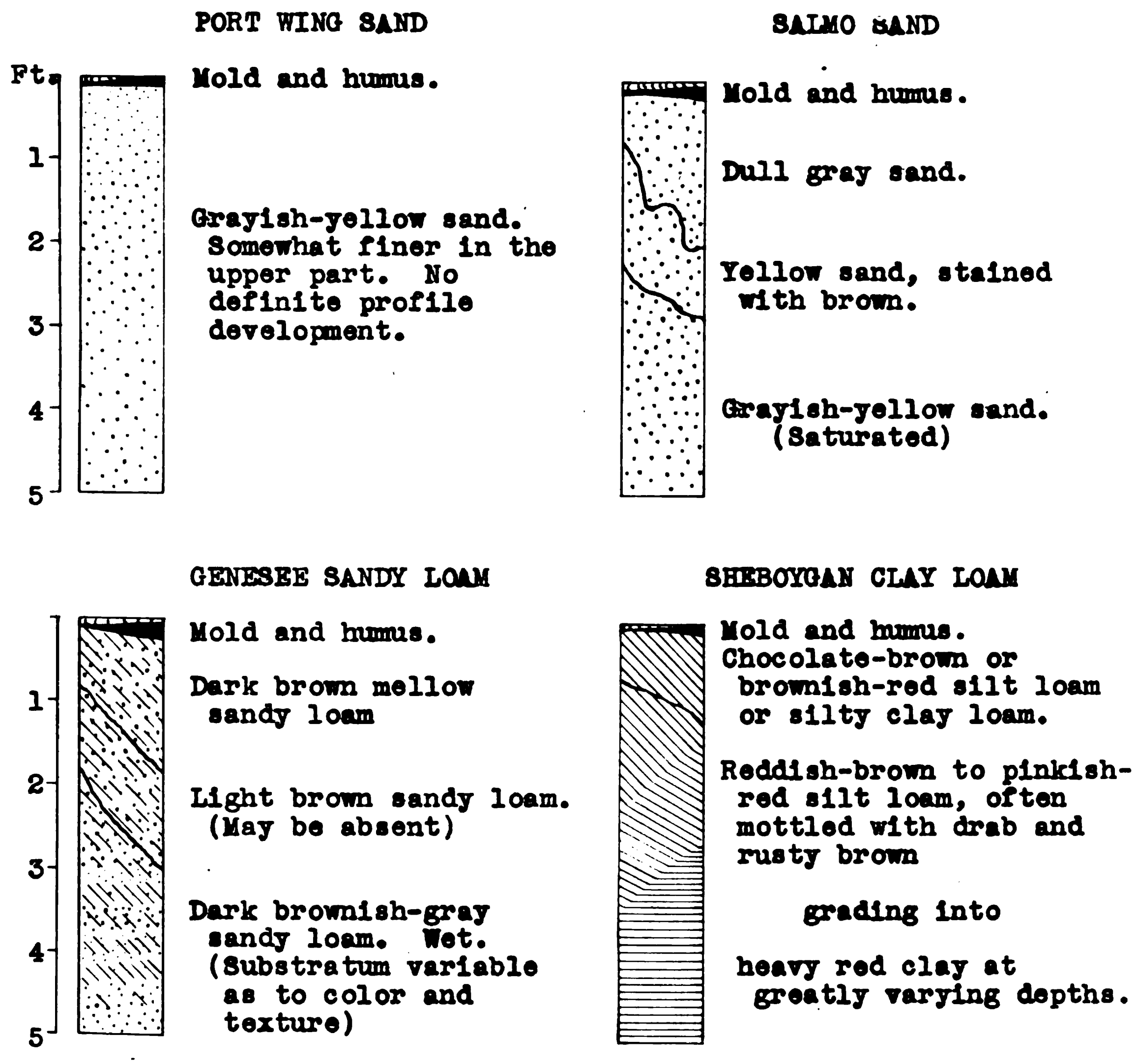

PORT WING SAND
Ft.
1
2
3
4
5
Mold and humus.
Grayish-yellow sand. Somewhat finer in the upper part. No definite profile development.
SALMO SAND
Mold and humus.
Dull gray sand.
Yellow sand, stained with brown.
Grayish-yellow sand. (Saturated)
GENESEE SANDY LOAM
Mold and humus.
Dark brown mellow sandy loam
Light brown sandy loam. (May be absent)
Dark brownish-gray sandy loam. Wet. (Substratum variable as to color and texture)
SHEBOYGAN CLAY LOAM
Mold and humus.
Chocolate-brown or brownish-red silt loam or silty clay loam.
Reddish-brown to pinkish-red silt loam, often mottled with drab and rusty brown
grading into
heavy red clay at greatly varying depths.

Figure VI

flats or benches and sometimes are a series of low ridges with swales between. Only a scanty vegetation has developed which gives rise to a very thin organic covering. The grayish-yellow sand, although derived largely from sandstone rocks, is only slightly acid or even neutral in reaction.

Salmo Sand is found limited to two or three small areas along the shore of Chequamegon Bay. In surface configuration it resembles Saugatuck. The land is nearly level and although the surface soil is dry the water table is sufficiently high to keep the material below about 28 inches saturated, as is the case with Saugatuck. The forest growth is largely pine and aspen with a ground cover of heath plants. The profile is shown in Figure 6. The weak development of a deep grayish horizon, extending down from 12 to 24 inches, with a brownish B horizon, underneath about 8 to 12 inches in thickness, points to the suggestion that this soil is the beginning of a Ground Water Podsol and may be considered as an earlier stage of Saugatuck.

Only a small area within the county is occupied by stream bottom land. Along some of the water courses narrow bands of stream deposited alluvium has accumulated. These accumulations have been thrown into two series on the basis of the texture of the substratum.

The Genesee Series is represented by the Sandy Loam

Type. There is very little actual profile development (Figure 6) as the material is still in the process of accumulation. The soil is associated with the Kennan Series and consists of material washed largely from the till areas. In the course of its deposition considerable organic matter has been incorporated with the mineral portion. The land generally overflows annually and drainage is poor so that small wet and mucky spots are common. As the streams cut deeper and drainage improves these soils will undoubtedly develope a profile similar in essential respects to the Antigo Series.

The Sheboygan Series is also formed from alluvial material along stream courses but it is associated with the Superior Soils and is confined to the Superior Lowland. The soil is found as a narrow band along some of the more prominent streams and also on fans built by them. If there is an escarpment some distance back from the margin of the lake with nearly level land between, the streams frequently build small fans between the escarpment and the water's edge.

Two types of Sheboygan were recognized on the basis of the texture of the surface soil. The Loam includes the lighter material while the Clay Loam is confined to the heavy textured soil. The profile of the latter type is shown in Figure 6. As we can see, no real soil development has taken place. When the drainage has improved a profile similar to the Superior may be expected.

Marsh Border Soils

Throughout the county there occur, in depressed areas, dark colored soils with very little definite profile development. These could probably be considered as the half-bog soils of Glinks's classification. Three series were recognized, largely on the basis of the texture of the underlying material. The surface consists of nearly black, quite well decomposed, organic matter, usually containing sufficient mineral soil to give it a mucky character.

The Poygan Series is confined to the black soils of the Superior Lowland having a heavy clay substratum and may be considered as the poorly drained counterpart of the Superior Series. The two types, Clay Loam and Fine Sandy Loam, are illustrated in Figure 7. A definite formation of glei has taken place, particularly in the Clay Loam. The Fine Sandy Loam is so variable by reason of being developed from sand deposited over clay that nothing can be said regarding its profile, other than what is indicated in the diagram. The Poygan Series is not important in this area because of its very limited occurrence. As

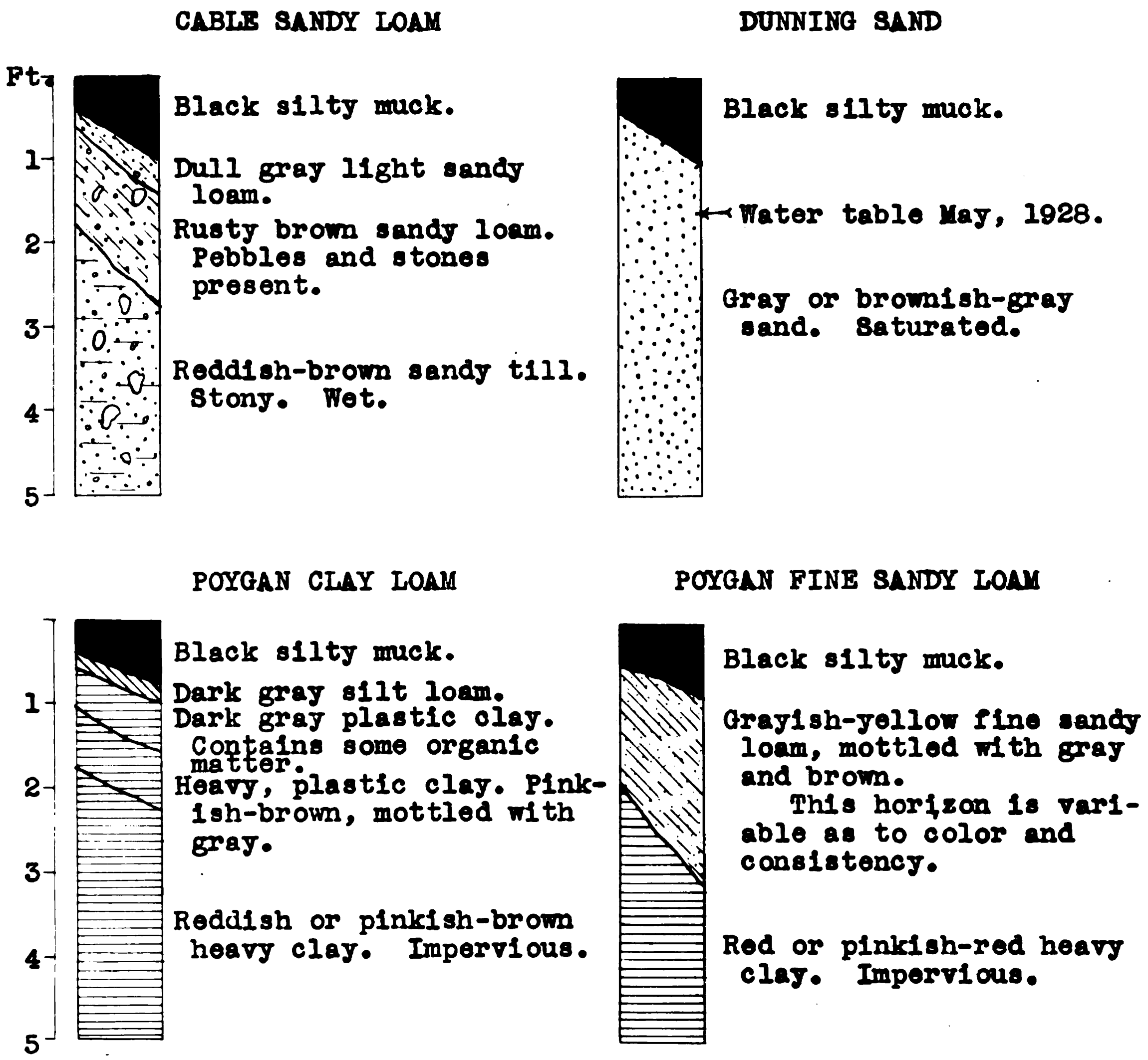

CABLE SANDY LOAM
Ft
1
2
3
4
5
Black silty muck.
Dull gray light sandy loam.
Rusty brown sandy loam. Pebbles and stones present.
Reddish-brown sandy till. Stony. Wet.
DUNNING SAND
Black silty muck.
Water table May, 1928.
Gray or brownish-gray sand. Saturated.
POYGAN CLAY LOAM
1
2
3
4
5
Black silty muck.
Dark gray silt loam.
Dark gray plastic clay. Contains some organic matter.
Heavy, plastic clay. Pinkish-brown, mottled with gray.
Reddish or pinkish-brown heavy clay. Impervious.
POYGAN FINE SANDY LOAM
Black silty muck.
Grayish-yellow fine sandy loam, mottled with gray and brown.
This horizon is variable as to color and consistency.
Red or pinkish-red heavy clay. Impervious.

Figure VII

recognized here the series is similar to the Bergland of northern Michigan (31).

As the Poygan Series is associated with the Superior, so is the Cable Series associated with the Kennan soils. Figure 7 shows the profile of the Sandy Loam Type. A definite glei horizon has been developed in this soil also. Small areas of Cable Loam, having essentially the same profile features, were observed. The Cable soils occur largely as relatively small areas within the till plain or morainic sections. In these depressed areas a large amount of bowlders have usually accumulated so that the Cable soils are very stony.

There is practically no profile development in the Dunning Series (Figure 7). The soil consists of black mucky material over wet sand. Dunning occurs associated with the Plainfield and Vilas Series.

The cover on the Marsh Border soils is quite variable. Soft maple, balsam fir, alder-willow and white spruce are usually found. Elm and ash were frequently present in the original forest, especially on the Poygan Series. White pine was also an element in the original cover.

Peat Soils

Under conditions of excess moisture bog soils have developed. As with the mineral soils, these have been classified on the basis of their intrinsic character. The names given to the various units correspond to the nomenclature of the United States Bureau of Soils.

Greenwood Peat

Yellowish-brown or reddish-brown, felty, fibrous peat, formed largely from small xerophytic shrubs and coarse reeds. The surface is spongy while the lower part is more felty. The material is very raw; decomposition has been but slight. The reaction is very strongly acid. The bog waters are usually brownish or yellowish in color. There is not adequate outlet for natural drainage waters and the water table fluctuates several feet during the season so that in the spring the bogs are very wet while in the late summer they are extremely dry on the surface. The natural vegetation is largely xerophytic - leather leaf, Labrador tea, etc. with occasional clumps of stunted black spruce. Cranberries are often found. This peat soil is associated with such soils as Plainfield, Vilas and Kennan and is most commonly found in regions of acidic drift.

Spalding Peat

Brown, woody (with some fibrous) peat. The surface is coarse, slightly decomposed, woody material with coarse, felty fibrous peat beneath. The woody material has mostly come from coniferous swamp species. Drak grayish-brown pulpy peat may be encountered at three feet or more. The reaction is strongly to very strongly acid. This peat is found under natural conditions in relatively wet swamps and the drainage water is usually stained with brown. The natural vegetation is largely spruce and tamarack, but no hardwoods. There is usually a ground cover of heath plants and sphagnum moss.

Rifle Peat

Dark brown or nearly black woody peat. This material has been derived from coniferous and hardwood forest accumulation. The surface 15 inches is medium to fairly well decomposed and has a rather fine texture. The lower part is more raw and a lighter brown color. At about 2.5 to 4 feet yellowish-brown fibrous peat is usually encountered. The fibrous material is somewhat matted. The reaction is slightly acid to neutral. The original drainaige was better in this class of peat than either of the others and the water table is fairly stable. The drainage water from swamps is clear. The native forest growth is mixed cedar, elm, ash, soft maple, white spruce, tamarack, alder, willow, etc. This soil includes the better peat land of the county.

These soils have but little agricultural importance in this area. The growing season is too short to justify the utilization of even the best grades for much more than pasture.

Discussion of Soils

From the descriptions presented, including the study of the base exchange capacity and the colloid content, it can be seen that there are important differences between the soil series as to their profile development. The Kennan, Vilas and Plainfield Sand represent the very weakly podsolized soils while the Cornucopia, Orienta, Saugatuck and Superior represent the soils with a stronger podsol development. The Plainfield Light Sandy Loam, Mason and Antigo may be considered as intermediate but with definite podsol development.

As pointed out under the discussion of the series in the case of the Cornucopia and Vilas we have two soils developed under almost identical conditions of forest cover, drainage, and elevation and from nearly the same parent material. The same may be said of the Plainfield Light Sandy Loam as compared to the Plainfield Sand. Yet the Vilas and Plainfield Sand have weak profiles while the other two, particularly the Cornucopia have much stronger podsol profiles. It was mentioned previously that the climatic conditions near Lake Superior were different from those which obtain more distant; this belt more nearly approaches the climatic conditions of the regions of well developed Podsol soils in northern Europe. During that portion of the year when the ground is not frozen evaporation is less and more water is allowed to percolate through the soil. It is interesting to note that nearly all of the cornucopia and Plainfield Light Sandy Loam occur north of the southern margin of this area, while the Vilas and Plainfield Sand are south of it. There is only a narrow region in which the Vilas and Cornucopia occur side by side; very few areas of the latter are found south of this general region. Although the largest and most typical areas of Plainfield Light Sandy Loam are found in a large outwash body within the climatic belt bordering Lake Superior, several areas are found farther south. These areas are generally small and may not have as well developed a podsol profile.

The Superior, Orienta and Saugatuck Series are almost entirely confined to the Superior Lowland. On these soils we also find the strongest podsol development in the most northern areas. In the case of the Superior, however, the difference is not enough to justify a separation. The best developed Orienta is also found near Lake Superior.

An attempt has been made to show by a single line the approximate boundary between the weak and stronger podsols.

(Figure 8). The region of stronger podsolization includes the Superior Lowland and the northern portion of the Bayfield Ridge which lies within the climatic region influenced by Lake Superior. Of course there are exceptions due to the local influences of drainage and forest cover. The most notable exception is in the neighborhood of Lake Namekagon in the southeastern part of the county. In this region a very few small areas of Saugatuck and Orienta and several of Plainfield Light Sandy Loam were observed.

As to whether this difference is due to the direct influence of climate is uncertain. All of the stronger profiles developed under a coniferous forest. Of the others the Kennan and the Mason had hardwoods and white pine; but the Plainfield Sand and Vilas had an entirely coniferous cover. If the coniferous forest explains the difference in some cases it certainly does not in others. Thus unless we assume some differences in drainage or chemical character of the parent material which are not apparent, climatic differences seem to offer the best explanation. These variations in climate may not seem to be sufficient to make such a variation in soil character but as we pointed out in the beginning a combination of factors are influencing the podsolization process. When

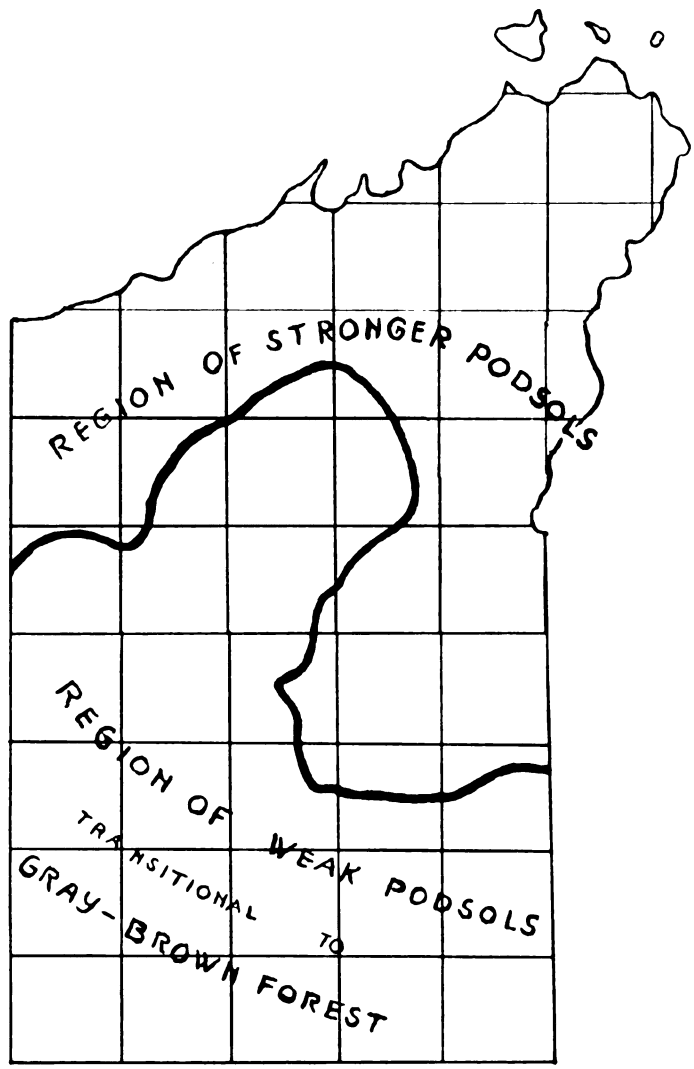


Figure VIII

Sketch Map Showing the Distribution of Weak and Stronger Podsols in Bayfield County .

any one factor becomes limiting only a small change in that one will be necessary to produce quite different results. This thought is perfectly analogous to nutrition results.

These studies have shown that the podsolization process brings about a change in the soil of tremendous importance. Neustrev (25), in reviewing the Russian work on Podsol soils, points out this fact; and the work of Tamm (28), to which we have already referred, leads to the same conclusion. We have seen from the data presented that in cases where there are no great differences in the total content of fine material there may be at the same time a considerable difference in the absorbing complex portion. That part of the fine material which has base exchange properties is the most mobile. In the case of the Superior Clay Loam the B horizon only has 1.25 times as great a content of colloids as the A_2 horizon but 3.32 times as much base exchange capacity. A similar comparison is true with the Orienta Fine Sand. There is a noticeable lack of correlation between these two soil properties.

Truog and his co-workers[1] find that the inorganic material concerned in the base exchange reaction is of

1. Unpublished data obtained by Professor Truog and his co-workers in the laboratories of the Wisconsin Agricultural Experiment Station. See also Kerr's work (15).

quite definite chemical nature. They are led to believe that the same substance, or very similar substances, in the soil are concerned; and that it is a chemical reaction. Organic matter in soils also possesses a high base exchange capacity and they find that it likewise appears to be a single weathering product, but differing from the inorganic substance. After depletion of the exchangeable bases subsequent leaching brings out these materials. Podsolization brings about a sorting of the colloid material with the result that the soil finally becomes impoverished of the greatest element in its fertility. In the case of the Superior Clay Loam the process so far has been beneficial in 'lightening' the texture of the surface soil and making for better conditions of tilth; as time goes on, however, the end result will be deleterious from the standpoint of soil fertility.

In the regions of highly developed podsol soils such as Latvia (34), Sweden(28) - in fact much of northern Europe and Asiatic Russia - there has been found to be a decided decrease in fertility. These well developed soils may not be much older, in point of years,[2] than those of Bayfield County. However, it is not time in the sense

2. Many of the podsol soils in northern Europe and Asiatic Russia are developed on glacial deposits of approximately the same age as the glacial deposits of America.

of years but the stage of development of the soil in relation to its environment which constitutes 'soil age'. Thus from the standpoint of the podsolization process the profiles in Bayfield County are young as compared to many of those described in northern Europe. But assuming no change in climate it can not be doubted that at some future time they will reach the same stage of development, or even a more advanced stage.

In order to obtain an idea of the average condition within the county the following table (XIV) was constructed:

Table XIV. Averages of Laboratory Results on all Soils Investigated

	Percent Colloids			Base Exchange Capacity as milliequivalents per 100 grams soil		
Horizon*	A_2	B	C	A_2	B	C
Stronger Podsols Average of 4 soils	23.98	31.41	35.29	3.91	11.85	13.03
Intermediate Average of 3 soils	14.13	14.87	18.37	5.61	5.19	2.60
Weak Podsols Average of 3 soils	12.96	12.52	7.95	6.65	3.45	3.06
Average of 10 soils	17.72	20.49	19.60	5.24	7.36	6.90

*The horizon of maximum accumulation was taken as B. This is sometimes B_1 and sometimes B_2 where B_1 is a transition layer.

Taking the average for all soils we notice that there is a tendency for an accumulation, in the B horizon, of the finer material and especially of the base exchange complex. In the case of the four soils showing the strongest podsol development this tendency is particularly pronounced. The C horizons of these soils average higher in both materials than does B. The descriptions have brought out that in conditions where the parent material, before soil building forces began, consisted of lighter textured material over less permeable drift, that the podsolization tendency is greater. In the case of those soils having only a weak profile development there is a larger percentage of fine material, especially that part having base exchange properties, in the A_2 horizon. It has been mentioned that a large part of this material is organic.

From the descriptions of the profile condition, together with the averages of the data for the area, it is evident that the base exchange capacity correlates closely with the weathering conditions as expressed by the character of the profile. This portion of the colloidal material is evidently the most active part. That this portion is of extreme importance in determining soil fertility need not be emphasized here. The importance of examining the profile, and studying its character, as influenced by weathering forces, in relation to experimental studies of the fertility of any soil becomes apparent at once. Comparisons between soils produced under different combinations of soil-building forces should be made with caution.

Summary

The profiles of the soils of Bayfield County have been examined in the field and laboratory and their development discussed. It was evident that all of the soils belong to the Podsol group but that some of them only weakly express the podsol profile.

The influence of forest cover and particularly of climate in the development of the soils within this area has been pointed out.

The content of base exchange material in the various horizons of the soil profile was found to correlate closely with its stage of development. A similar, but less striking, correlation was observed with the colloid content as measured by the hydrometer method.

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Biographical Sketch

Charles E. Kellogg was born on a farm in Ionia County, Michigan, August 2nd., 1902. His elementary education was received at a district school. In June 1919 he graduated from the high-school at Palo. Until the fall of 1920 he worked on his father's farm, leaving at that time to enroll in the Agricultural Short Course at Michigan State College. The following winter he began work for the Bachelors degree in Agriculture which was granted in June 1925. During the summers of '23 and '24 he mapped soils in northern Michigan for the Michigan Department of Conservation. At the time of his graduation with the B.S.degree he was appointed as Assistant in Soils in the Michigan Agricultural Experiment Station, mapping soils in the summer and assisting with laboratory investigations during the winter.

April, 1926, he received a fellowship in Soils, sponsored by the Michigan State Highway Department. For two years he studied the applications of soil classification to problems in highway design. April,1928, he came to Wisconsin as staff soil surveyor for the Wisconsin Geological and Natural History Survey, a position which he now holds.

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