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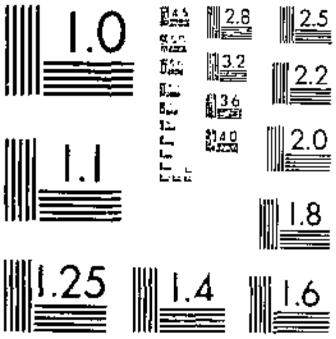

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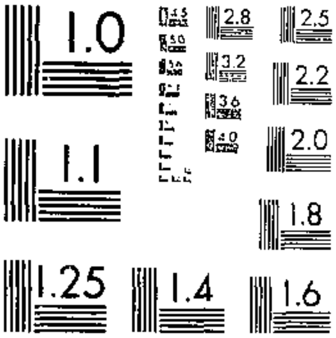

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Technical Bulletin No. 484 December 1935

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

DEPOSITORY

THE COMPOSITION AND CONSTITUTION OF THE COLLOIDS OF CERTAIN OF THE GREAT GROUPS OF SOILS

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INTRODUCTION

In his classification of soils on the basis of field data Marbut (*12*)[1] recognizes the existence of great groups of soils. He and his co-workers in the Division of Soil Survey have determined the general geographical positions of five of these great groups in the United States by means of careful and detailed soil surveys. Of these, four are found in the humid portion of the country and belong in the Pedalfer division of soils. These are named Podzol, Gray-Brown Podzolic, Prairie, and Lateritic. This latter group is sometimes subdivided into the Red and Yellow soils. In the Pedocal division of soils the only great group which has been extensively studied in the field is the Chernozem group. In addition, the existence of Chestnut-Brown, Brown, and Gray-Desert soils is recognized. From foreign sources it is known that there exists another great group of soils known as the Laterites. These are sometimes subdivided into aluminous and ferruginous Laterites. No true Laterites are known to exist in the continental limits of the United States.

In 1931 Anderson and Byers (*2*) published a paper dealing with the characteristics of the collodial materials in the profiles of certain of these major groups. In 1932 Byers (*6*) discussed the constitution of

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[1] Italic numbers in parentheses refer to Literature Cited, p. 38.

the hypothetical soil acids which were assumed to exist in the soil colloids and to be responsible for the characteristics of the great soil groups. In 1933 Brown, Rice, and Byers (*5*) presented the results of a study of claypan soils, belonging to the Prairie and Chernozem groups, in which was emphasized the uniformity of character of the colloid of not only the profile of a given soil type but also the close similarity of colloids derived from soils of closely similar types. This study was deemed to indicate within such groups the existence of a characteristic substance which is sufficiently dominant to make the resultant colloid material throughout the profile effectively one substance (not one compound). It is recognized, of course, that this substance must be impure, and also that the properties of the substance are the resultants of the properties of the individual compounds present.

In the paper by Anderson and Byers (*2*) and also in one by Brown and Byers (*4*) it is recognized that the uniformity of colloid composition within a soil profile does not always exist and diversity of composition is particularly marked in soils of the Podzol group. It therefore seemed worth while to make a study of the soils of the great groups which might be expected to differ widely from each other, in order to determine definitely some of these relationships. It also seemed possible by proper selection of typical representatives of each group to establish by analytical examinations the outstanding characteristics of each group.

For this purpose the Division of Soil Survey was requested to select the soil type which in its judgment best and most completely reflected the field characteristics of the major soil groups. The various inspectors of the Division most familiar with the respective groups were then asked to select and collect a profile sample which best presented the characteristics of the soil type which had been selected. To represent the Podzol group Mark Baldwin furnished the Au Train profile, later described. Baldwin also furnished the Miami silt loam as representative of the Gray-Brown Podzolic group. T. D. Rice furnished the Chernozem profile belonging to the Barnes series, also the Prairie profile of the Carrington series. W. E. Hearn furnished the profiles representing the Lateritic soils selected from the Cecil and Ruston soil series. Since no true Laterites exist in the United States, H. H. Bennett was requested to draw upon his knowledge of tropical soils and select a soil which as completely as possible would represent the aluminous Laterites. The soil selected, the Columbiana clay from Costa Rica, is not wholly satisfactory but is believed to be the best representative of its group obtainable in the Western Hemisphere. It was collected and shipped by the United Fruit Co.

To the above list was added a Podzol profile collected by H. E. Middleton and D. B. Lovejoy. It is the Caribou silt loam from Maine.

While the primary purpose of the investigation was, as above indicated, to find the chemical characteristics attendant upon the wide field differentiation of these soils, a very considerably increased scope developed as the study progressed. The description of each soil profile is given in conjunction with the results of analytical examinations.

METHODS OF EXAMINATION

The soil samples when received were air dried and carefully subsampled. The subsamples for mechanical analysis were examined by the pipette method described by Olmstead, Alexander, and Middleton (*16*) on the basis of the oven-dry sample. The chemical analyses of the whole soil were made by the methods described by Robinson (*17*). The colloids were extracted by the process described by Brown and Byers (*4*). The centrifuge speed and rate of flow were governed to collect that portion of the fine material consisting of particles of 0.3-micron or smaller particle diameter. After separation by the Pasteur-Chamberland filter the colloids were air-dried on porous clay plates and were not heated above room temperature at any time until the process of analysis was undertaken. This point is somewhat important by reason of the bearing it has on the water relationships of these same samples. In considering the derived data of the tables the water of combination of the soil acids does not include any combined water which may be evolved by heating the samples to 105° C. The colloids were analyzed by the usual methods except that special care was exercised in securing duplicate analyses.

Special attention is directed to the tables of derived data given in the following tables. The figures given are calculated from the analytical data. The much-used and familiar ratios, the silica-sesquioxide, silica-alumina, and silica-iron oxide ratios, are obtained by dividing the percentage quantities of the components by their respective formula weights, and the quotients obtained are compared in the ratios. The ratios represent the relative formula weights of silica as compared with the corresponding quantities of the other components named in each ratio. In a similar manner the formula weight ratio of the ferric oxide and alumina indicates the relative formula weights of these components. The silica-total base ratios indicate the relative number of formula weights of silica to the sum of the formula weights of the calcium oxide, magnesium oxide, manganese oxide, potassium oxide, and sodium oxide in the colloid. In this bulletin manganese oxide is included for the reason that certainly a part, although an unknown portion, is present as replaceable manganese. In colloids derived from soils containing large quantities of concretionary manganese dioxide it seems probable that manganese may well be omitted from the silica-base relation.

It has long been customary to include in chemical soil analyses a quantity known as the "water of combination" which is defined as the precentage loss on ignition less organic matter and carbon dioxide from carbonates.

In the considerations involved in this bulletin the soil colloid is assumed to consist chiefly of one or more complex acids in which a portion of the hydrogen is replaced by metals. If therefore one wishes to gain information concerning the constitution of these hypothetical acids, it is necessary to add to the combined water the water equivalent of the bases present. Strictly speaking, since the colloids are amphoteric, the water equivalent of the acid radicals present ought also to be included. In this bulletin this has not been done because the acidic components present are so small that no essential change would result were they included. The water equivalent of the bases is obtained by the calculation: Formula weight of base: percentage of base :: 18 : x. The sum of the values of x for the bases is added to the percentage of combined water. Since the colloid always contains organic matter and sometimes carbonates as well, the quantity obtained above is divided by 100 minus the percentage of organic matter and the calcium carbonate equivalent of the carbon dioxide present. The resulting number is the "water of combination of the soil acids." There are at least four inherent errors involved in these calculations: (1) The quantity of organic matter is not accurately determinable; (2) a portion of the bases is most certainly held by the organic matter; (3) a portion also of the bases may be present in unaltered parent material; and (4) a portion of the combined water of the soil may be lost in drying soils at 105° C. Despite these shortcomings the relationship so arrived at is most useful in considerations involving the relationship of the soil colloids to each other.

In order to bring the water of combination of the inorganic soil acid into a more usable relation to the other derived data, corresponding formula-weight ratios are calculated. Those given are the silica-water, water-alumina, and water-sesquioxide ratios. They are obtained by dividing the percentage quantities of combined water, plus the water-equivalents of the bases by the formula weight of water. The formula weight equivalents of water are then compared with the corresponding quotients obtained from the percentage quantities of silica, alumina, and ferric oxide.

THE BARNES LOAM PROFILE

The Pedocals are divided by Marbut (*12*) into four groups—Chernozem, Chestnut, Brown, and Gray. This classification is made on the basis of the color of the soil's surface horizon, which is determined by the quantity of organic matter present. A typical member of the Chernozem group is the Barnes. This soil and those related to it are dominant within the Chernozem belt of the Dakotas, and extend northward into Canada.

The sample of Barnes loam used in this investigation was taken 2 miles east of Le Bolt, S. Dak. It is considered typical of the Barnes group of soils.

The surface horizon is 9 inches in depth. It is black in color, due to the presence of organic matter. The second horizon extends from a depth of 9 to 17 inches. This layer is brown, containing less organic matter than the first. This is a transitional layer, as far as organic matter is concerned, between the black surface soil and the zone of carbonate accumulation, which extends from a depth of 17 to a depth of 33 inches. Beneath this zone of carbonate accumulation is the parent glacial drift, from which the soil has been derived. It is very calcareous. Above the zone of carbonate accumulation the soil does not effervesce with hydrochloric acid, although it undoubtedly contains minute quantities of carbonates or bicarbonates (*1*). In table 1 is shown the mechanical analysis of the Barnes soil profile samples.

TABLE 1.—*Mechanical analysis of Barnes loam (soil)*

Sample no.	Horizon	Depth	Fine gravel (2-1 mm)	Coarse sand (1-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.1 mm)	Very fine sand (0.1-0.05 mm)	Silt (0.05-0.005 mm)	Clay (0.005-0 mm)	Colloid[1] (0.002-0 mm)	Organic matter by H_2O_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
10305	A	0- 9	1.8	3.8	6.0	14.3	10.3	25.0	33.0	26.7	5.4
10306	B_1	9-17	1.6	4.0	8.1	22.7	14.0	17.9	29.1	25.3	2.2
10307	B_2	17-33	1.3	3.1	4.5	10.0	7.5	24.4	48.4	35.0	.3
10308	C	33-60	2.7	6.1	6.4	9.7	7.6	25.4	41.2	31.5	.4

[1] Included in clay.

The decrease in the percentages of fine gravel, coarse sand, and medium sand in horizons A, B_1, and B_2 of the Barnes soil over the corresponding percentages in the parent material, horizon C, shows that the fragmentation is proceeding more rapidly in the former. The higher values for clay and colloid in layer 3 indicate a removal of colloid from the first and second layers and accumulation in the third. The parent drift has a higher percentage of colloid than either horizon A or B_1, but less than B_2 where the accumulation has taken place. The amounts of organic matter, as determined by the hydrogen peroxide method, during mechanical analysis, agree very well with the amounts as determined by the combustion method. Attention will be called later to these figures in table 2. The greater difference in the third horizon is due to the presence of calcium carbonate which interferes with the peroxide method.

TABLE 2.—*Chemical analysis of Barnes loam (soil)*

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	SO_3	P_2O_5	Ignition loss	Total	Organic matter	CO_2 from carbonates
		Ins.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
10305	A	0- 9	69.32	3.84	11.30	0.92	1.61	1.80	1.14	0.49	0.16	0.14	0.17	9.53	100.51	5.05	0.0
10306	B_1	9-17	73.56	3.96	11.31	.72	1.53	1.76	1.16	.49	.12	.11	.01	5.26	99.99	2.30	.0
10307	B_2	17-33	53.43	3.70	10.18	2.00	13.42	1.42	.84	.46	.15	.07	.18	14.48	100.33	1.12	10.50
10308	C	33-60	57.58	3.93	10.39	2.37	10.52	1.02	.80	.48	.18	.06	.15	12.02	100.19	.59	8.60

Table 2 shows the results of the chemical analyses of the four layers of the Barnes profile. The higher percentages of silica in horizons[2] A and B_1 over those of B_2 and C are due to two factors. The first of these is that the removal of the originally present calcium carbonate from the upper layers has increased, relatively, the percentages of the remaining constituents. The second factor is the leaching downward of the colloid, which has a lower percentage of silica than the soil as a whole, raising the percentage of silica in the remaining soil. The percentages of iron and aluminum oxides are essentially constant throughout the profile. The magnesium oxide percentage indicates the presence of dolomite in the third and fourth horizons, but shows that no accumulation has taken place in the third. On the other

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[2] In considering the portions of the Chernozem and Prairie soils it is convenient at times to use the term "horizon." It is recognized, of course, that in these soils the profile development does not warrant the term. It is used for convenience only.

hand, the calcium oxide percentages show an accumulation in the third horizon, which is the defining characteristic of the pedocalic soils. The relatively high percentages of sodium and potassium oxides indicate the likelihood of considerable unweathered minerals. The factor titanium dioxide is not discussed in this or in any other soil because of ignorance of its role in the soil. The quantities of phosphorus pentoxide are so small that they have little bearing on the gross composition of either the soil or the soil colloid. The lack of carbonate carbon dioxide in horizons A and B_1 shows complete leaching of the original calcareous drift to a depth of 17 inches. The percentages of carbonate carbon dioxide in horizons B_2 and C indicate the quantities of calcium carbonate and of dolomite present in them. The same thing is shown by the calcium and magnesium oxide percentages already mentioned.

The colloidal material extracted in the manner described on page 3 was analyzed, and the results are shown in table 3. Excepting the values for organic matter and CO_2 from carbonates, the data indicate rather constant composition of soil colloid throughout the profile. The former reflects the higher percentages of organic matter near the surface and the latter the presence of lime carbonate below a depth of 17 inches in the colloidal fraction of the soil. It is noteworthy that most of the accumulated carbonate is not of colloidal size, or at least was not extracted as such. The relatively high percentages of magnesium oxide, potassium oxide, and sodium oxide indicate either one or two possibilities, namely, that there is present, even in the colloid, some mineral or minerals very resistant to hydrolysis, or that the colloid complex present has a very strong affinity for these bases. It is probable that the result is the effect of both factors. A comparison of the percentages of potassium in the soil with those in the colloid indicates that none of this constituent is lost from the soil during weathering conditions under which this soil was formed. This is not surprising in view of the limited rainfall. Since the sample came from a virgin area the problem of removal by crops does not enter.

TABLE 3.—*Chemical analysis of Barnes loam (colloid)*

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	Ignition loss	Total	Organic matter	CO_2 from carbonates	pH values
		Ins.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	
10305	A	0- 9	45.90	9.96	19.12	2.28	1.81	1.70	0.02	0.68	0.103	0.39	18.34	100.36	10.12	0.0	6.9
10306	B_1	9-17	48.21	10.93	20.23	2.40	1.73	1.43	.13	.74	.147	.25	14.15	100.44	5.77	.0	7.1
10307	B_2	17-33	49.21	9.76	19.44	2.68	5.03	1.44	.06	.74	.098	.31	11.76	100.53	1.94	2.59	8.1
10308	C	33-60	50.29	9.50	19.32	2.96	4.34	1.40	.20	.68	.133	.24	10.93	99.99	1.03	2.46	8.2

Table 4 shows some data derived from the chemical analysis of the colloid. The ratios indicate constancy of composition. This means that in all four horizons the same material is being dealt with. It does not indicate, however, whether a single component is being dealt with or a mixture of constant composition. Although in general the constancy of composition may be taken as an indication of the presence of a single substance, more evidence is necessary in order to draw definite conclusions as to the existence of definite compounds. It should be emphasized that the constancy of the ratios indicates nothing concerning the presence, or absence, of a single compound. This method of expression simply eliminates similarities or differences due to organic matter, carbonates, or other components not concerned with the components in question. Evidence of the presence of individual compounds would be directly furnished were methods available for purifications and for determination of molecular weights.

TABLE 4.—*Derived data: Barnes loam (colloid)*

Sample no.	Horizon	Depth	Molecular ratio								Combined water	Combined water of soil acid
			$\frac{SiO_2}{Fe_2O_3+Al_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$	$\frac{SiO_2}{H_2O}$	$\frac{H_2O}{Al_2O_3}$	$\frac{H_2O}{Fe_2O_3+Al_2O_3}$		
		Inches									*Pct.*	*Pct.*
10305	A	0–9	3.05	4.07	12.22	0.333	6.96	1.21	3.30	2.52	8.22	11.34
10306	B_1	9–17	3.00	4.01	11.68	.310	7.13	1.30	3.11	2.31	8.38	11.03
10307	B_2	17–33	3.25	4.29	13.35	.321	7.10	1.46	2.94	2.23	7.23	10.00
10308	C	33–60	3.36	4.41	14.04	.314	7.27	1.50	2.94	2.24	7.45	9.99

Careful examination of some of the ratios yields some information on the processes of soil formation. It was pointed out on page 5 that the first two layers or horizons have the same mechanical composition; that the third horizon shows an accumulation of colloid from the upper two horizons and hence is a mixture of horizons A and B, and the colloid from the parent material. The colloid from horizon C represents the parent drift where the influence of soil-forming processes, as distinguished from hydrolysis, have not reached. Horizons A and B_1 represent the soil colloid as modified by the soil-forming processes. Horizon B_2 should be intermediate in composition and properties. The silica-sesquioxide ratio of horizons A and B_1 averages 3.02; that of the parent colloid, 3.36; that of horizon B_2, intermediate, 3.25, with the influence of the parent material predominating as would be expected from the mechanical analysis. The silica-alumina ratio and the silica-iron oxide ratios indicate that this increase in the ratio of silica to sesquioxide is true of both alumina and iron, but more pronounced with the former. It has been pointed out by Brown, Rice, and Byers (*5*) that the iron present in the Chernozem type soils must be regarded as combined with silica. The ratios of silica to the combined water of the soil acid shows a steady increase from horizon A to horizon C, or if the reciprocal of this ratio be taken it is found that the ratio of water to silica is greater in the colloid of the surface layers than in that of the parent drift colloid. Likewise, the combined water-sesquioxide ratio shows a higher degree of hydration at the surface than at the greater depth.

These departures from constancy are very interesting because they bear on the question of weathering processes. From the trend of the silica-sesquioxide ratios it may be inferred that the weathering processes are such that some silica is lost from the colloid during weathering. The variations noted in the combined water-silica ratios and the water-sesquioxide ratios indicate that the more weathered the colloid is the more highly hydrated it is with respect to both silica and sesquioxide. It may be noted here, however, that one would expect, from the behavior of aluminum and iron hydroxides and of silicic acids that some irreversible dehydration (*5*) should take place at the surface where the forces of wetting and drying, and of heat, are most active.

THE CARRINGTON LOAM PROFILE

The Prairies are grassland soils developed under conditions of moderately high rainfall. They are similar to the Chernozems in that both are grassland soils high in organic matter. The Carrington loam is a typical member of this group. Both of these soils have been developed from calcareous glacial drift. The profile of the Carrington is acid in reaction excepting the parent glacial drift, whereas the Barnes is either neutral or alkaline throughout. Along the streams soil-forming processes have produced Gray-Brown Podzolic, Red, or Yellow soils. Indeed, the Prairie soils themselves have been podzolized to a very limited extent.

The profile used in this study was the Carrington loam, collected in Buchanan County, Iowa, 1 mile southwest of the town of Winthrop. The profile is described as follows:

Horizon A_1, 0 to 3 inches. This material is a very dark grayish-brown, loose, mellow, granular loam and contains much silt. It forms a turf loosely held by grass roots.

Horizon A_2, 3 to 13 inches. A very dark grayish-brown fine loam, made up of granules, mostly fine.

Horizon B_1, 13 to 22 inches. This is a transition layer ranging in color from very dark in the upper portion to brown in the lower. It represents the zone of transition from the surface soil to the subsoil. It is imperfectly granular in the upper portion and structureless in the lower.

Horizon B_2, 22 to 43 inches. This is a brown loam, slightly heavier in texture than the layers above. There is no carbonate present.

Horizon B_3, 43 to 70 inches. Brown clay loam splotched with yellow and rust brown, streaked by occasional dark tongues. A few boulders and gravel present. This is the partially decomposed parent drift, leached of its carbonates.

Horizon C, 70 to 80 inches. Yellowish-brown clay loam with lumps of heavy clay. There are faint colorings of gray and rust brown. This material is the weathered, but unleached, calcareous drift of Iowan age. The area from which the sample was taken had not been cultivated.

Table 5 shows the mechanical composition of the Carrington loam profile. Taken as a whole, the profile shows very little variation in texture. In the upper horizons the coarser material has broken down to give finer particles. A slight accumulation of clay in the fourth

TABLE 5.—*Mechanical analysis of Carrington loam*

Sample no.	Horizon	Depth	Fine gravel (2-1 mm)	Coarse sand (1-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.1 mm)	Very fine sand (0.1-0.05 mm)	Silt (0.05-0.005 mm)	Clay (0.005-0 mm)	Colloid (0.002-0 mm)	Organic matter by H_2O_2	pH
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
10082	A_1	0- 3	1.1	5.8	7.7	10.5	7.7	34.8	26.5	21.2	5.4	5.5
10083	A_2	3-13	1.2	6.2	7.8	10.1	0.6	36.2	27.8	22.5	3.8	5.2
10084	B_1	13-22	2.1	6.3	7.6	10.2	7.7	34.2	29.3	24.5	2.1	4.9
10085	B_2	22-43	2.2	7.3	9.6	14.1	11.4	23.7	30.4	26.2	1.0	5.1
10086	B^3	43-70	2.7	7.5	9.5	14.5	11.5	24.8	28.8	23.8	.4	6.4
10087	C	70-84	3.1	8.7	10.2	14.9	11.6	24.7	26.2	11.0	.4	8.1

horizon accounts for the heavier texture noted by the collector in the description of the sample. Given in this table also are the values found by the peroxide method for the organic matter. They correspond nicely to those given in table 6 by the combustion method. The principal point of interest in this table is that it shows the mechanical movement of colloid downward has been very small. This is in contrast to some of the soils to be considered later, in which the movement of the finer particles downward is the principal soil-forming process. The heavy cover of grass and the presence of the root mat have been an important factor in preventing this movement. In some grassland soils there is marked accumulation of colloid in subsurface layers (*1*, *2*, *3*, *4*, *5*).

TABLE 6.—*Chemical analysis of Carrington loam (soil)*

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	CO_2	N	pH
		Ins.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	
10082	A_1	0- 3	74.62	3.12	9.72	0.60	0.99	1.53	0.74	0.54	0.08	0.11	0.04	8.25	100.34	5.57	0.0	0.29	5.5
10083	A_2	3-13	75.69	3.33	10.50	.49	.90	1.53	.81	.60	.10	.10	.03	6.27	100.41	3.43	.0	.17	5.2
10084	B_1	13-22	76.25	3.62	11.28	.65	.60	1.54	.81	.60	.08	.07	.05	4.80	100.44	1.96	.0	.12	4.9
10085	B_2	22-43	76.95	4.07	11.36	.81	.62	1.45	.68	.60	.06	.07	.04	3.66	100.37	.75	.0	.05	5.1
10086	B_3	43-70	77.66	3.96	11.05	.68	1.00	1.52	.70	.54	.07	.06	.05	2.98	100.42	.34	.0	.03	6.4
10087	C	70-84	75.40	3.55	10.02	.99	2.81	1.52	.77	.49	.05	.04	.12	4.42	100.27	.00	2.70	.02	8.1

In table 6 are shown the results of the chemical analysis of the Carrington loam profile. The profile has an extreme degree of constancy of composition with respect to the major constituents. This is characteristic of the Prairie profiles. The unleached calcareous drift is indicated by the higher percentage of calcium oxide in the sixth horizon. Little if any of the 2.7 percent of carbonate carbon dioxide is present as dolomite, as shown by the magnesium oxide figures. The organic matter content and distribution is normal for a Prairie soil. The remaining constituents vary so little that they require no comment. The pH values for the first four horizons are all distinctly acid. As is usual, the upper layer is a little less acid than those immediately lower because of the bases combined with the organic matter. Due to the presence of unleached carbonates horizon C is basic, while horizon B_3 is intermediate in acidity between horizons B_2 and C. The calcium carbonate originally in horizon B_3 has been removed, but apparently exchangeable calcium remains sufficient to reduce the acidity shown by the upper horizons.

Table 7 gives the chemical analysis of the colloids extracted from the six horizons of the Carrington loam. The percentages of magnesium oxide, sodium oxide, titanium oxide, manganese oxide, and phosphorus pentoxide remain essentially constant throughout when the effect of the organic matter on them is considered. The percentage of calcium oxide in the first horizon is higher than in the horizons underneath it except the sixth. Calcium is an important mineral constituent of the grasses and the accumulation may be attributed to the decayed grass residues. Whether it is a part of the organic or inorganic portions of the colloid is not known.

TABLE 7.—*Chemical analysis of Carrington loam (colloid)*

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	Ignition loss	Total	Organic matter	CO_2	N
		Ins.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
10082	A_1	0- 3	41.12	10.36	20.90	1.52	1.31	1.44	0.12	0.62	0.10	0.37	22.56	100.42	12.92	0.0	----
10083	A_2	3-13	41.84	10.09	23.22	1.61	.97	1.38	.04	.55	.14	.30	20.18	100.39	9.94	.0	----
10084	B_1	13-22	43.82	10.07	24.31	1.71	.94	1.31	.06	.68	.09	.28	10.47	100.37	6.16	.0	----
10085	B_2	22-43	44.77	12.92	24.67	1.71	1.02	1.63	.01	.82	.08	.26	12.41	100.30	2.53	.0	----
10086	B_3	43-70	45.42	13.69	24.30	1.81	1.14	1.85	.05	.87	.07	.29	10.77	100.20	1.14	.0	----
10087	C	70-84	45.42	13.77	23.82	1.79	1.48	1.89	.13	.82	.08	.22	10.93	100.35	1.07	.10	----

The increase in calcium oxide in horizon C is due to the presence of a small quantity of calcium carbonate. It is worthy of note that although the parent material contained considerable quantities of carbonates, very little is in the colloidal form. This was not the case with the Barnes, where 2.5 percent of carbonate carbon dioxide was present in the colloid from the parent material. Carbonates must have been present in the colloid of the parent material of the Carrington, also, but due to the higher rainfall most of the fine particles of carbonates have been leached at 70 to 84 inches. In the Barnes this was not true at a depth of 17 to 33 inches. The relatively high percentages of potassium oxide indicate considerable unweathered mineral or an acid complex strong in its affinity for potassium. The low percentage of sodium oxide indicates that all of the sodium has been leached out. There are still sodium minerals in the coarse fraction as indicated by the percentage shown in the soil in table 6. The organic matter is rather concentrated in the colloidal fraction as there is more than twice as much in the colloid as in the soil. Organic matter exists at considerable depth, there being 1 percent in colloid of horizon C. Consideration of the silica, alumina and iron oxide percentages is facilitated by use of the derived data in table 8.

TABLE 8.—*Derived data: Carrington loam (colloid)*

Sample no.	Horizon	Depth	Molecular ratio								Combined water	Combined water of the soil acid
			$\frac{SiO_2}{Fe_2O_3+Al_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$	$\frac{SiO_2}{H_2O}$	$\frac{H_2O}{Al_2O_3}$	$\frac{H_2O}{Fe_2O_3+Al_2O_3}$		
		Inches									*Percent*	*Percent*
10082	A_1	0- 3	2.53	3.33	10.52	0.317	8.54	0.968	3.45	2.03	9.64	12.71
10083	A_2	3-13	2.39	3.03	10.08	.278	8.72	.964	3.17	2.48	10.24	12.90
10084	B_1	13-22	2.38	3.05	10.88	.281	9.64	1.052	2.90	2.26	10.31	12.44
10085	B_2	22-43	2.30	3.08	9.18	.335	9.34	1.151	2.68	2.00	9.88	11.61
10086	B_3	43-70	2.33	3.17	8.78	.361	8.60	1.198	2.65	1.94	9.63	11.32
10087	C	70-84	2.36	3.23	8.74	.370	8.02	1.155	2.80	2.04	9.92	11.74

Table 8 contains data derived from the figures shown for the composition of the colloid of the Carrington profile in table 7. The silica-sesquioxide and silica-alumina ratios are essentially constant. The silica-iron oxide ratios are indicative of slight accumulation of iron in the upper horizons. That is to say, the silica has been leached downward or dissolved to a greater extent than has the iron. The ratio of silica to total bases is fairly constant and rather high. The ratio of iron oxide to alumina indicates a more rapid removal of alumina than of iron oxide from the surface. The combined water of the soil acid, while in general uniform, shows a definite decrease with depth. This trend is also shown by the water-alumina and water-sesquioxide ratios.

The composition of the colloid from the six horizons of the Carrington is constant with respect to all of the constituents excepting combined water and organic matter. The sum of these two constituents constitutes the ignition loss. The combined water of the soil acid and the organic matter show a continual decrease from top to bottom of the profile.

The ignition loss is made up of three factors, (1) the combined water, (2) organic carbon, and (3) the hydrogen, oxygen, and nitrogen of the organic matter. Of these only the organic carbon may be accurately determined. In these analyses the organic matter has been calculated on the basis of 58-percent carbon content (using the Wolf factor $0.471 \times CO_2$). In many investigations of fractions of soil organic matter (*1*) from soils the carbon content has usually been found to be much lower than 58 percent. If in this profile the carbon content be assumed to be 45 percent the combined water becomes very nearly constant. If, therefore, the organic matter is uniformly low, as the quantity of it increases toward the surface of the profile, the combined water and therefore the combined water of the soil acid, appears larger than it really is. Unfortunately in other profiles this assumption does not suffice to eliminate variations in the water relations. It is possible also that at the surface the colloid may be more fully hydrated but this assumption does not seem logical in view of the fact that a normally wetter condition must be assumed in the subsoil than in the surface portion of the soil. There is also the probability that some of the higher base content of the surface colloid is associated with the organic matter. The increase of bases with depth is not sufficient to indicate a large quantity of unweathered colloid in the lower portion of the profile. This source of variation of the combined water of the soil acid will be stressed in the discussion of the Miami profile (p. 14).

THE MIAMI SILT LOAM PROFILE

The Miami soils occur in large areas in western Ohio and central and northern Indiana and southern Michigan. They are typical of the Gray-Brown Podzolic group as it occurs west of the Appalachian region. The sample used in this study was taken in Grant County, Ind., on a gentle upland slope in a section of undulating till plain, which has been mildly dissected. The drainage is good. The vegetation consists of hard maple, linden, and white oak. The land has never been cleared or plowed. The ground cover is a very thin scattering of grass and weeds.

The A_1 horizon is a very dark brownish-gray silt loam high in organic matter. It is 1½ inches thick and is overlain by a very thin leaf litter. The A_1 horizon is underlain by a transition layer 1 inch thick. This layer was not sampled because it is a mixture of the A_1 horizon with the A_2 horizon, brought about by the penetration of the A_1 into the A_2 through the paths of burrowing insects and worms.

The A_2 horizon extends from a depth of 2½ inches to a depth of 9 inches. It is light brownish-gray, friable, silt loam, definitely platy. Underneath this layer is a 2-inch transition layer which was not sampled.

The B horizon extends from a depth of 11½ inches to a depth of 23½ inches. It is a heavy, brown plastic silty clay with definite blocky structure.

Following the B horizon is a 4-inch transition layer which was not sampled. The C horizon consists of rather hard, medium-textured, calcareous till of late Wisconsin age. The layer extends from 27 to 48 inches.

Table 9 gives the mechanical analysis of the Miami silt loam.

TABLE 9.—*Mechanical analysis of Miami silt loam* [1]

Sample no.	Horizon	Depth	Fine gravel (2–1 mm)	Course sand (1–0.5 mm)	Medium sand (0.5–0.25 mm)	Fine sand (0.25–0.1 mm)	Very fine sand (0.1–0.05 mm)	Silt (0.05–0.005 mm)	Clay (0.005–0 mm)	Colloid (0.002–0 mm)	Organic matter by H_2O_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
10341	A_1	0 – 1½	0.1	2.1	3.5	6.4	6.0	46.0	20.7	18.1	6.0
10342	A_2	2½– 9	.1	2.0	3.5	6.4	5.7	47.0	32.5	20.2	2.5
10343	B	11½–23½	.0	1.4	2.1	4.8	4.8	26.1	60.6	50.0	.7
10344	C	27 –48	.1	2.8	2.9	6.0	6.5	38.2	42.9	31.0	.3

[1] Determinations by H. W. Lakin and T. M. Shaw.

The mechanical composition does not vary significantly except in the colloid and clay fractions. The accumulation of clay in the B horizon is typical of the podzolic soils. It is noted that the percentages of clay and colloid in the parent material (C horizon) is higher than in the A_1 and A_2 but lower than in the B because the colloid has been carried downward during the weathering process and in part has stopped in the B horizon. The percentages of organic matter removed by the hydrogen peroxide treatment, preliminary to mechanical analysis, agree fairly well with the percentages of organic matter shown in table 10.

The chemical analysis of the Miami silt loam soil is shown in table 10. The high percentages of silica in the A_1 and A_2 horizons reflect the large quantity of silt shown by the mechanical analysis, since the silt is principally silica. The accumulation of iron oxide and aluminum oxide in the B horizon is due to the higher percentage of these two constituents in the colloid, which has accumulated in this layer.

TABLE 10.—*Chemical analysis of Miami silt loam (soil)* [1]

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	N	pH
		Inches	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	
10341	A_1	0 – 1½	72.32	2.75	9.63	0.66	1.26	2.11	0.87	0.75	0.13	0.11	0.13	9.50	100.28	7.19	0.32	7.0
10342	A_2	2½– 9	75.49	2.95	10.58	.70	.76	2.25	.87	.78	.10	.11	.07	5.25	99.91	2.70	.16	6.4
10343	B	11 –24	64.29	6.52	16.54	1.60	.90	3.10	.73	.71	.12	.14	.06	6.73	100.56	.83	.09	6.3
10344	C	28 –48	47.43	4.30	11.39	4.78	12.59	2.48	.06	.53	.09	.11	.09	15.80	100.36	.34	.06	7.9

[1] Determinations by G. Edgington.

The high percentages of calcium oxide and magnesium oxide in the C horizon, together with the carbonate carbon dioxide present, indicate the presence of calcium carbonate and magnesium carbonate, probably as dolomitic limestone. The high percentages of potassium and sodium oxides indicate considerable unweathered mineral. The percentages of titanium dioxide, manganous oxide, phosphorus pentoxide, and sulphur trioxide are not indicative of anything unusual. The higher ignition losses in the A_1 and C horizons reflect the organic content of the A_1 horizon and the carbonate content of the C horizon. The hydrogen-ion concentration is normal for this type of soil. The more basic reaction at the surface horizon is due to the presence of base exchange calcium in this layer. That of the C horizon is due to presence of carbonates of calcium and magnesium.

The chemical analysis of the colloids extracted from the four horizons of the Miami silt loam are shown in table 11. The percentages of silica and alumina are essentially constant throughout the profile, that of iron oxide, however, increases in the B horizon and drops off again in the C horizon. This iron oxide accumulation in the B horizon is characteristic of the podzolic profiles. It will be noted that a considerable portion of the iron oxide presumably present in the original colloid has been leached from the A_1 and A_2 horizons. The increase in calcium oxide in the C horizon, together with its carbon dioxide content, indicates the presence of calcium carbonate of colloidal dimensions in the parent drift. The high percentages of potassium oxide in the B and C horizons may be taken to indicate a low degree of weathering with respect to the potassium minerals in these horizons. The sodium content is low throughout the colloid of all the horizons; this indicates that the sodium is probably leached out before it is fragmented to colloidal dimensions. The percentages of titanium dioxide, manganous oxide, phosphorus pentoxide, and sulphur trioxide are not significant in this study of the gross composition of the colloid. The percentage of organic matter indicates a wide distribution of particle size in this soil, there being relatively small increase of organic matter in the colloid fraction as compared with the whole soil.

TABLE 11.—*Chemical analysis of Miami silt loam (colloid)*

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	N
		Inches	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
10341	A_1	0 - 1½	44.86	7.40	22.01	1.07	1.71	2.08	0.20	1.05	0.22	0.51	....	17.78	100.51	10.20	0.86
10342	A_2	2½ - 9	47.46	7.04	22.98	1.30	1.20	2.00	.22	.70	.12	.40	0.22	14.90	100.43	6.52	.53
10343	B	11 -24	47.07	11.50	23.38	2.00	.90	4.37	.21	.67	.09	.33	.12	9.45	100.27	1.68	.19
10344	C	28 -46	40.13	10.00	22.07	2.14	[1] 2.65	4.25	.22	.60	.08	.37	.17	9.53	99.77	1.03	.18

[1] 1.02 CO_2=2.65 $CaCO_3$.

Table 12 shows the derived data from the chemical analysis of the colloid of the Miami silt loam. The silica-sesquioxide ratios show a decrease in the B horizon as compared with A_1 and A_2. That this is chiefly owing to transfer of iron from the A to the B horizon is shown by the nearly constant values of the silica-alumina ratios in the profile and the relative increase of iron oxide shown by the silica-iron oxide and iron oxide-alumina ratios. These relations indicate that a part of the iron, at least, is present uncombined with the silica complex. The silica-total base ratios are low in general and yet indicate considerable leaching from the A_2 horizon. The relatively low values of the silica-base ratio in the A horizons indicates probable exchangeable bases associated with the organic matter. The silica-water, water-alumina, and water-sesquioxide ratios all show a remarkable constancy throughout the solum proper but alter rather sharply in the C horizon. The silica-sesquioxide and silica-alumina ratios in this colloid are higher in the Miami colloid than in the Carrington and the combined water of the soil acid is lower (table 8). These relations, together with the exceptionally high content of potassium (table 11), may be taken to indicate a relatively low degree of hydrolysis of the soil minerals associated with a high degree of maturity of profile characteristics. In so far as unweathered material is present in the colloid, particularly if that unweathered material is feldspathic, it should raise the silica ratios and lower the water content of the soil acid. (See also p. 28.)

TABLE 12.—*Derived data: Miami silt loam (colloid)*

Sample no.	Horizon	Depth	Molecular ratio								Combined water	Combined water of soil acid
			$\frac{SiO_2}{Fe_2O_3+Al_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$	$\frac{SiO_2}{H_2O}$	$\frac{H_2O}{Al_2O_3}$	$\frac{H_2O}{Fe_2O_3+Al_2O_3}$		
		Inches									*Percent*	*Percent*
10341	A_1	0–1½	2.84	3.45	16.1	0.214	6.70	1.40	2.46	2.03	7.68	10.68
10342	A_2	2½–9	2.87	3.50	15.9	.220	8.00	1.46	2.40	1.96	8.08	10.44
10343	B	11–24	2.60	3.41	10.9	.314	6.49	1.42	2.41	1.83	7.77	10.11
10344	C	28–48	2.63	3.41	11.5	.296	6.79	1.66	2.05	1.58	6.28	8.46

THE RUSTON LOAMY SAND PROFILE

The Ruston soils belong to the Red soils of the coastal plains. They have developed from unconsolidated sand and clay material, identical in character with that from which the Norfolk soils have developed. They have developed, however, in areas where the relief is stronger because of more thorough dissection by the existing cycle of erosion. The ground-water level stands well below the surface. The drainage for a long time has been good, and oxidation has been sufficient to give to these soils a reddish color in the B horizon. The A horizon is essentially identical in character with the Norfolk soils. The Ruston soils occur mainly in Alabama, Mississippi, and Louisiana. They have reached their normal stage of profile development. The profile used in this study is a loamy sand, collected 8 miles west of Cuthbert, Ga. The terrain is rolling to hilly and exceptionally well drained.

The A horizon is a brownish to yellowish gray, grading into yellowish-red loamy sand. It extends to a depth of 14 inches. The B horizon, extending from 14 to 40 inches, is a yellowish-red, friable sandy clay. The C horizon, or parent material, was collected to a depth of 60 inches. It is mottled and streaked light-red, yellow, and grayish-yellow sandy clay material.

Table 13 shows the mechanical analysis of the Ruston profile just described. The significant fact pointed out by the data is the almost complete removal of the colloid from the A horizon and its accumulation in the B. This is brought about by the process of podzolization. The organic-matter content, as indicated by the hydrogen peroxide method, is very low.

TABLE 13.—*Mechanical analysis of Ruston loamy sand* [1]

Sample no.	Horizon	Depth	Fine gravel (2–1 mm)	Coarse sand (1–0.5 mm)	Medium sand (0.5–0.25 mm)	Fine sand (0.25–0.1 mm)	Very fine sand (0.1–0.05 mm)	Silt (0.05–0.005 mm)	Clay (0.005–0 mm)	Colloid (0.002–0 mm)	Organic matter by H_2O_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
161	A	0–14	5.7	22.0	20.2	24.3	6.8	10.7	9.2	7.3	0.7
162	B	14–40	3.3	14.1	10.3	13.0	9.0	11.4	38.6	37.4	0.1
163	C	40–60	3.3	18.2	14.3	15.6	8.2	8.0	32.2	29.6	0.0

[1] Determinations by H. W. Lakin and T. M. Shaw.

Table 14 gives the chemical analysis of the three horizons of the Ruston profile under consideration. The high percentages of silica, due to the sandy nature of this soil, cause the relative changes in the other components. It may be noted, however, that the soil, on the basis of gross composition, is much lower in iron oxide and alumina than the soils heretofore considered. The thorough leaching to which the soil has been subjected is indicated by the low content of bases. Practically all these have been removed from this soil. The ignition loss and organic matter are also low. It is also true that the hydrogen-ion concentration is much lower than in the soils previously studied. There is no carbonate, either accumulated or residual, in the profile.

TABLE 14.—*Chemical analysis of Ruston loamy sand (soil)* [1]

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	N	pH
		Ins.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
161	A	0–14	87.28	2.40	4.78	0.01	0.36	0.21	0.17	1.14	0.10	0.07	0.21	3.35	100.14	1.85	0.04	4.8
162	B	14–40	75.61	5.29	12.32	.12	.07	.29	.03	.73	.05	.05	.01	5.04	100.12	.50	.04	4.9
163	C	40–60	81.02	3.36	11.23	.00	.00	.30	.06	.56	.03	.05	.02	3.73	100.54	.21	.02	4.8

[1] Determinations by G. Edgington.

Much more information can be gained by a study of the chemical composition of the colloid than by a study of that of the whole soil. Table 15 shows the chemical composition of the colloidal material extracted from the three horizons of the Ruston loamy sand. These three colloids have compositions which are remarkably constant. The most significant difference is in the organic matter, which is of course higher in the surface layer. It would seem that the soil-forming process in the case of the Ruston is primarily dependent only on two things—the organic life in the surface layer and the mechanical movement downward of the finer fraction, especially the colloid. The colloid apparently has undergone little chemical change during the soil-forming period.

TABLE 15.—*Chemical analysis of Ruston loamy sand (colloid)*

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	N
		Ins.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
161	A	0–14	37.16	12.81	31.30	0.23	0.46	0.79	0.20	0.93	0.10	0.17	0.12	16.87	101.23	4.53	0.20
162	B	14–40	36.59	12.76	32.57	.20	.43	.70	.35	.99	.07	.20	.09	15.36	100.31	2.55	.14
163	C	40–60	38.40	12.08	33.87	.27	.43	.74	.41	.98	.04	.16	.10	13.37	100.01	1.27	.12

The derived data for the Ruston colloid are shown in table 16. The ratios are all so constant that little comment is necessary. The various silica ratios indicate some translocation of iron oxide to the B horizon and an alteration of the iron-alumina ratios. The combined water of the soil acid is sensibly higher in the solum proper. The latter indicates, possibly, inaccuracy of organic-matter determinations.

TABLE 16.—*Derived data: Ruston loamy sand (colloid)*

Sample no.	Horizon	Depth	Molecular ratio								Combined water	Combined water of soil acid
			$\frac{SiO_2}{Fe_2O_3+Al_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$	$\frac{SiO_2}{H_2O}$	$\frac{H_2O}{Al_2O_3}$	$\frac{H_2O}{Fe_2O_3+Al_2O_3}$		
		Ins.									*Pct.*	*Pct.*
161	A	0–14	1.60	2.01	7.71	0.261	21.8	0.866	2.32	1.84	12.34	13.46
162	B	14–40	1.53	1.90	7.46	.249	21.7	.823	2.32	1.85	12.81	14.67
163	C	40–60	1.57	1.93	8.17	.227	21.7	.913	2.11	1.72	12.40	12.79

THE CECIL SANDY CLAY LOAM PROFILE

The Cecil and related soil series are dominant in the piedmont region extending from Virginia southward to Georgia and Alabama. The two principal types are the sandy loam and the clay loam. Most of the area mapped as the latter is a sandy loam with the A horizon removed by erosion, exposing the B horizon which is high in clay. Some of the clay loams are, however, not eroded but derived from crystalline rocks low in quartz. Cecil soils are derived from granites, gneisses, and schists. The parent material of the soils is the partially weathered decomposition products of these rocks.

The profile used in this study was obtained on the erosion station at Statesville, N. C., and was taken near the sample described by Middleton, Slater, and Byers (*14*). In this case, however, the C horizon was taken, in addition to the samples of A_1, B_1, and B_2 used by the investigators just mentioned. The profile may be described as follows (*14, pp. 7–8*):

> From 0 to 6 inches, the A horizon of light-brown sandy loam containing very little organic matter but more than either horizon B_1 or B_2. From 6 to 32 inches, the B_1 horizon, is a red clay loam which is very uniform in character. From 32 to 60 inches, the B_2 horizon of red clay loam with brown mottlings. This material is very compact when exposed and has a tendency to crack.

The C horizon consists of completely disintegrated schist in numerous narrow bands of various colors. It is pervious to water and has been extensively hydrolyzed and leached.

Table 17 gives the mechanical analysis of the Cecil profile. If one examines carefully the percentages of sand in the four horizons, it will be seen that the sands have remained undisturbed during the soil-forming process. The silt, however, has moved downward and accumulated in the B_2 horizon. The colloid and clay fractions have likewise moved downward, but they have accumulated to a greater extent in the B_1. These inferences are drawn assuming that the parent material was uniform in texture.

TABLE 17.—*Mechanical analysis of Cecil sandy clay loam (soil)*

Sample no.	Horizon	Depth	Fine gravel (2-1 mm)	Coarse sand (1-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.1 mm)	Very fine sand (0.1-0.05 mm)	Silt (0.05-0.005 mm)	Clay (0.005-0 mm)	Colloid (0.002-0 mm)	Organic matter by H_2O_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
9415	A	0–6	2.8	7.4	8.0	10.3	10.2	15.2	38.1	30.6	1.0
9416	B_1	6–32	1.7	3.6	4.5	9.6	7.2	14.5	58.4	55.7	.2
9417	B_2	32–60	1.3	2.8	3.0	6.9	7.6	21.9	56.4	50.8	.0
9418	C	60–84	.2	5.0	4.2	8.9	8.5	21.1	51.8	44.2	.1

Table 18 shows the chemical analysis of the Cecil profile. The hydrogen-ion concentration of these samples indicates a rather acid soil. The acidity of the first two layers is tempered somewhat by the presence of calcium, as will be seen in table 19. That the percentage of silica should dominate the analysis of the A horizon is to be expected from the sandy nature of this layer as indicated by the mechanical analysis. The figures for iron oxide and alumina indicate the movement downward of the colloidal complex, as was also shown by the mechanical analysis. The bases are all low, but especially so in the lower horizons. The titanium percentages are normal. The ignition loss is principally due to combined water. The figures for organic matter are low in comparison with the soils of other great groups so far considered.

TABLE 18.—*Chemical analysis of Cecil sandy clay loam (soil)*

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	Ignition loss	Total	Organic matter	CO_2 from carbonates	pH values
		Ins.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	
9415	A	0–6	74.66	4.95	12.33	0.05	0.24	[1] 0.57	[1] 0.21	1.30	0.27	0.16	7.09	101.86	2.44	0.0	4.9
9416	B_1	6–32	55.02	11.17	22.37	.04	.20	[1] .47	[1] .17	1.40	.05	.15	9.28	101.31	.34	.0	4.8
9417	B_2	32–60	52.04	12.55	24.10	.16	.10	[1] .35	[1] .10	1.37	.05	.16	9.92	101.15	.12	.0	4.6
9418	C	60–84	54.50	11.27	23.05	(2)	.07	.34	.01	1.69	.10	.11	8.97	100.11	.11	.0	4.6

[1] From other Statesville samples.

[2] Trace.

In table 19 is given the chemical analysis of the colloid of the Cecil profile. The most notable thing about the table is the constancy of composition throughout the profile. The B_1 and B_2 horizons are almost identical in composition, while the A and C show some variation in opposite directions. The slightly greater percentage of silica in the B horizon, as compared with that of the A, is not usual in podzolized soils. It is a real difference even though somewhat accentuated by the rather high percentage of organic matter found in the A horizon. The degree of variation in composition is better brought out by table 20, which shows the various derived data.

TABLE 19.—*Chemical analysis of Cecil sandy clay loam (colloid)*

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	Ignition loss	Total	Organic matter	CO_2 from carbonates
		Ins.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
9415	A	0- 6	30. 90	14. 57	32. 58	0. 39	0. 60	0. 32	0. 05	1. 13	0. 35	0. 38	17. 85	99. 12	4. 42	0. 0
9416	B_1	6-32	33. 88	17. 11	32. 30	. 22	. 21	. 23	. 08	. 84	. 07	. 26	13. 91	99. 11	. 64	. 0
9417	B_2	32-60	34. 27	17. 10	33. 03	. 13	. 21	. 26	. 08	. 83	. 06	. 27	12. 97	99. 23	. 55	. 0
9418	C	60-84	35. 13	17. 54	30. 52	. 22	. 11	. 04	. 07	1. 05	----	----	12. 85	------	. 45	. 0

TABLE 20.—*Derived data: Cecil sandy clay loam (colloid)*

Sample no.	Horizon	Depth	Molecular ratio								Combined water	Combined water of the soil acid
			$\frac{SiO_2}{Fe_2O_3+Al_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$	$\frac{SiO_2}{H_2O}$	$\frac{H_2O}{Al_2O_3}$	$\frac{H_2O}{Fe_2O_3+Al_2O_3}$		
		Ins.									*Pct.*	*Pct.*
9415	A	0- 6	1. 25	1. 61	5. 62	0. 286	17. 4	0. 632	2. 55	1. 98	13. 42	14. 60
9416	B_1	6-32	1. 33	1. 78	5. 25	. 339	40. 1	. 743	2. 40	1. 79	13. 26	13. 60
9417	B_2	32-60	1. 32	1. 70	5. 31	. 331	47. 7	. 806	2. 18	1. 64	12. 41	12. 69
9418	C	60-84	1. 43	1. 95	5. 31	. 308	58. 8	. 830	2. 35	1. 72	12. 39	12. 63

The silica-sesquioxide and silica-alumina ratios show that the soil-forming process has brought about a decrease in these ratios. Thus the colloid of the sandy A horizon is more lateritic, even, than the lateritic material from which it is formed. The silica-iron ratio remains fairly constant throughout the profile although evidence of fractionation of the colloid appears in both this and the iron oxide-alumina ratios. The quantity of bases present is so small that a comparison of the silica-total bases ratios of the various horizons is not very reliable. It is noteworthy, however, that the ratio for the C horizon is more than three times that of the A. It has been mentioned that this higher quantity of bases in the A horizon is associated with the presence of organic matter in this layer. The combined water and combined water of the soil acid are rather constant throughout. The 1-percent higher value for combined water of the soil acid found in the A horizon may be due to error in the factor for estimating organic matter. The water-alumina and water-sesquioxide values in the A horizon may be high owing to the same error or to a greater degree of hydration in the A layer.

THE COLUMBIANA CLAY PROFILE

The Columbiana clay profile was selected by H. H. Bennett as a highly aluminous Laterite, occurring in the vicinity of Columbiana in Costa Rica. He describes it as "an extraordinarily friable red clay which is naturally well drained, is strongly resistant to erosion, is easily tilled, and highly productive. The land may be plowed immediately after a heavy rain." It is described by H. Rowe of the United Fruit Co. as derived from volcanic material. The profile, as collected, is described by T. D. Rice of the Division of Soil Survey as follows:

> 0 to 10 inches, very dark clay. When the material is broken out it falls apart into finely granular particles and occasionally forms rounded clods. The clods are brittle and break up readily under slight pressure, but do not fall apart or melt down when saturated with water.
>
> 10 to 25 inches, very dark brown clay with slight reddish tinge. The material breaks up forming aggregates that vary in size from fine granules to rounded clods an inch or more in diameter. The clods are more compact than those of the surface layer.
>
> 25 to 40 inches, dark-brown clay with more yellow color than the layers above. This layer is firm in position but breaks up into rounded clods and a small proportion of finely granular material. The clods are more compact and appear to be remnants of decomposed rock.
>
> 40 to 92 inches, partly decomposed parent material. The color is dark yellowish brown speckled with various colors of weathered minerals. The material is compact but can be crushed under considerable pressure.
>
> 92 to 104 inches, partly decomposed parent material; yellowish brown with white specks. It is not so compact as the layer above and breaks up under pressure into fine granules.
>
> 104 to 124 inches, this material in general is light colored with gray, white, and dark-brown streaks and concretions. It breaks up more readily than the layer above and forms a light grayish-yellow powder.

Table 21 shows the mechanical analysis of the Columbiana profile. In this case the mechanical analysis has very little significance, since the soil is made up almost entirely of aggregates. The amount of colloid or clay obtained depends on the quantity of these broken down and the permanence of dispersion obtained. These soils were very difficult to disperse and no adequate degree of dispersion was obtained of sample 9807 either during mechanical analysis or while extracting the colloid.

TABLE 21.—*Mechanical analysis of Columbiana clay*

Sample no.	Horizon	Depth	Fine gravel (2-1 mm)	Coarse sand (1-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.1 mm)	Very fine sand (0.1-0.05 mm)	Silt (0.05-0.005 mm)	Clay (0.005-0 mm)	Colloid (0.002-0 mm)	Organic matter by H_2O_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
9804	A_1	0- 10	0.4	0.9	2.0	5.1	12.8	28.8	45.2	37.9	4.5
9805	A_2	10- 25	.3	.9	2.2	5.2	7.8	28.6	52.4	52.1	2.3
9806	A_3	25- 40	.3	.7	1.7	6.3	8.3	22.5	58.9	50.8	1.0
9807	B	40- 90	2.3	9.2	8.3	18.9	21.2	29.2	9.8	5.1	.8
9808	C_1	92-104	5.6	8.5	5.3	8.0	8.5	30.1	33.7	22.3	.2
9809	C_2	104-124	2.4	7.0	5.3	9.0	10.0	32.3	33.3	22.1	.5

The results of the chemical analysis of the Columbiana clay are given in table 22. This table also shows the pH determinations on these samples. They are not so acid as the Cecil and Ruston, but more acid than the other soils considered previously. The organic matter by the hydrogen peroxide method (table 21) is considerably lower than the figures reported by the combustion method (table 22).

TABLE 22.—*Chemical analysis of Columbiana clay (soil)*

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	CO_2 from carbonates	pH
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
9804	A_1	0–10	19.80	15.60	37.09	0.50	0.25	0.14	0.23	2.02	0.26	0.31	0.24	24.10	100.54	6.01	0.0	5.1
9805	A_2	10–25	20.40	16.28	37.76	.43	.10	.14	.22	2.03	.23	.31	.15	22.03	100.08	3.07	.0	5.3
9806	A_3	25–40	19.66	17.00	38.47	.15	.19	.20	.00	2.44	.20	.28	.22	21.32	100.19	2.41	.0	5.0
9807	B	40–90	21.08	16.99	38.46	1.80	.29	.10	.00	2.17	.18	.67	.34	18.47	100.55	.59	.0	5.4
9808	C_1	92–104	33.54	17.00	32.82	.49	.28	.00	.00	1.76	.20	.34	.10	13.93	100.46	.14	.0	5.8
9809	C_2	104–124	39.79	0.78	36.90	.23	.18	.04	.00	1.95	.04	.19	.07	14.20	100.37	.11	.0	5.1

The low values are probably due to the catalytic action of manganese dioxide present (*16*). The organic matter in the soil remains relatively high to an unusual depth. It appears when all the characteristics of this soil are considered that the first three samples together form the A horizon. Whether any horizonal difference warrants the other designations is uncertain. The most striking point to be observed is the low percentage of silica throughout the profile. The source material presumably was originally volcanic ash and contained relatively little or perhaps no quartz. The silica present as combined silica has been progressively removed by leaching as the material decomposed. If it be assumed that the geologic material was uniform to the depth of the sample (124 inches) when deposited, then it follows that the silica percentage has been reduced in the first layer to one-half its original value. The iron oxide percentage, on the other hand, has more than doubled on the same basis. The percentage of alumina remains rather constant throughout the profile. The magnesium oxide percentage shows an increase in the fourth layer which is unexplainable on the basis of soil-forming processes. It is likely that the volcanic ash at this depth contained some material high in magnesium which was not present in the other layers, or present to less extent. The same is true of the phosphorus pentoxide content, which is high in this particular layer. There is not enough variation in the percentage of the other constituents to warrant any particular comment.

The results of the chemical analysis of the colloid extracted from the Columbiana clay shown in table 23 reveal a remarkable similarity to those of table 22. An examination of these two tables shows that the corresponding values in the two are very good duplicates of each other in many cases, particularly in the A-horizon samples. This can only mean that the whole soil is or was colloidal in character. The material must have been very fine volcanic ash and originally uniform in composition. The percentages of silica in the colloid of the first 3 layers are practically constant. They increase materially in the lower 3 layers. The iron oxide percentages remain practically constant, save in the last layer which has a much lower value. The colloid from this layer is white, indicating the absence of any ferric oxide. Layer 5, from standpoint of color, is a transition from the deep brown of the first 4 layers to the white of the bottom layer.

The color indicates the presence of the iron as the oxide. The percentage of alumina remains reasonably constant in the first 4 layers of the profile. The magnesium oxide percentage increases in the fourth layer colloid as it did in the soil analysis, but to less degree. The distribution of calcium is rather uniform and is normal throughout the profile. The colloids are, without exception, low in both potash and soda. Phosphorus pentoxide, as was the case in the soil analysis, is highest in the fourth layer. The organic matter concentrates to some extent in the extracted fraction, but not to the degree found in the profiles considered previously in this bulletin. The ignition loss indicates a high percentage of combined water.

TABLE 23.—*Chemical analysis of Columbiana clay (colloid)*

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	Ignition loss	Total	Organic matter	CO_2 from carbonates
		Inches	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
9804	A_1	0–10	22.04	15.36	36.02	0.23	0.33	0.18	0.07	1.83	0.18	0.48	24.11	100.83	6.44	0.0
9805	A_2	10–25	22.32	16.15	30.50	.43	.20	.17	.11	1.93	.15	.33	22.51	100.80	4.80	.0
9806	A_3	25–40	22.01	16.26	37.58	.35	.15	.18	.05	1.81	.14	.36	21.06	100.55	3.81	.0
9807	B	40–90	26.59	15.48	36.51	.77	.14	.08	.00	2.20	.12	.61	17.67	100.17	1.75	.0
9808	C_1	92–104	32.09	18.56	31.50	.15	.12	.15	.00	1.81	.34	.42	15.04	100.18	1.07	.0
9809	C_2	104–124	39.36	6.95	35.72	.13	.12	.04	.00	2.88	.08	.16	14.57	100.01	.55	.0

The derived data for the colloid of the Columbiana profile are shown in Table 24. The silica-sesquioxide ratio falls below unity in the first four layers, while it is 1.25 in the fifth and 1.66 in the sixth. The fact that this ratio for the first horizon is less than one-half that for the deepest layer indicates that the soil-forming process here is one of laterization. In the case of the Cecil we have lateritic soil forming from material which was already lateritic, while in the Columbiana we have a Laterite soil forming from less lateritic parent material. The fact that the material is relatively nonlateritic at the depth of the sixth layer indicates that, comparatively speaking, the soil may be of recent origin. The silica to iron oxide ratio shows clearly the relative increase of iron during the weathering of the material. The silica to alumina ratio remains essentially constant in the first 3 layers, and increases in the 3 deeper layers. This may be significant

TABLE 24.—*Derived data: Columbiana clay (colloid)*

Sample no.	Horizon	Depth	Molecular ratio								Combined water	Combined water of soil acid
			$\frac{SiO_2}{Fe_2O_3+Al_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$	$\frac{SiO_2}{H_2O}$	$\frac{H_2O}{Al_2O_3}$	$\frac{H_2O}{Fe_2O_3+Al_2O_3}$		
		Inches									*Percent*	*Percent*
9804	A_1	0–10	0.81	1.04	3.78	0.273	21.4	0.366	2.83	2.22	17.67	17.98
9805	A_2	10–25	.81	1.01	3.66	.283	18.5	.360	2.73	2.10	17.71	18.07
9806	A_3	25–40	.78	.99	3.50	.277	22.7	.362	2.74	2.15	17.85	18.14
9807	B_1	40–90	.97	1.24	4.55	.271	18.3	.486	2.54	2.00	15.92	16.35
9808	B_2	92–104	1.25	1.78	4.58	.377	43.6	.675	2.56	1.80	13.96	14.20
9809	C	104–124	1.66	1.87	15.00	.124	96.0	.831	2.25	2.00	14.02	14.14

as indicating that a quasi-equilibrium ratio between the silica and alumina is reached in the dispersed material. This ratio has a value of 1.04, 1.01, and 0.99 for the first 3 horizons. Prior to the time when this ratio is reached silica is removed in greater molecular quantities than is alumina. After this ratio has been reached, if solution takes place, it is in equimolecular proportions. There is a strong indication that the alumina and silica are combined in the proportion of 1 to 1. If the data given by Anderson and Byers (*2*) on the Nipe clay are recalculated to give the silica-alumina ratios the following are found: 0 to 12 inches, 1.10; 12 to 60 inches, 0.82; 100 to 144 inches, 1.22.

Even though the soil has a silica-sesquioxide ratio of 0.17 to 0.42, the silica-alumina ratio of the colloid does not fall appreciably below unity. The silica to total base ratio is high for two reasons: (1) The soil-forming material contained low percentages of bases, and (2) leaching has been very thorough.

The combined water and combined water of the soil acid are somewhat higher than the corresponding values for the Cecil soils. Again the upper portion of the soil colloid is more highly hydrated than the lower, indicating that the process of hydration proceeds along with the soil-forming processes. There is no evidence of irreversible dehydration of the colloid by wetting and drying, at least with respect to the water classed as combined water. The ratio of water to alumina increases from bottom to top. The same is true of the water-sesquioxide ratio. This progressive increase of water ratios is capable of the same divergent interpretations as those discussed on page 11.

THE PODZOL PROFILES

The soils considered so far in the Pedalfer group have represented progressive weathering of the minerals. The same forces which have brought about changes in the surface horizon have also acted on the lower layers, but to less extent. The accumulation of iron oxide and alumina in the B horizon has been brought about chiefly by mechanical rather than chemical forces. The Podzol soils present a somewhat different situation. The formation of Podzols represents not only mechanical accumulation of the finer materials in the B horizons but also a change in the chemical composition of the colloidal material accumulated. This material enriching the B horizon may consist of iron oxide, alumina, or organic matter. The organic matter may or may not be chemically combined with the sesquioxides.

Briefly, the Podzol profile as developed in the United States may be described as follows: Underneath the surface litter is a layer of well-decomposed organic matter mixed with rather sandy mineral matter. It is dark in color, owing to the presence of the organic matter. Underneath this layer is a gray one containing relatively little colloid and organic matter. It is very thoroughly leached. Beneath this layer is the B horizon, or zone of enrichment. It is a dark-brown layer rich in the oxides of iron, alumina, and organic matter, as already mentioned. The color is more intense at the upper portion of the layer and grades off as it ranges downward to the parent material. The C horizon may be a variety of materials but is lower in the oxides of iron and alumina than the B horizon.

Two Podzols are considered in this bulletin, the Caribou loam from Maine and the Au Train sand from Michigan.

THE CARIBOU LOAM PROFILE

The Caribou is the predominating soil series of the "big woods" area of the New England States and of a portion of Canada. This is the famous "potato" soil of Maine. The Caribou loam has developed on well-drained areas of heavy vegetative cover.

The soil profile used in this investigation was collected in a virgin spruce forest 5 miles northeast of Presque Isle, Maine. The soil profile is described as follows:

Horizon A_1, 0 to ¾ inch. Composed of black pellets which seem to be the casts of earthworms which were numerous.

Horizon A_2, ¾ to 2 inches. A gray layer varying from a mere film to 2 inches in thickness.

Horizon B_1, 2 to 4 inches. Rich brown, very variable in thickness, slightly heavier and more compact than A_2.

Horizon B_2, 4 to 6 inches. A bright yellow brown and heavier than the B_1.

Horizon C, 8 to 24 inches. A greenish blue-gray color and composed of unweathered glacial drift. Caribou parent material is glacial till derived from shaly limestone.

The mechanical analysis of the Caribou profile is shown in table 25. The most notable feature of the table is the indication that mechanical fragmentation is taking place, the first four grades of sand sizes being much more abundant in the C horizon than in the upper layers. This fragmentation may be caused both by mechanical and by chemical processes. The B_1 and B_2 horizons are, as in the podzolic soils already considered, heavier in texture than either the A or the C. The organic matter as indicated by the peroxide method is very high in the A_1 layer and drops sharply in the gray layer. The accumulation of organic matter in the B horizon is not marked in the soil as a whole.

TABLE 25.—*Mechanical analysis of Caribou loam* [1]

Sample no.	Horizon	Depth	Fine gravel (2-1 mm)	Coarse sand (1-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.1 mm)	Very fine sand (0.1-0.05 mm)	Silt (0.05-0.005 mm)	Clay (0.005-0 mm)	Colloid (0.002-0 mm)	Organic matter by H_2O_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
10540	A_1	0-¾	1.1	1.9	1.8	3.8	7.3	35.6	23.0	13.8	23.4
10541	A_2	¾-2	1.4	2.1	2.0	4.1	10.5	51.4	23.1	12.3	4.8
10542	B_1	2-4	2.7	3.1	2.4	4.3	9.4	42.5	29.9	18.3	4.9
10543	B_2	4-6	3.5	4.3	2.0	4.2	9.2	42.8	29.2	15.6	3.4
10544	C	8-24	10.8	12.0	7.4	11.8	10.9	28.4	16.0	10.7	.3

[1] Determinations by H. W. Lakin and T. M. Shaw.

Table 26 shows the chemical analysis of the Caribou profile. The silica percentage is relatively low in the A_1 owing to the diluting effect of the organic matter. In the gray layer the silica content runs very high and then shades off in the B_1 and B_2 due to the presence of the oxides of iron and alumina. The parent material, C, is higher in silica than the B horizon. The percentages of iron and alumina rise in a characteristic manner in the B_1 and B_2 and drop slightly in the C. There is nothing in the percentages of bases requiring comment. The ignition loss in this case is practically all organic matter. The pH determinations indicate a very acid condition throughout the profile, which is characteristic of all soils found under coniferous forests.

TABLE 26.—*Chemical analysis of Caribou loam (soil)* [1]

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	N	pH
		Inches	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	
10540	A_1	0-¾	57.49	2.47	7.83	0.63	1.25	0.87	0.99	0.75	0.20	0.21	0.29	27.18	100.10	25.26	0.86	5.1
10541	A_2	¾- 2	78.95	2.07	8.29	.45	.38	1.06	1.31	1.06	.08	.10	.20	6.25	100.20	3.86	.22	4.2
10542	B_1	2- 4	69.22	5.28	11.59	1.08	.50	1.21	1.36	.92	.09	.23	.13	8.54	100.15	5.52	.23	4.5
10543	B_2	4- 6	64.63	6.67	14.32	1.66	.41	1.30	1.36	.93	.06	.16	.16	8.40	100.06	4.17	.12	4.7
10544	C	8-24	70.89	5.27	13.89	1.80	.48	1.49	1.70	.85	.05	.11	.17	3.42	99.71	.86	.08	5.6

---

[1] Determinations by G. Edgington.

The results of the chemical analysis of the colloids extracted from the Caribou profile are shown in table 27. The percentages of silica are lower in the B_1 and B_2 than in the other horizons. This reflects the increase in iron oxide and alumina content, shown in the next two columns. In this particular Podzol it is seen that there has been enrichment only with respect to the iron oxide. There has been no marked accumulation of either alumina or organic matter relative to the soil as a whole. The distribution of bases throughout the profile is normal. The high percentages of magnesium and potassium indicate considerable unweathered minerals throughout the profile. The organic matter is very high, in comparison with the soils already studied, down to the C horizon.

TABLE 27.—*Chemical analysis of Caribou loam (colloid)*

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	N
		Inches	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
10540	A_1	0-¾	34.57	5.26	16.99	1.18	1.27	2.57	0.21	1.15	0.18	0.38	0.50	36.07	100.84	29.27	1.70
10541	A_2	¾- 2	43.31	4.82	21.84	1.33	.72	2.62	.16	1.25	.12	.57	.26	23.18	100.18	13.52	1.20
10542	B_1	2- 4	32.06	15.68	19.67	1.47	.67	2.07	.06	.81	.08	.65	.27	27.43	100.92	10.90	.94
10543	B_2	4- 6	28.09	17.62	22.16	1.77	.26	1.03	.33	.69	.05	.42	.34	27.44	100.20	14.55	.63
10544	C	8-24	38.29	13.08	25.40	2.80	.26	3.85	.09	.97	.18	.32	.11	14.04	99.99	5.43	.66

The derived data for the Caribou are given in table 28. The decreases in silica-sesquioxide ratio in the B_1 and B_2 horizons indicate

TABLE 28.—*Derived data: Caribou loam (colloid)*

Sample no.	Horizon	Depth	Molecular ratio								Combined water	Combined water of soil acid
			$\frac{SiO_2}{Fe_2O_3+Al_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$	$\frac{SiO_2}{H_2O}$	$\frac{H_2O}{Al_2O_3}$	$\frac{H_2O}{Fe_2O_3+Al_2O_3}$		
		Inches									*Pct.*	*Pct.*
10540	A_1	0-¾	2.89	3.47	17.5	0.198	8.76	1.40	2.48	2.03	7.40	12.63
10541	A_2	¾- 2	2.95	3.30	23.9	.141	9.25	1.34	2.50	2.19	9.66	12.80
10542	B_1	2- 4	1.83	2.76	5.43	.509	7.36	.811	3.41	2.28	10.53	14.25
10543	B_2	4- 6	1.43	2.15	4.24	.507	7.15	.596	3.59	2.38	12.80	16.46
10544	C	8-24	1.92	2.56	7.78	.320	5.35	1.01	2.53	1.90	9.21	12.00

the characteristic podzolization process. An examination of the silica-iron oxide and silica-alumina ratios indicates that there has been an accumulation of both these constituents in the B layers. The silica-sesquioxide ratio in the B_2 approaches that of the lateritic soils, while that of the A horizons corresponds to the Gray-Brown Podzolic group. The silica to total bases ratio shows a rather young soil colloid, since it is not leached to the extent of the Red and Yellow soils of the coastal plains, although it has a heavier rainfall. The profile development, however, is good. The calculation of combined water of the soil acid is limited in value in the case of this and other Podzol soil colloids, because the organic matter subtracted from the ignition loss involves the use of the organic factor which is very uncertain. The correction factor, therefore, renders the combined water values used to obtain the combined water of the soil acid quite inaccurate. Also, in this soil, the bases associated with the organic matter and the probable presence of unweathered colloid minerals make any conclusions based upon the water relations at best of only qualitative significance (p. 4).

THE AU TRAIN SAND PROFILE

The Au Train sand is also a Podzol, but differs from the Caribou in that it is derived from almost pure sand. The sample was collected in Luce County, Mich. The horizons are described as follows:

Horizon A_1, 0 to 2 inches. Leaf litter and mold.
Horizon A_2, 2 to 10 inches. Gray sand.
Horizon B_1, 10 to 12 inches. Very dark brown loamy sand.
Horizon B_2, 12 to 40 inches. Yellowish- or reddish-brown sand.
Horizon C, 40 to 60 inches. Pale-yellow sand.

The mechanical analysis of this profile is shown in table 29. With the exception of the organic matter in the A_1 horizon, this soil is almost all medium and fine sand. The quantities of colloid are so small that it is evident the collection of colloid and of significant analytical data presents a difficult problem. Since Podzols of like character are of extensive occurrence, the data presented have value, even though quantitative inferences are perhaps unwarranted.

TABLE 29.—*Mechanical analysis of Au Train sand* [1]

Sample no.	Horizon	Depth	Fine gravel (2-1 mm)	Coarse sand (1-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.1 mm)	Very fine sand (0.1-0.05 mm)	Silt (0.05-0.005 mm)	Clay (0.005-0 mm)	Colloid (0.002-0 mm)	Organic matter by H_2O_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
10644	A_1	0-2	0.1	2.8	14.4	22.2	2.6	5.7	5.7	4.6	44.7
10645	A_2	2-10	.8	13.2	40.3	36.4	3.7	3.5	1.4	.7	.3
10646	B_1	10-12	.8	9.4	30.2	46.2	5.5	1.4	2.8	.8	2.6
10647	B_2	12-40	.5	5.8	23.2	60.9	6.0	.8	1.1	1.3	1.2
10648	C	40-60	.0	3.2	32.2	60.2	3.6	.1	.5	.4	.0

[1] Determinations by H. W. Lakin and T. M. Shaw.

The chemical analysis of the Au Train profile is shown in table 30. The silica content represents almost all the sample in every case except the A_1 which has 42.49 percent ignition loss.[3] As was the case with the Caribou the percentage of alumina is highest in the B_1 and B_2 horizons. The iron percentages are so small that they mean but little. Both calcium and potassium are present to a surprising extent, which fact probably accounts for the vegetation being able to form the soil. Organic matter has accumulated in the B layers in excess of that in the A_2.

TABLE 30.—*Chemical analysis of Au Train sand (soil)* [1]

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	N	pH
		Ins.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	
10644	A_1	0- 2	51.84	0.47	2.39	0.07	0.86	0.86	0.13	0.14	0.24	0.12	0.28	42.49	99.80	-----	1.13	5.8
10645	A_2	2-10	95.49	.16	2.12	(2)	.15	.98	.18	.09	.01	.01	.01	.08	99.88	0.63	.02	4.3
10646	B_1	10-12	87.40	.79	4.92	.01	.26	1.96	.24	.17	.02	.06	(2)	3.70	99.53	2.11	.07	4.6
10647	B_2	12-40	90.84	.60	4.29	(2)	.20	1.73	.31	.11	.01	.03	(2)	1.41	99.49	1.02	.02	5.2
10648	C	40-60	92.99	.50	3.76	.02	.24	1.60	.36	.12	.01	.02	(2)	.24	99.92	.10	.01	5.9

[1] Determinations by G. Edgington.
[2] Trace.

The results of the chemical analyses of the colloids from the Au Train sand are given in table 31. As is evident from the texture of the soil (table 29), the extraction of the colloids in sufficient quantities was difficult because of the small amount present and it would seem to follow that if colloidal silica exists in the soil its presence would be exceptionally marked in these colloids. It was impossible to get even muddy water from the C horizon of the soil, hence no analysis for the colloid could be made. Included in the table is the analysis of the residue obtained by evaporation of the highly colored filtered extract from the A horizon. It has a certain interest as representing the character of the soluble material obtained from this soil. The data of table 31 show the accumulation of iron oxide, alumina, and organic matter in the B_1 and B_2 horizons which is characteristic of Podzol colloids. The organic carbon of these colloids is very high in all four of the colloids. Indeed, it is almost proper to consider them as organic colloids contaminated by mineral colloids.

TABLE 31.—*Chemical analysis of Au Train sand (colloid)*

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter	N
	Ins.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
10644	(1)	0- 2	1.00	0.25	1.08	0.53	2.73	0.83	0.80	(2)	1.00	0.54	----	90.64	[3]99.49	72.03	5.68
10644	A_1	0- 2	12.35	.98	3.81	.45	1.60	.32	.40	0.11	.43	.37	----	79.50	100.38	74.16	2.06
10645	A_2	2-10	47.27	3.51	14.19	.57	.48	.62	.66	(2)	.07	.37	----	31.75	99.39	25.53	1.40
10646	B_1	10-12	11.86	6.63	16.88	.33	.54	.62	.22	(2)	.09	.39	----	62.58	100.04	48.45	1.01
10647	B_2	12-40	12.38	4.70	23.95	.25	.41	.48	.30	.26	.09	.39	----	57.47	100.74	40.46	.87
10648	C	40-60	(4)	----	----	----	----	----	----	----	----	----	----	----	----	----	----

[1] The water-soluble extract of the soil.
[2] Quantities not determined.
[3] Total is low due to K and Na being estimated as oxides when they are largely carbonates.
[4] No colloid in quantity sufficient for examination could be obtained.

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[3] No organic-matter determination was made of the A_1 horizon, because the sample was lost before the analyses of organic carbon were started.

The derived data for the Au Train colloids are given in table 32. The high silica-sesquioxide and silica-alumina ratios of the A_1 and A_2 horizons are probably to be regarded as due to the presence of quartz particles of colloidal dimensions or of silica gel rather than as due to combined silica in an alumino-silica complex. The silica ratios all decrease in the B horizon in the manner characteristic of Podzols. In the presence of such large quantities of organic matter the water ratios are even less reliable in this profile than in the Caribou profile.

TABLE 32.—*Derived data: Au Train sand (colloid)*

Sample no.	Horizon	Depth	Molecular ratio								Combined water	Combined water of soil acid
			$\frac{SiO_2}{Fe_2O_3+Al_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$	$\frac{SiO_2}{H_2O}$	$\frac{H_2O}{Al_2O_3}$	$\frac{H_2O}{Fe_2O_3+Al_2O_3}$		
		Inches									*Percent*	*Percent*
10644	A_1	0- 2	4.72	5.49	33.7	0.163	3.70	0.578	9.51	8.17	5.40	24.81
10645	A_2	2-10	4.88	5.65	35.8	.158	20.0	2.04	2.70	2.39	6.22	9.30
10646	B_1	10-12	.95	1.19	4.82	.247	6.70	.242	4.91	3.95	14.13	28.47
10647	B_2	12-40	.78	.88	7.01	.125	8.02	.212	4.13	3.67	17.01	20.36

GENERAL DISCUSSION

The profile data presented in detail in tables 1 to 32, inclusive, are derived from a group of soils selected for the primary purpose of obtaining the distinguishing analytical characteristics associated with the field differentiation of the great soil groups. For the purpose of bringing the differences into clear relief the more instructive of the derived data are assembled into separate tables. For simplicity the portions of each horizon (or other subdivision) are averaged in tables 33 to 38. The data are arranged in the order of the previous treatment.

SILICA-SESQUIOXIDE RATIOS

The most widely used, and in some respects the most generally useful, ratio found in the tables of derived data is that of silica to sesquioxides. It was found by Holmes (*9*) and by Holmes and Edgington (*10*) that this ratio has a characteristic value for the colloid of a given soil series. Table 33 gives the silica-sesquioxide ratios for

TABLE 33.—*Silica-sesquioxide ratios for colloids of 8 soils*

Horizon	Ratios for soil series indicated							
	Barnes	Carrington	Miami	Ruston	Cecil	Columbiana	Caribou	Au Train
A	3.05	2.46	2.86	1.60	1.25	0.80	2.93	4.80
B	3.13	2.34	2.60	1.53	1.33	1.11	1.03	.87
C	3.36	2.36	2.63	1.57	1.43	1.06	1.92	----------

the soil colloids of the 8 soils considered in this investigation. For the first 5 of these no sharp differences appear, which would indicate no great difference in the colloids of the three horizons. In the Barnes colloid the lowest ratio appears in the upper portion of the profile. In the Carrington, Miami, and Ruston the highest ratio is in the upper portion. In the Cecil soil only a very moderate increase with depth is noted. The divergence in the profile is more marked in the last 3 soils. In the Columbiana soil the removal of silica from the A horizon is shown to be extensive. The 2 Podzols show the special characteristic of the Podzol colloids; high silica in the A horizon and marked decrease in the B.

The degree of uniformity of colloid composition in all the profiles, as shown by the silica-sesquioxide ratio, is taken to indicate that the colloid accumulation in the B horizon is effected chiefly by transfer downward of the whole colloid. In the Podzols definite fractionation is indicated, probably induced by the type of organic matter derived from coniferous vegetation usually found on these soils. The Miami soil, representative of the Gray-Brown Podzolic group, shows definite indication of similar behavior to a less marked degree.

A progressive lowering of the silica-sesquioxide ratio is observed in the first 6 colloids, with the exception of the Miami. It has been observed (p. 11) that the potassium content of this colloid indicates the probable presence of unweathered feldspars. If it be assumed that all the potassium is present as unweathered orthoclase, and the silica-sesquioxide ratios be calculated upon this assumption, the values obtained become 2.41, 2.22, and 2.01 for the A, B, and C horizons. This sweeping assumption is not warranted but it serves to indicate that the gross composition of the colloid may not be an accurate indication of the composition of the dominant colloid complex. McCaughey and Fry (*11*) found much feldspathic material in the sands and silts of the soils developed from glacial drift. It does not necessarily follow that such material is present in the colloid, but it seems extremely probable that it is.

SILICA-ALUMINA RATIOS

The silica-alumina ratios for the colloids are given in table 34. They show in general the same kind of variation from Chernozem to Laterite, as is shown in table 33 by the silica-sesquioxide ratios. In the Barnes and Carrington soils, part, if not all, of the iron present is assumed to be a portion of the characteristic colloid complex. These colloids are nearly white after treatment with hydrogen peroxide. Hence, for these soils, the ratios of table 33 are more indicative of the colloid complex than those of table 34. In the case of the Miami by no means all of the iron is a part of the silicate complex, but apparently a portion of it is. In the A and B horizons of the remaining soils, including the Podzols, the iron is probably present as the free oxide, or hydroxide, hence the silica-alumina ratio better characterizes the composition of these soil acid complexes. In the C horizon of the Columbiana, which is very light colored, it appears that the iron is probably partly combined with the silica. It is interesting to note that in the Columbiana the silica-alumina ratio does not go below 1. In the little-weathered Barnes, it is upward of 4, but the colloid acid complex, since it contains iron, is not properly so expressed. It would seem proper to assume that this complex is best represented by a value lying in the neighborhood of 3.5. The extremely high silica-alumina ratio of the Au Train A horizon is probably due to the presence of free silica of collodial dimensions. The mechanical analysis of this soil shows its extremely sandy character.

TABLE 34.—*Silica-alumina ratios for colloids of 8 soils*

Horizon	Ratios for soil series indicated							
	Barnes	Carrington	Miami	Ruston	Cecil	Columbiana	Caribou	Au Train
A	4.07	3.20	3.48	2.01	1.61	1.01	3.42	5.57
B	4.10	3.10	3.41	1.90	1.77	1.48	2.46	1.03
C	4.41	3.23	3.41	1.93	1.95	1.87	2.56	----------

SILICA-TOTAL BASE RATIOS

In table 35 are assembled the ratios by formula weights of the silica to total bases. The most striking feature of the relations between the soil groups illustrated by this table is the wide contrast between the total base content of the Laterite and lateritic soils as compared with the five other soils. The extremely low base content of the Ruston, Cecil, and Columbiana soils indicated by this ratio is further accentuated by the low content of silica. In this relation, as in the others, the failure of the Miami to correspond to what would appear to be its proper position in the series may with fair reason be ascribed to its unweathered mineral content. The relations shown by the Carrington, Miami, Caribou, and Au Train all indicate a higher base content and less weathering in the C horizon than in the A, with no similar uniformity showing itself with respect to the B. The relatively small variation in the Chernozem, the Barnes, is to be expected, by reason of the low rainfall under which it develops.

TABLE 35.—*Silica-total base ratios for the colloids of 8 soils*

Horizon	Ratios for soil series indicated							
	Barnes	Carrington	Miami	Ruston	Cecil	Columbiana	Caribou	Au Train
A	6.96	8.63	7.05	21.8	17.4	21.3	8.01	11.85
B	7.12	9.28	6.49	21.7	43.4	43.6	7.21	6.76
C	7.27	8.62	6.79	21.7	58.8	96	5.35	8.02

The very marked decrease in bases at greater depth in the Columbiana and Cecil may properly be ascribed to the retention of bases in the surface soils by organic matter and to the porous character of the substrata which permit ready percolation. Apparently, a different situation in the Ruston is owing in part at least to a more uniform distribution of organic matter.

The high base content of the high silica-sesquioxide soils is undoubtedly due in part to the immaturity of the soils, whether as a result of lack of hydrolysis or of leaching. Nevertheless, this fact may also be attributed in part to the more strongly acid character of the silica-alumina complexes, which is shown by their base-exchange capacities, pH values after electrodialysis (*2*), and low retention of phosphate ions (*8*).

COMBINED WATER OF THE SOIL ACIDS

In table 36 are assembled the comparative data for the colloids of the combined water of the soil acids (p. 3). While the determined values are subject to unavoidable errors (p. 4) in individual determinations, this comparative value is definite except in the case of the Caribou profile (p. 25). It will be observed that in general the quantities are found to increase as the silica-sesquioxide ratios decrease. The Miami colloid is not in its proper sequence, which is as should be expected from the previous relations discussed. Any trisilicate feldspar present would lower the water content found. The decrease in water content in the C horizon as compared with the solum proper is as should be expected. Attention is also again directed to the probability that the iron oxide content of the Barnes and Carrington colloids is, for the most part, associated with the silica complex, while in the Ruston, Cecil, and Columbiana it is probably both free and nearly, if not quite, dehydrated. In the Podzols it would seem preferable to assume that for the most part the iron oxide is almost, if not completely, hydrated, though adequate evidence for this assumption is not at hand.

TABLE 36.—*Combined water of the soil acids for the colloids of 8 soils*

Horizon	Combined water for soil series indicated							
	Barnes	Carrington	Miami	Ruston	Cecil	Columbiana	Caribou	Au Train
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
A	11.34	12.83	10.56	13.46	14.60	18.06	12.71	17.09
B	10.56	11.70	10.11	13.67	13.15	15.28	16.36	28.01
C	9.99	11.74	8.46	12.79	12.63	14.14	12.00	....

A more significant relation is brought out if the water-silica and water-alumina relations are compared, as is done in tables 37 and 38. In table 37 the water-silica relations are the reciprocals of the values given in the separate tables of derived data. It will be observed that the ratios in table 37 vary from considerably less than unity, in the Barnes profile, to a maximum of 2.73 in the A horizon of the Columbiana. The organic content and free silica of the Podzol colloids make the relationships shown for the Caribou and Au Train of doubtful significance in this connection. Again, the sequence is disturbed by the presumed presence of unweathered material in the Miami colloid. In table 38 a still more significant relationship is brought out by comparing the formula-weight ratios of water and alumina in the colloids. In the discussion of the constitution of the colloids (p. 31) attention will be called to the possible existence of certain soil acids. In this series of assumptions all colloid acids should have a maximum water-alumina ratio of 3 except when the iron present is wholly, or in part, a portion of the hypothetical alumino-silica complex. In the instances shown in table 38 only in the cases of the A horizon of the Barnes and Carrington and the B horizon of the Caribou is this limit exceeded (the Au Train profile again not considered for reasons given p. 25). In the Barnes and Carrington, it is clear that the iron is combined as indicated by the color of the complex, and in the Caribou it seems probable that the iron content is, for the most part, hydrated ferric oxide. Even if these variations be not taken into account, the mean water-alumina ratios shown by the first seven soils are for the A horizons, 2.81; for the B, 2.69; and for the C, 2.43.

TABLE 37.—*Water-silica ratios in colloids of 8 soils*

Horizon	Ratios for soil series indicated							
	Barnes	Carrington	Miami	Ruston	Cecil	Columbiana	Caribou	Au Train
A	0.83	1.04	0.70	1.16	1.58	2.73	0.72	2.93
B	.73	.88	.70	1.22	1.29	1.72	1.42	4.42
C	.67	.87	.60	1.10	1.21	1.20	.99	----------

TABLE 38.—*Water-alumina ratios for colloids of 8 soils*

Horizon	Ratios for soil series indicated							
	Barnes	Carrington	Miami	Ruston	Cecil	Columbiana	Caribou	Au Train
A	3.36	3.31	2.43	2.32	2.55	2.77	2.49	0.13
B	3.03	2.74	2.41	2.32	2.29	2.55	3.50	4.52
C	2.94	2.80	2.05	2.11	2.35	2.25	2.53	----------

CONSTITUTION OF THE COLLOIDS

The development and the characteristics of the colloids of a soil profile may be considered as the result of two types of processes. One type consists of those processes which produce fine material from the parent minerals, the other of the processes which involve additions to and subtractions from this material and effect changes in composition and distribution. The profile development proper is largely a consequence of the operation of the second type of process. It is obvious that both types of process operate simultaneously, under normal conditions, and it is impossible to consider them or their effects wholly independently.

The production of the fine material, so far as the inorganic colloid is concerned, may without serious error be considered a result of two primary operations—mechanical weathering and hydrolysis. Mechanical weathering appears to be chiefly responsible for the production of the disintegrated rock which, directly or indirectly, is the material of the soil. This mechanical disintegration may not be considered to have a minimum limit and therefore if it were to operate alone should produce material of colloidal fineness. Recently one of the writers (*6*) presented a series of postulates based on the assumption that the chief colloid-forming process consists in the hydrolysis of crystalline rocks, or of their secondary products. It was assumed that the extent of the hydrolytic process and its rate varied with environmental conditions. It was further assumed that as this process continued the resultant products should reach a state of pseudo-equilibrium under given conditions and that these products characterized the soil colloids.

According to the hypotheses, the products constituting the fundamental inorganic colloid complexes are definite amphoteric aluminosilicic "acids" with the properties to be expected of such compounds. The colloids themselves are assumed to be salts of these acids, with more or less replacement of acid hydrogen by metals and of hydroxyl groups by acid ions. The iron content of the soils is assumed to play the same role as alumina except that its compounds more readily reach complete hydrolytic decomposition. The possible existence of the following compounds was assumed:

$3H_2O.Al_2O_3.6SiO_2$	montmorillonitic acid.
$3H_2O.Al_2O_3.4SiO_2$	pyrophyllic acid.
$3H_2O.Al_2O_3.2SiO_2$	halloysitic acid.
$3H_2O.Al_2O_3$	aluminium hydroxide.

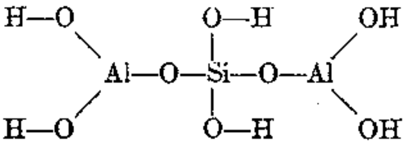
It must, however, be emphasized that no inorganic colloid could reasonably be expected to consist wholly of the derivatives of any one of these acids. It is perhaps reasonable to assume that a given soil colloid may be dominated by one of them. The dominant colloid, however, is marked by the presence of parent material of colloidal dimension, by unremoved decomposition products and variations resulting from the second type of soil profile forming processes referred to above.

A number of facts bearing on the validity of the above assumptions are presented by the study of the soils under consideration.

First and perhaps most important is the fact that the Columbiana soil furnishes in the A horizon a colloid in which the ratio of water to alumina and silica is $2.77\ H_2O.Al_2O_3$: $1.01\ SiO_2$. This is the only aluminous Laterite available for examination. A ferruginous Laterite, Nipe clay, examined by Anderson and Byers (*2*) gave a colloid having the composition $3.53\ H_2O.Al_2O_3.1.08\ SiO_2$, without correction of the ignition loss for organic matter present.

Martin and Doyne (*18*) have made a study of the clay fractions obtained from the Laterite and lateritic soils of Sierre Leone. While they found the whole soil and its coarser fractions to have silica-alumina ratios of less than 1, they were not able to obtain dispersed material with a ratio lower than 1.

In view of these facts the writers make the tentative suggestion that there may exist a laterite colloid "acid", the composition of which may be expressed by the formula



If it exists it may be expected only in soils subjected to intense hydrolytic conditions (high temperature and high rainfall), since clay of the halloysitic type is very stable. A careful examination of soils of the Laterite great group is very desirable since if the compound exists its isolation in fairly pure condition may be possible. For this hypothetical amphoteric compound the name allophanic acid is suggested. Allophane is a clay mineral of very similar composition.

The first three layers of the Columbiana clay are essentially alike (tables 22 and 23). If it is assumed that all the combined water of the soil acid is associated with the alumino-silicate complex, the following percentages are found: 0 to 10 inches, 23.7; 10 to 25 inches, 23.5; 25 to 40 inches, 23.3. The percentage of water in the fully hydrated hypothetical compound is 25.

A second point of importance demonstrated by the examination of this group of colloids is that no satisfactory evidence of the existence of a colloid containing the complex $3H_2O.Al_2O_2.6SiO_2$ is presented. This is not surprising since "immature" colloids from trisilicates are probably of rare development. It may be also that hydrolytic processes sufficiently intense to hydrolyze albite and orthoclase at rates greater than correspond to erosional effects are sufficiently intense to carry the reaction further and remove the silica freed. The fact that the colloid of the A horizon sometimes exceeds four is not believed to indicate the montmorillonitic type of colloid but rather the existence of free silica.

The expression of the chemical composition of the acid complex of the colloids is recapitulated in table 39. In this table the water and silica content are compared with alumina taken as unity. In making this comparison the assumption, possibly gratuitous, is that in all but the first three colloids all the iron is present as free oxide or hydroxide. In the first three the relations are also expressed on the assumption that the iron is all combined in the ferro-silicate complex. The truth probably lies between these extremes.

The Barnes colloid presents the nearest approach to a composition corresponding to the hypothetical pyrophyllic acid. Were the assumption warranted that the alumino-silicate is the only complex present, then the indication would be faulty in showing excess water of constitution in both the A and B sections of the soil, and the excess silica might be either free silica or due to a complex of a higher silica-alumina ratio. Were the assumption warranted that all iron is combined in the complex, then the ratio is intermediate between the halloysitic and pyrophyllic ratios and might be due either to a mixture of colloids or a dominant colloid acid with the silica-sesquioxide ratio of 3. It is of course improper to make dogmatic assertion in the matter. It may be noted however, that the colloids of the Chernozem, or closely related types reported by Anderson and Byers (*2*) and Brown, Rice, and Byers (*5*) give for the A fractions of the Chernozems a mean value of the ratios: $Al_2O_3.\ 4.31\ SiO_2.\ 3.32\ H_2O$ and $M_2O_3.\ 3.39\ SiO_2.\ 2.66\ H_2O$.

TABLE 39.—*Molecular composition of the acid complex of the soil colloid for 8 horizons of 8 soils*

Soil	Horizon A		Horizon B		Horizon C	
	Calculated with Al_2O_3 equal to 1.0	Calculated with sesquioxides (M_2O_3) equal to 1.0	Calculated with Al_2O_3 equal to 1.0	Calculated with sesquioxides (M_2O_3) equal to 1.0	Calculated with Al_2O_3 equal to 1.0	Calculated with sesquioxides (M_2O_3) equal to 1.0
Barnes	1.0 Al_2O_3	1.0 M_2O_3	1.0 Al_2O_3	1.0 M_2O_3	1.0 Al_2O_3	1.0 M_2O_3.
	4.1 SiO_2	3.1 SiO_2	4.2 SiO_2	3.1 SiO_2	4.4 SiO_2	3.4 SiO_2.
	3.4 H_2O	2.5 H_2O	3.0 H_2O	2.3 H_2O	2.9 H_2O	2.2 H_2O.
Carrington	1.0 Al_2O_3	1.0 M_2O_3	1.0 Al_2O_3	1.0 M_2O_3	1.0 Al_2O_3	1.0 M_2O_3.
	3.2 SiO_2	2.5 SiO_2	3.2 SiO_2	2.8 SiO_2	3.2 SiO_2	2.4 SiO_2.
	3.3 H_2O	2.6 H_2O	2.7 H_2O	2.1 H_2O	2.8 H_2O	2.0 H_2O.
Miami	1.0 Al_2O_3	1.0 M_2O_3	1.0 Al_2O_3	1.0 M_2O_3	1.0 Al_2O_3	1.0 M_2O_3.
	3.5 SiO_2	2.9 SiO_2	3.4 SiO_2	2.6 SiO_2	3.4 SiO_2	2.6 SiO_2.
	2.4 H_2O	2.0 H_2O	2.4 H_2O	1.8 H_2O	2.1 H_2O	1.6 H_2O.
Ruston	1.0 Al_2O_3		1.0 Al_2O_3		1.0 Al_2O_3	
	2.0 SiO_2		1.9 SiO_2		1.9 SiO_2	
	2.3 H_2O		2.3 H_2O		2.1 H_2O	
Cecil	1.0 Al_2O_3		1.0 Al_2O_3		1.0 Al_2O_3	
	1.6 SiO_2		1.8 SiO_2		2.0 SiO_2	
	2.6 H_2O		2.3 H_2O		2.4 H_2O	
Columbiana	1.0 Al_2O_3		1.0 Al_2O_3		1.0 Al_2O_3	
	1.8 SiO_2		1.5 SiO_2		1.9 SiO_2	
	2.8 H_2O		2.6 H_2O		2.3 H_2O	
Caribou	1.0 Al_2O_3		1.0 Al_2O_3		1.0 Al_2O_3	
	3.4 SiO_2		2.5 SiO_2		2.6 SiO_2	
	2.5 H_2O		3.5 H_2O		2.5 H_2O	
Au Train	1.0 Al_2O_3		1.0 Al_2O_3			
	5.0 SiO_2		1.0 SiO_2			
	6.1 H_2O		4.5 H_2O			

The Carrington colloid shows a marked decrease in the silica, as compared with the Barnes colloid, whether compared with alumina or with the sesquioxides. There is relatively less alteration in the water ratios. That the ratios expressed in table 39, for the Carrington, are characteristic for Prairie soils is to be seen by comparison with the mean ratios for the surface portion of the Prairie soils reported by Middleton, Slater, and Byers (*14*), and by Brown, Rice, and Byers (*5*). These are Al_2O_3. 3.39 SiO_2. 2.87 H_2O and M_2O_3. 2.68 SiO_2. 2.28 H_2O. It is to be noted that in the Prairie soils it is to be expected that a portion, but by no means all, of the iron is in the free condition, i. e., as iron oxide.

In the Miami colloid the frequently mentioned presence of unweathered material must be considered. If the same drastic assumption is made as was the case in recalculating the silica-sesquioxide ratios (p. 28) the composition becomes

A. Al_2O_3. 3.06 SiO_2. 2.67 H_2O
B. Al_2O_3. 2.76 SiO_2. 2.76 H_2O
C. Al_2O_3. 2.76 SiO_2. 2.31 H_2O

Undoubtedly this assumption goes beyond the truth in that some of the potassium is associated with the colloid acid and a portion, though perhaps the smaller portion, of iron is associated with the silica alumina complex.

It is of special interest to compare the composition of this profile, as given in table 39, of the Miami with the mean composition recalculated from the data for nine Miami profiles from various points in Indiana and Michigan by Holmes and Edgington (*10*). The mean composition of the A horizon is Al_2O_3. 3.33 SiO_2. 2.25 H_2O and for the B horizon Al_2O_3. 3.24 SiO_2. 2.27 H_2O.

There is, of course, no sharply defined division between the Gray-Brown Podzolic great group and the Red and Yellow Podzolic soils (lateritic soils). Data are available, however, from a number of profile examinations of soils which doubtless belong in the Gray-Brown Podzolic group. Among these are the mean of 7 profiles of the Leonardtown silt loam reported by Holmes (*9*); the Clinton, Muskingum, Vernon, and Kirvin soils, reported by Middleton, Slater and Byers (*15*); and the Susquehanna sandy loam reported by Baver and Scarseth (*3*). The mean values for the A horizons of these six soils expressed as in table 39 are: Al_2O_3. 2.92 SiO_2. 2.76 H_2O.

It is evident, therefore, if these six soils be taken as representative of the Gray-Brown Podzolic group, that the hypothetical colloid acid has a composition intermediate between the pyrophyllic acid and halloysitic acid. Whether these relations correspond to an intermediate colloid complex, as is assumed by some, or whether to a mixture of complexes, is not determinable from present data. Regardless of the view held as to the character of the constitution of the complex it seems clear that the Gray-Brown Podzolic group has a characteristic colloid complex. This is the case whether the iron-oxide component be regarded as largely free or largely combined.

The two lateritic soils considered in detail represent soils developed under very similar climatic conditions from different parent materials. In both, the silica-sesquioxide ratios lie well below 2, while the silica-alumina ratios are reasonably near to 2 if the whole profile is considered. If it be assumed that nearly, if not quite, all of the iron present is free ferric oxide, then the composition of the silica-alumina complex approaches as closely to the halloysitic acid composition as may be reasonably expected. As mentioned above, no sharp division is to be expected between the Gray-Brown Podzolic soils and the Red and Yellow soils of the South and Southwest. From the available profiles studied in this laboratory three may be selected to compare with the formulas given in table 39. These are the B horizon of the Davidson, reported by Brown and Byers (*4*); the A and B of the Nacogdoches, by Middleton, Slater, and Byers (*15*); and the mean of the A horizon of eight profiles of the Chester by Holmes and Edgington (*10*). The data for the A horizon of the Davidson are not available. The mean composition of the hypothetical colloid acid for these four soils is Al_2O_3. 1.96 SiO_2. 2.62 H_2O.

If the data presented for the lateritic soil colloids correctly represents the colloidal soil acid of this group its composition is close to halloysitic acid. It may be assumed that the less weathered colloids contain some colloid of higher silica-alumina ratio than 2, and in the more weathered colloids the composition approaches more closely that of the laterites.

The composition of the Columbiana colloid shown in table 39 cannot be directly compared with any like colloid studied in this laboratory. The same general relations are shown by the Nipe colloid reported by Anderson and Byers (*2*) but in that colloid organic matter and manganese were not determined.

The composition of the Podzol colloids as shown in table 39 represents the only cases of a water content of more than three formula weights where the color of the colloid indicates much free iron oxide. In the table the widely different A_1 and A_2 horizons are averaged.

If the composition of each section is expressed separately, the relations become:

For the Caribou, A_1 Al_2O_3. 3.47 SiO_2. 2.48 H_2O
A_2 Al_2O_3. 3.36 SiO_2. 2.53 H_2O
For the Au Train, A_1 Al_2O_3. 5.49 SiO_2. 9.51 H_2O
A_2 Al_2O_3. 5.65 SiO_2. 2.76 H_2O

The same type of relations is shown by the Emmet fine sandy loam reported by Denison (7) and for the Superior fine sandy loam and Becket loam reported by Anderson and Byers (2), but these are also subject to the same lack of quantitative value as are the Caribou and Au Train profiles. The organic matter is more than twice as great as the combined water in the A_1 horizon of the Caribou colloid (table 27) and almost five times as great in the A_1 of the Au Train colloid (table 31). If, then, the known unsatisfactory character of the factor 1.724, be considered, the unsatisfactory character of the above results is readily understandable. It is clear, therefore, that no definite conclusions, except of a qualitative character, can be based upon the water relations of the inorganic colloid of soils in which the organic matter exceeds the combined water. Such considerations must await a satisfactory means of estimation of organic matter. It also follows that there is an element of uncertainty in all cases, due to this difficulty as well as to the other uncertainties mentioned on page 4.

In considering the assembled data of table 39 it appears that in general the water of combination of the soil acid is higher in the surface colloid than in the colloids of the lower portions of the profile. This relation is undoubtedly in part owing to the relatively higher organic content of the surface colloid, but is also in part due to the probable presence in the B and C horizon colloids of unweathered material in the colloid. If the general relation of hydrolysis is as outlined, hydrolysis of most minerals adds more water than corresponds to base present in unweathered materials.

GROUP DISTINCTIONS

What degree of validity is to be attached to the hypothetical considerations is open to question. There can be no question of the fact that the analyses presented supplemented by the examination of many other profiles show that each of the great groups presents a distinctive type of colloid. It would appear that the environmental conditions under which Chernozem soils develop produce the same general type of colloid characterized by high silica-sesquioxide and silica-alumina ratios, low silica-base ratios, and high pH values. The Prairie colloids are lower in all these respects than are those from Chernozem soils. The colloids of the Gray-Brown Podzolic group are characterized by silica-sesquioxide and silica-alumina ratios approximating in magnitude those of the Prairie soils and with a higher silica-base ratio. In part these higher values appear to be due to the presence of colloidal unweathered or partially weathered materials.

The Lateritic great group is characterized by a silica-sesquioxide ratio of less than 2, a silica-alumina ratio of approximately 2, a silica-base ratio which is very high as compared with previous groups, and by the presence of iron oxide in a free condition and apparently dehydrated. The colloid of the Laterite group has not been adequately investigated, but it appears to be characterized by the presence of a silica-sesquioxide ratio of less than one-half, a silica-alumina ratio of nearly 1, and by a very extreme paucity of bases.

The colloid of the Podzol great group is characterized by very high silica-sesquioxide and silica-alumina ratios in the A horizon and by strikingly lower values of these ratios in the B horizon. The most striking characteristic is therefore the fractionation of the colloid accumulated in the B horizon.

The colloids of all the great groups are characterized by an essentially constant water-alumina ratio.

It may be added that the broad distinctions just outlined are supplemented by less striking differences. Thus, the Chernozem and Lateritic great groups have a colloid which is remarkably constant for the whole profile. The Gray-Brown Podzolic group shows podzolic fractionation to less degree than the Podzols themselves. In all the groups characteristics seem to be largely independent of the present mineral sources.

Since the environmental conditions presumably responsible for the development of the colloid characteristics merge into one another in a geographical sense, it is to be expected that transitional soil profiles also exist.

SUMMARY

Detailed analytical data have been presented for 8 soil profiles representing 6 of the great groups of soils. These include mechanical and chemical analyses of the soils and chemical analyses of the colloids. Derived data from the analytical results are tabulated.

The results show that the colloids of the great groups of soils differ from each other, and that there exists a chemical basis for the characteristics manifested in the field. The Chernozems are characterized by high silica-sesquioxide and silica-alumina ratios and by uniformity of colloid composition throughout the profile. The Prairie colloids have distinctly lower silica ratios than the Chernozems but are essentially free from carbonates. The colloid profile is constant in composition. The Gray-Brown Podzolic colloids are not sharply different in silica ratios from the Prairie colloids but show more variation in profile. The lateritic and Laterite groups have low silica-alumina ratios but very high silica-base ratios. The Podzol soils reflect in colloid composition the extensive fractionation which has taken place within the profiles.

The analytical data have been correlated to develop a systematic relationship between the soil colloids independently of any assumptions with regard to the causes of these relationships.

The results have been discussed from the standpoint of the genetic relationships of the inorganic colloids and the light they throw on hypothetical considerations of colloidal acid composition. Modification and extension of previously published views are based on the present study and on comparisons with selected data from other sources. In these considerations the possible existence of five fundamental compounds resulting from the hydrolysis of minerals is postulated. In addition to the final hydrolytic products, aluminum hydroxide and ferric hydroxide, the hypothetical acids are assumed to have the composition (1) $3H_2O.Al_2O_3.6SiO_2$. (2) $3H_2O.Al_2O_3.4SiO_2$. (3) $3H_2O.Al_2O_3.2SiO_2$ and (4) $3H_2O.Al_2O_3.SiO_2$. The names suggested for these compounds are (1) montmorillonitic acid, (2) pyrophyllic acid, (3) halloysitic acid, and (4) allophanic acid, and are derived from

the clay minerals of approximately similar composition. It is emphasized that no single inorganic colloid can reasonably be expected to consist wholly of the derivatives of any one of these acids.

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