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THE FRACTIONATION

BROWN, I. C., BYERS, H. G.

USDA TECHNICAL BULLETINS

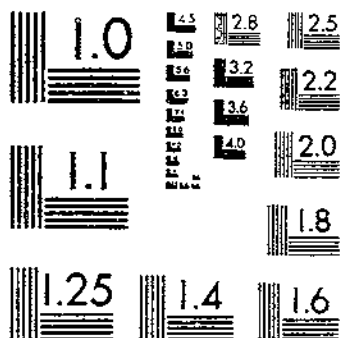
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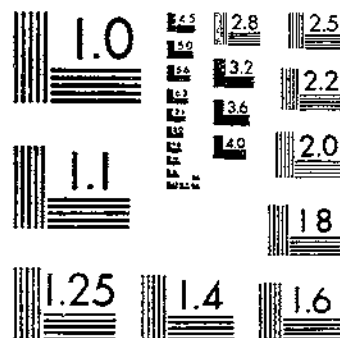
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UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

THE FRACTIONATION, COMPOSITION, AND HYPOTHETICAL CONSTITUTION OF CERTAIN COLLOIDS DERIVED FROM THE GREAT SOIL GROUPS

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INTRODUCTION

In the intensive investigations of soil colloids, which have engaged the attention of soil chemists in recent years, it has been customary to regard the material separated from a given soil by dispersion in water as essentially homogeneous. It does not follow, however, that it has been considered a chemical unit. The material extracted has usually been considered as fairly representative of the total colloid, although a complete separation of the colloid is never obtained. In the work by Bradfield (9)¹ the material not separated from a suspension of Putnam silt loam subsoil after 30 days' standing was separated into three fractions by means of a centrifuge, and two of these fractions were analyzed and the difference noted and commented upon. In the work of Gile et al. (15) attempts were made to fractionate the colloid material of several soils by repeated dispersion and separation by the centrifuge. The absorptive capacities of these fractions of the total "extractable" colloid were determined and though differences were noted, the conclusion reached was that "on the whole the different fractions were similar in absorptive capacity to the first sample extracted." In the work reported by Robinson and Holmes (23) the chemical analyses of the same fractions are given, and again, though differences were noted, the conclusion was reached that there is comparatively little variation in the composition of the colloidal material extracted from the same soil. In the same bulletin Robinson and Holmes reported the result of their efforts to fractionate soil colloids by precipitation and by freezing and thawing. The results were negative. Also, in the bulletin by Gile et al., previously cited, the authors concluded (15, p. 38):

¹ Italic numbers in parentheses refer to Literature Cited, p. 42.

The adsorptive capacity of a small sample of extracted colloidal material differs by about 10 per cent from the adsorptive capacity of all the colloidal material which is extractable by the methods employed. However, the colloidal material which can not be extracted has, in many soils, a much lower adsorptive capacity than that which is extractable.

Iwanow (18) separated the colloidal material from the sodium-saturated chernozem soils and after redispersion filtered the suspension through a Birkfeld filter. After evaporation, ignition, and leaching with water, he analyzed the residue and compared the values so obtained with the analyses of the colloid retained by the filter. The results obtained showed striking differences in the colloid fractions, but the results are not very significant since the material passing the Birkfeld filter contains not only the very small colloid particles but also the ash of the organic material and soluble inorganic material. The fine material estimated to be 0.1 micron in diameter constituted about 4 per cent of the extracted colloid.

Denison (14) attempted the fractionation of the colloid from certain horizons of three soil types, a Durham sandy loam and a Cecil sandy clay loam from Georgia, and a Cecil clay loam from North Carolina. He confined his attention to portions of the C horizon, since previous work on A and B horizons had indicated the existence of no marked variations in the colloid fractions obtained by successive dispersions. His method of extraction is described by him as follows: (14, p. 476-477):

The first fraction was made as follows: A 10 to 20 g² sample of soil material was moistened with water and the mass worked to a somewhat plastic consistency by rubbing the particles between the fingers. A small quantity of water made alkaline with ammonia was then added and after settling for a few minutes the suspension was decanted into a 500 c c glass cylinder. The settled portion was rubbed between the fingers as before, and the process repeated until the cylinder was filled. The suspension was now allowed to settle until microscopic examination showed that the suspension to a certain depth was practically free of particles more than 1 micron in diameter. The colloidal solution was then drawn off to this depth and evaporated to dryness. The second fraction was prepared in a similar manner except that the silty material obtained by removal of the greater part of the colloid (explained under Methods) was employed instead of the soil material. In preparing this second fraction about 50 g of material were dispersed in 3 liters of water (alkaline to phenolphthalein) contained in a beaker and the colloidal solution drawn off when nearly all particles more than 1 micron in diameter had settled. The quantities of colloid obtained in all cases were very small, averaging not more than 0.5 g.

The results obtained from such small fractions were somewhat inconclusive, but were so remarkable as to warrant a more extended investigation. The present investigation was begun for the purpose of extending the work of Denison, and large samples of the soils from the same localities were obtained by one of the authors. In the interval before securing these samples a preliminary examination of the Davidson clay loam subsoil was made, and the results indicated the desirability of an alteration of the method to be employed. As the data were accumulated it became apparent that they threw much light upon the question of colloid constitution and soil origin, and they have therefore been made the basis of a brief general discussion of these topics.

² g is the abbreviation for gram or grams.

PRELIMINARY STUDY

A preliminary study was made on the B₁ horizon of a sample of Davidson clay loam collected 9 miles north of Greensboro, N. C., by R. C. Journey, of the division of soil survey. It is the same sample on which complete profile data are reported by Middleton (22). The silica-sesquioxide ratio of the colloid of the B₁ horizon is 1.50. The colloid content by mechanical analysis is 64.8 per cent.

The fractionation of this soil was effected as follows: One kilogram of the air-dried soil was well shaken in 18 liters of N/200 sodium oxalate solution and poured through a 300-mesh sieve. The resulting suspension had a pH of 8.4. After 20 hours the suspended portion was syphoned off and filtered. The operation was repeated 15 times with the filtrate as a dispersing agent, until the supernatant liquid was clear after standing 20 hours. The suspended particles were 1 micron or less in diameter. The residual material was then dispersed in the same manner as later described for the size fractionation (step 3) and all the colloid obtained that could be centrifuged off after eight dispersions with N/200 sodium oxalate. The residual material was then dispersed and centrifuged eight times with N/400 sodium hydroxide solution.

The residual material was again dispersed, using N/200 sodium hydroxide solution as a dispersing agent. This operation was repeated eight times. The total colloid obtained in the four fractions was 441.4 g when dried on the steam bath. Examination of the material which failed to pass the 300-mesh sieve, as well as the silt and clay fractions of the repeatedly dispersed material, revealed the presence of much undispersed material.

A recapitulation of the method of extraction and the analyses of the four fractions of colloid are given in Table 1.

inferences are, however, not warranted and the general conclusion was reached that more satisfactory results might be obtained by attempting the fractionation on the basis of size distribution, the results of which effort form the body of this bulletin. The size separation of the colloidal material was made not only on the colloidal material, as ordinarily separated from soils, but was also carried out, as later described, on the colloid material ordinarily described as "unextracted" colloid (15, p. 19).

DESCRIPTION OF SAMPLES

The soils investigated in this study were selected in the first instance to obtain colloids that were presumably mixtures of materials and that might therefore be expected to furnish fractions of diverse composition. They are also soils of which the laboratory possesses complete profile samples upon which considerable work had already been done. As the work developed it seemed desirable to include two samples of less weathered soils which, on the basis of information at hand, were not to be expected to show widely different fractions. The samples chosen and their descriptions are tabulated in Table 2.

TABLE 2.—Description and location of soil samples

Laboratory No.	Soil type	Depth	Horizon	Description	Parent material	Location
4575	Amarillo silty clay loam.	Inches 10-20	2	Rich-brown color with faint tint of red.	High plains deposits.	Nash, Tex.
191	Marshall silt loam.....	0-14	1	Dark-brown color, moderately compact but friable and easily crumbled, plastic, and sticky when wet.	Loess.....	Maynard, Nebr.
4447	Becket silt loam.....	13-24	B ₁	Yellowish-brown, grading to pale yellowish-brown color, friable.	Glacial till from crystalline calcareous rocks.	Washington, Mass.
6263	Durham sandy loam.	90-102	C ₁	Very light gray slightly decomposed rock.	Granite.....	Stone Mountain, Ga.
4440	Davidson clay loam.	9-36	B ₁	Reddish heavy brittle clay.	Diorite.....	Greensboro, N. C.
6278	Cecil clay.....	36-72	B ₁	Red stiff brittle clay.....	Gneiss.....	Rutherfordton, N. C.
6274	Cecil sandy clay loam.	180-196	C ₄	Grayish-brown disintegrated rock.	Mica schist.....	Stone Mountain, De Kalb County, Ga.
6281	Cecil clay loam.....	112+	C ₃	Gray soft disintegrated rock.	Gneiss.....	Rutherfordton, N. C.

The mechanical and chemical analyses of the samples are given in Tables 3 and 4, respectively.

TABLE 3.—Mechanical composition of soil samples

Sample No.	Soil type	Depth	Horizon	Fine gravel	Coarse sand	Medium sand	Fine sand
				2-1 mm	1-0.5 mm	0.5-0.25 mm	0.25-0.1 mm
		Inches		Per cent	Per cent	Per cent	Per cent
4575	Amarillo silty clay loam	10-20	2	0.0	0.1	0.2	1.9
191	Marshall silt loam	0-14	1	0	1	1	2
4447	Becket silt loam	13-24	B ₂	3.1	5.5	6.9	21.2
6263	Durham sandy loam	90-102	C ₂	9.7	16.1	10.3	15.4
4440	Davidson clay loam	9-36	B ₁	1	7	9	5.4
6278	Cecil clay loam	36-72	B ₂	1.5	14.0	14.6	26.8
6274	Cecil sandy clay loam	180-196	C ₁	6.1	17.2	14.0	32.8
6281	Cecil clay loam	112+	C ₂	9.8	28.0	15.4	19.8

Sample No.	Soil type	Depth	Horizon	Very fine sand	Silt	Clay	Inorganic colloid	Loss on treatment
				0.1-0.05 mm	0.005 mm	<0.005 mm	<0.002 mm	with H ₂ O ₂
		Inches		Per cent	Per cent	Per cent	Per cent	Per cent
4575	Amarillo silty clay loam	10-20	2	8.3	41.0	47.4	42.8	1.1
191	Marshall silt loam	0-14	1	2.0	62.2	31.2	27.8	4.3
4447	Becket silt loam	13-24	B ₁	18.4	30.2	9.0	5.5	5.6
6263	Durham sandy loam	90-102	C ₁	9.2	9.5	29.7	28.4	0
4440	Davidson clay loam	9-36	B ₁	8.9	22.3	60.4	54.0	1.3
6278	Cecil clay loam	36-72	B ₁	15.4	18.5	8.3	6.3	0
6274	Cecil sandy clay loam	180-196	C ₁	17.7	9.1	3.0	1.7	0
6281	Cecil clay loam	112+	C ₂	8.7	10.3	8.0	6.2	0

TABLE 4.—Chemical composition of soil samples

Sample No.	Soil type	Depth	Horizon	SiO ₂	FeO ₂	Al ₂ O ₃	Molecular ratio	MgO	CaO	K ₂ O
				SiO ₂	FeO ₂	Al ₂ O ₃	SiO ₂	FeO ₂ +Al ₂ O ₃	MgO	CaO	K_{2}O
		Inches		Per cent	Per cent	Per cent		Per cent	Per cent	Per cent
4575	Amarillo silty clay loam	10-20	2	70.48	4.40	13.83	7.14	1.35	0.97	2.50
191	Marshall silt loam	0-14	1	72.06	3.66	11.18	9.78	.66	.90	2.60
4447	Becket silt loam	13-24	B ₂	72.67	3.58	10.32	11.94	.41	.62	3.45
6263	Durham sandy loam	90-102	C ₂	70.51	1.02	17.40	6.61	.18	.24	6.22
4440	Davidson clay loam	9-36	B ₁	52.70	10.62	22.87	3.01	.40	.51	.45
6278	Cecil clay loam	180-196	C ₁	61.51	7.82	19.25	4.39	1.64	.22	3.10
6274	Cecil sandy clay loam	9-36	B ₂	49.24	9.65	26.14	2.58	1.49	.22	2.44
6281	Cecil clay loam	112+	C ₁	54.18	7.49	23.90	3.19	1.64	.57	2.41

Sample No.	Soil type	Depth	Horizon	Na ₂ O	TiO ₂	MnO	P ₂ O ₅	Ignition loss	N	SO ₄	pH
				Na ₂ O	TiO ₂	MnO	P ₂ O ₅	Ignition loss	N	SO ₄	pH
		Inches		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	
4575	Amarillo silty clay loam	10-20	2	1.01	0.71	6.09	0.69	4.97	0.08	0.07	7.8
191	Marshall silt loam	0-14	1	1.02	.67	.05	.21	8.94	.23	.12	
4447	Becket silt loam	13-24	B ₂	.67	.70	.02	.08	7.27	.09	.14	4.1
6263	Durham sandy loam	90-102	C ₂	.52	.08	.02	.32	3.85			5.1
4440	Davidson clay loam	9-36	B ₁	.00	1.39	.07	.12	10.55	.02	.12	5.1
6278	Cecil clay loam	180-196	C ₁	.21	1.04	.17	.12	5.27		.05	
6274	Cecil sandy clay loam	9-36	B ₂	.05	1.79	.12	.29	9.40		.07	
6281	Cecil clay loam	112+	C ₂	.24	1.26	.11	.49	8.55		.07	

METHOD OF EXTRACTION OF THE COLLOID FRACTIONS

The colloid was separated from the soils and fractionated by the use of two Sharples supercentrifuges (6). The larger of these had a maximum safe operating speed of 17,000 revolutions per minute and a bowl diameter of 4 inches, therefore developing at this speed 17,000 gravity. The smaller centrifuge had a maximum operating speed of 40,000 revolutions per minute, a bowl diameter of 2 inches, and developed 40,000 gravity.

One-half to 2 kg of soil were dispersed with 10 to 15 liters of water in a stirring apparatus described by Holmes and Edgington. (17), to which was added just sufficient ammonium hydroxide to render the suspension faintly alkaline. The liquid was allowed to stand sufficiently long for the sands to settle and this supernatant liquid decanted through a 300-mesh sieve. This operation was repeated until a total of about 20 gallons of suspension was obtained.

The suspension of fine silt, clay, and colloid was then run through the larger centrifuge operating at 17,000 revolutions per minute and the liquid poured through at a rate of 1 liter per 35 seconds. The liquid was filtered through Pasteur-Chamberland filters. The material left in the centrifuge bowl was then redispersed by rubbing between the hands and by agitation in the stirring apparatus. The water used for this operation was obtained by filtration of the previously separated colloid. This operation of centrifuging and redispersing was continued from 5 to 10 times until the liquid from the centrifuge showed almost no colloid content; i. e., the liquid showed but faint opalescence.

The colloid so collected on the filters contained no significant number of particles of a diameter greater than 0.3 micron, as shown by examination with an ultra microscope. The residue of colloid coarser than 0.3 micron was separated from the fine silt and clay by exactly the same treatment except that the rate of flow through the centrifuge was increased to 1 liter per 17 seconds. This part of the colloid was separated by filtration. Examination of this fraction with the ultra microscope revealed the presence of no significant number of particles larger than 1 micron and surprisingly few of less than 0.3 micron.

The noncolloidal residue was then separated into two fractions by redispersion and centrifuging at a rate of flow of 1 liter per 4 seconds, with a centrifuge rate of 7,000 revolutions per minute. This operation had to be repeated several times in order to effect complete separation into fractions 1 to 5 microns and 5 to 50 microns, respectively. The clay fraction was collected by filtration; the fine silt remained in the bowl of the centrifuge.

In order to separate the fraction of colloid of a 0.3 micron and smaller sizes into two fractions, the small supercentrifuge was employed. This colloidal material was again dispersed and run through the centrifuge at a rate of 40,000 revolutions per minute and a rate of flow of 1 liter per two minutes. The centrifugate contained from 25 to 60 per cent of the colloid so treated, and by the ultra microscope the particles so obtained were exceedingly minute. This fraction is estimated to contain no significant number of particles greater than 0.1 micron.

The same water was used throughout the series of separations and at the end had a pH value ranging from 8.3 to 8.7.

The method of separation and its results are recapitulated in Table 5.

TABLE 5.—*Fraction sizes of particles at various steps in the process of extracting the colloids*

Step	Centrifuge rate	Gravity	Rate of flow per liter	Particle size
	<i>Revolutions per minute</i>		<i>Seconds</i>	
1.....	40,000	40,000	120	<0.1 μ (colloid).
2.....	17,000	17,000	37	<0.3 μ (colloid).
3.....	17,000	17,000	16	0.3 μ to 1.0 μ (colloid).
4.....				1 μ to 5 μ (clay).
5.....	7,000	2,800	4	5 μ to 50 μ (silt).

It is to be emphasized that, in order to obtain the size separation shown in Table 5, each operation was repeated from 5 to 10 times, until the centrifugates obtained showed that no further separation would be effective in materially increasing the quantities of the successively smaller fractions. Considerable differences in the rapidity with which the operations were completed were noted in the different soils. The quantities of colloid so obtained were always smaller than those indicated by either the pipette method of mechanical analysis (25) or the water vapor absorption method (26), except in the case of the C₂ horizon of the Cecil clay loam, where the amount extracted is essentially the same as the percentage indicated by mechanical analyses. It is recognized that both methods are approximations and that the pipette method includes particles of the sizes 1 to 2 microns. Nevertheless, the differences between the amounts obtained and those indicated by the mechanical analysis (Table 3) were sufficiently wide to encourage attempts at further extraction. It has been shown by Olmstead, Alexander, and Middleton (25) that increased dispersion may be effected by using sodium hydroxide at pH values well above 7. Three of the samples under investigation were therefore selected, and the combined silt and clay fractions were redispersed, using pH values of 10.5 to 11.0. The quantities of colloid (<1 μ) extracted by the two methods are given in Table 6.

TABLE 6.—Quantities of colloid extracted from the soil samples by using two methods

Sam- ple No.	Soil type	Depth	Colloid, percentage of whole soil, ex- tracted by water and ammonia, pH 7-3.7	Colloid, percentage of whole soil, ex- tracted by NaOH from silt and clay fraction
		<i>Inches</i>		
4575	Amarillo silty clay loam.....	10-20	31.7	1.1
191	Marshall silt loam.....	0-14	21.3	
4447	Becket silt loam.....	13-24	3.1	1.2
6263	Durham sandy loam.....	90-102	23.4	
4440	Davidson clay loam.....	9-36	34.4	.8
6278	Cecil clay loam.....	36-72	4.9	
6274	Cecil sandy clay loam.....	180-196	1.5	
6281	Cecil clay loam.....	112+	6.1	

After extraction with sodium hydroxide the silt and clay fractions were examined by W. H. Fry and found to contain very small quantities of residual colloids. It will be observed by comparison with the data in Table 3 that there is a considerable margin between the total colloid extracted and the sum of the colloid and organic matter by mechanical analysis. A part of the discrepancy is accounted for by the fact that the concretionary colloid remaining with the sands on the 300-mesh screen is not included in the samples examined. A part is to be ascribed to the fact that the colloid by mechanical analysis includes the particles up to 2 microns. It is also to be kept in mind that unavoidable losses occur in extraction operations. On the whole, the fractions of the total colloid included in the analyses represent an unusually large part of the total colloids present in the soils.

METHODS AND RESULTS OF THE EXAMINATION OF THE FRACTIONS

The soil fractions, obtained as described, of the eight soil horizons from seven different soils were examined by subjecting them to fusion analysis, using the methods described by Robinson (27). The water vapor absorption over 3.3 per cent sulphuric acid, over 30 per cent sulphuric acid, and the heat of wetting were determined as described in previous publications of this bureau (1, 21, 26). The data obtained are given in Tables 7 to 16. Each determination was made in duplicate and the individual determinations and their mean values are recorded.

The sequence of the tables is not that in which the data were obtained, but the tables are arranged in the order given for convenience of discussion and because of relationships brought out in the general discussion.

TABLE 7.—Chemical composition of fractions of soil colloids, clay, and silt from a southern chernozem, Amarillo silty clay loam, horizon 2, 10-20 inches depth

Fraction of whole soil (per cent)	Size	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	Molecular ratio					
					$\frac{\text{SiO}_2}{\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3}$	$\frac{\text{SiO}_2}{\text{Fe}_2\text{O}_3}$	$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3}$	$\frac{\text{Fe}_2\text{O}_3}{\text{Al}_2\text{O}_3}$	$\frac{\text{SiO}_2}{\text{Total oxides}}$	
		Per cent	Per cent	Per cent						
10.1	<0.1 μ	50.95	8.50	22.95	3.04					
	Duplicate.....	50.83	8.61	22.87	3.03					
	Mean.....	50.91	8.56	22.91	3.04	15.8	3.76	0.238		6.65
6.2	0.1 μ -0.3 μ	49.60	8.65	22.27	3.03					
	Duplicate.....	49.65	8.70	22.23	3.03					
	Mean.....	49.63	8.67	22.25	3.03	15.4	3.77	.248		6.53
6.4	0.3 μ -1 μ	51.05	7.41	22.13	3.22					
	Duplicate.....	51.00	7.52	22.05	3.22					
	Mean.....	51.03	7.46	22.09	3.22	18.2	3.95	.214		6.70
4.7	1 μ -5 μ	57.98	6.16	16.54	4.80					
	Duplicate.....	58.10	6.12	16.53	4.81					
	Mean.....	58.04	6.14	16.52	4.81	25.1	5.94	.237		8.70
12.7	5 μ -50 μ	76.00	2.62	10.93	10.22					
	Duplicate.....	75.98	2.61	10.85	10.26					
	Mean.....	75.99	2.62	10.89	10.24	78.8	11.83	.155		6.72

Fraction of whole soil (per cent)	Size	MgO	CaO	K ₂ O	Na ₂ O	TiO ₂	MnO	P ₂ O ₅	Organic matter	Combined water
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
10.1	<0.1 μ	2.90	1.72	2.22	0.14	0.43	0.10	0.09	1.57	8.42
	Duplicate.....	2.82	1.65	2.17	.18	.46	.10	.09	1.57	8.49
	Mean.....	2.86	1.69	2.20	.16	.46	.10	.09	1.62	8.45
6.2	0.1 μ -0.3 μ	2.69	1.30	2.08	.28	1.00	.12	.18	3.70	7.16
	Duplicate.....	2.60	1.30	2.93	.24	1.00	.12	.17	3.81	7.08
	Mean.....	2.69	1.30	2.98	.28	1.00	.12	.18	3.76	7.12
6.4	0.3 μ -1 μ	2.65	1.30	2.92	.34	.89	.16	.17	4.27	6.97
	Duplicate.....	2.66	1.42	2.93	.28	.89	.16	.16	4.17	7.13
	Mean.....	2.66	1.39	2.92	.31	.89	.16	.17	4.22	7.05
4.7	1 μ -5 μ	1.69	1.16	3.27	.82	1.25	.29	.26	6.05	4.08
	Duplicate.....	1.60	1.18	3.29	.93	1.21	.19	.24	6.08	4.73
	Mean.....	1.65	1.17	3.28	.87	1.23	.20	.25	6.07	4.70
12.7	5 μ -50 μ	1.25	.46	2.85	1.80	1.01	.05	.11	2.94	.48
	Duplicate.....	1.22	.40	2.84	1.73	1.00	.05	.10	2.79	.61
	Mean.....	1.24	.43	2.85	1.77	1.00	.05	.10	2.87	.54

The data presented in Table 7 show the chemical composition of the fractions of the second layer of Amarillo silty clay loam. The material used is a part of the same profile sample reported on by Anderson and Byers (8). It is a representative of the southern chernozems, and the whole profile is characterized by marked uniformity of the colloid, in particular of the first three horizons, in which the silica-sesquioxide ratio is 3.10, 3.09, and 3.13, respectively. The colloid content (<0.002 mm), as shown by mechanical analysis, is 23.9 per cent in the upper layer and 42.8 per cent in the stratum examined. In the first three fractions represented in Table 7, 31.7 per cent was extracted. The largest fraction, 19.1 per cent, consists of the particles of smallest size, i. e., smaller than 0.1 micron.

The chemical analyses of the fractions reveals a very striking similarity between 0.1-micron and 0.3-micron fractions. The silica-sesquioxide ratios are identical. The chief difference is in the organic matter. The mean value of the organic matter is 4.02 per cent, and the smaller value in the finest fraction indicates a low degree of decomposition of the organic matter, a fact quite in harmony with the low rainfall of the region in which this soil occurs. There is a moderate

difference in the combined water of the finer colloid fractions, which is clearly significant of a higher degree of hydration of the finest particles. Indeed there are no marked differences in the three fractions of colloid, except that in the fraction 0.3 to 1 micron the slightly increased silica-sesquioxide ratio, the silica-alumina ratio, and the silica-iron oxide ratio all point to the presence of quartz particles in colloidal form, especially when considered in the light of the enormous increase in these ratios in the clay and silt fractions. That quartz is present in the clay fraction is established by petrographic microscopic inspection by W. H. Fry.

In this colloid there is some indication of increase in the iron-oxide content of the finer fractions of the colloid, as indicated by the silica-iron oxide ratio, though the alteration is not large. The change of ratio of iron oxide to the alumina also indicates a slight tendency of the iron oxide to drift to the finer particles.

All these ratios, together with the constancy of the molecular ratio of the silica to the sum of the bases present in the colloid fractions, may be taken to indicate in this colloid the presence of an acid complex of constant composition. This conclusion is in harmony with the data on the colloids of the whole profile presented by Byers and Anderson (10).

The material used for the data presented in Table 8 is from the surface layer of the soil profile of Marshall silt loam, on which data are reported by Robinson and Holmes (28) and also by Byers and Anderson (10). It is a northern prairie soil developed under much the same conditions as the Amarillo soil but with a sufficiently high rainfall to prevent the accumulation of a layer of calcium carbonate. It is to be noted that this is a surface soil material, whereas the Amarillo is a lower stratum. With this in mind the similarity of the two colloids is striking. Although the Amarillo soil has a lower total silica content than the Marshall, the colloid of the Amarillo is about 5 per cent higher. This fact, coupled with the small but definite increase of the silica-sesquioxide ratio with increasing particle size, may be taken to indicate that the process of removal of silica from the finer fractions has been operative as the process of weathering has developed. However, leaching has not been extensive, though it is sufficient to prevent calcium carbonate accumulation.

In both the Amarillo and Marshall soils, the silica-base ratio³ does not alter sharply until the clay-size particles, 1 to 5 microns, are reached, and it is of essentially the same order of magnitude. This may be taken to indicate the same type of acid complex in both soils. This conclusion is also in harmony with the general similarity of the silica-iron oxide and silica-alumina ratios. The meaning of the decrease of the silica-base ratio in the 0.3-micron fraction of the colloid is not clear.

In the Marshall soil, there is a smaller quantity of organic matter in the smaller fractions of the colloid and an increased combined water content. These facts again point, as in the Amarillo soil, to greater hydration of the finer fractions of inorganic colloid and to a less degree of decomposition of the organic material.

In the Marshall colloid fractions there is a small but definite decrease in the relative iron-oxide content of the coarser particles,

³ It is to be observed that the silica-base ratio is not quite valid in detailed consideration except in Tables 7 and 8, since the other colloids were extracted, using a small quantity of ammonia, thus removing a portion of exchangeable bases.

which becomes marked when the clay size is reached. This is, as in the case of the Amarillo soil, to be expected as indicating a more extensive hydrolytic decomposition of the finer particles.

TABLE 8.—Chemical composition of fractions of soil colloids, clay, and silt from a northern prairie soil, Marshall silt loam, 0-14 inches depth

Fraction of whole soil	Size	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	Molecular ratio					
					SiO ₂ / Fe ₂ O ₃ +Al ₂ O ₃	SiO ₂ / Fe ₂ O ₃	SiO ₂ / Al ₂ O ₃	Fe ₂ O ₃ / Al ₂ O ₃	SiO ₂ / Total bases	
<i>Per cent</i>		<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>						
10.0	<0.1μ	45.10	9.07	22.20	2.73					
	Duplicate	45.05	9.07	22.10	2.74					
	Mean	45.08	9.07	22.15	2.74	13.2	3.44	0.261		6.76
	0.1μ-0.3μ	44.30	8.76	20.70	2.85					
4.5	Duplicate	44.30	8.91	20.69	2.85					
	Mean	44.30	8.83	20.70	2.85	13.4	3.62	.270		6.23
	0.3μ-1μ	44.40	8.54	19.62	3.00					
6.8	Duplicate	44.50	8.67	19.62	3.00					
	Mean	44.45	8.56	19.62	3.00	13.8	3.83	.278		6.61
	1μ-5μ	51.20	7.00	18.99	4.24					
5.3	Duplicate	51.20	6.89	16.01	4.25					
	Mean	51.20	6.94	16.00	4.25	19.6	5.42	.283		8.68
	5μ-50μ	79.00	2.00	9.44	12.50					
27.2	Duplicate	79.20	1.97	9.55	12.45					
	Mean	79.10	1.99	9.49	12.47	104.5	14.11	.135		7.19

Fraction of whole soil	Size	MgO	CaO	K ₂ O	Na ₂ O	TiO ₂	MnO	P ₂ O ₅	Organic matter	Combined water
<i>Per cent</i>		<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
10.0	<0.1μ	2.28	1.76	1.89	0.16	0.46	0.29	0.22	7.60	8.84
	Duplicate	2.29	1.72	1.86	.11	.44	.28	.21	7.58	9.12
	Mean	2.29	1.74	1.82	.14	.45	.29	.22	7.64	8.98
	0.1μ-0.3μ	2.14	1.92	2.61	.18	.73	.35	.31	10.34	7.35
4.5	Duplicate	2.21	1.88	2.50	.18	.75	.35	.30	10.25	7.40
	Mean	2.18	1.95	2.55	.18	.74	.35	.31	10.28	7.38
	0.3μ-1μ	2.17	1.49	2.57	.17	.80	.33	.34	11.75	7.49
6.8	Duplicate	2.28	1.58	2.52	.16	.78	.33	.33	11.77	7.28
	Mean	2.22	1.53	2.55	.17	.79	.33	.34	11.76	7.30
	1μ-5μ	1.74	1.18	2.87	.33	.90	.23	.43	12.10	5.41
5.3	Duplicate	1.68	1.14	2.94	.35	.98	.20	.44	12.01	5.54
	Mean	1.71	1.16	2.90	.34	.95	.22	.44	12.08	5.48
	5μ-50μ	.55	.74	2.51	1.61	.74	.03	.14	2.03	1.16
27.2	Duplicate	.55	.70	2.48	1.47	.73	.03	.10	1.85	1.40
	Mean	.55	.72	2.49	1.49	.74	.03	.12	1.94	1.27

The data of Table 10 show the composition of the B₂ horizon of Becket silt loam. The sample examined is a part of the profile sample reported on by Anderson and Byers (5). The B₁ horizon is a very thin highly ferruginous layer. The B₂ horizon was chosen for this study as representing a more nearly normal B horizon of the podzol type and because an abundance of the sample was available.

There are a number of striking contrasts between results obtained with the podzol B₂ and the subsurface soil colloid of the Amarillo soil (Table 7) and the surface soil colloid of the Marshall soil. (Table 8.) The silica content is less than half that of the soils mentioned and in the finest fraction (0.1 micron) is approximately one-third. This is in part due to the enormous content of organic matter, but even on the inorganic basis the relative quantities of the three cited constituents taken as 100 are as shown in Table 9 for the 0.1-micron fraction.

The variation among these three soils is obviously much more marked in the iron oxide content and is apparent for the aluina.

The wide differences in the character of the colloid are, of course, also indicated by the silica-sesquioxide ratio, the silica-iron oxide ratio, and the silica-alumina ratio.

TABLE 9.—The relative silica, alumina, and iron-oxide content of the 0.1μ fraction of the Becket, Amarillo, and Marshall colloids

Components	Becket	Amarillo	Marshall
SiO ₂	32.83	61.80	60.23
Fe ₂ O ₃	28.16	10.39	12.12
Al ₂ O ₃	39.22	27.81	27.65

TABLE 10.—Chemical composition of fractions of soil colloids, clay, and silt from a podzol, Becket silt loam, E₂ horizon, 10-20 inches depth

Fraction of whole soil (per cent)	Size	Molecular ratio							
		SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	SiO ₂ / Fe ₂ O ₃ +Al ₂ O ₃	SiO ₂ / Fe ₂ O ₃	SiO ₂ / Al ₂ O ₃	Fe ₂ O ₃ / Al ₂ O ₃	SiO ₂ / Total bases
		Per cent	Per cent	Per cent					
0.6	<0.1μ	15.78	13.67	18.95	0.97				
	Duplicate	15.78	13.57	18.98	.97				
	Mean	15.78	13.62	18.96	.97	3.68	1.41	0.458	3.60
	0.1μ-0.3μ	22.23	11.89	20.99	1.32				
	Duplicate	22.27	11.89	21.00	1.32				
	Mean	22.25	11.89	21.00	1.32	4.66	1.79	.361	4.04
	0.3μ-1μ	26.83	11.39	20.51	1.64				
	Duplicate	27.00	11.39	20.62	1.64				
	Mean	26.94	11.39	20.56	1.64	6.26	2.21	.352	5.76
	1μ-5μ	28.50	11.55	20.42	1.73				
	Duplicate	28.50	11.64	20.46	1.73				
	Mean	28.50	11.60	20.44	1.73	6.52	2.38	.262	6.44
	5μ-50μ	50.38	7.18	18.77	2.65				
	Duplicate	50.22	7.21	18.92	3.64				
	Mean	50.30	7.20	18.85	3.65	18.55	4.52	.249	7.74

Fraction of whole soil (per cent)	Size	MgO	CaO	K ₂ O	Na ₂ O	TiO ₂	MnO	P ₂ O ₅	Organic matter	Combined water
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
0.6	<0.1μ	1.12	1.48	1.28	0.31	0.73	0.07	0.56	33.45	12.58
	Duplicate	1.15	1.44	1.27	.31	.71	.07	.58	33.39	12.70
	Mean	1.14	1.45	1.27	.31	.72	.07	.56	33.37	12.63
	0.1μ-0.3μ	1.26	1.33	1.93	.37	.56	.11	.49	29.21	9.69
	Duplicate	1.29	1.27	1.88	.36	.54	.11	.47	29.28	9.43
	Mean	1.28	1.30	1.91	.37	.55	.11	.45	29.25	9.51
	0.3μ-1μ	1.23	.78	2.51	.49	.93	.08	.27	25.55	9.13
	Duplicate	1.23	.74	2.47	.44	.93	.08	.27	25.38	9.42
	Mean	1.23	.76	2.49	.47	.93	.08	.27	25.46	9.28
	1μ-5μ	1.38	.89	2.96	.42	.94	.07	.27	23.50	9.45
	Duplicate	1.38	.85	2.75	.42	.92	.07	.28	23.38	9.04
	Mean	1.38	.87	2.86	.42	.93	.07	.28	23.18	9.26
	5μ-50μ	1.31	.93	4.22	1.23	1.10	.07	.64	9.68	5.52
	Duplicate	1.32	.98	4.32	1.14	1.10	.07	.64	9.57	5.56
	Mean	1.32	.90	4.27	1.19	1.10	.07	.64	9.63	5.54

There is in the Becket soil a much more pronounced segregation of iron oxide in the direction of the smaller particle sizes and this segregation is evidenced also in the distribution of the alumina.

The sharp differentiation which occurs in the Amarillo and the Marshall soils between the largest colloid particles and clay does not appear in the Becket soil until the silt size is reached, and even here the contrast is not so great. The relation between the total base content and the silica in the Becket is of considerable interest. The ratio

is smaller than in the more nearly saturated colloids and alters rapidly with increasing particle size. This condition is probably due to the enormous organic content and does not indicate even a close approach to saturation of the colloid acid complex. The pH value for this soil is 4.1 and the base saturation is but 16.8 per cent (3). The organic-matter content is greatest in the finest particles, which is in contrast with the Amarillo and Marshall colloids. Since the Becket profile has a much greater organic content in the B horizon than in the bleicherde (10), the inference may be drawn that not only is the organic matter of the Becket soil decomposed to an advanced degree, but that it has been carried down through the profile in intimate association, perhaps chemical combination, with the iron of the colloid. That it exists in the B horizon in chemical combination does not follow. (See General Discussion.)

TABLE 11.—Chemical composition of fractions of colloids, clay, and silt from a lateritic soil, Davidson clay loam, B₁ horizon, 9-36 inches depth

Fraction of whole soil	Size	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	Molecular ratio				
					SiO ₂ Al ₂ O ₃ +Fe ₂ O ₃	SiO ₂ Fe ₂ O ₃	SiO ₂ Al ₂ O ₃	Fe ₂ O ₃ Al ₂ O ₃	SiO ₂ Total bases
Per cent		Per cent	Per cent	Per cent					
14.0	<0.1 μ	32.95	15.44	32.02	1.46				
	Duplicate	33.05	15.60	31.87	1.46				
	Mean	33.05	15.52	31.96	1.46	6.21	1.91	0.303	12.71
20.9	<0.3 μ	26.13	16.05	31.45	1.47				
	Duplicate	26.20	15.90	31.43	1.47				
	Mean	26.17	15.98	31.46	1.47	6.00	1.94	.324	22.27
7.5	0.3 μ -1 μ	38.65	14.72	30.73	1.55				
	Duplicate	36.75	14.69	30.86	1.55				
	Mean	36.70	14.71	30.80	1.55	6.61	2.01	.304	24.16
2.4	1 μ -2 μ	39.76	12.26	30.30	1.77				
	Duplicate	39.80	12.30	30.22	1.77				
	Mean	39.78	12.28	30.26	1.77	8.60	2.22	.259	29.85
6.0	2 μ -6 μ	49.38	8.51	27.53	2.53				
	Duplicate	49.30	8.53	27.47	2.53				
	Mean	49.34	8.52	27.50	2.53	15.37	3.27	.193	23.85
12.6	6 μ -30 μ	63.40	6.52	19.77	4.41				
	Duplicate	63.35	6.51	19.73	4.42				
	Mean	63.37	6.52	19.75	4.42	25.80	5.43	.210	42.22

Fraction of whole soil	Size	MgO	CaO	K ₂ O	Na ₂ O	TiO ₂	MnO	P ₂ O ₅	Organic matter	Combined water
Per cent		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
14.0	<0.1 μ	0.65	0.60	0.34	0.23	0.56	0.13	0.19	2.08	12.04
	Duplicate	.65	.62	.35	.25	.58	.13	.17	2.05	11.94
	Mean	.65	.61	.35	.24	.57	.13	.18	2.06	11.99
20.9	<0.3 μ	.61	.59	.34	.24	.61	.07	.13	1.45	12.24
	Duplicate	.60	.62	.32	.22	.63	.08	.14	1.49	12.32
	Mean	.61	.60	.33	.23	.62	.08	.14	1.47	12.28
7.5	0.3 μ -1 μ	.62	.61	.56	.56	1.46	.07	.19	1.50	12.32
	Duplicate	.49	.59	.56	.56	1.40	.07	.18	1.29	12.33
	Mean	.61	.65	.56	.56	1.43	.07	.19	1.30	12.33
2.4	1 μ -2 μ	.69	.38	.50	.50	1.76	.08	.28	1.60	11.80
	Duplicate	.65	.51	.56	.56	1.74	.09	.29	1.44	11.80
	Mean	.67	.55	.53	.53	1.75	.09	.29	1.47	11.83
6.0	2 μ -6 μ	.73	.18	1.05	.15	1.81	.04	.16	1.40	9.96
	Duplicate	.83	.18	1.01	.13	1.81	.04	.16	1.51	9.81
	Mean	.77	.18	1.03	.14	1.81	.04	.16	1.46	9.83
12.6	6 μ -30 μ	.00	.16	.73	.08	1.81	.08	.02	.76	8.99
	Duplicate	.55	.12	.70	.13	1.61	.08	.02	.76	7.01
	Mean	.69	.14	.72	.11	1.81	.08	.02	.77	7.00

In Table 11 are shown the analytical data for the fractions of the B₁ horizon of Davidson clay loam. This sample is a part of the same profile reported by Middleton (22). The soil is a mature red soil from the piedmont area and is highly lateritic, as indicated by the silica-sesquioxide ratio. The iron oxide content of the soil is high. In the A horizon it is 6.1 per cent; in the B₁ horizon, 10.62 per cent; in the B₂ horizon, 14.87 per cent; and in the C horizon, 13.37 per cent (22). While this marked alteration of the iron oxide content within the profile is occurring, the change in the alumina content of the B₁ and B₂ horizons alters but 0.18 per cent. These facts indicate clearly a distinct transfer of iron oxide from the surface soil to the lower part of the profile, although to less marked extent than in the Becket and Superior podzols examined by Anderson and Byers (9). A much less distinctly marked alteration of alumina content occurs in the soils.

In accord with this behavior of the soils a distinct concentration of iron oxide is found in the finer part of the colloid, as indicated by the silica-iron oxide ratios of 6.61 and 6.00 for the 0.3 to 1-micron and below 0.3-micron fractions. (It is to be noted that in Table 10 the 0.3-micron fraction includes the material below 0.1 micron.) This alteration of the iron-oxide content is less marked than in the Becket colloid. The fact that a corresponding concentration of alumina in the finer fraction does not occur is shown by the iron oxide-alumina ratios 0.324 and 0.304. When these facts are considered in the light of the corresponding data of Table 9 and those given for the B₂ horizon of Cecil clay loam (Table 12) and for the profile of the same soil reported by Denison (14), it is difficult to avoid the conclusion that iron oxide is carried from the upper to lower levels in a very fine state of subdivision, or possibly in true solution, with organic acids of the humus type. That alumina is not so transferred, or at least is not deposited, is also clear. The close approach of the silica-alumina ratio to 2.0 in the colloid fractions indicates the presence in the colloid of but little free alumina and that the "laterization" of the colloid is confined largely, if not wholly, to the iron compounds of the soil material.

The extremely high silica-base ratios are of marked interest because they indicate the high degree of leaching which has taken place. It would appear, however, that the silica-alumina ratio should indicate a fair base-exchange capacity. The base-exchange capacity of this profile has been shown by Anderson and Byers (9) to be 0.183, 0.126, and 0.158 milliequivalents for the A, B₁, and B₂ horizons, respectively. This is in marked contrast with a true ferruginous laterite, Nipe clay, which has nearly zero base-exchange capacity (10).

In this colloid a distinct accumulation of organic matter is found in the finer fractions, but this accumulation is relatively and in quantity not quite so great as in the podzol (Table 9) and is not associated with so large an alteration of the content of combined water. No very definite conclusions are to be based on data so quantitatively uncertain as are the organic and combined water values (5), but it seems probable that these differences are to be associated with the mean annual temperatures under which these soils have been developed.

Table 12 contains the data on the chemical composition of the size fractions of the colloid of a B₂ horizon of a Cecil clay loam from North Carolina. It is derived from the same profile but not the same sample reported by Denison (14). It is a more highly laterized soil than the Davidson, and the soil material is disintegrated to a much greater depth. The profile analyses of the colloid show close similarity to the extensive investigation of Cecil colloids as reported by Holmes and Edgington (17).

TABLE 12.—Chemical composition of fractions of soil colloids, clay, and silt, from a lateritic soil, Cecil clay loam, B₂ horizon, 36-72 inches depth

Fraction of whole soil (per cent)	Size	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	Molecular ratio				
					SiO ₂ /Al ₂ O ₃	SiO ₂ /Fe ₂ O ₃	SiO ₂ /Al ₂ O ₃	Fe ₂ O ₃ /Al ₂ O ₃	SiO ₂ /Total bases
1.4	<0.1 μ	33.83	15.50	32.17	1.27				
	Duplicate	33.72	15.62	32.25	1.35				
	Mean	33.78	15.81	32.21	1.36	5.78	1.77	0.307	21.91
2.5	0.1 μ -0.3 μ	34.04	13.02	34.26	1.35				
	Duplicate	34.25	13.01	34.04	1.37				
	Mean	34.15	13.02	34.15	1.36	6.96	1.67	.243	23.56
1.0	0.3 μ -1 μ	35.80	11.00	32.29	1.64				
	Duplicate	35.78	11.00	32.24	1.64				
	Mean	35.79	11.00	32.27	1.64	8.77	1.87	.247	21.23
1.4	1 μ -5 μ	37.20	10.55	33.71	1.68				
	Duplicate	37.21	10.59	33.61	1.66				
	Mean	37.21	10.67	33.65	1.57	9.35	1.87	.200	17.23
9.5	5 μ -50 μ	41.50	8.00	33.73	1.81				
	Duplicate	41.49	8.20	33.63	1.79				
	Mean	41.45	8.10	33.63	1.80	13.58	2.07	.163	16.17

Fraction of whole soil (per cent)	Size	MgO	CaO	K ₂ O	Na ₂ O	TiO ₂	MnO	P ₂ O ₅	Organic matter	Combined water
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
1.4	<0.1 μ	0.43	0.41	0.36	0.24	0.94	0.24	0.29	3.33	12.71
	Duplicate	.40	.41	.37	.23	.92	.23	.31	3.52	12.64
	Mean	.42	.41	.36	.24	.93	.23	.30	3.43	12.77
2.5	0.1 μ -0.3 μ	.33	.31	.27	.13	1.12	.21	.30	3.65	12.97
	Duplicate	.35	.35	.26	.16	1.14	.21	.31	3.58	12.77
	Mean	.34	.33	.27	.14	1.13	.21	.31	3.62	12.76
1.0	0.3 μ -1 μ	.51	.42	.44	.20	1.46	.24	.50	4.89	11.93
	Duplicate	.51	.41	.42	.20	1.48	.24	.52	4.91	12.05
	Mean	.51	.42	.43	.20	1.47	.24	.51	4.90	12.02
1.4	1 μ -5 μ	.81	.46	.68	.06	.84	.20	.65	2.69	12.20
	Duplicate	.76	.43	.72	.01	.78	.18	.70	2.71	12.10
	Mean	.79	.45	.70	.01	.81	.19	.68	2.65	12.15
9.5	5 μ -50 μ	.79	.34	1.17	.29	1.25	.13	.02	1.16	11.60
	Duplicate	.75	.34	1.19	.28	1.23	.13	.02	1.03	11.97
	Mean	.77	.34	1.18	.29	1.25	.13	.02	1.10	11.88

Here the evidence of podzolization as shown by increase of the silica-iron oxide ratio, silica-alumina ratio, and by the change of the ferric oxide-alumina ratio in colloid fractions is also found, as was also shown by Byers and Anderson (10) for the A and B horizons of the profiles of Cecil soils in general. In accordance with these properties of the colloid of the Cecil profile distinct alteration of colloidal properties with colloidal size are found. (Table 11.) As with the Davidson colloid, the silica-alumina ratio is fairly close to 2.0 and increases

gradually toward the coarser particles. The schist from which the soil is formed contains but little quartz, and hence there is not the sudden increase of the various silica ratios as the clay and silt sizes are reached. The analyses of both silt and clay fractions indicate unquestionably the presence of increasing quantities of undecomposed, or only partly decomposed, schistose material. In this colloid no marked alteration of the organic content or of the combined water occurs, and in this respect it resembles the behavior of the colloids of the Amarillo and Marshall soils. It is probable that this fact is due in part to the extremely deep and porous character of the profile, which allows the finely divided material to penetrate to greater depths before deposition.

The very high silica-base molecular ratios show the soil to be extremely highly leached, despite the relatively high organic content which might be expected to aid the retention of the bases.

In Table 13 are presented data from the C₃ horizon of a lateritic soil, Durham sandy loam, from near Stone Mountain, Ga. It is the decomposition material from granite, and the decay has proceeded sufficiently far for rather complete disintegration of the rock. The profile is the same as that on which data are reported by Denison (14), but the sample is not identical. The soil is derived from a rock low in iron, and the colloid is therefore low in iron oxide, though there is a much larger amount in the colloid than in the whole soil. The value of the silica-alumina ratio indicates a mature soil, as does also the extremely extensive removal of the bases. On the other hand, the rapid increase in the potassium content of the coarser particles indicates the presence of much undecomposed micaceous or feldspathic material. The presence of these is confirmed by petrographic examination. The presence of such relatively large amounts of organic material at so great a depth and its failure to be present in increased quantity in the finer fractions indicates the transfer of considerable material from the upper soil strata and that it probably acts as a cementing material to limit the ease of dispersion. In the analytical data the fraction below 0.3 micron includes the finer fraction below 0.1 micron. The relatively high combined water also indicates the presence of hydrated oxides or colloidal mica. It is with these facts in mind that the authors hazard the opinion that this material consists in part of raw colloid of high silica-sesquioxide ratio, formed in place and in part of completely laterized material carried down from the upper strata. This assumption is in harmony with the data presented by Denison (14) on a different sample of the same soil, though the silica-sesquioxide ratio for the corresponding horizon in that sample is much less than in the present one, and the organic and combined water content are correspondingly greater.

TABLE 13.—Chemical composition of fractions of soil colloids, clay, and silt, from a lateritic soil, Durham sandy loam, C₂ horizon, 90–102 inches depth

Fraction of whole soil (per cent)	Size	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	Molecular ratio				
					SiO ₂ / Al ₂ O ₃ +Fe ₂ O ₃	SiO ₂ / Fe ₂ O ₃	SiO ₂ / Al ₂ O ₃	Fe ₂ O ₃ / Al ₂ O ₃	SiO ₂ / Total bases
		<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>					
10.7	<0.1 _μ	41.38	3.57	37.90	1.75				
	Duplicate	41.60	3.67	38.00	1.76				
	Mean	41.44	3.62	37.95	1.75	30.32	1.85	0.060	30.8
20.5	<0.3 _μ	41.57	3.56	39.15	1.70				
	Duplicate	41.53	3.64	39.38	1.69				
	Mean	41.55	3.55	39.27	1.70	31.06	1.79	.087	27.0
2.9	0.3 _μ –1 _μ	40.13	3.15	39.38	1.64				
	Duplicate	40.13	3.20	39.48	1.64				
	Mean	40.13	3.17	39.43	1.64	33.59	1.74	.051	20.0
2.9	1 _μ –5 _μ	39.39	3.48	37.39	1.69				
	Duplicate	39.37	3.39	37.44	1.68				
	Mean	39.38	3.43	37.42	1.68	30.66	1.78	.058	14.3
6.5	5 _μ –50 _μ	48.73	2.28	33.22	2.38				
	Duplicate	48.80	2.36	33.17	2.38				
	Mean	48.77	2.32	33.20	2.38	52.50	2.45	.045	18.2

Fraction of whole soil (per cent)	Size	MgO	CaO	K ₂ O	Na ₂ O	TiO ₂	MnO	P ₂ O ₅	Organic matter	Combined water
		<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
10.7	<0.1 _μ	0.54	0.44	0.50	0.29	0.31	0.03	0.13	1.39	13.50
	Duplicate	.55	.45	.52	.24	.29	.03	.12	1.38	13.53
	Mean	.55	.46	.51	.27	.30	.03	.13	1.39	13.52
20.5	<0.3 _μ	.41	.23	.66	.30	.39	.03	.03	.98	13.45
	Duplicate	.37	.25	.66	.32	.39	.02	.03	.91	13.47
	Mean	.39	.24	.66	.31	.39	.03	.03	.94	13.45
2.9	0.3 _μ –1 _μ	.43	.33	.97	.38	.43	.06	.10	1.93	13.58
	Duplicate	.43	.31	.97	.40	.43	.06	.10	1.87	13.68
	Mean	.43	.32	.97	.38	.43	.06	.10	1.90	13.63
2.9	1 _μ –5 _μ	.65	.45	1.42	.45	.41	.04	.24	3.39	13.08
	Duplicate	.68	.45	1.39	.48	.41	.05	.22	3.37	12.77
	Mean	.67	.45	1.40	.47	.41	.05	.23	3.34	12.93
0.5	5 _μ –50 _μ	.53	.46	2.37	.48	.36	.05	.20	1.63	10.51
	Duplicate	.50	.45	2.45	.46	.36	.05	.21	1.66	10.39
	Mean	.52	.46	2.41	.47	.36	.05	.21	1.56	10.45

The soil fractions represented by the data in Table 14 are derived from the C₂ horizon of a Cecil sandy clay loam from De Kalb County, Ga. It is from the same location as the profile reported by Denison (14) but is a different sample. The profile is that of a highly developed laterite in which the weathering of the micaceous schist has penetrated to considerable depth. The soil material, making up the various layers of the C horizon, consists of numerous wavy bands of material of different colors. The material represented in Table 14 consists of several such bands. The analyses of the colloidal fractions indicate a very high degree of weathering, even at a depth of more than 112 inches. The total colloid, as estimated by mechanical analysis, (2 microns and less) is but 1.7 per cent (Table 3), and of this quantity 88 per cent (1.5 per cent of the soil) is represented in the analytical data and approximately two-thirds of it in the fractions below 0.3 micron. Although the colloid of this profile contains a considerable quantity of iron oxide, its concentration is greatest in

the very fine fraction. That this content of iron oxide is greater in the fraction between 0.3 and 1 micron is perhaps due to the difficulty in dispersing the incipient "iron" concretions observable in larger sizes in soils of the general character of the Cecil series. Attention is also called to the fact that although the silica-sesquioxide ratio indicates a highly laterized colloid, the silica-alumina ratio closely approaches that of kaolin. If the considerations presented later are accepted as well grounded, this may be taken to indicate that practically all the iron content of the soil is present as the sesquioxide and that most of the aluminium is present as aluminosilicate. The high organic-matter content of this deep-lying material is to be taken as evidence that the source of at least a large part of the colloid is from the overlying strata. The extreme poverty of the colloid of the finer fractions in bases is in accord with this assumption.

TABLE 14.—Chemical composition of fractions of soil colloids, clay, and silt from a lateritic soil, Cecil sandy clay loam, C₄ horizon, 180-196 inches depth

Fraction of whole soil (per cent)	Size	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	Molecular ratio				
					$\frac{SiO_2}{Fe_2O_3+Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$
		<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>					
0.3	<0.1 μ	33.88	14.15	30.34	1.46				
	Duplicate	33.84	14.16	30.33	1.46				
	Mean	33.86	14.16	30.33	1.46	6.35	1.89	0.297	27.11
.8	0.1 μ -0.3 μ	38.66	9.21	33.55	1.87				
	Duplicate	38.60	9.18	33.42	1.67				
	Mean	38.63	9.20	33.48	1.87	11.14	1.95	.175	26.30
.4	0.3 μ -1 μ	35.06	13.92	29.75	1.54				
	Duplicate	35.04	13.94	29.73	1.53				
	Mean	35.05	13.93	29.74	1.54	6.09	1.99	.292	13.77
.8	1 μ -5 μ	34.64	18.44	29.30	1.43				
	Duplicate	34.50	18.25	29.49	1.42				
	Mean	34.57	18.35	29.40	1.43	4.96	1.99	.400	10.14
4.0	5 μ -50 μ	41.91	11.15	30.02	1.91				
	Duplicate	41.91	11.19	29.97	1.91				
	Mean	41.91	11.17	30.00	1.91	9.97	2.36	.237	9.98

Fraction of whole soil (per cent)	Size	MgO	CaO	K ₂ O	Na ₂ O	TiO ₂	MnO	P ₂ O ₅	Organic matter	Combined water
		<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
0.3	<0.1 μ	0.65	0.43	0.56	0.14	0.80	0.54	0.20	6.86	11.68
	Duplicate	.65	.39	.53	.13	.80	.56	.22	6.71	11.75
	Mean	.65	.41	.55	.14	.80	.55	.21	6.79	11.72
.8	0.1 μ -0.3 μ	.55	.39	.79	.05	.64	.22	.30	3.86	11.94
	Duplicate	.67	.39	.78	.08	.64	.32	.28	3.81	12.04
	Mean	.66	.39	.79	.06	.64	.32	.29	3.84	11.99
.4	0.3 μ -1 μ	1.05	.51	.42	.21	.99	.56	.39	5.09	11.91
	Duplicate	1.03	.45	.44	.28	1.01	.56	.40	5.15	11.80
	Mean	1.04	.48	.43	.25	1.00	.56	.40	5.12	11.85
.3	1 μ -5 μ	1.40	.34	1.28	.20	1.22	.62	.44	3.08	11.77
	Duplicate	1.32	.36	1.30	.13	1.24	.62	.42	2.90	11.95
	Mean	1.36	.35	1.28	.17	1.23	.62	.43	2.99	11.86
4.0	5 μ -50 μ	1.60	.33	1.91	.31	1.05	.42	.18	1.65	10.05
	Duplicate	1.55	.39	1.76	.21	1.07	.40	.17	1.63	10.03
	Mean	1.58	.38	1.83	.26	1.06	.41	.18	1.66	10.04

TABLE 15.—Chemical composition of fractions of colloids, silt, and clay, from Cecil clay loam, C₂ horizon, 112+ inches depth

Fraction of whole soil (per cent)	Size	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	Molecular ratio				
					SiO ₂ Al ₂ O ₃ +Fe ₂ O ₃	SiO ₂ Fe ₂ O ₃	SiO ₂ Al ₂ O ₃	Fe ₂ O ₃ Al ₂ O ₃	SiO ₂ Total bases
		Per cent	Per cent	Per cent					
2.6	<0.1 _μ	13.95	2.03	53.08	0.436				
	Duplicate	14.10	2.02	53.02	.443				
	Mean	14.02	2.03	53.05	.439	1.83	0.46	0.024	7.24
5.2	<0.3 _μ	13.01	1.89	66.75	.371				
	Duplicate	13.06	1.81	56.50	.378				
	Mean	13.04	1.85	56.85	.376	1.87	.39	.021	16.93
2.9	0.3 _μ -1 _μ	15.47	2.48	51.73	.484				
	Duplicate	15.58	2.45	51.66	.489				
	Mean	15.52	2.47	51.69	.487	1.66	.51	.031	10.38
3.9	1 _μ -5 _μ	19.78	4.11	45.73	.692				
	Duplicate	19.82	4.11	45.84	.694				
	Mean	19.80	4.11	45.78	.693	1.28	.73	.055	8.14
6.0	5 _μ -50 _μ	34.70	7.26	35.33	1.47				
	Duplicate	34.09	7.22	35.40	1.47				
	Mean	34.70	7.24	35.36	1.47	1.27	1.66	.130	9.51

Fraction of whole soil (per cent)	Size	MgO	CaO	K ₂ O	Na ₂ O	TiO ₂	MnO	P ₂ O ₅	Organic matter	Combined water
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
2.6	<0.1 _μ	0.48	0.60	0.22	0.19	0.48	0.31	1.68	4.02	23.80
	Duplicate	.46	.62	.20	.22	.46	.33	1.06		
	Mean	.47	.61	.21	.21	.47	.32	1.06		
5.2	<0.3 _μ	.34	.35	.26	.17	.35	.16	.76	2.73	24.39
	Duplicate	.35	.37	.26	.15	.35	.16	.78	2.74	24.30
	Mean	.34	.36	.26	.16	.35	.16	.77	2.74	24.35
2.9	0.3 _μ -1 _μ	.51	.63	.45	.35	.44	.08	.85	4.56	22.80
	Duplicate	.53	.61	.43	.37	.43	.08	.86	4.56	22.96
	Mean	.52	.62	.44	.38	.43	.08	.86	4.56	22.92
3.9	1 _μ -5 _μ	.89	.41	.74	.21	.49	.17	.87	5.80	20.40
	Duplicate	.91	.39	.72	.16	.49	.16	.86	5.77	20.40
	Mean	.90	.40	.73	.19	.49	.16	.87	5.79	20.40
6.0	5 _μ -50 _μ	1.25	.47	1.56	.29	.93	.16	.78	2.51	14.35
	Duplicate	1.26	.47	1.56	.27	.91	.17	.79	2.54	14.11
	Mean	1.25	.47	1.56	.28	.92	.17	.78	2.53	14.23

The analytical data presented in Table 15 are derived from the C₂ horizon of the same profile sample as the B₂ horizon which is the source of the data of Table 12. The data given for this horizon by Denison (14) are derived from the same locality but from a different sample. It is to be observed that this Cecil soil is presumably derived from gneiss, whereas the soil represented by Table 14 is derived from micaceous schist. The sample under consideration is the composite of but two or three bands of nearly white coarsely granulated material, high in sands and gravel, and containing an unusually large percentage of colloid at such great depth. The silica-sesquioxide, silica-iron oxide, and silica-alumina ratios are all abnormally low. The organic matter and combined water content are abnormally high, as is also the phosphate. The organic matter may be considered as limiting to some extent the ease of dispersion. There is no regularity in the silica-base ratio, but the concentration of the bases as well as of the phosphoric acid is greatest in the finest fraction.

There is of course a strong inclination to assume that colloid accumulation at so great a depth in material having a pH value of less than 5 has been formed in place. It would be necessary in this case to assume further that the feldspathic decay produces aluminum hydroxide as a primary step, or, at least, as a secondary result, which keeps almost abreast of the primary hydrolysis. Such formation of aluminium hydroxide is highly improbable. In view, however, of the high content of organic matter, which presumably must have been carried down, the writers prefer to assume that both the alumina and the organic matter have been deposited at this depth either from colloidal suspension or from solution as a result of the surface alkalinity of the feldspathic material to which attention has been strongly directed by Cushman (12) and others. The process may, in this case, be assumed to be a species of podzolization in which the iron oxide may have been deposited at higher levels and the alumina carried to greater depths. Whether such a process has actually occurred is not to be asserted positively, but it leads to the suspicion that the same type of fractionation of colloids, which results in the production of podzolic ortstein layers, may also result in the segregation of alumina at lower levels. This accords with the data on the precipitation of aluminium hydroxide by Blum (8).

WATER VAPOR ABSORPTION AND HEAT OF WETTING

In Table 16 are presented the data on the water vapor absorption over 3.3 per cent sulphuric acid, over 30 per cent sulphuric acid, and the heat of wetting of the fractions of the eight colloids examined. The ratio of the amount of water absorbed over 3.3 per cent acid to that over 30 per cent is also given. The determination of the water vapor absorption over 30 per cent sulphuric acid was made because it is known, as was pointed out by Anderson (2) and Anderson and Mattson (4), that even when colloids absorb approximately equal quantities of water from a nearly saturated atmosphere, the quantities may vary widely at lower humidity.

TABLE 16.—Physical properties of fractions of colloids from various soils

Sample No.	Soil type	Size	Water vapor absorbed over—		Absorption ratio 3.3 per cent 30 percent	Heat of wetting
			3.3 per cent H ₂ SO ₄	30 per cent H ₂ SO ₄		
4575	Amarillo silty clay loam.....		<i>Per cent</i>	<i>Per cent</i>		<i>Calories</i>
		<0.1 μ.....	36.25	19.95	1.82	19.2
		Duplicate.....	36.80	20.18	1.82	19.0
		Mean.....	36.48	20.07	1.82	19.1
		0.1-0.3 μ.....	27.02	13.84	1.95	12.6
		Duplicate.....	26.85	14.00	1.92	12.8
		Mean.....	26.94	13.92	1.94	12.7
		0.3-1 μ.....	25.80	13.51	1.91	12.6
		Duplicate.....	25.30	13.25	1.91	12.8
		Mean.....	25.55	13.38	1.91	12.7
		1-5 μ.....	12.24	6.93	1.70	6.7
		Duplicate.....	12.15	6.14	1.87	6.7
		Mean.....	12.20	6.50	1.87	5.7
		5-50 μ.....	2.53	1.31	1.93	1.2
		Duplicate.....	2.55	1.28	1.99	1.1
		Mean.....	2.54	1.30	1.96	1.2

TABLE 16.—Physical properties of fractions of colloids from various soils—Contd.

Sample No.	Soil type	Size	Water vapor absorbed over—		Absorption ratio 3.3 percent 30 percent	Heat of wetting Calories
			3.3 per cent H ₂ SO ₄	30 per cent H ₂ SO ₄		
191	Marshall silt loam	<0.1 μ	30.66	53.49	2.27	14.5
		Duplicate	31.44	12.80	2.45	14.6
		Mean	31.05	13.14	2.36	14.5
		0.1-0.3 μ	25.80	9.18	2.81	10.8
		Duplicate	26.20	9.32	2.81	11.4
		Mean	26.00	9.25	2.81	11.1
		0.3-1 μ	24.58	9.55	2.57	10.0
		Duplicate	23.20	9.59	2.63	9.9
		Mean	24.89	7.57	2.60	10.0
		1-5 μ	16.25	9.02	2.31	9.5
		Duplicate	15.59	7.15	2.18	9.7
		Mean	15.92	7.08	2.25	9.6
		5-50 μ	2.35	.96	2.46	2.5
		Duplicate	2.31	.99	2.33	2.3
		Mean	2.33	.97	2.39	2.4
447	Becket silt loam	<0.1 μ	32.62	19.63	1.64	18.4
		Duplicate	29.90	18.38	1.02	18.6
		Mean	30.26	18.53	1.63	18.5
		0.1-0.3 μ	23.78	13.36	1.78	17.7
		Duplicate	24.01	13.56	1.77	17.5
		Mean	23.89	13.46	1.78	17.6
		0.3-1 μ	25.02	15.78	1.59	18.0
		Duplicate	24.66	15.16	1.63	18.0
		Mean	24.84	15.47	1.61	18.0
		1-5 μ	17.61	9.75	1.81	13.4
		Duplicate	17.81	9.06	1.79	13.4
		Mean	17.71	9.86	1.80	13.4
		5-50 μ	7.49	4.17	1.80	6.5
		Duplicate	7.18	4.27	1.68	6.4
		Mean	7.33	4.22	1.74	6.5
623	Durham sandy loam	<0.1 μ	34.71	6.07	5.72	6.8
		Duplicate	34.18	5.93	5.78	6.6
		Mean	24.44	6.00	5.75	6.8
		<0.3 μ	18.19	2.39	5.87	2.6
		Duplicate	18.56	3.40	5.32	4.1
		Mean	18.37	2.44	5.35	3.9
		0.3-1 μ	16.15	3.67	4.40	3.6
		Duplicate	15.30	3.89	3.94	4.0
		Mean	15.72	3.78	4.17	3.8
		1-5 μ	8.65	2.61	3.06	2.5
		Duplicate	8.27	2.41	3.43	2.7
		Mean	8.16	2.51	3.26	2.6
		5-50 μ	7.02	1.81	3.88	1.5
		Duplicate	7.48	1.83	4.07	1.5
		Mean	7.24	1.82	3.97	1.5
446	Davidson clay loam	<0.1 μ	38.61	7.21	5.40	6.4
		Duplicate	38.99	7.27	5.38	6.0
		Mean	38.65	7.24	5.38	6.2
		<0.3 μ	29.32	7.44	5.26	4.1
		Duplicate	38.72	7.39	5.13	4.3
		Mean	39.02	7.42	5.21	4.2
		0.3-1 μ	34.16	5.62	6.08	4.7
		Duplicate	33.94	5.43	6.26	4.6
		Mean	34.05	5.62	6.17	4.7
		1-5 μ	14.32	3.44	4.11	3.6
		Duplicate	14.56	3.43	4.25	2.8
		Mean	14.44	3.44	4.18	3.7
		5-50 μ	8.05	1.44	3.51	1.6
		Duplicate	5.20	1.51	3.44	1.5
		Mean	6.12	1.47	3.47	1.6
624	Cecil sandy clay loam	<0.1 μ	35.00	5.43	6.46	—
		Duplicate	36.17	5.56	6.59	—
		Mean	35.58	5.49	6.48	—
		0.1-0.3 μ	15.13	3.36	4.53	4.7
		Duplicate	15.59	3.27	4.77	4.6
		Mean	15.36	3.32	4.64	4.7
		0.3-1 μ	17.10	3.66	4.82	—
		Duplicate	17.64	3.08	5.73	—
		Mean	17.40	3.32	5.28	—
		1-5 μ	9.78	3.25	2.92	3.5
		Duplicate	9.77	3.23	3.01	3.4
		Mean	9.78	3.30	2.97	3.5
		5-50 μ	5.72	2.12	2.70	2.7
		Duplicate	5.86	2.21	2.55	2.6
		Mean	5.79	2.17	2.68	2.7

TABLE 16.—Physical properties of fractions of colloids from various soils—Contd.

Sample No.	Soil type	Size	Water vapor absorbed over—		Absorption ratio 3.3 per cent 30 per cent	Heat of wetting calories
			3.3 per cent H ₂ SO ₄	30 per cent H ₂ SO ₄		
6278	Cecil clay loam	<0.1 μ	35.75	5.57	6.42	5.9
		Duplicate	35.90	5.75	6.24	6.4
		Mean	35.81	5.66	6.33	6.2
		0.1-0.3 μ	21.89	3.42	6.11	3.6
		Duplicate	22.90	3.73	6.13	3.8
		Mean	22.39	3.58	6.12	3.7
		0.3-1 μ	13.45	3.35	4.02	3.6
		Duplicate	14.22	2.98	4.83	3.8
		Mean	13.88	3.16	4.43	3.7
		1-5 μ	9.40	2.69	3.63	2.8
		Duplicate	8.58	2.81	3.41	2.9
		Mean	9.43	2.75	3.47	2.9
		5-50 μ	7.80	1.79	4.36	2.2
		Duplicate	7.20	1.89	3.81	2.5
		Mean	7.50	1.84	4.08	2.4
		<0.1 μ	14.32	3.54	4.05	
		Duplicate	14.35	3.08	4.65	
		Mean	14.34	3.31	4.35	
		<0.3 μ	15.13	3.13	4.84	4.9
		Duplicate	15.60	3.28	4.82	5.3
Mean	15.46	3.20	4.83	5.1		
0.3-1 μ	13.01	3.35	3.89	5.8		
Duplicate	14.10	3.77	3.74	5.3		
Mean	13.56	3.56	3.81	5.6		
1-5 μ	10.22	2.91	3.51	4.7		
Duplicate	10.21	2.84	3.60	4.4		
Mean	10.22	2.88	3.56	4.6		
5-50 μ	7.93	2.56	3.09	4.2		
Duplicate	8.16	2.55	3.20	4.0		
Mean	8.05	2.56	3.14	4.1		
6281	Cecil clay loam	<0.1 μ	14.32	3.54	4.05	
		Duplicate	14.35	3.08	4.65	
		Mean	14.34	3.31	4.35	
		<0.3 μ	15.13	3.13	4.84	4.9
		Duplicate	15.60	3.28	4.82	5.3
		Mean	15.46	3.20	4.83	5.1
		0.3-1 μ	13.01	3.35	3.89	5.8
		Duplicate	14.10	3.77	3.74	5.3
		Mean	13.56	3.56	3.81	5.6
		1-5 μ	10.22	2.91	3.51	4.7
		Duplicate	10.21	2.84	3.60	4.4
		Mean	10.22	2.88	3.56	4.6

Of the heat of wetting little need be said except that in numerical values the calories of heat evolved per gram are parallel with and nearly the same as the percentage of water absorbed over 30 per cent sulphuric acid. This parallelism has already been mentioned by Anderson (1) and by Anderson and Mattson (4). The heat of wetting may, of course, be considered as a measure of the energy involved in the absorption process. In general, the values for all three measurements decrease with increasing particle size. In the B₂ horizon of Becket silt loam, the 0.1 to 0.3 micron fraction shows somewhat smaller absorptive values than the fraction of larger size. It is probable that this divergence is associated with the presence in these fractions of exceptionally large amounts of organic matter which, though an excellent absorbent of water, does not necessarily have properties paralleling those of the inorganic material. A lack of uniformity is also shown, though to less degree, by the Marshall surface soil sample, in which the organic matter is also high.

The moisture absorption over 3.3 per cent sulphuric acid varies with the particle size and this fact emphasizes strongly that the method of Robinson (26) and of Gile et al. (15) for estimation of the quantity of colloid in the soil, is at best a rough approximation, since the absorption varies in the three colloidal fractions (0 to 1 micron sizes) from 13.66 per cent for the coarsest fraction of the Cecil clay loam, C₂ horizon, to 38.91 per cent for the finest fraction of the Davidson clay loam, a difference of 285 per cent of the smaller value. The widest difference in an individual soil is in the B horizon of the Cecil clay loam, where the variation is from 13.88 per cent to 35.73

per cent, about 260 per cent of the smaller value. Of course, the variation from the approximate mean value of the weighted fractions is not so divergent, but it is clear that with a fine colloid the water vapor absorption has not the same significance as in the coarser colloid.

It may be remarked, however, that the method of estimation of colloid was developed, using colloid of about 0.3-micron maximum particle size. If consideration is limited to the smaller fractions, the variation is not so great as when the 0.3 to 1 micron size is included.

That other influences than the particle size, i. e., the surface exposed, plays a part in the vapor absorption is clear from the wide variation in the colloids of the different types. Although the size limits are not necessarily an indication of exact equality of surface, they are near enough to equality to preclude the possibility of surface differences being able to account for the wide differences between similar size fractions of Davidson clay loam and the C₃ horizon of Cecil clay loam (No. 6281), nor for the wide difference between the 0.1 and 0.3 micron fractions of Durham sandy loam and the lack of such difference between the corresponding sizes of the C₃ horizon (No. 6281) of Cecil clay loam. It is possible that the various compositions of the colloids may have an indirect result in altering the size and porosity of the fractions as they are dried down in preparation for the determinations, and these differences are responsible for the variations observed.

That composition probably has a most marked effect is also indicated by the ratio of the moisture absorbed over 3.3 per cent sulphuric acid and over 30 per cent sulphuric acid. The vapor tensions over these solutions at 35° C. are, respectively, 41.36 and 31.31 mm, and the ratio of the water vapor absorbed over 3.3 per cent and 30 per cent acid varies from 6.33 in the 0.1-micron fraction of the B horizon of Cecil clay loam (No. 6278) to 1.64 in the corresponding particle size of Becket silt loam. In each colloid the ratio of moisture absorbed over 3.3 per cent acid to that over 30 per cent is fairly constant in each profile, though the actual quantities of water absorbed vary widely, the widest variation for the same soil being in Cecil sandy clay loam, from 6.48 to 2.68. There is a marked divergence between the group of soils represented by the Amarillo, Marshall, and Becket soils on the one hand and the group represented by the Durham, Davidson, and Cecil soils on the other. In the first group, the mean value for the three colloids of the low silica-base ratio is 2.06, for the high silica-base ratio group of four samples, the Durham, Davidson, Cecil sandy clay loam and Cecil clay loam (No. 6278), is 4.67, and for the C₃ horizon of the Cecil clay loam the mean value of the ratio for the three colloid sizes is 3.86. The meaning of this divergence is not wholly clear. It is true that the colloids in which the difference in water absorption is most seriously affected by a change in humidity are those in which bases are lacking in comparison with the silica. Where the total base is low, i. e., where the silica-base ratio is very high, the water absorption ratio is also high. In the Cecil clay loam, C₃ horizon, the silica-base ratio is intermediate. (Tables 7 to 16.) This relationship is also shown when the silica-base ratio alters markedly with coarsening of the fractions, e. g., compare the value 30.8 for the silica-base ratio with 5.72, the 3.3 : 30 per cent aqueous vapor ratio for the 0.1-micron fraction of the Durham soil with 20 and 4.17 for the 0.3 to 1 micron fraction of the same colloid.

Anderson (2) has shown considerable variation in the water vapor absorption over 30 per cent sulphuric acid by colloids where they are saturated with different bases. Although the variations are considerable, it does not appear that they will account for the ratios given in Table 16. Since the corresponding variations, if any, over 3.3 per cent sulphuric acid were not determined, it is not possible, from his data, to determine to what extent the various bases would modify the observed ratios.

There is a possibility that the greater absorption of water by the Amarillo, Marshall, and Becket colloid fractions at lowered humidity might be ascribed to the hydration of the metal cations in the colloidal micelles, but such an assumption is not very reasonable and the evidence is not adequate to support it.

There seems no possible correlation between the 3.3 : 30 per cent moisture ratio and the iron oxide or alumina content of the colloids. The iron oxide content is relatively high in the Amarillo, Marshall, and Davidson soils, in Cecil sandy clay loam, and in the B horizon of Cecil clay loam. It is low in the Durham soil and in the C₃ horizon of Cecil clay loam. The silica-alumina ratio is high in the Amarillo and Marshall samples, moderately high in the Durham, and low in the Davidson and Cecil.

It would be very interesting were it possible to correlate this phenomenon with the assumption of the existence in the colloids of aluminosilicic acids which are hydrated readily and retain their water of hydration when the humidity is low if the acid complexes are true clays of the montmorillonite type, and which are more easily dehydrated if of the halloysitic and lateritic types (16). The correlation is shown by the Amarillo, Marshall, and Becket samples which are colloids of the former type, and the Durham, Davidson, and Cecil of the latter types.

Additional evidence that the colloids of high silica-sesquioxide ratio retain water at low humidity is found in the work of Anderson previously cited (2). The colloids examined, their silica-sesquioxide ratio, and the water vapor absorption are shown in Table 17, collected from his data.

TABLE 17.—Water vapor absorption variation of colloids with variation of silica-sesquioxide ratio

Source of colloid	Silica-sesquioxide ratio	Water absorption per gram over 30 per cent H ₂ SO ₄
Fallon loam (surface soil).....	3.88	0.171
Sharkey clay (surface soil).....	3.12	.150
Marshall silt loam (surface soil).....	2.74	.134
Sassafras silt loam (surface soil).....	1.86	.101
Norfolk fine sandy loam (subsoil).....	1.60	.081
Cecil loam (subsoil).....	1.22	.042
Nipe clay (surface soil).....	.35	.054

Also Middleton (21) has determined the water vapor absorption of four colloids over varying concentrations of sulphuric acid. From his tables the following data have been abstracted. (Table 18.)

TABLE 18.—Water vapor absorbed per gram of colloids over varying strengths of sulphuric acid expressed by weight percentages in 120 hours at 35° C.

Soil type	2 per cent	3.3 per cent ¹	5 per cent	7.5 per cent	10 per cent	16 per cent	30 per cent	42 per cent
	Gram	Gram	Gram	Gram	Gram	Gram	Gram	Gram
Cecil clay loam.....	0.2933	0.2780	0.2204	0.1768	0.1381	0.0659	0.0446	0.0291
Norfolk fine sandy loam.....	.3449	.3358	.3163	.2981	.2541	.1806	.0768	.0462
Clarksville silt loam.....	.2959	.2846	.2697	.2521	.2363	.1904	.1098	.0678
Sharkey clay.....	.4125	.3967	.3552	.3243	.2997	.2646	.1855	.1293

¹ Time exposed, 168 hours.

In all cases the quantity of water absorbed is by no means the same for the four colloids at any humidity, and although it decreases with decrease in humidity the rate of decrease is markedly different in the different colloids. The outstanding differences are shown by the colloid from the Cecil clay loam and that from the Sharkey clay. In the former, alteration between 2 per cent and 42 per cent sulphuric acid is tenfold, whereas in the latter the alteration is but threefold.

In order to bring these differences into sharp relief parts of the data are segregated and the water vapor absorption ratios calculated from them are presented in Table 19. Added to these data are the silica-sesquioxide ratios of the corresponding colloids, as given by Robinson and Holmes (28). The colloid samples analyzed were not identical with those used for absorption data but were extracted from the same soil sample.

TABLE 19.—Water absorbed per gram of colloid over 3.3, 30, and 42 per cent sulphuric acid, and the absorption ratios

Soil type	Silica-sesquioxide ratio	3.3 per cent H ₂ SO ₄ (168 hours)	30 per cent H ₂ SO ₄ (120 hours)	42 per cent H ₂ SO ₄ (120 hours)	Ratio of 3.3:30 acid	Ratio of 3.3:42 acid
		Gram	Gram	Gram		
Cecil clay loam.....	1.34	0.2780	0.0446	0.261	6.23	9.55
Norfolk sandy loam.....	1.87	.3358	.0766	.462	4.38	7.27
Clarksville silt loam.....	2.18	.2846	.1098	.0678	2.59	4.18
Sharkey clay.....	3.23	.3967	.1835	.1293	2.20	3.06

It would appear, therefore, that colloids of high silica-sesquioxide ratio are distinctly more avid for moisture than those more completely weathered. That the differences of avidity shown are due to differences in composition seems clear. It must be admitted, however, that the evidence does not adequately support the assumption made above, though it does make it probable. Also, as will be shown, it is in harmony with the structures given in the general discussion. If this relation be justified it may be assumed further that the colloid characteristic which determines the retention of moisture at low humidity is the same cause which determines the base-holding capacity.

THE DIFFICULTLY EXTRACTABLE COLLOID

As mentioned on page 8, the silts and clays obtained after exhaustive dispersion in water or water made slightly alkaline with ammonia still contain quantities of material of the same general character as that extracted. This is demonstrable by microscopic examination as well as by the differences between the quantities of colloid obtained and the total colloid content obtained by either mechanical analysis or water vapor absorption. That such colloid may differ in character from that extracted by water and ammonia has been recognized. (Pp. 1 and 9.) It seemed desirable to extract

some of this material from the residues so exhaustively extracted as in the samples studied. This was accomplished in the manner and to the extent shown on page 9 for three of the silt and clay fractions; those from a chernozem soil (the Amarillo), a podzol (the Becket), and a lateritic soil (the Davidson). These fractions were then redispersed and separated into two parts; that less than 0.1 micron and that between 0.1 and 1 micron. The analytical data on these samples are shown in Table 20.

TABLE 20.—Analysis of separates from silt and clay extracted with N/50 NaOH

Sample No.	Soil type	Fraction of whole soil	Size	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	Molecular ratio					
							$\frac{\text{SiO}_2}{\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3}$	$\frac{\text{SiO}_2}{\text{Fe}_2\text{O}_3}$	$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3}$	$\frac{\text{Fe}_2\text{O}_3}{\text{Al}_2\text{O}_3}$	$\frac{\text{SiO}_2}{\text{MgO, CaO, K}_2\text{O}}$	
4575	Amarillo silty clay loam.	Per cent 0.30	<0.1 μ	39.27	8.90	21.74						
			Duplicate.....	39.48	8.92	21.52						
			Mean.....	39.37	8.91	21.63	2.45	11.75	3.10	0.284	6.75	
		.75		0.1 μ -1 μ	45.94	7.08	19.31					
				Duplicate.....	47.00	7.02	19.30					
				Mean.....	46.97	7.05	19.30	3.41	19.35	4.14	.214	7.23
		.55		<0.1 μ	15.20	16.14	15.76					
				Duplicate.....	15.24	16.25	15.85					
				Mean.....	15.22	16.19	15.80	.99	2.50	1.64	.856	4.53
4447	Becket silt loam	.60	0.1 μ -1 μ	27.69	16.34	18.11						
			Duplicate.....	27.73	16.23	18.15						
			Mean.....	27.69	16.28	18.13	1.65	4.52	2.60	.576	5.12	
	.18		<0.1 μ	29.24	19.42	24.31						
			Duplicate.....	29.32	19.40	24.53						
			Mean.....	29.28	19.41	24.42	1.35	4.911	2.041	.509	13.12	
4440	Davidson clay loam	.61	0.1 μ -1 μ	35.51	12.68	28.90						
			Duplicate.....	35.43	12.64	28.63						
			Mean.....	35.50	12.66	28.76	1.64	7.46	2.10	.282	24.73	

Sample No.	Soil type	Fraction of whole soil	Size	MgO	CaO	K ₂ O	Na ₂ O	TiO ₂	MnO	P ₂ O ₅	Organic matter	Combined water	
4575	Amarillo silty clay loam.	Per cent 0.30	<0.1 μ	2.19	1.32	1.73	0.43	0.55	0.23	0.33			
			Duplicate.....	2.27	1.32			.57	.21	.31			
			Mean.....	2.23	1.32	1.73	.43	.59	.22	.32			
		.75		0.1 μ -1 μ	1.73	1.10	3.08	.48	1.30	.26	.21	11.05	7.55
				Duplicate.....	1.76	1.06	3.08	.48	1.30	.27	.22	11.06	7.76
				Mean.....	1.74	1.08	3.08	.48	1.30	.27	.22	11.06	7.66
		.55		<0.1 μ74	1.18	1.32	3.17	1.09	.19	.49	36.55	8.28
				Duplicate.....	.98	1.16	1.30	3.20	1.03	.17	.48	36.90	8.02
				Mean.....	.85	1.17	1.31	3.18	1.06	.18	.48	36.72	8.14
4447	Becket silt loam	.60	0.1 μ -1 μ	1.53	1.59	2.06	1.33	1.15	.21	.31	20.96	8.81	
			Duplicate.....	1.68	1.63	2.10	1.36	1.13	.21	.33	20.80	8.71	
			Mean.....	1.60	1.59	2.08	1.34	1.14	.21	.32	20.88	8.76	
	.18		<0.1 μ.....	.85	.72	.30	1.11	.99	.17	.32		
			Duplicate.....	.85	.72			.99	.17	.32			
			Mean.....	.85	.72	.30	1.11	.99	.17	.32			
4440	Davidson clay loam	.61	0.1 μ -1 μ.....	.52	.24	.67	.70	1.65	.27	.17	18.99	
			Duplicate.....	.40	.37	.69	.75	1.61	.25	.22	18.69		
			Mean.....	.46	.30	.68	.75	1.63	.26	.20	18.69		

¹ Ignition loss, organic matter, and combined water not determined separately.

These more difficultly extractable colloids differ materially from the colloids obtained in the usual manner, as may be observed by comparison of the data in Table 20 with the corresponding data for the same soils as found in Tables 7, 10, and 11. In order to facilitate their comparison the three major constituents are recalculated for the <0.1-micron fraction on the basis of 100 per cent and brought together in Table 21.

TABLE 21.—The major constituents of the <0.1-micron fractions of the normal and difficultly extractable colloids

Soil type	Colloid	Percentage of whole soil	Silica	Iron oxide	Alumina
		Per cent	Per cent	Per cent	Per cent
Amarillo silty clay loam	Normal	19.1	61.80	19.39	27.81
	Difficultly extracted	.3	58.18	12.72	31.10
Becket silt loam	Normal	.6	32.65	28.16	39.22
	Difficultly extracted	.65	32.27	34.27	33.46
Davidson clay loam	Normal	14.9	43.16	18.49	38.35
	Difficultly extracted	.18	40.97	26.61	33.32

That some alteration in the relative quantities of these major colloid constituents may have been produced as a result of solution of silica and alumina by the sodium hydroxide used as a dispersing agent is possible, and that it does occur is shown in the examination of the dispersing solution reported in the data given on the Becket sample in Table 24, but it is not believed to be sufficiently great to produce the alteration of composition shown in Table 21.

The extent and character of the differences in composition may be brought into still greater relief by expressing them as given in Table 22.

TABLE 22.—Differential percentages of the major constituents in normal and difficultly extractable colloids
[Data from Table 21]

Soil type	Silica, percentage change	Iron oxide, percentage change	Alumina, percentage change
Amarillo silty clay loam	-5.62	+2.33	+3.29
Becket silt loam	-.38	+6.11	-5.76
Davidson clay loam	-3.09	+8.12	-5.03

It will be observed that in all these samples the iron-oxide content of the difficultly extractable colloid is greater than that of the normally extracted material. In all three samples there is a smaller silica content. In the Amarillo sample the alumina is greater, and in the Becket and Davidson samples it is smaller. The change in relative iron oxide-alumina content is also indicated by the greatly increased numerical value of these ratios, though the alteration is less marked, as should be expected, in the Amarillo colloid. Two explanations of these differences may be considered. It is possible that the sodium-hydroxide dispersing agent brings into suspension in the finest colloid fraction larger amounts of material present in the soil as concretionary material higher in iron oxide content than is the body of the colloid. If this be the case, it must also be granted that in the Amarillo sample this concretionary material is likewise richer in alumina.

It is also possible that the difficultly dispersible material is, for the most part, the film of colloid adhering firmly to the quartz or other undecomposed mineral particles. If this be the case, the differential percentage change should be greatest in the soil which has been subjected to the more intense weathering conditions. In the samples under consideration, the Amarillo has suffered the least and the Davidson the greatest alteration. The intensity of weathering of these soils is undoubtedly in this order. It must be confessed, however, that the present data are inadequate to decide which explanation is better, or whether both are invalid. The colloids coarser than 0.1 micron show the same character of divergence from the more easily extracted material but not to so marked degree. In all three colloids slightly higher silica-sesquioxide and silica-alumina ratios indicate the existence of unhydrolyzed mineral particles, or of quartz in the coarser colloids, and if it be assumed that the iron-oxide content is free from combination with silica, the silica-alumina ratios indicate montmorillonitic clay in the Amarillo colloid, some admixture of montmorillonitic clay in the Becket, and halloysitic clay in the Davidson. (See General Discussion.)

The relative quantity of the difficultly extractable colloid is much greater in the colloid of Becket silt loam than in that of the other two soils. That this difference is due to the influence of the organic matter is without question. It is probable that the influence is exerted through the cementing effect of the "humic acid" rather than through chemical combination with the iron oxide component. M. S. Anderson, of this bureau, has accumulated data, as yet unpublished, tending to show that ferrous iron is capable of direct combination with humic acid, but that ferric oxide is not. The cementing organic matter may, however, be associated with bases, particularly with calcium and magnesium. It is therefore suggested that under humid conditions, organic ferrous compounds are leached from the bleicherde and deposited in intimate mixture, instead of in chemical combination, in the ortstein layer as ferric hydroxide and humic acid. The ferric hydroxide is, of course, partly dehydrated, and the humic acid is, in part, associated with bases. This mixture may be assumed to be more effectively dispersed by sodium hydroxide of the hydrogen-ion concentration employed in the second dispersion because of the increased solubility of the humic acid. That considerable organic matter is dissolved is shown and will be commented on more fully later. That organic matter in the soil may be a large factor in limiting the dispersibility of the colloid material and the effect of higher pH values is also shown by the increased organic content up to and including the clay fraction of the Amarillo colloid, as shown in Table 3. The quantity of the difficultly extractable colloid obtained from this sample was insufficient to allow the determination of the organic matter in it, but the ignition loss indicates beyond question the still greater organic content of the finer fractions of this material. The Davidson colloid shows the same effect of the sodium hydroxide used in the extraction process in increasing the organic content of the difficultly dispersible colloid.

It was to have been expected that the use of sodium hydroxide as a dispersing agent would modify the base content of the difficultly dispersible colloid in two ways. There would be more exchangeable bases brought into aqueous solution, particularly when, as in the case of the Amarillo sample, only water was used in the first extraction.

The acid hydrogen (exchangeable hydrogen) should be more completely neutralized by the stronger base, and the sodium salts of the colloid would be more stable than when ammonia of a smaller pH value was employed, as in the Becket and Davidson samples. These expectations are justified by the event. Note the relatively immensely greater increase of sodium content of the Becket and Davidson colloids, as compared with the increase in the Amarillo. The explanation is obvious. The absorption of the sodium is due in but small part to exchange of bases (as indicated by the small quantity of exchangeable bases found in the extract). (Table 24.) The chief cause is the direct neutralization of the soil acids by the sodium hydroxide. Since the sodium salts of the organic material are soluble in water, it is to be presumed that the sodium is held by the inorganic acids.

WATER VAPOR ABSORPTION OF THE DIFFICULTLY EXTRACTABLE COLLOID

In Table 23 are given the percentage quantities of the water vapor absorption over 3.3 per cent sulphuric acid and over 30 per cent sulphuric acid, and the ratio of these values. In the difficultly extractable colloid of the Amarillo sample the percentage values are materially lower than for the corresponding size fractions given in Table 16; indeed, 50 per cent lower in the coarser material, which differs very strikingly from the finer fraction. At the same time, the absorption ratio is higher. This decrease in water absorption is at the same time accompanied with an increase in the percentage of organic matter. (Tables 10 and 20.)

TABLE 23.—Physical properties of difficultly extractable colloid

Sample No.	Soil type	Size	Water vapor absorbed over—		Absorption ratio 3.3 per cent 30 per cent
			3.3 per cent H ₂ SO ₄	30 per cent H ₂ SO ₄	
4575	Amarillo silty clay loam	<0.1 μ	29.85	11.45	2.61
		Duplicate.....	29.77	11.62	2.66
		Mean.....	29.81	11.53	2.59
		0.1 μ -1 μ	12.53	5.45	2.30
		Duplicate.....	12.65	5.36	2.35
		Mean.....	12.59	5.41	2.33
4447	Becket silt loam	<0.1 μ	32.61	14.50	2.25
		Duplicate.....	31.82	14.20	2.24
		Mean.....	32.22	14.35	2.25
		0.1 μ -1 μ	25.73	11.23	2.31
		Duplicate.....	25.64	11.15	2.30
		Mean.....	25.69	11.14	2.31
4440	Davidson clay loam	<0.1 μ	32.20	6.67	4.83
		Duplicate.....	31.64	6.66	4.82
		Mean.....	31.92	6.61	4.83
		0.1 μ -1 μ	23.23	3.45	6.79
		Duplicate.....	23.14	3.15	7.35
		Mean.....	23.19	3.30	7.07

In the case of the Becket colloid the difficultly extractable colloid differs much less from the easily extractable colloid in the absorption of vapor, and indeed, the values are somewhat greater in the former for the absorption over 3.3 per cent acid. (Table 16.) At the same

time, the organic content of the two fractions of the difficultly extractable colloid differ from each other by the difference between 36.72 per cent for the finer material and 20.96 per cent for the coarser colloid, and in silica-alumina ratio by the difference between 1.64 and 2.60. The organic content of the finer fraction is 3 per cent greater than in the corresponding size of the readily extractable material (Tables 20 and 10) and is nearly 5 per cent less than in the most nearly comparable coarser fraction. The absorption ratio is essentially the same for both fractions, but materially higher than for the more readily extractable colloid. (Table 16.)

In the Amarillo colloid the percentage absorption values over 3.3 per cent sulphuric acid are strikingly lower than for comparable size fractions of the more readily extractable colloid and differ more sharply from each other. For the 30 per cent acid the water vapor absorbed is also sharply different, and, as compared with the more readily extractable colloid, the finer fractions are nearly alike and the coarser fractions differ markedly. The number of samples is not sufficient to permit the drawing of extended conclusions, but it is important to note that the same relationship of the absorption ratio holds with difficultly dispersible colloid, as was noted in the more readily dispersible, viz, the absorption ratio is more than twice as great for the colloids of the montmorillonitic type (see general discussion). Again, it would appear that a plausible explanation is found in the greater stability of the hydrated form of the more complex aluminous acidoid. As a general observation, based on the limited evidence available, it may be said that although the difficultly dispersed colloids differ in many detailed respects from those more readily dispersed, yet in general character the two forms are very similar. It is also clear from the data that the acidoid complexes in the three colloids are of different types.

THE PASTEUR-CHAMBERLAND FILTRATE

In the extraction of the colloids, especially when the addition of ammonia is required to produce approximate neutrality of the dispersing agent, the filtrate through the Pasteur-Chamberland filters (grade F) sometimes shows evidence of the solution of the material, both in the color of the filtrate and in a more or less marked opalescence. That this material is in part colloidal is also evident through the Tyndall effect. In this series of extractions, the depth of color of the filtrate of the Becket silt loam was especially marked, both with the readily and the difficultly dispersed colloid. These filtrates were therefore collected and evaporated to dryness on a steam bath. The filtrates from the extraction with ammonia, with a maximum of 8.5 pH, amounted to 40 gallons and the dry residue weighed 8.8 g or 0.44 per cent of the whole soil. The analysis is given in the first three lines of Table 24. The residue consists of more than 50 per cent organic matter and about 25 per cent moisture. Since the factor 1.724 is by no means accurate (5), the organic matter and combined water are not accurately differentiated, but the total quantity, loss-on-ignition, is accurate. Therefore, only about 2 g of ignited inorganic material were carried through the filters in treating 2 kg of the soil. This inorganic material is shown by the analyses to have a considerably higher silica-sesquioxide ratio and a somewhat higher silica-alumina ratio than the colloid (Table 10), but the differences

are suprisingly small. It may be assumed that some extremely finely divided silica, produced by hydrolysis of ammonium silicate, may have found its way into this residue, but if so, the quantity was extremely small. The necessary conclusion is that the extremely finely divided colloid is essentially the same as that constituting the bulk of the finely divided material. The high base content of the ignited residue is without doubt an indication of the nature of the organic matter removed, i. e., that in part it consists of salts of humic acid. It must be kept in mind that this filtrate was from material dispersed with ammonia.

TABLE 24.—Analyses of residues from wash water of the Becket soil, No. 4447

Source of material	Fraction of whole soil (per cent)	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	Molecular ratio				
					SiO ₂ / Fe ₂ O ₃ +Al ₂ O ₃	SiO ₂ / Fe ₂ O ₃	TiO ₂ / Al ₂ O ₃	Fe ₂ O ₃ / Al ₂ O ₃	SiO ₂ / Total bases
Residue from 40 gallons of wash water in which the colloid was dispersed at pH 8.5 with NH ₄ OH. Part of the residue from the wash water from dispersion to pH 10.5-11 with NaOH which precipitates with HCl at pH 5.5, and washed Cl free.	0.44.....	Per cent 6.53	Per cent 1.33	Per cent 3.89					
	Duplicate.....	6.48	1.37	3.88					
	Mean.....	6.53	1.35	3.89	2.33	13.1	2.86	0.219	1.37
Part of filtrate from the above which did not precipitate with N/20 HCl, but after ignition to dull redness all the salts soluble in hot water were removed.	0.13.....	7.05	2.40	31.12	3.66	7.8	3.84	.005	1.76
Soluble salts from the above of which more than 90 per cent had been added in the successive treatments, 10.5 grams obtained.	0.52.....	0	0	0	.38	113.0	.354	.0003	.574

Source of material	Fraction of whole soil (per cent)	MgO	CaO	K ₂ O	Me ₂ O	TiO ₂	MnO	P ₂ O ₅	Organic matter	Combined water
Residue from 40 gallons of wash water in which the colloid was dispersed at pH 8.5 with NH ₄ OH. Part of the residue from the wash water from dispersion to pH 10.5-11 with NaOH which precipitates with HCl at pH 5.5, and washed Cl free.	0.44.....	Per cent 0.48	Per cent 2.65	Per cent 2.09	Per cent 4.45	Per cent 0.15	Per cent Trace	Per cent 3.43	Per cent 53.10	Per cent 23.80
	Duplicate.....	.44	2.53	2.03	4.39	.12	do	.39	51.70	21.17
	Mean.....	.48	2.54	2.06	4.42	.14	do	.41	52.40	24.49
Part of filtrate from the above which did not precipitate with N/20 HCl, but after ignition to dull redness all the salts soluble in hot water were removed.	0.13.....	2.17	.86	.27	.36	.16			41.64	14.16
Soluble salts from the above of which more than 90 per cent had been added in the successive treatments, 10.5 grams obtained.	0.52.....	0	2.43	1.38	48.95	0			0	1.45

The aqueous filtrate from the extraction of the silt and clay residues at a pH value of 10.5 to 11 with sodium hydroxide was particularly highly colored, and its evaporated residue was expected to consist

almost wholly of sodium humate. The residue amounted to 18.6 g of material dried at 105° C. This was redispersed with a small quantity of water and brought to a pH of 5.5 by addition of N/20 HCl. This suspension was allowed to stand for 48 hours and was filtered and washed until free from chlorine. The dried insoluble material was then analyzed. The analysis is given in the fourth line of Table 24. The material lost 56 per cent of its weight on ignition, and the organic material is approximately 42 per cent of the whole. This colloid has a low silica content but has a high silica-sesquioxide and silica-alumina ratio. The suspicion is raised that the greater part of both the silica and alumina is derived from reaction of the sodium hydroxide, used in the extraction, with silicic acid and aluminium hydroxide existing in the silt and clay or produced by hydrolysis in the process of extraction. This suspicion obtains added color from the data discussed in the next paragraph. In any case the quantity of such material, if it exists, must be extremely small, since a part of this material must certainly be normal but extremely finely divided colloid.

The filtrate from the material just described was evaporated to dryness, and, after the carbon content of the residue was determined, it was ignited at low heat. The ignited residue was washed until free from chlorides, and analyzed. The analysis is shown in the fifth line of Table 24. It will be observed that the ignition loss is about 52 per cent, and the analysis indicates that the nonvolatile residue probably is essentially a mixture of sodium silicate, sodium aluminate, and the sodium and other salts of humic acid. The washings from this material were evaporated and analyzed. The analysis shows the residue to be, as was expected, the chlorides of sodium, calcium, and potassium.

The examination of the materials which pass through the Pasteur-Chamberland filters in the case of the Becket silt loam shows that, except for removal of organic matter, the loss of material is extremely slight. That this is in part normal colloid, with addition of small amounts of other material, is indicated. The aqueous extracts from the other colloids were not examined, since it was not believed that the results obtained would pay for the labor expended.

GENERAL DISCUSSION

The data obtained during this study, taken in conjunction with other data, obtained from a study of the same or closely related soils and published elsewhere (9, 13, 23), warrant a certain amount of general discussion concerning the nature of soil colloids. It has already been brought out by Byers and Anderson (10) that the soil colloids of the great soil groups, as established by the soil survey, represent various stages of a progressive degradation of soil material. This degradation is the result of hydrolytic action on the soil minerals and on their primary and secondary products. The degree of hydrolysis, as has been repeatedly pointed out, is governed by a number of agencies. Chief among these are rainfall, temperature, and the character of soil vegetation. Only to a relatively minor degree is the character of the product determined by the character of the primary material. The conclusion that the soil material is of minor importance in determining the character of the soil colloid may be more or less illusory. As estimated by Clarke (11), the igneous rocks are approxi-

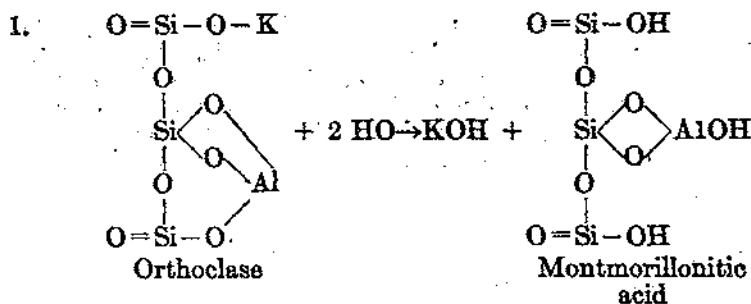
mately 60 per cent feldspars, the remaining igneous material being quartz, 12 per cent; hornblende and pyroxene, 16.8 per cent; mica, 3.6 per cent; and but 7.9 per cent accessory minerals. It may be then, since hornblende and mica are so frequently associated with feldspars and quartz in granite and similar rocks, that directly or indirectly the soils all have, as far as their primary mineral source is concerned, an essentially common origin. It would follow, therefore, that their immediately antecedent mineral source would be of less moment than the other soil-forming influences in determining their character.

It is assumed that the hydrolysis follows the same course, whether the minerals are ferruginous or aluminous silicates, when they are of the same type, but that in general the hydrolysis proceeds at a slower rate under like conditions for the aluminous silicates. It may further be assumed that since, to a very great extent, in the silicate minerals which contain iron it is in the ferrous state, the behavior of this element in the primary hydrolysis will be analogous to that of magnesium and calcium rather than to that of aluminum. If these assumptions are correct it should follow that the soil colloids produced by hydrolysis should differ from each other chiefly with respect to the extent of the hydrolytic action which has occurred and to the extent of transfer of the resultant materials, which in turn will depend on the character of the products. The study of the composition of the colloids of soils representative of the great soil groups (10) reveals the fact that there are three general types: Colloids which are essentially aluminous silicates of high silica-alumina ratio and correspond in general character to the colloid of montmorillonite; colloids which are essentially of the general type of halloysite with a silica-alumina ratio of approximately 2; and those in which the dominant colloid consists essentially of a mixture of the hydroxide of aluminum, more or less dehydrated, and of iron oxide, more or less hydrated. In the colloids the quantity of ferric oxide may be very variable. The probable existence of these colloid types is strongly supported by recent publications by Hendricks and Fry (16), Kelley, Dore, and Brown (19), and Bayer and Scarseth (7).

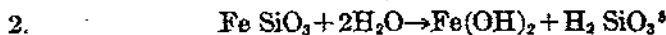
It must be kept in mind that not only the hydrolytic products of minerals themselves are subject to further hydrolysis, but that they are both acidic and basic at the same time, i. e., amphoteric, as recently emphasized by Mattson (20). They are therefore associated with varying amounts and to varying degrees with both basic and acidic ions. The character of a given colloid is also profoundly influenced by the basic, and more especially by the acidic radicals derived from the organic debris accumulated in the soil. With the foregoing facts and assumptions in mind, the character and relationships of the soil colloids may, perhaps, be made clearer by presenting a set of purely hypothetical reactions based on structural formulas of minerals and designed to show the probable results of hydrolysis.⁴

The simplest of the numerous structural formulas which have been proposed for orthoclase is that given below and the general character of hydrolytic action first to be expected is shown in equation 1.

⁴ In suggesting these structural formulas it is emphasized that no direct experimental evidence for them is available. They are designed only to present a picture of the sort of changes which, if they occur, would account for the colloid relationships actually found. It is scarcely necessary, perhaps, to add that they have no spatial significance but express chemical relationships only.



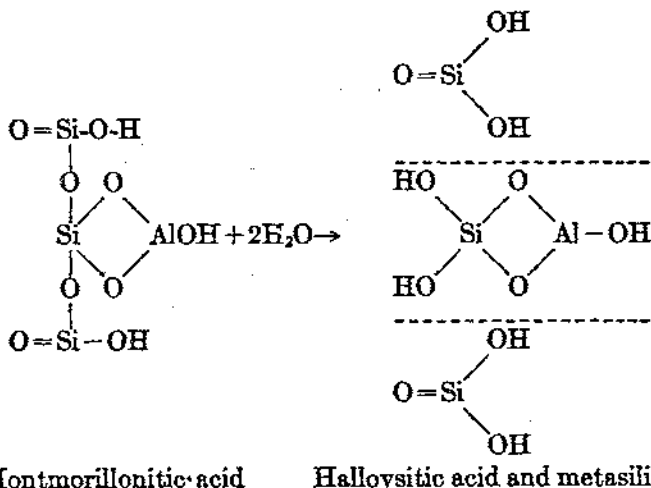
If this reaction takes place as indicated the product called montmorillonitic acid should have a maximum silica-alumina ratio of 6 and should be an amphoteric substance. No such pure compound has been prepared and in view of the known behavior of the polysilicic acids it could not be expected to exist in nature. The nearest approach to it is probably the montmorillonite reported by Ross and Shannon (29) in which the silica-sesquioxide ratio is 5.26. This material is not free from iron and yet so far as the original mineral contains ferric iron as a replacement of the aluminium, it may be expected to function in like manner. So far as the iron present in the original material from which the colloid is derived is ferrous iron, it may be expected to behave as indicated in the hypothetical equation for the hydrolysis of hornblende. (Equation 2.)



In case ferrous hydroxide is produced its further course may vary in detail, but eventually it appears in the soil colloid as ferric oxide or one of its hydrated forms.

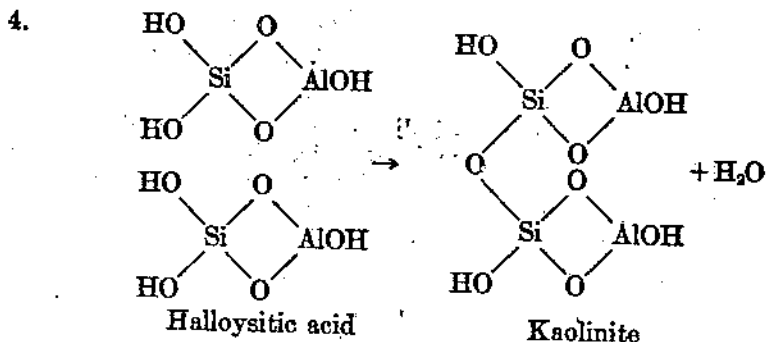
If montmorillonitic acid or its acid salts be subjected to further decomposition by hydrolysis the change may be postulated to take place as shown in equation 3.

3.



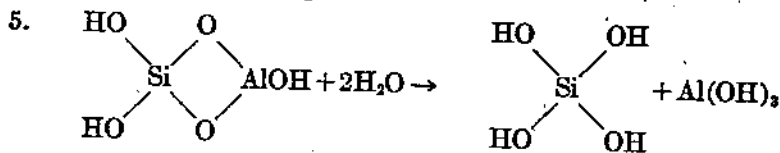
[†] In hornblende, augite, and many similar minerals, the ferrous iron is present as a salt of metasilicic acid. The following statement is taken from Miers (24) and is in point. "Groth, following Zambonini, makes hornblende (like augite) a mixture of $\text{CaMg}_2(\text{SiO}_3)_2$ with $(\text{MgFe}^{2+})(\text{Al Fe}^{3+})_2(\text{O})_2$ (in pargasite), with the addition in black hornblende of $(\text{Fe}^{2+} \text{ Al})_2(\text{SiO}_3)_2$."

The mixture resulting from the assumed hydrolysis has, if the silicic acid is not removed by leaching, the same silica-alumina ratio as the montmorillonitic material but if completely freed from silicic acid the residue, called halloysitic acid, has the silica-alumina ratio of kaolinitic clay. If it has the assigned formula it differs from the mineral kaolinite by its water content. The distinction may be shown by equation 4.



That such a reaction may occur, even in the presence of water, is quite in harmony with the occurrence of many reactions of like type in the case of carbon compounds, and which must be assumed to take place with the silicic acids to account satisfactorily for the existence of salts of the polysilicic acids in minerals. This noncrystalline material is assumed to be the actual "colloidal clay" of highly matured soils which are not laterites. It loses a part of its water readily on heating, as should be expected if it has the structure indicated. It is nevertheless a very stable compound, as shown by the fact that it does not lose all its water component until heated above 550° C. Its stability is also indicated by the enormous quantities of it existing in nature. The corresponding iron compound, nontronite, appears to be much less resistant to change.

It must not be assumed, however, that the halloysitic acid is not subject to further change. The same type of reaction which has occurred as indicated above may be expected to continue with the results as indicated in equation 5.



If this hydrolytic step is followed by leaching of the orthosilicic acid from the material, or its conversion to secondary quartz, we have the last stage of soil formation. The residual material is a true laterite, a dead soil, consisting essentially of the hydroxide of aluminum, which does not dehydrate readily, and of ferric hydroxide, which does dehydrate readily, even in the presence of water, and which in warm or dry areas may become almost completely "hematitized." Complete laterization and removal of silica is not common, and even in tropical areas the hydrolysis of the halloysitic acid must be considered as exceedingly slow. The normal soil for tropical regions ought therefore to contain varying quantities of the halloysitic acidoid complex.

It would then appear, if the writers' speculations are correct, that the progressive hydrolysis of minerals should produce three types of colloids which may be distinguished by the terms montmorillonitic, halloysitic, and lateritic. It must be kept in mind that this hydrolysis is progressive and that therefore any soil sample (except, perhaps, the completely weathered laterite) may have present at the same time colloid of all three types and yet one be dominant and be the characteristic form. Besides quartz, the soil may contain undecomposed complex minerals which are subject to hydrolysis, hydrated slowly decomposing mineral matter such as mica, hydrated silica, and such minor mineral particles as may have constituted the rock which formed the parent material. Which of the colloids are present to a dominant degree will be determined by the extent of the weathering that has occurred. The soil-forming processes being very slow, the situation at any one period of time will be that presented by a system in equilibrium even though the reactions are actually in progress. It is therefore a pseudoequilibrium. The situation is comparable with a series of almost infinitely slow moving pictures and the progress of the action may not be followed in any one soil; it can only be followed by comparing pictures of different soils representing different stages of the process.

It also follows from the assumptions made that the amphoteric substances comprising the essential colloid complexes of the normal soils of the Temperate Zone should always contain both basic and acidic radicals derived from the hydrolytic processes on the minerals themselves or from adjacent mineral bodies and carried through the colloids by percolating waters. These "adsorbed" materials may be considered as held by true chemical combination with the colloids. This assumption in no way contradicts the assumption that colloid composition and behavior may also be modified by "surface phenomena."

The passage of water through the soil may occur either essentially in a perpendicular direction or in a direction roughly parallel with the surface. In the former case all materials brought into true solution or colloidal suspension are subject to possible redeposition at greater depths or to complete removal in drainage waters. In the latter case ordinary erosion occurs, and what happens to the suspended material does not concern the soil at lower levels, though it may profoundly affect the soil situation in areas where the eroded material may be deposited. The character of the eluviation by percolating waters will not only be affected by the rate at which it passes but by the character of the material through which it passes before reaching the soil proper. Carbon dioxide absorbed from the air (or possibly other acids from polluted air such as air polluted by smelter or other smoke) or from organic matter, and the organic acids, whether of the humic acid or other types, probably are materials having a very great effect on the soil. In the case of soils developing in areas where the rainfall is insufficient to produce percolation to the depth of the normal water table, no removal of soluble or of colloid material from the profile occurs. Through eluviation and illuviation, alteration of the distribution of colloid within the profile does occur, as is indicated by the zone of accumulation in the chernozem soils. This may be presumed to occur through solution, as calcium bicarbonate, and its redeposition as carbonate at the mean maximum depth of water

penetration. The dry periods following rains do not return the calcium carbonate toward the surface to the same extent as is the case with salts such as the carbonates, sulphates, and chlorides of magnesium, sodium, and potassium. Where percolating water reaches the water table or moves in considerable volume in a horizontal direction, complete removal of soluble or colloidal material from the soil profile may take place.

These elementary considerations may now be applied to the soils examined and reported on in this bulletin. Neither in the profile nor in the colloid fractions in the Amarillo silt loam is there found any material alteration of composition. The chief difference in the profile lies in the quantity of colloid in the different horizons. It is least in the A horizon (23.9 per cent) and greatest in the next lower stratum. It is difficult to escape the conclusion that the part of the colloid not formed in place has moved downward as a whole.⁴ There is evidence of alteration of the relative amounts of iron oxide and alumina, as shown by the iron oxide-alumina ratio both for the profile (3) and in the fractions. (Table 7.) This may be taken to indicate the presence of some free iron oxide in the colloid. There is also some increase in the silica-sesquioxide ratio of the coarsest colloid. This may be taken as evidence of the presence of free quartz in this fraction. The free quartz is abundantly evident in the clay and silt fractions. The colloid seems to conform closely to the composition of the montmorillonitic type of colloid. This is confirmed by the X-ray examination (16). The same type of colloid is present in the Colby silt loam from Kansas reported by Middleton, Slater, and Byers (23), and in the Barnes silt loam from South Dakota (14) reported by Denison.

The Marshall silt loam, from Nebraska, is not a pedocal soil but is developed under grass cover with sufficient rainfall to produce percolation through the profile and prevent calcium carbonate accumulation. Otherwise the soil is essentially of the chernozem type. Its colloid is rich in bases, though not saturated. The colloid analyses of the profile, so far as determined, show essential constancy of composition. To a minor degree the iron oxide-alumina ratios of the A and B horizons show a slight concentration of iron oxide in the B horizon, yet in view of the increased concentration of colloid in the B horizon the colloid transported downward must have been transported as a whole. The same condition is shown by the fractions of the colloid from the surface layer. (Table 8.) This composition is essentially the same, with slightly greater indication of "podzolization" as indicated by the changes of the iron oxide-alumina ratios. The X-ray photographs (16) indicate a colloid of the montmorillonitic type. The silica-alumina ratios indicate the same type. Similar colloids exist in the profile of the Marshall silt loam from Iowa and in the profiles of Shelby silt loam, Houston clay, and Palouse silt loam reported by Middleton, Slater, and Byers (23). The evidence so far accumulated therefore shows the prairie soils to contain colloids which have not yet been weathered to the degree corresponding to the products indicated in equation 3 but are intermediate between that condition and the one shown in equation 1.

⁴ It is to be recognized that with movements of soil water, particularly in areas of limited rainfall, translocation of soil material may be either downward or upward through the soil profile (10), with consequent alteration of colloid content. The point emphasized here is that whatever translocation has occurred has not altered the character of the colloid to a marked degree.

Turning to the soils of the podzol type there is found a strikingly different situation both in the profile and in the colloid fractions. In the Becket silt loam profile the inorganic colloid increases from 0.9 per cent in the surface layer to 5.8 per cent in the B_1 and 5.5 per cent in the B_2 horizons, and the analytical data show marked divergences. (3) The soil is developed under heavy rainfall at low annual mean temperature and in the presence of the debris of coniferous forests. The organic matter is carried in large relative quantity to considerable depths. The pH values are extremely low (3). The iron oxide-alumina ratios (3) indicate very great alteration in passing from the upper to the lower horizons. The silica-sesquioxide ratios for the B_1 and B_2 horizons indicate an apparently lateritic stage of degradation. Even the silica-alumina ratios of the B_1 and B_2 horizons do not reach those required for the montmorillonitic colloid. The X-ray examination, nevertheless, indicates the colloid to be of this type (16). The fractions of the colloid (Table 9) also show marked divergences in composition, and the finest fraction shows the highest iron-oxide content. The evidence of the nonhomogeneity of the colloid is very convincing and, in contrast with the chernozem and prairie colloids, indicates that the colloid is fractionated in being transported from higher to lower levels. The base content indicates the probable presence in the colloid of some unhydrolyzed mineral. The same general relations are also shown by the tabulated data for the podzol soil colloids of the Superior fine sandy loam from Wisconsin and the Emmet fine sandy loam from Michigan, and with the podzolic soils of the Miami and the Leonardtown series. It may then be assumed that in the podzol soils the first stage of hydrolysis of soil minerals is represented by the aluminous silicate and a part of the iron content (equation 1), and that with this stage of hydrolysis a large part of the iron-oxide content is derived from either the hydrolysis of ferrous minerals (equation 2) or arises as a result of the final hydrolysis of ferruginous clay. (Equation 5.)

When the group of red and yellow soils represented by the five samples examined is considered, a very interesting difference is found between the B horizons, as represented by the Davidson clay loam and Cecil clay loam, and the lower strata of the Durham sandy loam, Cecil clay loam, and Cecil sandy clay loam. In these soils, developed under deciduous forest cover and high temperature and moisture conditions, no such wide contrast is found between the A and B horizons (3, 10, 14) as in the podzols, yet the differences are quite distinct and in the same direction. The silica-sesquioxide ratios are less than 2, but the silica-alumina ratios approach closely those required for a colloid of the halloysitic type. (Equation 3.) In the colloid fractions there is a distinct segregation of iron oxide in the finer fractions and a close approach to the proper silica-alumina ratio for clay of the kaolinitic type. The debris of the deciduous forests may produce organic colloid of a less acid type, or the high temperature with alternating dry periods may be responsible for a less complete removal of the iron content of the surface soils as compared with the podzols. This incomplete removal of the laterized iron content does not prevent the almost complete removal of the bases from the hypothetical halloysitic acid which is, as indicated by the work of Baver and Scarseth (7), a less active acid than that characterizing the colloids of the chernozem, prairie, and podzol soil types.

The lower degree of hydration of these colloids at lower humidity (Table 6) also indicates that the acid is less stable than the acids of the less weathered soils.

The general relations shown by the two Cecil soils are in harmony with the data presented on a series of soil profiles of the Cecil series, as well as with the data on the Chester series presented by Holmes and Edgington (17). When the deep-lying strata of these lateritic soils are considered the quantity of colloid is found to be less than in the strata higher in the profile, and they also have a lower iron-oxide content (10). Also, in the fractions of these colloids, small, though distinct, segregation of iron oxide occurs in the finer fractions. In the Durham sandy loam sample, there is little evidence in the C₂ horizon (Table 13) of the existence of free aluminum hydroxide either in the silica-alumina ratio or in the quantity of combined water. The same statement holds for the deep sample of Cecil sandy clay loam. (Table 14.) In the deep stratum of the Cecil clay loam sample (Table 15), on the contrary, there is segregation of iron oxide in the finer colloid fractions, even though the total iron content is small. The extraordinarily low silica-alumina ratio and the high water content indicate either a segregation of alumina or an abnormal local situation. If the former, it would appear possible that a true or colloidal solution of an aluminorganic complex, aluminum humate, has been carried to a point where the surfaces of the weathering feldspars furnish a pH value sufficiently high to induce flocculation. Proof of this statement is admittedly lacking.

In conclusion it should be stated frankly that the writers are quite aware that the above discussion is, in part, not new, and that also, in part, the data presented in the bulletin itself are not adequate to furnish sufficient basis for the assumptions made. It is believed that the comprehensive view, as stated, is warranted by the body of soil colloid data and that the views expressed furnish a basis of correlation of available information which lends itself to the organization of future work. It is further recognized that the statements given are not so fully buttressed by facts as they might be if it were not desirable to make the outline extremely brief.

SUMMARY

The results of an analytical study of eight soil samples derived from seven different profiles are presented.

The samples were fractionated and five fractions analyzed. The fractions were the silt (5 to 50 microns), clay (1 to 5 microns), and three colloidal sizes—finer than 0.1 micron, 0.1 to 0.3 micron, and 0.3 to 1 micron. The dispersion of the colloids was effected by water and, in some instances, with ammonium hydroxide at a maximum pH of 8.7.

The silt and clay fractions of three of the samples were further dispersed with sodium-hydroxide solution at a maximum pH of 11.

The samples included a chernozem, a prairie, a podzol, and three lateritic soils, and from these samples the writers deduce the existence of colloids of three distinct types.

The fractions of the colloids of the chernozem and of the prairie soils show marked similarity in composition and properties within the range of colloidal size. This is interpreted as indicating the presence of a definite and predominating type of colloidal acid.

Fractions of the podzol colloid are characterized by marked variation in chemical composition indicating the existence of a natural fractionation process which is in operation in the soils of this group. The inference is drawn that the podzol colloid is a mixture of at least two substances; iron oxide and the acidoid complex characteristic of the chernozem soils.

The fractions of the lateritic colloids studied show definite differences in composition but not so marked as in the podzols. These differences, when considered along with the profile data published elsewhere, are interpreted to indicate the existence of a colloid complex different from that found in the chernozem, prairie, and podzol colloids.

Certain colloids derived from soil parent material at considerable depths show marked peculiarities of composition, and the data lead to the inference that the colloidal material is in part carried down from higher levels and in part formed in place. The presence in these colloids of completely lateritized material is also inferred.

The water vapor absorption over 3.3 per cent sulphuric acid and over 30 per cent sulphuric acid, and the heat of wetting of the soil fractions were also determined. Variations in water vapor absorption between the size fractions of individual soils were very marked, as was also the variation between corresponding soil fractions. From these values and the ratio of the vapor absorbed over 3.3 per cent and 30 per cent sulphuric acid, the inference is drawn that water vapor absorption can not be ascribed to surface alone but is also dependent on chemical composition.

The study of the "difficultly extracted" colloid shows it to be of the same general character as that more easily extracted, though there are marked differences. The fractions are also more divergent in composition than is the case with the more readily dispersed material.

The examination of the filtrates obtained in the extraction of the colloid from one of the samples indicates that the dissolved material is largely organic matter, the inorganic material being less than 0.1 per cent of the whole soil and essentially of the same composition as the fine colloid.

The general discussion of the data, together with data assembled previously, presents a theoretical outline of the origin and nature of soil colloids which the writers believe to be in harmony with the facts presented. According to this outline, the soil colloids represent progressive stages of degradation of complex silicates through hydrolysis, in which are to be distinguished the montmorillonitic acid and halloysitic acid stages and the final or lateritic stage. The two hypothetical acids are both amphoteric. The colloids themselves consist of the partly neutralized salts of these acids and contain both acidic and basic radicals, together with organic colloid. The lateritic colloids possess only very limited base-holding capacity. Since the process of soil formation is continuous, no single colloid can be expected to contain one colloid component only, but in each colloid one component may be expected to dominate. The behavior of the soil will be in general harmony with the chemical properties of its dominant colloid, modified by the presence of other components so far as they occur.

LITERATURE CITED

- (1) ANDERSON, M. S.
1924. THE HEAT OF WETTING OF SOIL COLLOIDS. Jour. Agr. Research 28: 927-935.
- (2) ———
1929. THE INFLUENCE OF SUBSTITUTED CATIONS ON THE PROPERTIES OF SOIL COLLOIDS. Jour. Agr. Research 38 : 565-584.
- (3) ——— and BYERS, H. G.
1931. CHARACTER OF THE COLLOIDAL MATERIALS IN THE PROFILES OF CERTAIN MAJOR SOIL GROUPS. U. S. Dept. Agr. Tech. Bul. 228, 24 p.
- (4) ——— and MATTHEW, S.
1926. PROPERTIES OF THE COLLOIDAL SOIL MATERIAL. U. S. Dept. Agr. Bul. 1452, 47 p., illus.
- (5) ALEXANDER, L. T., and BYERS, H. G.
1932. A LABORATORY REVIEW OF METHODS OF DETERMINING ORGANIC MATTER AND CARBONATES IN SOILS. U. S. Dept. Agr. Tech. Bul. 317.
- (6) AYRES, E. E., JR.
1917. THE EFFECT OF CENTRIFUGAL FORCE ON COLLOIDAL SOLUTIONS. Metall. and Chem. Engin. 16 : 190-196, illus.
- (7) BAYER, L. D., and SCARSETH, G. D.
1931. THE NATURE OF SOIL ACIDITY AS AFFECTED BY THE SiO_2 SESQUIOXIDE RATIO. Soil Sci. 31 : 159-173, illus.
- (8) BLUM, W.
1917. DETERMINATION OF ALUMINUM AS OXIDE. U. S. Dept. Com., Bur. Standards Sci. Paper 286 : 515-534, illus. (U. S. Dept. Com. Bur. Standards Bul. v. 13, p. 515-534.)
- (9) BRADFIELD, R.
1923. THE CHEMICAL NATURE OF A COLLOIDAL CLAY. Missouri Agr. Expt. Sta. Research Bul. 60, 60 p., illus.
- (10) BYERS, H. G., and ANDERSON, M. S.
1932. THE COMPOSITION OF SOIL COLLOIDS IN RELATION TO SOIL CLASSIFICATION. Jour. Phys. Chem. 36 : [348]-366.
- (11) CLARKE, F. W.
1914. THE CONSTITUTION OF THE NATURAL SILICATES. U. S. Geol. Survey Bul. 588, 128 p.
- (12) CUSHMAN, A. S.
1905. THE EFFECT OF WATER ON ROCK POWDERS. U. S. Dept. Agr., Bur. Chem. Bul. 92, 24 p., illus.
- (13) ——— and HUBBARD, P.
1907. THE DECOMPOSITION OF THE FELDSPARS. U. S. Dept. Agr., Pub. Roads Bul. 28, 29 p., illus.
- (14) DENISON, I. A.
1930. THE CHEMICAL COMPOSITION OF COLLOIDAL MATERIAL ISOLATED FROM THE HORIZONS OF VARIOUS SOIL PROFILES. Jour. Agr. Research 40 : 469-483.
- (15) GILE, P. L., MIDDLETON, H. E., ROBINSON, W. O., FRY, W. H., and ANDERSON, M. S.
1924. ESTIMATION OF COLLOIDAL MATERIAL IN SOILS BY ADSORPTION. U. S. Dept. Agr. Bul. 1193, 42 p.
- (16) HENDRICKS, S. B., and FRY, W. H.
1930. THE RESULTS OF X-RAY AND MICROSCOPICAL EXAMINATIONS OF SOIL COLLOIDS. Soil Sci. 29 : 457-479, illus.
- (17) HOLMES, R. S., and EDGINGTON, G.
1930. VARIATIONS OF THE COLLOIDAL MATERIAL EXTRACTED FROM THE SOILS OF THE MIAMI, CHESTER, AND CECIL SERIES. U. S. Dept. Agr. Tech. Bul. 229, 24 p., illus.
- (18) IWANOW, D. W.
1926. DER ABSORBIENDE KOMPLEX DES TSCHERNOSEMBOEDENS. Jour. Landw. Wiss. 3 : 268. [In Russian, summary in German.]
- (19) KELLEY, W. P., DORE, W. H., and BROWN, S. M.
1931. THE NATURE OF BASE-EXCHANGE MATERIAL OF BENTONITE, SOILS, AND ZEOLITES AS REVEALED BY CHEMICAL INVESTIGATION AND X-RAY ANALYSIS. Soil Sci. 31 : 25-55, illus.
- (20) MATTHEW, S.
1931. THE LAWS OF SOIL COLLOIDAL BEHAVIOR. VI. AMPHOTERIC BEHAVIOR. Soil Sci. 32 : 343-365.

- (21) MIDDLETON, H. E.
1928. THE ADSORPTION OF WATER VAPOR BY SOILS AND SOIL COLLOIDS. First Internatl. Cong. Soil Sci. Comn. 1, Proc. and Papers 1: 446-455, illus.
- (22) ———
1930. PROPERTIES OF SOILS WHICH INFLUENCE SOIL EROSION. U. S. Dept. Agr. Tech. Bul. 178, 16 p.
- (23) SLATER, C. S., and BYERS, H. G.
1932. PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE SOILS FROM THE EROSION EXPERIMENT STATIONS. U. S. Dept. Agr. Tech. Bul. 316. In press.
- (24) MIERS, H. A.
1929. MINERALOGY; AN INTRODUCTION TO THE SCIENTIFIC STUDY OF MINERALS. Ed. 2, rev. by H. L. Bowman. 658 p., illus. London.
- (25) OLINSTEAD, L. B., ALEXANDER, L. T., and MIDDLETON, H. E.
1930. A PIPETTE METHOD OF MECHANICAL ANALYSIS OF SOILS BASED ON IMPROVED DISPERSION PROCEDURE. U. S. Dept. Agr. Tech. Bul. 170, 23 p., illus.
- (26) ROBINSON, W. O.
1922. THE ABSORPTION OF WATER BY SOIL COLLOIDS. Jour. Phys. Chem. 26: 647-653.
- (27) ———
1930. METHOD AND PROCEDURE OF SOIL ANALYSIS USED IN THE DIVISION OF SOIL CHEMISTRY AND PHYSICS. U. S. Dept. Agr. Cir. 139, 20 p.
- (28) ——— and HOLMES, R. S.
1924. THE CHEMICAL COMPOSITION OF SOIL COLLOIDS. U. S. Dept. Agr. Bul. 1311, 42 p.
- (29) ROSS, C. S., and SHANNON, E. V.
1926. THE MINERALS OF BENTONITE AND RELATED CLAYS AND THEIR PHYSICAL PROPERTIES. Jour. Amer. Ceramic Soc. 9 : [77]-96, illus.

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