DIVISION OF CHEMISTRY

Ammonia-Soluble Inorganic Soil Colloids

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

CHARLES PURYEAR, *President Pro Tem.*

TEXAS AGRICULTURAL EXPERIMENT STATION
BOARD OF DIRECTORS

E. B. CUSHING, *President,* Houston...... Term expires 1915
JOHN I. GUION, *Vice-President,* Ballinger...... Term expires 1919
E. H. ASTIN, Bryan...... Term expires 1919
L. J. HART, San Antonio...... Term expires 1919
R. L. BENNETT, Paris...... Term expires 1917
T. E. BATTLE, Marlin...... Term expires 1917
J. S. WILLIAMS, Paris...... Term expires 1917
J. ALLEN KYLE, Houston...... Term expires 1915
WALTON PETEET, Waco...... Term expires 1915

GOVERNING BOARD, STATE SUBSTATIONS

†WILL H. MAYES, *President,* Brownwood...... Term expires 1915
P. L. DOWNS, *Vice-President,* Temple...... Term expires 1919
CHARLES ROGAN, Austin...... Term expires 1917
...... Term expires 1915

STATION STAFF

ADMINISTRATION
B. YOUNGBLOOD, M. S., *Director*
A. B. CONNER, B. S., *Assistant Director*
CHAS. A. FELKER, *Chief Clerk*
A. S. WARE, *Secretary*

DIVISION OF VETERINARY SCIENCE
M. FRANCIS, D. V. S., *Veterinarian in Charge*
H. SCHMIDT, D. V. M., *Assistant Veterinarian*

DIVISION OF CHEMISTRY
G. S. FRAPS, Ph. D., *Chemist in Charge*
J. B. RATHER, M. S., *Assistant Chemist*
WILLIAM LEVIN, A. B., *Assistant Chemist*
J. W. CHEWNING, B. S., *Assistant Chemist*

DIVISION OF HORTICULTURE
H. NESS, M. S., *Horticulturist in Charge*
W. S. HOTCHKISS, *Horticulturist*

DIVISION OF ANIMAL HUSBANDRY
J. C. BURNS, B. S., *Animal Husbandman in Charge*
————————, *Animal Husbandman*

DIVISION OF ENTOMOLOGY
WILMON NEWELL, M. S., *Entomologist in Charge*
F. B. PADDOCK, B. S. E., *Entomologist*

DIVISION OF AGRONOMY
A. B. CONNER, B. S., *Agronomist in Charge*
A. H. LEIDIGH, B. S., *Agronomist in Charge of Soil Improvement*
H. H. JOBSON, B. S., *Assistant Agronomist*
R. E. DICKSON, B. S., *Assistant Agronomist*

DIVISION OF PLANT PATHOLOGY AND PHYSIOLOGY
F. H. BLODGETT, Ph. D., *Plant Pathologist and Physiologist in Charge*

*DIVISION OF FARM MANAGEMENT
REX E. WILLARD, M. S., *Farm Management Expert in Charge*

DIVISION OF FEED CONTROL
W. L. BOYETT, *State Feed Inspector*
J. H. ROGERS, *Deputy Feed Inspector*
W. H. WOOD, *Deputy Feed Inspector*
T. H. WOLTERS, *Deputy Feed Inspector*
R. B. EHLINGER, *Deputy Feed Inspector*

SUBSTATION NO. 1: **Beeville, Bee County**
E. E. BINFORD, B. S., *Superintendent*

SUBSTATION NO. 2: **Troup, Smith County**
W. S. HOTCHKISS, *Superintendent*
R. W. COX, B. S., *Scientific Assistant*

SUBSTATION NO. 3: **Angleton, Brazoria County**
N. E. WINTERS, B. S., *Superintendent*
J. W. JACKSON, B. S., *Scientific Assistant*

*SUBSTATION NO. 4: **Beaumont, Jefferson County**
H. H. LAUDE, B. S., *Superintendent*

SUBSTATION NO. 5: **Temple, Bell County**
A. K. SHORT, B. S., *Superintendent*

SUBSTATION NO. 6: **Denton, Denton County**
T. W. BUELL, B. S., *Superintendent*

SUBSTATION NO. 7: **Spur, Dickens County**
I. S. YORK, *Superintendent*
E. W. HARRISON, B. S., *Scientific Assistan*

SUBSTATION NO. 8: **Lubbock, Lubbock County**
V. L. CORY, B. S., *Superintendent*

SUBSTATION NO. 9: **Pecos, Reeves County**
H. C. STEWART, B. S., *Superintendent*
J. M. THOMSON, B. S., *Scientific Assistant*

SUBSTATION NO. 10: **Feeding and Breeding Substation, College Station, Brazos County**
C. S. SCHARFF, *Acting Superintendent*

SUBSTATION NO. 11: **Nacogdoches, Nacogdoches County**
G. T. MCNESS, *Superintendent*

CLERICAL ASSISTANTS

STATION
J. M. SCHAEDEL, *Stenographer*
C. A. CASE, *Stenographer*
C. L. DURST, *Mailing Clerk*

FEED CONTROL
DAISY LEE, *Registration Clerk*
MATTIE THOMAS, *Stenographer*
P. K. BROWNLEE, *Shipping Clerk*

*In cooperation with Bureau of Plant Industry, United States Department of Agriculture.
†Resigned April 1, 1914.

AMMONIA-SOLUBLE INORGANIC SOIL COLLOIDS

G. S. FRAPS, PH. D., Chemist.

The colloidal constituents of the soil are considered as of considerable importance. Van Bemmerlen[1] has pointed out that there is a relation between the power of soils to absorb bases and the quantity of colloid-like silicates present. His conclusion that soils which contain the most colloidal silicates and humus, are the most productive, has been emphasized by others, especially Ehrenberg.[2] Others have pointed out that the plasticity of clay is related to the colloidal clay present and that any agency which increases the colloidal properties of a clay soil, also makes it more impervious, sticky, and difficult to work. Lime, and other substances which coagulate clay, tend to make clay soils less sticky, more permeable to water, and more easily worked.[3]

The colloidal constituents of the soil also affects the solubility of the unabsorbed salts, and also the gases present.[4]

The colloidal constituents of the soil may consist of: (a) Organic substances. (b) Inorganic substances, such as aluminum hydroxide, ferric hydroxide, hydrated silicic acid, hydrated aluminum silicates, and other silicates.

The colloidal constituents may also be present in two forms: (1) In such forms as may enter into colloidal solution in water or other solvents. (2) In gelatinous particles which are too large to enter into colloidal solution, but which are yet in a gelatinous colloidal condition and capable of exercising colloidal properties. The condition of these gelatinous particles may also vary from a fully expanded state to a more or less shrunken condition, and the characteristics of the soil may be affected by such variations.[3]

METHODS OF INVESTIGATION.

Methods of study vary according as they deal with: (1) The colloids capable of entering into colloidal solution; or (2) the total colloids or colloid-like substances.

The only method as yet proposed for approximately estimating the total colloids is by staining the colloidal particles, and estimating their number or quantity by means of a microscopic examination.[5] Indirect methods have also been proposed such as:

(a) By estimating, colorimetrically, the absortion of soils for dye stuffs.

(b) By estimating the absorbtive power of the soils for bases.[6]

(c) By estimating the salts made soluble by an electric current.[6]

These indirect methods, however, do not really estimate the colloidal constituents of the soil, but compare soils with respect to certain properties, which may be partly dependent upon other soil constituents in addition to the colloidal particles.

Schloesing[7] has prepared the colloidal constituents which enter into aqueous solution. He brought the clay in suspension with water as in the mechanical analysis of a soil, and precipitated it with a small amount of acid, collected it in a filter, and washed with distilled water. The residue on the filter was treated with ammonia, and diffused in a considerable quantity of distilled water. This was allowed to stand until particles no longer settled out, which required several months. Particles of visible dimensions could then no longer be detected in the solution by means of the microscope. The liquid was then decanted off, and the colloidal clay precipitated by the addition of a small quantity of acid. It dried to a translucent, horn-like mass. According to Schloesing, even the stiffest natural clays seldom contain over 1.5 per cent of such soluble colloidal clay.

Gedroitz[12] has done some work on the colloids in aqueous extracts of the soil.

METHOD OF ESTIMATION.

This article deals with the soluble colloidal soil substances, and not with the total, or insoluble, colloids.

It has been shown by Smith[8] that when a mixture of soil and ammonia water is poured in a filter, if the mixture is shaken thoroughly, and the soil also put upon the filter, a clear filtrate may easily be secured. This method he proposes for securing a clear filtrate in the estimation of the ammonia-soluble organic matter of the soil. It has been found in this laboratory, however, that when ammonium carbonate is added to the clear ammoniacal filtrate, a precipitate is formed which is composed largely of inorganic material. The use of ammonium carbonate, for precipitating the clay, is the method proposed by Rather[9] for purifying the ammoniacal humus filtrate.

The method used for estimating the soluble colloidal material of the soil is based upon these observations, and is describes as follows:

Method.—Digest 100 grams of the soil with 2000 c.c. of fifth-normal hydrochloric acid at room temperature for twenty-four hours. Filter and wash thoroughly. Wash back into the bottle with 2000 c.c. of 4 per cent ammonia and let digest at room temperature for twenty-four hours, shaking every half hour for four hours. Filter on a large folded filter, getting as much of the soil as possible on the filter, and continue to pour back the filtrate until it comes through clear, as per the Smith method. Discard the residue. Take 1500 c.c. of the filtrate, coagulate with the ammonium carbonate (and heat, if necessary), let settle, collect on ash-free filter, ignite, and weigh.

Fuse the precipitate with sodium and potassium carbonates; dissolve in hydrochloric acid and evaporate to render silica insoluble. Filter off and weigh silica, if pure; if contaminated with iron, purify. Precipitate the iron and alumina in the filtrate with ammonia, ignite, and weigh precipitate. Fuse with potassium acid sulphate and dissolve, reduce the iron with zinc, and titrate with permanganate.

The methods as used above was intended only for soils low in lime, and for this reason only one extraction with hydrochloric acid was made. If the soils contain much lime, several extractions must be made in order to remove all the lime, and, if the soil is high in lime, the acid must be made decidedly stronger.

AMMONIA-SOLUBLE INORGANIC COLLOIDS.

The percentages of colloidal inorganic material in the soils studied is given in Table No. 1. The soils are divided into four groups, arranged according to their total content of ammonia-soluble inorganic colloids: (1) .00-.050 per cent; (2) 0.051-.101 per cent; (3) 0.101-.200 per cent; (4) 0.201-.600 per cent. For the purposes of comparison, the total nitrogen, the acid-soluable iron and alumina, and the acid-soluble lime, are also given in the table.

PERCENTAGE OF TOTAL COLLOIDAL (INORGANIC) MATTER IN THE SOILS.

Laboratory Number.		Total Colloidal Precipitate.	Colloidal Silica. (SiO_2)	Colloidal Iron. (Fe_2O_3)	Colloidal Alumina. (Al_2O_3)	Total Nitrogen.	Acid-soluble, Iron and Alumina.	Acid-soluble, Lime.
3634	Houston black clay, 12″-24″	.004	.003	.002	.000	.051	18.65	.80
981	Norfolk fine sand, surface	.006	.004	.003	.000	.030	1.77	.05
860	Orangeburg fine sand, 0″-24″	.017	.010	.003	.001	.020	1.01	.08
312	Norfolk sand, 0″-10″	.035	.020	.006	.002	.030	...54	.28
4231	Black clay, upland S. S.	.039	.024	.006	.003	.055	13.51	.43
348	Norfolk fine sand	.047	.024	.006	.003	.020	1.13	.09
316	Norfolk fine sandy loam, 0″-20″	.049	.028	.007	.005	.030	.82	.09
	Average (8)	.028	.015	.004	.002	.034	5.36	0.26
3662	Orangeburg clay, 0″-18″	.052	.025	.010	.006	.132	17.95	.26
318	Lufkin fine sand, 0″-12″	.058	.032	.007	.007	.030	.89	.15
937	Orangeburg fine sandy loam, 0″-12	.065	.035	.007	.007	.030	1.61	.12
172	Norfolk sand	.070	.037	.007	.011	.030	.83	.05
3663	Orangeburg clay, 18″-30 ″	.093	.048	.017	.011	.112	17.94	.30
1202	Victoria clay, 0″-10″	.096	.054	.007	.026	.063	13.81	2.35
	Average (7)	.072	.039	.009	.011	.066	8.82	0.54
4380	Red clay "Post Oak Land," "0-8″	.102	.053	.011	.025	.072	16.70	.64
4998	Post Oak upland, 12″-24″	.106	.053	.011	.028	.079	16.30	.23
819	Norfolk fine sandy loam, 0″-22″	.133	.065	.014	.042	.020	1.29	.07
4543	Post Oak land, S. S.	.143	.083	.013	.041	.067	15.21	.30
180	Orangeburg fine sandy loam	.145	.074	.017	.046	.040	.52	.02
4327	Oranburg fine sand, 5″-18″	.180	.088	.024	.066	.058	14.12	.21
	Average (6)	.135	.069	.015	.041	.054	10.69	.24
112	Lufkin fine sandy loam	.212	.122	.017	.064	.040	1.19	.91
823	Orangeburg fine sandy loam,'12″-36″	.230	.109	.031	.090	.090	29 22	.49
3423	Black Musquite land, 9″-21″	.233	.118	.020	.072	.034	1.24	.19
4343	Sandy upland, 12″-24″	.241	.117	.028	.102	.050	23.03	.17
875	Norfolk fine sandy loam, 22″-36″	.276	.127	.039	.101	.030	6.76	.05
3366	Laom upland, 6″-18″	.313	.140	.047	.121	.062	19.58	.13
3368	Light red sandy loam, 7″-19″	.590	.224	.104	.243	.055	19.60	.25
	Average (7)	.299	.137	.041	.113	.052	14.36	.31

There is an average relation between the acid-soluble iron and alumina of the soil, and its total soluble inorganic colloids. On an average, the iron and alumina increase as the percentages of ammonia-soluble colloids increase. However, there are very striking instances where a high iron and alumina content is accompanied by a low colloid content, and also other instances where a high soluble colloid content is accompanied by low iron and alumina. The results are not sufficient to trace a relation.

COMPOSITION OF THE INORGANIC COLLOIDAL PRECIPITATE.

Table No. 2 shows the percentage compositon of the inorganic colcoidal precipitate. The soils in this table are likewise arranged in groups, ascending to the total colloidal precipitate secured from the soil. The quantity of the precipitate secured from the soils of the first group was so small that the analytical error is very large. This applies particularly to the first four soils.

The average composition of the four groups is as follows:

Group.	Silica.	Per cent Iron Oxide.	Alumina.	Difference.
0.00-.05 per cent colloids...	59.7	24.3	8.7	7.3
0.051-.10 per cent coliloids..	53.3	12.6	16.9	17.2
0.101-.20 per cent colloids..	51.5	11.0	29.9	7.6
0.201-.60 per cent colloids..	47.5	12.6	36.9	3.0

The most striking fact about these averages is the decrease in percentage of silica, and the increase in percentage of alumina, as the soluble colloid content of the soil increases.

The molecular ratio of the constituents is as follows:

0.00-.05 per cent colloids: $12SiO_2:2Fe_2O_3:Al_2O_3$.
0.0511.10 per cent colloids: $11SiO_2:2Fe_2O_3:2Al_2O_3$.
0.101-.20 per cent colloids: $12SiO_2:F_2O_3:4Al_2O_3$.
0.201-.60 per cent colloids: $10SiO_2:Fe_2O_3:4Al_2O_3$.

PERCENTAGE COMPOSITION OF COLLOIDAL PRECIPITATES.

Laboratory Number.		Silica. (SiO_2)	Iron. (Fe_2O_3)	Alumina. (Al_2O_3)
4380	Red clay "Post Oak land", 0"-8"	52.0	10.8	24.5
4298	Post Oak upland, 12"-24"	50.0	10.4	26.4
819	Norfolk fine sandy loam, 0"-22"	48.9	10.5	31.6
4543	Post Oak land, S. S.	58.0	9.1	28.7
180	Orangeburg fine sandy loam	51.0	11.7	31.7
4327	Orangeburg fine sand, 5"-18"	48.9	13.3	36.7
	Average (6)	51.5	11.0	29.9
112	Lufkin fine sandy loam	57.6	8.0	30.2
823	Orangeburg fine sandy loam, 12"-36"	47.4	13.5	39.1
2423	Black Mesquite land, 9"-12"	50.6	8.6	30.9
4343	Sandy upland, 12"-24"	48.5	11.4	42.9
875	Norfolk fine sandy loam, 22"-36"	46.0	14.1	35.6
3366	Loam upland, 6"-18"	44.7	15.0	38.7
3368	Light red sandy clay, 7"-19"	38.0	17.6	41.2
	Average (7)	47.5	12.6	36.9

PERCENTAGE COMPOSITION OF COLLOIDAL PRECIPITATES.

Laboratory Number.		Silica. (SiO²)	Iron. (Fe²O³)	Alumina. (Al²O³)
3634	Houston black clay, 12″-24″	75.0	50.0	0.0
287	Probably Laredo silt loam, 12″-20″	50.0	16.7	33.3
981	Norfolk fine sand surface, S	66.7	50.0	0.0
860	Orangeburg fine sand, 0″-24″	58.8	17.7	5.9
312	Norfolk sand, 0″-10″	57.1	17.1	5.7
4231	Black clay, upland S	61.5	15.4	7.7
348	Norfolk fine sand	51.1	12.8	6.4
316	Norfolk fine sandy loam, 0″-20″	57.2	14.3	10.2
	Average (8)	59.7	24.3	8.7
3662	Orangeburg clay, 0″-18″	48.1	19.2	11.5
318	Lufkin fine sand, 0″-12″	55.2	12.1	12.1
3270	Black waxy upland, 12″-22″	55.2	10.4	29.2
937	Orangeburg fine sandy loam, 0″-12″	53.8	10.8	10.8
172	Norfolk sand	52.9	10.0	15.7
3663	Orangeburg clay, 18″-30″	51.6	18.3	11.8
1202	Victoria clay, 0″-10	56.3	.73	27.0
	Average (7)	53.3	12.6	16.9

In kaolin the ratio of silica to alumina is $2SiO_2 : Al_2O_3 : 2H_2O$. If we assume that all the alumina is present as kaolin, then there is an excess of five-sixths of the silica in the first group, seven-elevenths in the second group, one-third of the silica in the third group, and one-fifth of the silica in the fourth group. However, there were other bases present in the precipitate which were not estimated. It appears probable that he soluble colloidal material consists of hydrated silica, hydrated oxides of iron, hydrated silicates of alumina with other bases, and possibly hydrated silicate of alumina.

ACKNOWLEDGMENT.

REFERENCES.

1. Van Bemmerlen, Landw. Versuchsstat., 1878, p. 135; 1879, p. 265; 1888, p. 69.

2. Ehrenberg, Zeitschr. f. Chem. & Ind. d. Colloids, 1908, pp. 193-244. Abstract Experiment Station Record, 22, 610.

3. Fraps, "Principles of Agricultural Chemistry," pp. 88-89.

4. Findlay and Creighton, "Colloid," Zeitschr., 3, p. 169.

5. Endell, "Kolloid," Zeitschr., 1909, p. 244; Sjollema, Exp. Sta. Record, 17, p. 119, from J. Landw., 53, p. 70.

6. Koenig, HaGsenbaumer & Hassler, Landw. Versuchstat., 1911, p. 377.

7. Schloesing, Chemie Agricole, 1885.

8. Smith, Proc. Ass. of Agr. Chem., 1912.

9. Rather, Bull. 139, Texas Experiment Station.

10. List of articles on Colloids by Ehrenberdg, Mitt. Landw. Inst., Breslau, 6, p. 1.

11. Rohland, Landw. Jahrbuch, 39, p. 369.

12. Gedroitz, Russ. Jan. Expt. Landw., 13, p. 363; Exp. Sta. Record, 28, p. 516.

SUMMARY AND CONCLUSIONS.

1. When a soil, previously extracted with acid, is digested with ammonia, and the soil and ammoniacal solution poured ona filter, as suggested by Smith, a clear filtrate is secured which contains inorganic substances that are precipitated by ammonium carbonate.

2. Colloidal inorganic matter is dissolved from the soil by ammonia.

3. The maximum quantity present in the soils examined was 0.59 per cent.

4. The average of seven soils rich in colloidal matter was 0.299 per cent inorganic colloidal material.

5. The colloidal precipitate contains from 47 to 59 per cent silica, from 11 to 24 per cent oxide of iron, and from 8 to 36 per cent aluminum oxides.

6. The quantity of iron oxide is, on an average, fairly constant. The quantity of aluminum was found, on an average, to increase with the quantity of total inorganic colloidal matter in the soil.

7. It is probable that the ammonia-soluble colloidal material consists of hydrated silica, hydrated oxides of iron, hydrated silicate of aluminum with other bases, and possibly hydrated silicates of aluminum.

8. The method given is not supposed to estimate the total colloidal constituents of the soil.