STUDIES OF A SCOTTISH DRIFT SOIL.

PART II.

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The Absorptive Power of the Soil and its Mechanical Fractions.

The problems connected with absorption by soils have been studied by many investigators for well-nigh a century, but in spite of this, comparatively little is known even now regarding this important phenomenon. Its importance cannot be too strongly emphasised when we consider its bearing on soil fertility in general, and in particular on the part played by fertilisers.

It is still a matter of dispute whether soil absorption is a physical or a chemical phenomenon or partly one and partly the other. The question of the soil constituents to which absorption is chiefly to be attributed is also undecided. Some workers lay special emphasis on the amount of surface exposed by the absorbing material, while others lay stress on its origin, constitution and mass.

The literature of the subject has recently been reviewed by Prescott (1)*, to whose résumé the reader is referred.

Attempts have been made from time to time to make use of absorption phenomena as indicators as to fertility and manurial requirements, but the difficulty has been to get a good basis for comparison of different soils.

Soils differ greatly in their mechanical and chemical composition and in their content of organic matter, and all these factors may profoundly affect absorption.

Other things being equal, a soil composed largely of "fine silt" and "clay" would, according to most investigators, have a greater absorptive power than one composed chiefly of coarse materials. Conclusions,

* Publication of this paper was delayed on account of the war, and since it was drafted a more complete résumé of the literature by Prescott has appeared in this Journal. A review of the literature has therefore been omitted.

therefore, derived only from comparing absorptions by complete soils might be quite misleading.

The object in this investigation, in addition to determining the absorption of the soil as a whole, is to determine the absorptive power of the various fractions obtained by mechanical analysis.

It is hoped in this way to obtain useful information as to the part played in the absorption by the various soil fractions and to arrive at a sound basis for comparing the absorptive power of this soil with others in this district and elsewhere.

The soil with which our investigations were made has already been described in Part I of this paper(2). It has these characteristics in particular:

1. It is a glacial drift soil derived from granitic rocks and its constituents are still in a comparatively undecomposed state. According to van Bemmelen the production of the colloids on which absorption depends is largely a question of decomposition.

2. It contains no carbonate of lime. Calcium carbonate has been persistently associated in this country with absorption and the interchange of bases in soils, as if it were a necessary factor, though Way as early as 1850 had shown that this is not the case.

3. The clay fraction is comparatively small—see Mechanical Analysis, Table I, Part I. It is to this fraction that most of the absorptive power is usually ascribed.

4. It is fairly rich in organic matter, containing about 9 % as determined by ignition. This is generally considered to play a considerable part in soil absorption.

The first difficulty met with in carrying out this investigation was the separation of the soil into fractions without producing any alteration in their chemical nature and absorptive power.

The ordinary British method of mechanical analysis involving the use of weak acid and ammonia could not be followed, since it seems obvious that the action of such reagents would alter the absorptive power of the soil particles, so an attempt was made at a separation by means of water alone.

As a preliminary trial, 10 gram samples were treated according to the sedimentation method as adopted by the Agricultural Education Association(3) (the ordinary British method), except that treatment with dilute hydrochloric acid and ammonia was omitted.

The results did not accord very closely with those from the ordinary

method with use of acid and ammonia, the clay being much less and the coarser fractions greater, indicating, as was to be expected, an incomplete breaking down of the compound particles.

The operation was repeated with these differences: (*a*) The samples were soaked a couple of days in distilled water and thoroughly rubbed up with a rubber pestle before the fractionation was commenced. (*b*) They were shaken in bottles on a mechanical shaker for an hour between periods of settling. The results obtained in this way agree much better with those from the ordinary method, but the amount of clay obtained still fell short of the total present.

Table I. *Mechanical Analysis.*

	1		2		3	
	Analysis using distilled water in separation		Analysis using distilled water and subjecting soil to thorough pestling		Analysis according to method of Agricultural Education Association	
	At 100° C.	After ign.	At 100° C.	After ign.	At 100° C.	After ign.
Fine gravel ...	10·58	10·46	10·19	10·07	10·09	9·93
Coarse sand ...	34·79	33·59	31·41	31·03	30·08	29·73
Fine sand... ...	32·25	29·41	26·54	26·01	26·20	25·80
Silt	12·68	9·89	14·72	12·44	14·18	12·47
Fine silt	7·98	5·76	9·64	7·07	9·62	7·63
Clay	0·90	0·43	6·53	3·09	8·88	3·80
Total	99·18	89·54	99·03	89·71	99·05	89·36
Loss on ignition ...	—	9·64	—	9·32	—	9·69
Dissolved and loss (by difference)...	—	0·82	—	0·97	—	0·95

Table I shows the different results obtained by modifying the method of analysis as described above.

No. 1 is the mechanical analysis using distilled water, and without previous treatment with dilute acid and alkali.

No. 2 the same with additional soaking, shaking and pestling with a rubber pestle.

No. 3 the analysis by the ordinary British method with dilute acid and ammonia. Duplicate samples agreed closely except in the coarsest fractions.

Since the shaking and pestling in No. 2 and the reagents in No. 3 bring an undue proportion of the humus into the finest fractions, it is only the columns after ignition that are strictly comparable.

Hall (4), in comparing methods of mechanical analysis obtained similar results. Attempts at a separation by mechanical means alone, failed to remove all the clay from the coarser fractions. From his

experiments, he concluded that treatment of the soil with dilute acid before commencing analysis does not dissolve any appreciable amount of the mineral matter except $CaCO_3$, and that all it does is to resolve completely the temporary aggregates.

According to Dumont(5), the mineral particles of the soil are covered with a humus-clay coating very difficult to remove. But whether it is as a coating to the larger particles or in the form of aggregates the tenacity with which the clay is held may be judged from a comparison of the results in Table I.

For the purpose of this investigation fairly large quantities of each fraction were required, so the mechanical method described above was now applied on a large scale. 1000 grams of soil passing the 3 mm. sieve were soaked, pestled and shaken as before and a mechanical analysis (corresponding to No. 2, Table I) carried out, using vessels suitable for the increased quantity of material.

It was found that 40 to 50 decantations were necessary to remove the clay, and even then the supernatant liquid was not perfectly clear, and the difficulty arose of removing the small amount of clay from the very large volume of water. Settling was slow and incomplete, and it was obviously inadmissible to employ any flocculating agent; filtration was useless as the fine particles quickly clogged up the pores; evaporation was undesirable both on account of the time required and because of the danger of altering the properties of the clay; no suitable centrifugal machine was at hand so at the suggestion of one of us an ordinary cream separator was tried and this proved very successful.

It was found, if the inlet were regulated to allow only a small stream to enter, and if a fairly high speed were kept up (8000–10,000 revolutions of the bowl per minute), that an almost perfect separation was effected.

The plates of the separator bowl which at the end of a milk separation are coated with a slime of impurities removed from the milk, retained the clay. The bowl was removed and dried in an air oven at a low temperature, and when dry, the clay was easily removed from the plates.

The other fractions were obtained without difficulty, and the sizes of their particles checked with the microscope.

The Presence of Organic Matter in the Fractions and its Distribution.

There was present in the soil examined, a considerable amount of organic matter which in the mechanical analysis became distributed among the fractions. That the organic matter plays some part in absorption by soils has long been recognised, but its exact share is very difficult to determine, since removal of the humus by ignition or by solvents would alter the properties of the mineral particles and colloids.

Hall and Gimingham (6), from experiments with peat, concluded that its influence was comparable to that of clay. This, however, must vary according to the nature and stage of decomposition of the humus, and would differ in different samples and in different fractions of the same sample. To enable us to make, if possible, some allowance for its influence on the absorptive power of the fractions, and to facilitate comparisons with future work on other soils, humus was estimated in each fraction separately. This was carried out in two ways: (*a*) loss on ignition was determined, (*b*) the carbon in the various samples was determined by a modification of the chromic acid method (Cameron and Brazeale (7)), and the organic matter calculated on the assumption that soil organic matter contains 58 % of carbon.

Table II. *Organic Matter in the Soil and its Fractions.*

Fraction	Chromic Acid Method (Cameron and Brazeale) per cent.	Loss on ignition per cent.
Fine gravel	1·04	1·38
Coarse sand	0·92	1·07
Fine sand	0·98	1·36
Silt	9·52	11·81
Fine silt	20·76	28·52
Clay	24·52	34·59
Original soil	6·11	9·69

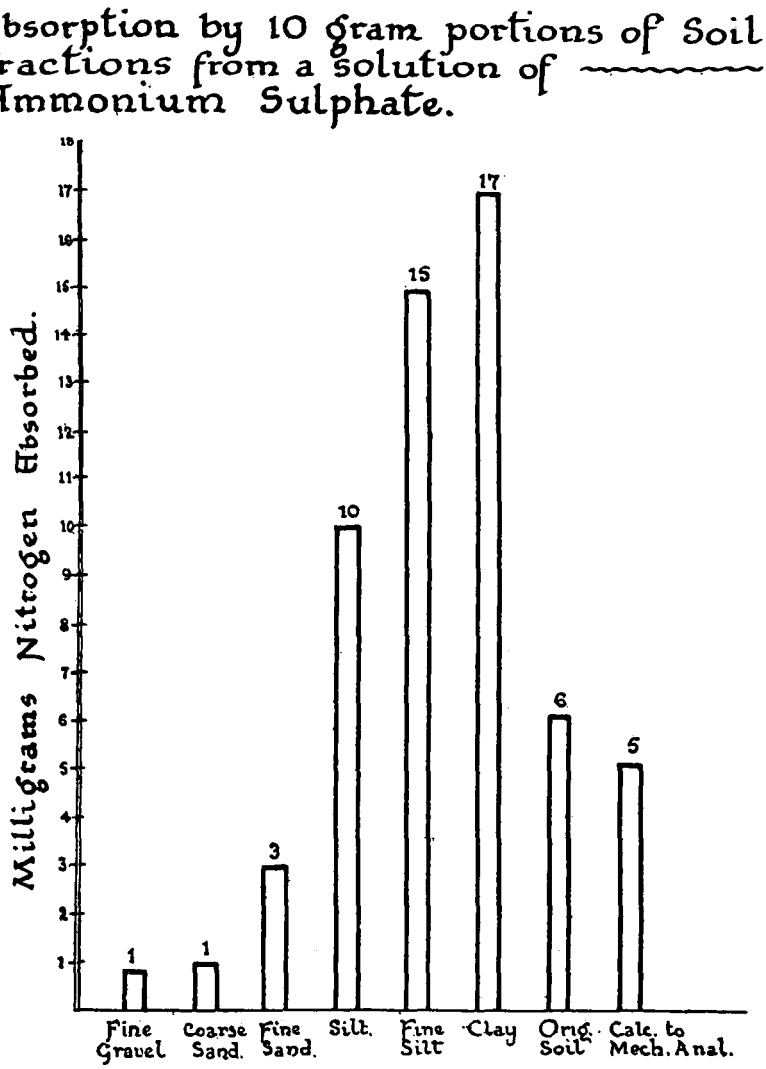
An examination of the soil showed the organic matter to be well decomposed. No fresh vegetable remains were to be seen and the humus appeared to be well decayed.

The amount in the original soil (over 9 % as shown by ignition) is about normal for soil of the district, and the process of mechanical analysis naturally brought the bulk of the organic matter into the finest fractions.

The amounts as shown by loss on ignition are considerably greater than by the Chromic Acid Method, and this is doubtless due to the breaking up of hydrated compounds by ignition.

ABSORPTIVE POWER FOR AMMONIA OF THE SOIL AND ITS FRACTIONS.

The method adopted for determining the absorptive power was to shake up small quantities of the soil and its fractions with a certain volume of a weak solution of ammonium sulphate. After contact for



a period long enough to make sure equilibrium had been attained, the solution was separated by means of filtration and the amount of ammonia removed determined by distillation with magnesia. The results have

been expressed throughout this paper as grams nitrogen removed by 10 grams of the soil or of the soil fractions from 50 c.c. of solution.

The solution used was obtained by dissolving 5 grams ammonium sulphate in distilled water and making up to 1 litre. 50 c.c. of this solution was added to 10 gram portions of the air dried soil fractions in stoppered bottles, and these were shaken at intervals for 24 hours.

After settling to allow solid materials to fall to the bottom, the supernatant liquid was poured off and filtered through one thickness of ordinary Swedish filter paper. The filtrate was analysed for nitrogen by distillation with magnesia using N/10 NaOH and N/10 H_2SO_4.

By taking 20 c.c. at a time for an estimation, the determinations were carried out in duplicate.

Filter paper has a small absorptive capacity but a blank was carried out on the original ammonium sulphate solution, and this was first passed through a filter paper. Again, as it was not the object of this investigation to get an accurate mathematical expression, but to get a general workable idea of the absorptive power of the soil itself, and of its various fractions, with a view to comparison with other soils, no account was taken of temperature, but as the experiments were all carried out at ordinary laboratory temperature which did not vary much, any differences due to this cause could only have been very small.

Table III. *Absorption by Soil and its Fractions.*

Fraction	Absorption by 10 grms. of material from 50 c.c. solution of ammonium sulphate. (grms. nitrogen)
Fine gravel	·001
Coarse sand	·001
Fine sand	·003
Silt	·010
Fine silt	·015
Clay	·017
Original soil	·006

Table III gives the absorptive power as grams of nitrogen absorbed by 10 gram portions of the soil and its fractions.

Duplicates were found to vary to an extent not greater than ·2 c.c. N/10 NaOH, equal to ·00028 gm. N. This variation was due probably to the separation not being perfect and the samples not being perfectly uniform, but as it does not affect the third decimal place, it is not important.

The samples could not be completely dried before being used in the

absorption experiments, as that might have interfered with colloid matter which they contained, and hence with their absorptive capacity. As the different fractions contained different amounts of moisture separate estimations of the moisture were made by drying portions of 10 grams at 100° C.—the results in Table III being based on the dry weight.

The following conclusions may be drawn from Table III:

1. The soil itself before separation into fractions has a fairly high absorptive power for ammonia from a solution of ammonium sulphate.

2. There is a very considerable absorption by each fraction beginning with "fine sand."

3. "Silt" and "fine silt" have a very high absorptive power—approaching that of "clay." This may be partly due to the organic matter, but the fact stands out clearly—that these fractions can play an important part in soil absorption.

4. The absorptive power of "clay" is highest, but is not so high compared with that of "silt" and "fine silt" as might have been expected, considering the enormously greater surface.

Distribution of the Absorptive Power among the Soil Fractions.

Although the "clay" has the highest absorptive power its actual share in the total absorption by soil depends on the amount present. In Craibstone soil, as we have seen, there is but a small amount of "clay," especially if the weight after ignition is taken.

To compare the shares of the different fractions in the total absorption, the absorption of each fraction must be multiplied by the percentage of the fraction which the soil contains. This has been calculated both from the percentages before and after ignition. Table IV (A) shows the absorption calculated on the mechanical analysis by distilled water (Table I, No. 2). Table IV (B) shows the absorption calculated on the mechanical analysis by the ordinary British method.

It will be seen from these tables that "fine silt" and "silt" take a very large part in the absorption by this particular soil and even the "fine sand" has a considerable influence.

This may of course be largely due to the organic matter in these fractions, but it at any rate shows that a soil which contains but little "clay" may from its other fractions have a considerable absorptive power.

The presence of organic matter and the other limitations in these determinations make it impossible to ascertain whether the absorptive power is proportional to the amount of surface, but the evidence seems to indicate that the "silt" and "fine silt" have at any rate as great an absorptive power in this soil as the "clay."

Table IV (A).

Distribution of the Absorptive Power among the Fractions of Craibstone Soil.

(Calculated on the Mechanical Analysis by distilled water alone (Table I, No. 2).)

Fraction	Absorption by 10 grms. of fraction (grms. nitrogen)	Percentage of fraction in soil (before ignition)	Percentage of fraction in soil (after ignition)	Absorption × percentage (before ignition)	Absorption × percentage (after ignition)
Fine gravel ...	·001	10·19	10·07	·01	·01
Coarse sand ...	·001	31·41	31·03	·03	·03
Fine sand ...	·003	26·54	26·01	·08	·08
Silt	·010	14·72	12·44	·15	·12
Fine silt ...	·015	9·64	7·07	·14	·11
Clay	·017	6·53	3·09	·11	·05
Total	—	—	—	·52	·40

Table IV (B).

Distribution of the Absorptive Power among the Fractions of Craibstone Soil.

(Calculated on the Mechanical Analysis by the ordinary British method (Table I, No. 3).)

Fraction	Absorption by 10 grms. of fraction (grms. nitrogen)	Percentage of fraction in soil (before ignition)	Percentage of fraction in soil (after ignition)	Absorption × percentage (before ignition)	Absorption × percentage (after ignition)
Fine gravel ...	·001	10·09	9·93	·01	·01
Coarse sand ...	·001	30·08	29·73	·03	·03
Fine sand ...	·003	26·20	25·80	·08	·08
Silt	·010	14·18	12·47	·14	·12
Fine silt ...	·015	9·62	7·63	·14	·11
Clay	·017	8·88	3·80	·15	·06
Total	—	—	—	·55	·41

There are probably other factors than area of surface determining the amount of absorption. It has already been shown, in Part I, that the different fractions differ greatly in composition, so it is at least possible that differences in composition of the various fractions have some influence on the absorptive power.

SUMMARY.

1. Craibstone soil—a glacial drift soil which has not undergone very profound weathering and is free from calcium carbonate—has a considerable absorptive power for ammonia from a solution of sulphate of ammonia.

2. It was found possible to make a mechanical analysis of a large quantity of this soil without the use of acid and alkali, and although the separation into fractions was by no means perfect, a very fair comparison was obtained of the absorptive capacities of the different fractions.

3. The absorptive power per unit weight of the fractions, as would be naturally expected, increases with the decrease in size of the particles, reaching a maximum in the case of "clay."

4. "Fine silt" and "silt" have also a high absorptive power. This may be partly due to the presence of organic matter, but allowing for that, these fractions have a high power of absorption.

5. It was not the object of these experiments to draw any detailed conclusions as to the relation between surface and absorptive power, but it seems probable, from the results obtained, that the absorptive power is not determined by surface alone, and that the chemical composition of the fractions has an influence on the absorptive power.

6. The distribution of the absorptive power among the various fractions showed that in this particular soil with its comparatively small amount of "clay," the "fine silt" and the "silt" take a large share in the total absorption.

7. By thus dividing soil samples into fractions and comparing the absorptive power of the fractions, surface differences are largely eliminated, and it may be possible to throw some light on the influence of differences of chemical nature and geological origin on absorptive power.

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