SOILS OF CAMBRIDGESHIRE.

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INTRODUCTORY NOTE¹.

IN 1904, Sir James Blyth, Bart., a member of the Cambridge University Board of Agricultural Studies, offered a Scholarship tenable by a student who had taken the University Diploma in Agriculture, for the purpose of enabling him to spend a year in research. The offer was gratefully accepted, and the Scholarship was awarded to Mr F. W. Foreman. Mr Foreman submitted as a subject for investigation the Composition of certain of the Soils of Cambridgeshire. This subject was approved, and the work was carried out in the winter months of 1904—1905. The results are given in the following pages.

As I was partly responsible for the general plan of the work, I may explain the objects in view. In the first place, we were desirous of obtaining some general information about our local soils. Of recent years, the methods of mechanical analysis have been entirely recast, and it was obviously desirable that we should make use of these methods for the purpose of obtaining the fullest possible knowledge of the soils of the district. In the second place, we were anxious to ascertain whether there exists any close connexion between local soils and the underlying rock formation. On the subject of the relation of soil to rock, a good deal of work was done in the middle of last century, but for 50 years the question has received very little attention in Britain. Thus while both geologists and agricultural chemists have made great additions to their respective subjects, little that is new has been published in this country on the relations of Agriculture to Geology.

The Cambridge district is most interesting to the agricultural geologist. On the north-west and west of the county, and within a

¹ By Professor T. H. Middleton.

few miles of the town, one meets with stretches of Oxford, Ampthill, Kimeridge, Gault, and Boulder Clays; and also with the Lower Greensand, and Glacial and Post Glacial gravels; while the eastern half of the county contains the rich Chalk Marl, the Grey Chalk, the Middle and Upper Chalks, and a second stretch of Boulder Clay. The whole district is intersected by deep ditches and other surface sections, and the subsoils are easily studied. For reasons given in his paper, Mr Foreman did not investigate the whole of this area, but confined his work to the soils lying west of Cambridge.

In working out the relationship of soil and rock, the immediate purpose was to ascertain the accuracy of the information which an agriculturist could obtain from a geological map, and for this purpose, the clay formations in the area selected were particularly suitable. It is obvious that in the absence of surface deposits, a soil on a clay like the Gault must present a marked contrast to the soil on a sand like the Lower Greensand; but it is not so obvious that different clay formations will produce soils having distinctive features. It is not certain, for example, that a Kimeridge clay soil would more closely resemble a Kimeridge clay ten miles away than it would a Gault in the same neighbourhood. If well marked mechanical and chemical characters are to be found in any particular clay, then the geological map would be of great use to the agriculturist who for any reason might wish to obtain a knowledge of the general character of the soils of a district.

The one-inch drift map of the country round Cambridge is, unfortunately, rather old; and surface deposits have not received the same attention that is given to them in the maps now being published by the Geological Survey. Dr Teall, Director of the Survey, kindly offered to place the information in his office at our disposal, but for the preliminary work described in this paper, we did not find it necessary to make use of the six-inch maps. Mr W. G. Fearnside, M.A., of Sidney Sussex College, gave us the benefit of his local knowledge, and thus enabled us to find typical samples, in different parts of the district, of those soils of which we were in search.

The samples of Boulder Clay were collected in a strip of country about 8 miles long between Haddenham and Hatley; the Gault samples were taken between Landbeach and Harlton, which are ten miles apart; the Greensand samples were taken between Aldreth and Potton, 20 miles apart; the Kimeridge Clays between Haddenham and Lolworth, 10 miles apart; and the Oxford Clays between Abbotsley and St Neots, 4 miles apart. In the last case, samples from other

districts would have been desirable, but in the time at his disposal, Mr Foreman could not deal with a greater number of soils than those described in his paper.

It may be objected that our selected samples representing typical Oxford Clay etc. represent at the same time a condition of things which could not occur in practice, as no surveyor would make a note of all the trifling deviations from the type which might affect the character of the surface soil, for most of these deviations would be without geological importance. There is a good deal of force in this objection; but while it may be admitted that we can never expect the colours of a one-inch map to have a precise agricultural meaning, it is clear that unless we are prepared to sample every field, and thus obtain average figures, that is, unless we are prepared to make an independent soil survey, we must confine our sampling to the type for which the colour stands.

In tracing the relationship between soils, Mr Foreman has made use of four sets of features: (1) the mechanical composition, (2) the chemical composition, (3) the common weeds, (4) the agricultural systems. The two last have been introduced chiefly to supply some facts of general interest about the soils; and the paper is more particularly concerned with laboratory characters. The question we ask is: "Does mechanical or chemical analysis show that any close relationship exists between the soils situated on the same formations?" Taking first the mechanical analyses, we find that they clearly disclose the wide differences existing between the clays and the sands. On the other hand, they sometimes show that very considerable variations occur between soils on the same formation. In the Greensands for example, the clay varies from 2·6 per cent. in soil No. 7 to 12 per cent. in soil No. 16; while in the subsoil of No. 12 (Kimeridge Clay) we have 42·6 per cent. of clay, and in No. 15 26·5 per cent. only. While these variations indicate the necessity for further figures before making general deductions from the analyses, the majority of the mechanical analyses do show a relationship between all the soils on the one formation. All the Gaults for example contain distinctly more fine silt and clay in the surface soil than do the Kimeridge Clays; and with the mechanical analysis of typical Gault before one, it would be impossible to mistake soils Nos. 1, 2, and 4, for Gault although they rest upon this formation, and to the casual observer closely resemble true Gault soils.

Apart from the proportions in which sand and clay are blended, the quality of soil depends chiefly on the quantities of lime, potash,

phosphoric acid, and nitrogen which are present. Of the first three, Mr Foreman gives the percentage found in the soils examined by him, and it is interesting to compare the clay soils in respect of these and other chemical characters. The Oxford is sharply marked off from the Kimeridge and Ampthill clays by the much higher percentage of lime present¹. All the clays are abundantly supplied with potash, and contain very similar quantities of phosphates. The soils of the Gault contain more lime than those of the Oxford Clay, and containing little visible iron oxide, they differ much in appearance from the Kimeridge Clays.

Even with the limited material which Mr Foreman's work has placed at our disposal, we are justified in concluding that in the Cambridge area the soils are closely related in mechanical and chemical composition to the underlying formations, so that an agriculturist in possession of these analyses would find a good geological map of great use to him. From the agricultural standpoint, a good map is one which indicates the presence of any material that would much modify the character of the soil of any particular formation; such for example as lime, sand, or gravel on clay formations, or of clay on the surface of sandy beds. Mr Foreman's analyses afford illustrations of the kind of information required. Typical Kimeridge clay is very deficient in lime, but here and there thin bands of limestone occur, and when these mix with the soil, they entirely change its character, as is the case with soil No. 17. The agriculturist would therefore wish that the surveyor in mapping clays, should notice the smallest limestone deposits. Again, gravels have covered much of the Gault near Cambridge, and the presence of even small quantities in the surface have greatly modified the clay soils near Impington. See page 172. These gravels may have disappeared, and may only be traceable in pockets, or by pebbles in the surface soil, so that they may have no geological importance. But an indication of their presence on the map would put the agriculturist on his guard, and thus enhance the value of the map.

In drift-covered areas, the agriculturist cannot expect geological maps to have the same value to him as where drift is absent, but Mr Foreman's analyses show that in the case of the Boulder Clay lying west of Cambridge, the only notable difference between the soils is in the percentage of lime which is present; and the very different

¹ One Kimeridge clay does contain lime. For this there is an explanation. See page 173.

types found in soils Nos. 14 and 19 would at once be suggested if the map indicated that one Boulder Clay was chalky while the other was not.

T. H. M.

THE DISTRICT INVESTIGATED.

In the neighbourhood of Cambridge the following strata are represented :

Recent Alluvium

River Gravels

Boulder Clay

Cretaceous :—

	Chalk	{ Upper	
		{ Middle	
		{ Lower	
	Cambridge Greensand—(at one time dug for coprolites)		
	Gault		
Lower Greensand			

Jurassic :—

	Upper Oolites {Kimeridge Clay		
	Middle Oolites	{ Corallian	{ Amphill Clay = { Coral Rag
			{ Lower Calcareous Grit
			{ Oxford Clay

In collecting soils from these formations some care is necessary. In many cases the one-inch drift map only serves as a general guide to the character of the surface soil. Gault for example may be mixed with Gravel or Boulder Clay, at the surface, or the soil of a Greensand may be mixed with Kimeridge Clay. The analyses given below, except Nos. 1, 2, 4, and 17, represent the composition of typical soils. For advice and assistance in selecting samples I am indebted to the kindness of Mr W. G. Fearnside, M.A.

At the time of sampling notes were made upon aspect, elevation, drainage, the system of farming and the characteristic weeds. The agricultural information was usually obtained from the farmer himself.

The depth to which samples were taken varied slightly in different cases; the surface soil was sampled to its full depth, and the subsoil to a further depth of seven inches unless its character changed before this depth was reached.

The following is a list of the samples collected :

Reference No.	Formation	Parish	Survey No. of field or local name	Owner	Occupier
1	Gault	Impington	48	Mr J. Unwin	Mr J. Unwin
2	"	"	62	Mr J. T. Horrocks	Mr J. T. Horrocks
3	"	Laudbeach	'Old Hole'	Worts' Charity	Mr Hy. Cranfield
4	"	Impington	39	Mrs W. Millar	Mr W. Millar
5	Lower Greensand	Gamlingay	—	Downing College	Mr Hy. Dew
6	Amphill Clay	"	140	Capt. Duncombe	Mr Plowman
7	Gault	Hariton	'Poundgate piece'	Christ's Hospital, London	Mr C. Whitechurch
8	"	Madingley	79	Trinity College	Mr P. Papworth
9	Lower Greensand	Oakington	'Cottenham Field'	Mr J. H. H. Linton	Mr I. Cock
10	Oxford Clay	Abbotsley	67	Capt. Duncombe	Mr Wm. Rothery
11	"	"	101	"	"
12	Kimeridge Clay	Oakington	'Cuckoo Hill'	Mr J. H. H. Linton	Mr I. Cock
13	River Gravel	"	'Pens Hill'	"	"
14	Boulder Clay	Hardwick	'Home Field'	Mr J. Hodson	Mr J. Hodson
15	Kimeridge Clay	Lolworth	2	Clare College	Mr J. Mitham
16	Lower Greensand	Oakington	173	Queens' College	Mr W. C. Cole
17	Kimeridge Clay	Haddenham	836	Mr P. A. S. Hickey	Mr A. Hephher
18	Lower Greensand	Aldreth	'Sandway'	Mrs Scott (Ely)	Mr I. Gay
19	Boulder Clay	Boxworth	163	Sir R. P. Cooper	Mr H. Eyre
20	"	Bourn	'Red House Field'	Lord Clifden	Mr Jas. Broadway
21	"	East Hatley	113	Downing College	Mr J. E. Ireland
22	Oxford Clay	St Neots	'Twenty-three acre'	Mr G. Fyde	Mr Rd. Aughton
23	Lower Greensand	Potton	175	Mr Geo. Smith	Mr J. Pibworth

METHODS OF ANALYSIS.

The method employed in making the mechanical analyses of the soils was that recommended by the Chemical Committee of the Agricultural Education Association¹.

Carbonates were estimated by the method devised by Amos².

The sizes of the particles aimed at in the mechanical analyses were as under:

TABLE I.

	Diameter in millimetres		Described as
	maximum	minimum	
Stones and Gravel...	—	25	Stones
	25	10	Small Stones
	10	3	Gravel
	3	1	Fine Gravel
Earth	1	.2	Coarse Sand
	.200	.040	Fine Sand
	.040	.010	Silt
	.010	.002	Fine Silt
	.002	—	Clay

} Separated
by sifting

} Separated
by subsidence

¹ *Journ. Agric. Sci.* Vol. I. Part 4, p. 470.² *Journ. Agric. Sci.* Vol. I. p. 322.

In the chemical analyses the method of extraction employed was that of the Agricultural Education Association as described by A. D. Hall¹.

The phosphoric acid and potash were determined by the method of Neubauer² which was found to work very well.

It will be convenient to present the results of analyses in the following order:

Clay soils.

Boulder Clay

Gault

Kimeridge Clay

Amphill Clay

Oxford Clay

Sandy soils.

River Gravel

Lower Greensand

SOILS OF THE BOULDER CLAY.

Boulder Clay covers all the western side of the Cambridgeshire area "capping the high ground on the north of the Rhee valley and spreading in a sheet over the upland region between the valleys of the Ouse and the Cam; and further north a broad mass runs roughly from Kingston to Coton and Madingley, thence in a N.W. direction to Dry Drayton and Lolworth passing through Elsworth and Papworth into Huntingdonshire³."

The clay itself consists mainly of a dark grey or bluish mass weathering to a drab or brownish colour to the depth of several feet. The soil directly derived from it has a brownish colour and does not much differ in appearance from the underlying weathered mass. In the subsoil hydrated oxide of iron is visible. The amount of calcium carbonate in the soil and subsoil is nearly the same and runs about 1 per cent.

The soils themselves are extremely tenacious. The season must be very favourable indeed if a satisfactory tilth is to be obtained, and the crops are apt to be mediocre in the best of weather. In the summer wide cracks develop which are ruinous to pastures. When not cultivated the land soon becomes covered over with thorns and it may frequently be seen in a derelict condition. Draining and liming are very beneficial but the cost often makes these improvements

¹ *The Analyst*, November, 1900.

² *Landw. Versuchsstat.*, 1905, LXIII. 141—149.

³ Reed, *Geology of Cambridgeshire*.

impossible, amounting to more than the land is worth. The poorest type of pasture is found on undrained Boulder Clay, the roots of the grasses extending only a few inches into the soil, and as the closeness of the texture prevents movements of any kind there is an inadequate supply of air, and a spongy accumulation of undecayed roots collects at the surface.

The following table gives the mechanical analyses of the Boulder Clay soils, all of which were uniform in appearance.

TABLE II.
Mechanical Analysis of Boulder Clay Soils.

	No. 14 Boulder Clay above Gault		No. 19 Boulder Clay above Greensand		No. 20 Boulder Clay above Gault		No. 21 Boulder Clay above Grey Chalk	
	Soil	Subsoil	Soil	Subsoil	Soil	Subsoil	Soil	Subsoil
Depth of sample in inches	7	7	6	7	7	6	6½	6½
Stones, diam. over 3 mm....	2·0	2·4	1·8	1·1	5·0	15·2	2·1	5·3
Fine Gravel	·38	·40	·67	·63	·50	1·07	·86	1·52
Coarse Sand	10·67	10·52	14·79	14·19	14·97	14·03	17·67	16·93
Fine Sand	14·95	14·72	18·55	17·66	15·57	13·87	12·74	14·71
Silt	11·85	12·11	16·37	16·79	12·36	12·05	11·29	11·88
Fine Silt	13·53	13·99	12·35	13·13	12·88	12·18	13·23	12·22
Clay	26·95	29·07	22·28	25·41	28·71	33·00	25·15	28·05
Moisture	3·66	3·44	3·24	3·58	4·40	4·21	4·44	4·46
Loss on ignition (less CO ₂) ..	9·69	8·51	7·73	6·51	7·78	6·58	10·93	7·31
Calcium Carbonate.....	5·71	4·29	·58	·61	1·35	·99	1·02	1·30
	97·39	97·05	96·56	98·51	98·52	97·98	97·33	98·38

It will be seen that in spite of the fact of a different formation underlying the Boulder Clay, in each case there is a fairly close agreement in mechanical composition. As geologists have pointed out, the Boulder Clay of this district has had the same derivation and the underlying strata do not much influence the composition.

The merging of the rock through the subsoil into the soil is reflected very clearly in the analyses, there being a similar preponderance of the smaller particles in the subsoils and *vice versa* with the larger particles in the soils.

. Chemical analyses of the surface soils were made with the following results:

TABLE III.

Chemical Composition of Boulder Clay Soils.

	No. 14	No. 19	No. 20	No. 21
Moisture.....	3.66	3.24	4.40	4.44
Organic Matter, etc.....	9.69	7.73	7.78	10.93
Insoluble Siliceous Matter ...	63.87	73.62	70.02	68.01
Lime (CaO)	3.95	.78	1.22	1.325
Magnesia (MgO)	.285	.28	.35	.60
Phosphoric Acid (P ₂ O ₅)	.14	.113	.107	.102
Potash (K ₂ O)	.948	.785	.994	.963

Here the agreement is more marked than in the mechanical analyses, and it will be observed that all are low in phosphoric acid, high in potash, and fairly high in magnesia.

For comparison with the mechanical and chemical analyses the following agricultural notes are tabulated:

TABLE IV.

Crops grown on Boulder Clay Soils.

No. 14	No. 19	No. 20	No. 21
A better soil than the others, containing more Chalk and Phosphoric Acid.	A very difficult soil to work.	Very difficult to work.	A very poor pasture which was greatly improved by a dressing of 10 cwt. Basic Slag per acre. See <i>Journ. Agr. Sci.</i> i. 125.
<i>Crops.</i> 1900 Barley 1901 Clover 1902 Wheat 1903 Oats 1904 Wheat	<i>Crops.</i> 1898 Mangolds and Vetches (in place of usual bare fallow) 1899 Barley 1900 Oats, manured, but moderate crop 1901 Clover, moderate crop 1902 Wheat, moderate crop 1903 Beans, fair crop 1904 Wheat, manured with 15 loads Farmyard but only 20 bushels per acre owing to bad sowing season	<i>Crops.</i> 1899 Bare fallow 1900 Barley, 20—24 bushels per acre 1901 Beans, manured with 14—15 loads Farmyard, 12—16 bushels per acre 1902 Wheat, 16—20 bushels per acre 1903 Clover, 1½ tons hay per acre 1904 Wheat	
All fair crops except the last wheat crop which yielded only 20 bushels per acre			

The common weeds were :

TABLE V.

Weeds of Boulder Clay Soils.

Specific name	Common name	Remarks
<i>Avena fatua</i>	Wild Oat	Gives great trouble
<i>Ranunculus repens</i>	Kingeob	" " "
<i>Brassica sinapis</i>	Charlock	Very abundant "
<i>Sonchus arvensis</i>	Sowthistle	" "
<i>Carduus arvensis</i>	Thistle	" "
<i>Carduus acaulis</i>	Dwarf Thistle	" "
<i>Rumex crispus</i>	Dock	" "
<i>Galium aparine</i>	Goose grass	Plentiful "
<i>Agrostis stolonifera</i>	Bent	Very troublesome
<i>Daucus carota</i>	Wild Carrot	} Fairly numerous
<i>Geranium molle</i>	Dove's foot Geranium	
<i>Plantago media</i>	Plantains	
<i>Veronica agrestis</i>	Speedwell	
<i>Taraxacum densleonis</i>	Dandelion	
<i>Tussilago farfara</i>	Coltsfoot	In small quantity
<i>Stellaria media</i>	Chickweed	
<i>Senecio vulgaris</i>	Groundsel	" "
<i>Ononis arvensis</i>	Rest Harrow	A scourge in the pastures

SOILS OF THE GAULT.

An irregular and fairly wide strip of Gault extends from the S.W. to the E. of the County of Cambridgeshire and thence into Norfolk to Stoke Ferry and beyond. Gault, on weathering, changes to a creamy colour, and gives rise to quite a light coloured soil. No hydrated ferric oxide can be seen. The soils are thus readily distinguished from those of the Kimeridge and Boulder Clays. In this district Gault soils contain a good deal of calcium carbonate which may vary from 3 to 10 per cent. The subsoil nearly always contains a layer of the small rounded chalk pebbles in various stages of disintegration, termed "race" by geologists. In every case a higher percentage of chalk is found in the subsoil after removal of the pebbles than in the soil. Gault soils are very stiff and sticky, but though containing more "clay" are not quite so tenacious as those of the Boulder Clay. The higher content of calcium carbonate modifies the physical properties considerably. Gault soils are very difficult to till, a bare fallow is absolutely necessary at frequent intervals. As a rule it is found however that fair crops can be obtained on these soils in favourable seasons if they are well cultivated.

Three of the Gaults (Nos. 1, 2 and 4) were among the first soils sampled, and as they proved not to be typical, the analyses are given separately. These soils represent a common type, where Gault is mixed with Gravel. They were taken in the neighbourhood of Impington.

The composition of typical Gault soils is shown in Table VI.

TABLE VI.

Mechanical Analyses of typical Gault Soils.

	No. 3		No. 7		No. 8	
	Soil	Subsoil	Soil	Subsoil	Soil	Subsoil
Depth of sample in inches...	5½	6	5½	6½	6½	6½
Stones, diam. over 3 mm....	percent. 3·4	percent. 9·0	percent. 1·0	percent. ·6	percent. ·6	percent. 1·0
Fine Gravel	1·18	1·17	·19	·05	·50	·38
Coarse Sand	18·53	13·01	4·33	1·16	9·87	8·21
Fine Sand.....	7·08	5·53	4·53	2·30	7·80	7·38
Silt	6·06	6·79	11·97	10·65	10·60	9·23
Fine Silt	13·89	14·68	21·27	18·22	15·57	14·62
Clay	33·04	40·36	31·68	39·96	34·64	38·38
Moisture	4·42	4·86	3·82	4·26	3·14	3·78
Loss on ignition (less CO ₂)	10·52	8·28	10·83	7·45	10·51	9·15
Calcium Carbonate.....	2·05	3·23	8·30	14·71	5·34	8·11
	96·77	97·91	96·92	98·76	97·97	99·24

The increase of the larger particles and decrease of the carbonate of lime as rock passes upwards into soil is again plainly shown in all.

Table VIII. shows the chemical composition of the typical Gault soils.

The percentages of lime and potash are high, while all three soils, and especially No. 8 (a worn-out pasture), are deficient in phosphates.

The agricultural notes relating to the typical Gault soils are given in Table IX.

The common weeds found are given in Table X.

Dandelion appears to be especially favoured by the Gault.

TABLE VII.

Mechanical Analyses of Gault mixed with Gravel.

	No. 1		No. 4		No. 2	
	Soil	Subsoil	Soil	Subsoil	Soil	Subsoil
Depth of sample in inches	5	5½	6	6½	4½	5½
Stones, diam. over 3 mm....	percent. 1·5	percent. 1·5	percent. 1·1	percent. 1·3	percent. 4·4	percent. 3·9
Fine Gravel	·55	·80	1·13	·70	·88	1·48
Coarse Sand.....	9·43	11·75	12·97	11·70	33·37	26·88
Fine Sand.....	11·18	11·21	11·35	12·25	14·69	13·48
Silt	18·60	18·73	15·44	14·21	13·40	9·75
Fine Silt	13·63	11·61	13·39	13·13	8·78	7·77
Clay	18·46	20·03	18·43	20·79	14·12	23·50
Moisture	3·74	2·32	3·72	4·03	2·30	2·40
Loss on ignition (less CO ₂)	8·92	6·44	8·29	8·32	8·57	7·46
Calcium Carbonate.....	10·98	11·40	10·28	9·91	1·21	5·22
	95·49	94·29	95·00	95·04	97·32	97·94

TABLE VIII.

Chemical Composition of Gault Soils.

	No. 3	No. 7	No. 8
Moisture	4·42	3·82	3·14
Organic Matter, etc.	10·52	10·83	10·51
Insoluble Siliceous Matter...	63·67	56·29	60·35
Lime (CaO)	3·87	7·28	4·74
Magnesia (MgO)	·29	·15	·215
Phosphoric Acid (P ₂ O ₅)	·14	·127	·097
Potash (K ₂ O)	1·14	1·143	1·30

TABLE IX.
Crops grown on Gault Soils.

No. 3	No. 7	No. 8
<i>Crops.</i> 1901 Wheat 1902 Clover 1903 Barley 1904 Barley again, because owing to bad season wheat could not be sown. Steam cultivated but very light crop. Other crops fair.	1901 Wheat, fairly good crop 1902 Vetches, fairly good crop 1903 Oats, bad sowing-time and poor crop 1904 Wheat, moderate crop	Very worn-out pasture broken up and two crops of oats taken without manure; each yielded about 8 bushels per acre.

TABLE X.
Weeds of Gault Soils.

Specific name	Common name	Remarks
<i>Taraxacum densleonis</i>	Dandelion	Very abundant
<i>Ranunculus repens</i>	Kingscob	" "
<i>Tussilago farfara</i>	Coltsfoot	" "
<i>Carduus arvensis</i>	Thistle	" "
<i>Rumex crispus</i>	Dock	" "
<i>Brassica sinapis</i>	Charlock	" "
<i>Euphorbia peplus</i>	Petty spurge	In smaller quantity
<i>Geranium molle</i>	Dove's foot Geranium	" "
<i>Veronica agrestis</i>	Speedwell	" "
<i>Senecio vulgaris</i>	Groundsel	" "
<i>Potentilla reptans</i>	Cinquefoil	" "
<i>Stellaria media</i>	Chickweed	" "

SOILS OF THE KIMERIDGE AND AMPHILL CLAYS.

The principal outcrop of the Kimeridge Clay is in the neighbourhood of Ely and Haddenham, a narrow band also runs from Knapwell through Boxworth, Oakington and Cottenham beyond which it spreads out beneath the Fenland of North Cambridgeshire. The Kimeridge Clay consists of dark blue or dark grey clays. Thin layers of limestone in continuous bands or as lines of septarian nodules are found in it, but the clay between these bands is absolutely devoid of chalk; crystals of selenite however are scattered throughout its mass. Except where these thin bands of limestone reach the surface, the soils derived from

the clay are quite devoid of calcium carbonate and in many cases distinctly acid in character.

The clay weathers to a reddish-brown colour and a large quantity of the red hydrated oxide of iron is present. The soils have a dark brown colour, and are quite different from the light coloured Gault and Oxford Clay soils. They are very stiff, sticky, and troublesome, necessitating a frequent bare summer fallow.

The only sample of Amphill Clay examined was taken from the small outcrop at Gamlingay. Amphill Clay very closely resembles Kimeridge Clay, and the soil derived from it was similar to those from the Kimeridge in every respect.

TABLE XI.

Mechanical Analyses of Kimeridge Clay and Amphill Clay soils.

	Kimeridge Clay Soils						Amphill Clay Soil	
	No. 12		No. 15		No. 17		No. 6	
	Soil	Subsoil	Soil	Subsoil	Soil	Subsoil	Soil	Subsoil
Depth of sample in inches	6	6½	6½	6½	6	6½	6½	6½
Stones, diam. over 3 mm....	per cent. 1·8	per cent. ·1	per cent. 3·3	per cent. 1·8	per cent. ·1	per cent. 1·0	per cent. ·7	per cent. ·6
Fine Gravel	1·31	·73	1·65	1·54	·29	·47	1·13	1·40
Coarse Sand	21·17	11·58	20·45	20·30	9·98	9·44	19·22	17·37
Fine Sand	12·46	7·33	12·89	11·31	10·67	12·43	8·49	8·37
Silt	14·97	9·80	10·88	11·48	12·79	13·66	16·46	15·68
Fine Silt	11·94	15·18	13·71	14·38	14·39	14·17	14·97	11·38
Clay	28·29	42·68	25·12	26·52	29·87	35·02	24·10	33·86
Moisture	1·62	2·62	3·94	4·54	5·16	4·93	3·70	3·72
Loss on ignition (less CO ₂)	7·84	8·10	9·03	7·43	9·28	6·54	10·37	7·20
Calcium Carbonate.....	nil	nil	·35	·07	3·32	2·18	·204	·09
	99·60	98·02	98·02	97·57	95·75	98·84	98·644	98·57

The only soil which contains chalk in quantity is the Haddenham one, and here, as may be seen from a section in the local brickpits, some thin bands of limestone outcrop and mix with the soil. No. 12 was acid in reaction and Nos. 6 and 15 contained very little chalk.

TABLE XII.

Chemical Composition of soils of the Kimeridge and Amphthill Clays.

	Kimeridge			Amphthill
	No. 12	No. 15	No. 17	No. 6
Moisture	1.62	3.94	5.16	3.70
Organic Matter, etc.	7.84	9.03	9.28	10.37
Insoluble Siliceous Matter...	74.62	71.34	64.22	69.20
Lime (CaO)	.425	.515	2.425	.48
Magnesia (MgO)	.134	.18	.155	.145
Phosphoric Acid (P ₂ O ₅)	.147	.098	.093	.096
Potash (K ₂ O)	1.13	1.00	1.58	.655

The soils are all poor in lime except No. 17, and all are poor in phosphates and magnesia.

The system of farming adopted upon the Kimeridge Clay soils is shown in the following statement.

TABLE XIII.

Crops grown on Kimeridge and Amphthill Clays.

No. 12	No. 15	No. 17	No. 6
<i>Crops.</i> 1901 White Clover 1902 Wheat 1903 Linseed* 1904 Oats Field rather exhausted and crops all moderate.	<i>Crops.</i> 1901 Wheat, 32 bus. per acre 1902 Fallow, mustard sown in June 1903 Oats, 48 bus. per acre 1904 Swedes, very poor crop, bad tilth. Land unsuited for Swedes.	<i>Crops.</i> 1899 Summer fallow 1900 Beans, 28 bus. per acre 1901 Wheat, 32—36 bus. per acre. 1902 Clover 1903 Wheat 1904 Summer fallow	<i>Crops.</i> 1901 Oats 1902 Oats 1903 Beans 1904 Wheat, so wet had to sow twice and poorish crop Will grow fair crops as a rule.

* A very unusual crop in this district.

TABLE XIV.

Weeds of the Kimeridge and Amphill Clays.

Specific name	Common name	Remarks
<i>Avena fatua</i>	Wild Oat	Very troublesome
<i>Tussilago farfara</i>	Coltsfoot	" "
<i>Carduus arvensis</i>	Thistle	" "
<i>Carduus acaulis</i>	Dwarf Thistle	" "
<i>Rumex crispus</i>	Dock	" "
<i>Brassica sinapis</i>	Charlock	" "
<i>Stellaria media</i>	Chickweed	Fairly prevalent
<i>Taraxacum densleonis</i>	Dandelion	" "
<i>Galium aparine</i>	Goosegrass	" "
<i>Veronica agrestis</i>	Speedwell	" "
<i>Geranium molle</i>	Dove's foot Geranium	" "

SOILS OF THE OXFORD CLAY.

The principal outcrop of this formation unobscured by Drift is to the west of the county of Cambridgeshire where it borders with Huntingdonshire. One of the samples (No. 22) came from St Neots,

TABLE XV.

Mechanical Analyses of Oxford Clay soils.

	No. 10		No. 11		No. 22	
	Soil	Subsoil	Soil	Subsoil	Soil	Subsoil
Depth of sample in inches	6½	7	6	7	6½	6½
Stones, diam. over 3 mm....	percent. 1·3	percent. 1·7	per cent. 3·0	per cent. 1·6	per cent. 3·4	per cent. 1·8
Fine Gravel.....	·75	1·16	·85	1·16	1·17	·46
Coarse Sand.....	14·64	13·27	12·33	10·44	15·56	15·15
Fine Sand	7·92	7·91	8·63	7·81	12·86	9·75
Silt	11·67	11·51	14·81	14·24	11·80	7·56
Fine Silt	13·81	14·49	13·40	14·45	12·55	13·39
Clay	29·97	34·96	29·63	30·74	27·16	27·39
Moisture	3·24	2·46	3·25	2·10	4·18	3·72
Loss on ignition (less CO ₂)	9·87	7·38	9·99	7·64	7·59	6·66
Calcium Carbonate.....	3·04	6·63	4·72	8·90	4·46	11·27
	94·91	99·77	97·61	97·48	97·33	95·35

another (No. 11) from the experimental field of the Cambridge University Department of Agriculture at Abbotsley, which was laid down to pasture in 1900, and the third (No. 10) from an arable field in the vicinity.

In the district mentioned the Oxford Clay itself is a bluish grey clay weathering to a light colour, and the soil and subsoil are not unlike those of the Gault, perhaps a shade darker in colour. The subsoil contains a little hydrated ferric oxide which is just visible. The Clay is distinguished by containing crystals of selenite and nodules of pyrites. At the surface quite a quantity of a characteristic fossil (*Gryphaea dilatata*) is to be found. The subsoil contains small chalk pebbles resembling those in the subsoil of the Gault.

The soils are not quite so sticky as those of a typical Gault, but in all other respects they are much the same. Very little difference can be seen between the subsoil and soil, and the passage upward from rock to soil is not pronounced.

TABLE XVI.

Chemical Composition of Oxford Clay soils.

	No. 10	No. 11	No. 22
	per cent.	per cent.	per cent.
Moisture	8.24	8.25	4.18
Organic Matter, etc.	9.87	9.99	7.59
Insoluble Siliceous Matter...	65.01	65.58	67.18
Total Lime (CaO)	3.23	3.22	3.08
Magnesia (MgO)	.215	.47	.25
Phosphoric Acid (P ₂ O ₅)	.118	.145	.138
Potash (K ₂ O)	1.06	1.11	1.09

These soils resemble each other closely.

The experiments carried out on No. 11 showed basic slag to be a very profitable manure. The soils are intractable, unless dry, and bare fallowing is necessary every four or five years as couch (*Agropyrum repens*) otherwise becomes very abundant.

The following is a list of recent crops and yields:

TABLE XVII.

Crops grown on the Oxford Clay.

No. 10	No. 11	No. 22
1899 Clover, very fair crop 1900 Wheat " " 1901 Fallow " " 1902 Barley, very fair crop 1903 Beans " " 1904 Wheat, very bad crop, bad weather at seed-time	1896 Fallow 1897 Barley, good crop 1898 Beans " " 1899 Wheat " " 1900—1904 Pasture	1901 Summer fallow, per- manent pasture seeds failed 1902 Wheat, 20 bus. per acre *1903 Oats, 56 bus. per acre 1904 Wheat, 20 bus. per acre (bad seed- time)

* Manured with 15—20 tons mixed London dung and farmyard manure per acre.

TABLE XVIII.

Weeds of the Oxford Clay.

Specific name	Common name	Remarks
<i>Tussilago farfara</i>	Coltsfoot	Very troublesome
<i>Brassica sinapis</i>	Charlock	" "
<i>Ranunculus repens</i>	Kingcob	" "
<i>Carduus arvensis</i>	Thistle	" "
<i>Rumex crispus</i>	Dock	" "
<i>Geranium molle</i>	Dove's foot Geranium	Abundant
<i>Anthemis Cotula</i>	Stinking Mayweed	"
<i>Sherardia arvensis</i>	Field Madder	"

SOIL DERIVED FROM RIVER GRAVEL.

It will be seen that this is quite a similar type of soil to those of the Lower Greensand. The sample was taken from a field adjoining a small watercourse. This was considered by the occupier to be very good land indeed. The recent crops were:

- 1901 Barley, good crop.
- 1902 Peas, good crop, had Farmyard manure.
- 1903 Wheat, very good indeed.
- 1904 Barley, moderate crop on account of dry season.

The weeds were very similar to those found on the Greensand soils with, in addition, a very large quantity of what is locally termed "Hardhack" (*Centaurea nigra*).

TABLE XIX.

Mechanical Analyses of River Gravel soil and subsoil.

	No. 13	
	Soil	Subsoil
Depth of sample in inches...	6½	6½
Stones, diam. over 3 mm....	per cent. 9·0	per cent. 10·7
Fine Gravel	2·22	2·40
Coarse Sand	49·80	51·90
Fine Sand	18·14	16·81
Silt	7·20	7·64
Fine Silt	5·90	5·70
Clay	9·74	8·97
Moisture	1·00	·96
Loss on ignition (less CO ₂)	5·20	5·12
Calcium Carbonate.....	·045	nil
	99·245	99·50

SOILS OF THE LOWER GREENSAND.

The principal outcrops of the Lower Greensand in Cambridgeshire are :

- (1) Around Aldreth and Haddenham.
- (2) A narrow strip running from Lolworth through Oakington to Cottenham.
- (3) At Gamlingay and extending through Potton and Sandy into Bedfordshire.

The weathered Greensand is red because of the oxidation of the ferrous iron in the original glauconitic grains, and it is characterised by the "box stones" and iron stones it contains. These are ferruginous concretions. Greensand gives rise to red soils which are liable to be severely scorched in summer.

Here the larger sized particles are very abundant, as much as from 60 to over 80 per cent. were stopped by a sieve with 100 meshes to the linear inch. The percentage of "clay" (which is of a totally

TABLE XX.
Mechanical Analyses of Lower Greensand soils.

	No. 5			No. 23			No. 18			No. 9			No. 16		
	Soil		Subsoil	Soil		Subsoil	Soil		Subsoil	Soil		Subsoil	Soil		Subsoil
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Depth of sample in inches	6½	6½	6½	7	6	6	6	6½	7	6½	5½	6	5½	6	
Stones, diameter over 3 mm.	5.3	4.2	5.7	9	8	3	6.1	10.2	2.7	3.8					
Fine Gravel	2.62	1.73	7.15	6.57	1.57	1.84	3.25	4.93	3.03	2.7					
Coarse Sand	71.90	73.93	81.78	77.65	67.93	70.63	54.54	47.16	55.78	52.81					
Fine Sand	4.62	5.08	3.37	6.14	7.35	6.36	9.92	8.22	11.14	8.54					
Silt	4.23	4.37	1.80	1.33	4.49	3.92	8.81	9.87	8.05	7.86					
Fine Silt	2.21	2.01	.81	1.01	3.89	2.89	4.15	4.66	4.20	4.43					
Clay	7.20	6.74	2.63	3.57	7.67	11.10	7.88	18.39	12.06	17.16					
Moisture	1.24	1.77	.57	.74	1.70	1.22	1.40	1.92	1.56	2.16					
Loss on ignition (less CO ₂)	5.58	3.99	2.47	2.16	4.58	3.16	5.94	7.02	5.20	4.86					
Calcium Carbonate	nil	nil	nil	nil	.318	.038	nil	nil	nil	nil					
	99.60	99.62	100.58	99.17	99.498	101.158	95.89	102.17	101.02	100.52					

different nature from that of the heavy soils, being red in colour and nearly all ferric oxide) is sometimes higher than would be expected. A noteworthy feature is the total absence of calcium carbonate. The soils are very dependent upon the addition of humic matter to increase their water-holding capacity. Those found in the Gamlingay and Potton district are coarser grained than those from the Lolworth and Oakington Greensand. In the latter some of the "clay" has been washed through into the subsoil, forming a hard pan when dry. Most of the samples were found to be acid in reaction. The soils around Gamlingay and Potton grow market garden produce. They are heavily manured with London dung and respond to liberal treatment. The soils near Lolworth and Oakington which contain a higher percentage of clay are naturally superior to those of Gamlingay. All the Greensand soils are easy to work, the great difficulty of the farmer being lack of moisture, but the liberal use of London dung or farmyard manure greatly increases their water-holding power.

TABLE XXI.

Chemical Composition of Greensand soils.

	No. 5	No. 23	No. 18	No. 9	No. 16
Moisture	1·77	·57	1·70	1·40	1·56
Organic Matter, etc.	5·58	2·47	4·58	5·94	5·20
Insoluble Siliceous Matter ...	82·08	91·22	85·13	80·94	80·97
Lime (CaO)	·065	·085	·34	·26	·15
Magnesia (MgO)	·08	·125	·24	·17	·14
Phosphoric Acid (P ₂ O ₅)	·204	·259	·197	·169	·146
Potash (K ₂ O)	·236	·278	·47	·443	·47

It will be seen that these correspond very closely, revealing a fairly high content of phosphate, little potash, and very little magnesia and total lime.

The quality and cropping powers of these soils may be inferred from the following particulars.

TABLE XXII.

Crops grown on the Greensand.

No. 5	No. 23	No. 18	No. 9	No. 16
Fairly elevated situation.	Elevated situation and very liable to scorching. Land had been barren for 20 years, then—	Very good soil.	A very fertile field.	Good soil.
1901 Potatoes, fair crop	1902 Potatoes, very bad crop	1902 Clover, 1½ tons hay per acre	1902 Clover, 1½ tons hay 1st crop,	1902 Wheat, 28 bus. per acre
1902 Oats " "	1903 Rye, 20 bus. per acre	1903 Wheat 32 bus. per acre	1 ton hay 2nd crop	1903 Swedes, good crop fed off by sheep
1903 Potatoes " "	1904 Peas, 12 bus. per acre	1904 Swedes, a little finger and toe in patches	1903 Barley, averaged 40 bus. per acre	1904 Barley, 24 bus. per acre only, because of dry weather
1904 " " "	20 tons dung per acre used for Peas.	1905 Barley	1904 Barley, averaged 40 bus. per acre	1905 White Clover
Scorching in summer a difficulty.		Soil suited to a damp season.		Beans used as an alternative to clover because of clover sickness.

TABLE XXIII.

Weeds of the Greensand.

Specific name	Common name	Remarks
<i>Stellaria media</i>	Chickweed	Very large quantities
<i>Chenopodium album</i>	Fat hen	Large quantities
<i>Polygonum aviculare</i>	Knot grass	" "
<i>Capsella bursa pastoris</i>	Shepherd's purse	" "
<i>Senecio vulgaris</i>	Groundsel	" "
<i>Spergula arvensis</i>	Field Spurrey	" "
<i>Rumex acetosa</i>	Sorrel	" "
<i>Lychnis vespertina</i>	Campion	" "
<i>Papaver Rhoeas</i>	Poppy	" "
<i>Veronica agrestis</i>	Speedwell	" "
<i>Crysanthemum segetum</i>	Wild Marigold	Especially where acid
<i>Viola tricolor</i>	Field pansy	Large quantities
<i>Plantago lanceolata</i>	Plantain	Fairly numerous
<i>Anthemis Cotula</i>	Stinking Mayweed	" "
<i>Sherardia arvensis</i>	Field Madder	" "
<i>Daucus carota</i>	Wild Carrot	" "

On No. 16, *Crysanthemum segetum* and sorrel grew almost exclusively on those patches where "Finger and Toe" attacked the swede crop. This was also the case on soil No. 9.