THE MACAULAY INSTITUTE FOR SOIL RESEARCH

FOUNDED 1930

ANNUAL REPORT 1949-1950

The Macaulay Institute is situated in Countesswells Road, about three miles from the centre of Aberdeen. Buses (Route 18) run at frequent intervals from Union Street to the Seafield terminus which is within 10 minutes walk of the Institute.

Telephone—ABERDEEN 33223

MACAULAY INSTITUTE

THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN
(Founded 1930)

COUNCIL OF MANAGEMENT

1949–1950

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STAFF

1949–1950

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Deputy Director	A. B. Stewart, M.A., B.Sc., Ph.D., F.R.I.C.
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	Miss I. M. Mutch, B.Sc., A.R.I.C.
	A. M. Ure, B.Sc.
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	R. B. Duff, B.Sc., Ph.D.
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	*T. M. Forrester, B.Sc.
Peat Investigations	S. E. Durno, B.Sc.
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Scientific Instrument Maker	*A. M. Fraser.
Secretary	Miss E. J. Dey.
Librarian	Miss A. M. B. Geddes, M.A., F.L.A.

RESEARCH WORKERS

Seconded . . . . . †J. D. Ovington, B.Sc., Ph.D. (Forestry Commission).

*T. W. Wright, B.Sc.(For.) (Forestry Commission).

Visiting . . . . . G. T. Chamberlain (East African Research Organization).

A. H. Cottenie (Landbouwhogeschool, Gent).

V. Hernando Fernandez (Instituto de Edafologia y Fisiologia Vegetal, Madrid).

A. Hoyos de Castro (University of Granada).

Th. Hügi (University of Berne).

D. Laing (University of Aberdeen).

E. Letelier (Ministry of Agriculture, Chile).

C. Rodriguez Muñoz (University of Zaragoza).

W. M. H. Saunders (Soils Bureau, Department of Scientific and Industrial Research, New Zealand).

A. Strasheim (South African Council of Scientific and Industrial Research).

D. J. Swaine (University of Melbourne).

M. Muñoz Taboadela (Instituto de Edafologia y Fisiologia Vegetal, Madrid).

H. M. Thompson (Colonial Office, Jamaica).

Ornella Vergnano (University of Florence).

*Appointed 1950

†Resigned 1950

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

ANNUAL REPORT

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COUNCIL

The Council of Management records with deep regret the death of Dr. J. M. Caie, C.B., F.R.S.E., which occurred with tragic suddenness in Aberdeen on 22nd December, 1949. Dr. Caie was appointed one of the representatives of the Department of Agriculture on the Council in 1945, and gave valuable service as Convener of the Finance Committee. Although his tenure of office was short he had for many years taken a keen and active interest in the development and progress of the Institute.

Mr. R. G. White, C.B.E., M.Sc., F.R.S.E., has been appointed one of the representatives of the Department of Agriculture for Scotland in succession to the late Dr. J. M. Caie.

STAFF

(*a*) *Resignations :*

Department of Pedology—

Mr. W. M. Crooke, B.Sc. (Soil Survey).

Department of Soil Organic Matter—

Mrs. D. J. Eastwood, B.Sc. (Microbiology).
Dr. J. D. Ovington (Forestry Commission Research Scholar).

(*b*) *Appointments :*

Department of Pedology—

Mr. R. Grant, B.Sc. (Soil Survey).

Department of Soil Organic Matter—

Mr. T. M. Forrester, B.Sc. (Microbiology).
Mr. T. W. Wright, B.Sc. (For.) (Forestry Commission Research Scholar).

Department of Plant Physiology—

Mr. W. M. Crooke, B.Sc.
Mr. A. H. Knight, B.Sc. (Radioactive Studies).

Mr. A. M. Fraser has been appointed Scientific Instrument Maker and Designer.

Dr. J. G. Hunter, Department of Plant Physiology, was granted leave of absence to visit the University of California and various research centres in the United States, under an award made to him in terms of the Fulbright and Smith-Mundt Acts, U.S.A. Grants were given by the Agricultural Research Council and the Department of Agriculture for Scotland whereby members of staff were enabled to attend the Fourth International Congress of Soil Science in Amsterdam and the First Microchemical Congress in Graz, Austria.

LABORATORIES

New buildings have been completed for the Soil Survey Analytical Section and for Radioactive Investigations. The alterations and re-allocation of laboratories within the main building have also been completed.

VISITING RESEARCH WORKERS

During the year the following workers have studied at the Institute :

(*a*) *Department of Pedology :*

Physico-Chemical and X-ray Sections—

A. Hoyos de Castro (University of Granada, Spain).
M. Muñoz Taboadela (Instituto de Edafologia y Fisiologia Vegetal, Madrid, Spain).

(*b*) *Department of Soil Fertility :*

E. Letelier (Ministry of Agriculture, Chile).
V. Hernando Fernandez (Instituto de Edafologia y Fisiologia Vegetal, Madrid, Spain).

(*c*) *Department of Plant Physiology :*

D. Laing (Soil Science Department, University of Aberdeen).
C. Rodriguez Muñoz (University of Zaragoza, Spain).
Ornella Vergnano (University of Florence, Italy).

(*d*) *Department of Spectrochemistry :*

G. T. Chamberlain (East African Research Organization).
A. H. Cottenie (Landbouwhogeschool, Gent, Belgium).
Th. Hügi (University of Berne, Switzerland).
A. Strasheim (South African Council of Scientific and Industrial Research).
D. J. Swaine (University of Melbourne, Australia).
H. M. Thompson (Department of Agriculture, Jamaica).

Visitors welcomed to the Institute have included delegates to the Commonwealth Agricultural Bureaux Review Conference in London, the members of The Nature Conservancy, delegates to the British Council Course in Forestry, and research workers from the United States, South America, Australia, New Zealand, Africa, Finland, Norway, Turkey and the Lebanon.

POLICY

The policy of the Institute continues to be the study of the soil in all its aspects—its origin and its properties—with a view to the maintenance and improvement of soil fertility. With this object a survey of the soils of Scotland is in progress and a study of the fertility of various types is being made. Fundamental investigations are in progress into the trace element content of rocks, soils and plants, the structure and properties of clays, the nature of soil organic matter, and soil-plant relationships. The Macaulay Institute collaborates with other Research Institutes and with the Colleges of Agriculture in Scotland in so far as the fundamental properties of the soil are related to problems of crop production and animal health.

Representation on Committees

The Institute is represented on the following committees appointed by—

(1) *Agricultural Research Council :*
- (*a*) Conference on Fertilizer Application to Agricultural and Horticultural Crops.
- (*b*) Conference on Mineral Deficiencies of Agricultural and Horticultural Crops.
- (*c*) Land Drainage Conference.
- (*d*) Soil Survey Research Board.

(2) *Department of Agriculture for Scotland :*
- (*a*) Technical Advisory Committee.
- (*b*) Field Trials Sub-Committee.
- (*c*) Scottish Grassland Sub-Committee.
- (*d*) Sugar Beet Sub-Committee.
- (*e*) Consultative Committee for the Development of Spectrographic Work, and its Technical Sub-Committee.

(3) *Forestry Commission :*

The Sub-Committee dealing with Nutritional Problems in Tree Nurseries.

(4) *Colonial Office :*

Soils Sub-Committee of the Committee for Colonial Agriculture, Animal Health and Forestry Research.

(5) *Development Commission :*

Survey of Agricultural, Forestry and Fishery Products and their Utilization.

(6) *Secretary of State for Scotland :*
- (*a*) Hill Farm Research Committee and its Sub-Committees dealing with (i) Trace Elements and (ii) Heather.
- (*b*) The Scottish Standing Committee for the Calculation of the Residual Values of Fertilizers and Feeding Stuffs.
- (*c*) The Scottish Peat Committee, and Sub-Committee on the Survey of Peat Deposits in Scotland.
- (*d*) The Nature Conservancy (Scottish Committee).
- (*e*) The Standing Advisory Committee, Fertilizer and Feeding Stuffs Act, 1926.

Acknowledgements

The Council of Management tenders thanks to the Department of Agriculture for Scotland, to the Agricultural Research Council, and to the Forestry Commission for grants received, and to other benefactors for their generous support.

September, 1950.

PEDOLOGY

SOIL SURVEY (SCOTLAND)

The Soil Survey Section—with a personnel of eight officers—has been engaged on reconnaissance soil surveys (2·5 in. to 1 mile) in Banffshire, in Kincardineshire and Angus, in Roxburghshire, and in Ayrshire. With these four teams approximately 420 square miles have been mapped during the 1950 field season.

NORTH-EAST SCOTLAND

Banffshire (*Geological Survey Sheet* 96)

An area of about 50 square miles has been mapped. It is bounded in the north by the Moray Firth coast from Portsoy to Buckie, and extends inland for approximately 6 miles.

The topography of the area is determined to a large extent by the geology and is broadly rolling to hilly, falling into a series of north-east to south-west ridges such as Durn Hill, Hill of Fordyce, Hill of Summerton, Hill of Maud and the Bin of Cullen (1050 ft.). The main streams, the Burns of Durn, Fordyce, Deskford and Buckie, flow northwards in the intervening valleys. A well-defined alluvium-filled former channel runs east to west parallel to the coast about a mile and a half inland.

The land is cultivated up to about 750 ft.; the higher ground is under calluna heath and moor, some of which is planted with conifers.

The solid geology comprises rocks of the Keith Division of the Highland schists, forming more or less parallel bands with a north-east to south-west strike. The predominant types are massive and flaggy quartzites on the higher hills, and micaceous flags, mica schists, phyllites and limestone bands on the slopes. A more recent intrusion of norite and hypersthene gabbro occurs in the south-east part of the area. Old Red Sandstone conglomerate covers an area of some 3 to 4 square miles east of Kirkton of Deskford. Patches of fluvio-glacial sands and gravels are scattered throughout the area. Stratified clay and silty clay of the Interglacial Coastal Deposits (*Mem. Geol. Surv. Scot.*, 86–96) are found west and south from Sandend Bay. Boulder clay covers most of the area.

The agriculture of the area is somewhat varied, and to some extent can be correlated with the soil type. Rearing and fattening of cattle are commonly practised. Dairy farms supplying local needs are found between Portsoy and Cullen. The average size of farm is about 100 acres, of which one half is cropped and the other in grass. Smallholdings of less than 40 acres are commonly found on the upper slopes where soils are derived from very acidic parent material.

Soil Associations

The following Associations are found in this area:

1. Insch — *see* Annual Report, 1939–1940.
2. Boyndie (formerly Memsie) — *see* Annual Report, 1942–1943.
3. Strichen — *see* Annual Report, 1943–1944.

4. Tarves — *see* Annual Report, 1943–1944.
5. Corby — *see* Annual Report, 1944–1945.
6. Durnhill — *see* Annual Report, 1945–1946.
7. Leslie — *see* Annual Report, 1945–1946.
8. Bogtown — New Association.
9. Unnamed Association on Old Red Sandstone till.

Insch Association

Distribution . . A small area near Bogmuchalls.
Parent Material . Till derived from basic-igneous rocks.
Dominant Series . Poorly drained.

Profile :

Horizon	Depth	
* S	0–9 in.	Greyish, light-brown loam; cloddy structure. Sharp change into G_1.
G_1	9–24 in.	Brownish-yellow clay loam; strong grey and ochreous mottling; strong prismatic structure; grey coating and sharp angles to structural units; many of the basic stones decomposed. Merging into
G–C	24–48 in.	Brownish-yellow clay loam; very intense ochreous mottling; massive structure.

The topography of the association in this area is smooth to flat. Large boulders sometimes interfere with cultivation.

Boyndie Association

Distribution . . Scattered areas south of Cullen; in the valley north of the Bin from Woodside to Rannas; around Shirralds and up both sides of the Deskford Burn as far as Inaltry; in smaller isolated areas at Sandend Bay, Dytack, Shielburn and Rathven.
Parent Material . Fluvio-glacial sand.
Dominant Series . Freely drained.

Profile :

Horizon	Depth	
S	0–12 in.	Grey-brown loamy sand; soft nutty structure. Merging into A_1.
A_1	12–20 in.	Grey-brown (at top) to yellow-brown (at 20 in.) sand; soft and loose.
B_1	20–30 in.	Yellowish, light-brown sand; single-grain structure. Sharp change into C.
C	30–50 in.	Medium-brown sand with patches of grey, yellow and brown; relatively compact.

The topography is generally smooth with a slight slope.

* S is the cultivated horizon.

Strichen Association

Distribution . . Between the Burn of Deskford and the Durnhill ridge; north of Cotton Hill; almost the entire area west of the Hill of Summertown; south of the ridge from the Bin of Cullen to the Hill of Maud; a small area east of the Hill of Summertown to the Burn of Durn.

Parent Material . Till derived from schistose rocks, mainly quartzose micaceous flags, with subsidiary micaceous quartzites, mica schists and calcareous flags.

Dominant Series . Freely drained.

Profile:

Horizon	Depth	
S	0–10 in.	Greyish-brown, fine sandy loam; crumb to soft nutty structure. Relatively sharp change into B_2.
B_2	10–18 in.	Yellow, fine sandy loam, very soft cloddy structure. Sharp change into B_3.
B_3	18–24 in.	Yellowish-grey loamy sand; indurated; rock fragments less weathered.

The B_3 horizon merges into a pale-yellow, stony sandy loam till.

The absence of stone dykes is a feature of the Strichen landscape and the topography is rolling.

Tarves Association

Distribution . . The vicinity of Bogmuchalls, extending from the Hill of Fordyce to Cornhill.

Parent Material . Till derived from both acid and basic rocks. The acidic rocks are quartzites and various quartzose schists; the basic are norite, gabbro, amphibolite and serpentine.

Dominant Series . Poorly drained.

Profile:

Horizon	Depth	
S	0–9 in.	Grey-brown loam; cloddy structure. Sharp change into G_1.
G_1	9–22 in.	Yellow-brown, sandy clay loam with grey and ochreous mottling; strong prismatic structure; many of the basic stones decomposed. Merging into G–C.
G–C	22–48 in.	Yellowish-grey, sandy clay loam; moderate ochreous mottling; massive structures.

The topography in this area is flat with micro-relief. Certain parts formerly cultivated have been planted with spruce. Large boulders of "blue heathen" norite rock are conspicuous in the fields and stone dykes.

Corby Association

Distribution . . Isolated morainic mounds.

Parent Material . Water-sorted gravel.

Dominant Series . Freely drained.

Profile :

Horizon	Depth	
A_0L	0–1 in.	Undecomposed litter.
A_0F	1–4 in.	Partially decomposed, dark-brown, felty, fibrous organic matter. Sharp change into A_2.
A_2	4–9 in.	Grey with dark-brown coarse sandy gravel.
B_1	9 in.	Discontinuous thin iron pan. Sharp change into B_2.
B_2	9–20 in.	Yellow-brown, cobbly gravel ; compact. Merging into C.
C	20–48 in.	Pale yellow-brown, cobbly gravel ; compaction decreasing to single-grain structure.

A variant of the B_1 horizon is a cemented humus horizon.

The topography in this area is moundy to undulating.

Durnhill Association

Distribution . . Generally on high ground. Occurs immediately east of Sandend Bay ; on the ridge formed by the hills of Durn, Fordyce and Summertown ; about Crannoch Hill ; the Bauds of Cullen ; the Moor of Findochty ; the Moor of Scotstown ; on the lower ground south of Portessie : on the Bin of Cullen and the Hill of Maud.

Parent Material . Till derived from quartzite, quartzose flags and quartzose schists.

Dominant Series . Imperfectly drained.*

Profile :

Horizon	Depth	
A_0L	0–2 in.	Undecomposed litter.
A_0F	2–7 in.	Partially decomposed, black, felty, fibrous mor humus ; many roots.
A_0H	7–9 in.	Black, greasy mor humus ; sticky and plastic.
A_2	9–17 in.	Dark-grey, drying light grey, stony sand.
B_1	17–18 in.	Thin $\frac{1}{8}$ in. continuous iron pan ; root concentration above pan. Sharp change into B_2.
B_2	18–30 in.	Yellow-orange, stony sand ; compact. Merging into B_3.
B_3	30–40 in.	Yellow-grey, stony sand ; strongly indurated. Merging into C.
C	40 in.+	Pale-yellow, stony sand.

The topography is generally hilly but occasionally smoothly rolling, and peaty gleyed soils with iron pan are found on flat areas.

* To conform with the new terminology agreed upon by the Scottish and English Soil Surveys, the term " slightly-poorly drained ", previously used, has been replaced by " imperfectly drained ", thus giving the sequence—freely drained, imperfectly drained, poorly drained, and very poorly drained.

Leslie Association

Distribution . . An area between Auchips and Toux Wood.
Parent Material . Till derived from serpentine.
Dominant Series . Freely drained.

Profile :

Horizon	Depth	
S	0–10 in.	Brown loam ; crumb to nutty structure. Merging into
B_2	10–16 in.	Brownish-yellow, sandy loam ; soft cloddy structure. Merging into
B_3	16–28 in.	Greyish-yellow, stony sandy loam ; moderately compact. Merging into
C	28 in.+	Yellowish-grey, stony sandy loam till.

The topography is rolling.

Bogtown Association

Distribution . . Occurs below the 200 ft. contour about the farms of Broom and Bogtown ; along the coastal strip from Redhythe Point to Logie Head ; on cliffs above Cullen Bay ; in old channel from Glasshaugh to Lintmill.
Parent Material . Stratified clays of the Coastal Deposits.
Dominant Series . Poorly drained.

Profile :

Horizon	Depth	
S	0–11 in.	Grey-brown, silty clay loam ; cloddy structure. Sharp change into G_1.
G_1	11–36 in.	Reddish-brown, silty clay ; strong prismatic structure ; grey and ochreous mottling ; blue-grey coating to faces of structural units. Merging into G–C.
G–C	36 in.+	Brown silty clay ; laminated structure.

The topography is either flat or gently sloping.

Unnamed Association

A small area of till overlaying Old Red Sandstone conglomerate covers an area of 3 to 4 square miles east of Deskford. It appears to fit into two previously described associations, one the Hatton Association on excessively cobbly, reddish-brown, loam textured till, and the other the Ordley Association on mixed reddish-brown drift with a high content of schist fragments.

Skeletal Soils

Quartzite

Distribution . . Top of the Durnhill–Hill of Fordyce ridge ; on the Bin of Cullen and the Hill of Maud.
Parent Material . Quartzite.

Profile :

Horizon	Depth	
A_0L		Trace of undecomposed litter.
A_0F	0–2 in.	Partially decomposed, dark-brown, fibrous mor. Sharp change into A_2.
A_2	2–6 in.	Grey, stony, sandy gravel ; no structure ; stones angular.

The A_2 horizon merges into shattered angular quartzite.

Hill and Basin Peat

Hill peat overlying Strichen parent material is found on the hill-tops of Black Hill and Old Fir Hill, but it is seldom deeper than 4 ft. Deep basin peat occurs at Shiel Muir, The Goul, and Addie Moss.

EAST SCOTLAND

Angus and Kincardineshire (Geological Survey Sheets 66 and 57)

Approximately 150 square miles have been surveyed in Angus and Kincardineshire. In this area two distinct geographical regions are involved. About 100 square miles consist of hill country lying north and south of Glen Esk to the west of the Highland Boundary Fault ; the remaining fifty square miles is arable land around the lower reaches of the North Esk.

The hilly region forms a rectangle extending from Loch Lee in the west to Sturdy Hill in the east, and from the Hill of Cat in the north to Nathro Hill in the south. The country consists of steep, heather-covered hills rising to altitudes of from 1,000 to 2,000 ft.

The arable region is bounded in the north by a west-east line from Edzell to the sea, in the west by a north-south line from Edzell to Trinity, and in the south by an irregular west-east line from Trinity, through Dun, to the North Esk estuary. This is an area of low undulations 100 to 350 ft. high, with a tendency to an east-west orientation, with the exception of the Canterland-Garvock range which rises to between 400 and 600 ft. in the north-east.

The rocks of the hilly region comprise porphyritic red granites extending north from Rough Bank, Mount Battock and Hill of Cat, with metamorphic quartz gneiss, quartzite, and quartz mica schists extending southwards and terminating at the Highland Boundary Fault. The metamorphic rocks include minor limestone bands and occasional smaller areas of basic hornblende schist ; they are cut by minor intrusions, mainly of felsitic but occasionally of basaltic material. Thin boulder clay covers most of the area.

Superficial deposits of glacial till and fluvio-glacial outwash gravels cover the arable area which is underlain by sandstone and conglomerates of Lower Old Red Sandstone Age. These strata include considerable strips of contemporaneous andesitic lava forming the core of the Garvock Hills and lower parallel ridges and hills to the south-east.

Two types of farming are found in this area. Hill farms predominantly concerned with sheep raising are mostly confined to the Glenesk-Lethnot area. These usually have a small acreage of arable ground and 1,000 to

2,000 acres of hill grazing. Between the North and South Esk the farms are large arable holdings of between 300 and 500 acres, which tend to specialize in one or two cash crops such as wheat, barley, sugar-beet or seed potatoes. Grass leys more than two years old are uncommon.

Soil Associations

Nine Associations have been distinguished in this area :

1. Fraserburgh *see* Annual Report, 1942–1943.
2. Corby *see* Annual Report, 1944–1945.
3. Strichen *see* Annual Report, 1944–1945.
4. Stonehaven *see* Annual Report, 1946–1947.
5. Laurencekirk *see* Annual Report, 1946–1947.
6. Strathfinella *see* Annual Report, 1947–1948.
7. Auchinblae *see* Annual Report, 1947–1948.
8. Boyndie *see* Annual Report, 1948–1949.
9. Craigo New Association.

Fraserburgh Association

Distribution . . Below the 100 ft. contour line south-east from Dun, through Hillside, to the coast at St. Cyrus, bounded on the south by the Montrose Tidal Basin ; a discontinuous narrow coastal strip north of St. Cyrus with a maximum width of ¼ mile.

Parent Material . Raised beach sand, sometimes shelly.

Dominant Series . Freely drained.

Profile :

Horizon	Depth	
S	0–11 in.	Medium-brown sandy loam ; weak nutty structure. Merging into B_1.
B_1	11–22 in.	Pale-brown sandy loam ; weak cloddy structure. Moderately sharp change into B_2.
B_2	22–31 in.	Pale-brownish-yellow, gravelly coarse sand ; slight patches of organic staining. Merging into C.
C	31 in.+	Gravelly coarse sand ; single-grain structure.

The topography is gently sloping to flat.

Corby Association

Distribution . . Glenesk between the alluvium and the hill slopes ; at Tarfside and Millden ; in upper Glen Lethnot and an area east from Edzell golf course.

Parent Material . Fluvio-glacial gravel.

Dominant Series . Freely drained.

Profile :

Horizon	Depth	
S	0–8 in.	Light-brown, gravelly loamy sand ; crumb structure. Sharp change into B_2.
B_2	8–17 in.	Yellow-brown, gravelly loamy sand ; loose nutty structure. Sharp change into B_3.

B_3	17–25 in.	Brownish-yellow, coarse sandy gravel; strongly indurated. Merging into C.
C	25 in.+	Gravel; single-grain structure.

Two topographic variants have been distinguished—(*a*) flat and (*b*) moundy. The flat areas are river terraces and are largely cultivated, while the moundy areas are valley moraines and are mainly uncultivated or planted with conifers.

Strichen Association

Distribution . . The hill area to the south of Mount Battock, with the exception of the morainic sand and gravel and the alluvium of Glen Esk. It is bounded to the south-east by the Highland Boundary Fault.

Parent Material . Till derived from quartz schist and some mica schist and quartzite.

Dominant Series . Freely drained.

Profile:

Horizon	Depth	
A_0L	0–1 in.	Undecomposed *Calluna* and moss litter.
A_0F	1–4 in.	Partially decomposed, dark-brown, felty, fibrous mor. Sharp change into A_2.
A_2	4–8 in.	Grey loamy sand with dark-brown organic stained patches. Changing sharply into B_1.
B_1–B_2	8–14 in.	Yellowish-brown sandy loam; soft cloddy structure some dark-brown organic staining. Sharp change into B_3.
B_3	14–22 in.	Greyish-yellow, stony loamy sand; indurated. Merging into C.
C	22 in.+	Greyish-yellow, very stony, sandy loam till.

The hills tend to be less steep south of the River North Esk.

Stonehaven Association

Distribution . . The Logie Pert area; the Garvock Hill to Hill of Canterland area; the Ecclesgreig to Lauriston area.

Parent Material . Till derived from sandstone and conglomerate beds, with some lava of Old Red Sandstone Age.

Dominant Series . Imperfectly drained.

Profile:

Horizon	Depth	
S	0–11 in.	Brown loam; soft cloddy structure. Sharp change into B–G.
B–G	11–36 in.	Reddish-brown, heavy loam; slight ochreous and grey mottling; cloddy structure. Merging into C.
C	36 in.+	Red, stony, sandy clay loam till; massive structure.

The topography is broadly rolling.

Laurencekirk Association

Distribution . . From Balmakewan Wood eastwards to the lower slopes of the Kirton and Garvock Hills.

Parent Material . Till derived from red marl strata of the Old Red Sandstone formation.

Dominant Series . Imperfectly drained.

Profile :

Horizon	Depth	
S	0–11 in.	Reddish-brown clay loam; cloddy structure. Merging into B–G.
B–G	11–22 in.	Red clay loam; cloddy, prismatic structure; slight ochreous mottling.

The B–G horizon merges into a massive, bright-red, clay till.

The topography is gently rolling.

Strathfinella Association

Distribution . . The Hill of Edzell; Garvock Hill and the area to the south and west; a narrow strip on the north-west facing slope of the Hill of Stracathro.

Parent Material . Till derived from arenaceous Old Red Sandstone strata, with metamorphic erratics.

Dominant Series . Freely drained.

Profile :

Horizon	Depth	
S	0–10 in.	Red-brown, heavy sandy loam; crumb structure. Sharp change into B_2.
B_2	10–17 in.	Orange-red sandy loam; nutty structure. Sharp change into B_3.
B_3	17–25 in.	Pale-greyish-red sandy loam strongly indurated.

The B_3 horizon merges into a pale-red, stony, sandy loam till.

The topography is strongly rolling to hilly.

Auchinblae Association

Distribution . . Along the edge of the Grampians near the Hill of Edzell; small areas south and south-west of Garvock Hill.

Parent Material . Red, fluvio-glacial sand and gravel.

Dominant Series . Freely drained.

Profile :

Horizon	Depth	
S	0–12 in.	Medium-brown loamy sand; weak crumb structure. Merging into B_2.
B_2	12–25 in.	Reddish-brown loamy sand; very weak, cloddy structure. Merging into B_3.
B_3	25–31 in.	Reddish-brown sand; moderately compact.

The B_3 horizon merges into a single-grain stratified red sand and gravel.

The topography is undulating to moundy.

Boyndie Association

Distribution . . A small area east of Edzell Wood.
Parent Material . Fluvio-glacial sand.
Dominant Series . Freely drained.

Profile :

Horizon	Depth	
S	0–11 in.	Grey-brown loamy sand : incoherent structure. Merging into A_1.
A_1	11–20 in.	Transitional ; grey-brown at top, yellow-brown at base ; sand ; single-grain structure. Merging into B_2.
B_2	20–30 in.	Yellow-brown sand ; single-grain structure. Sharp change into B_3.
B_3	30-47 in.	Medium brown sand ; compact ; organic staining. Sharp change into C.
C	47 in.+	Coarse sand ; single-grain structure.

The topography is either flat or moundy.

Craigo Association

Distribution . . The Huntly Wood area ; a coastal strip from St. Cyrus to Johnshaven.
Parent Material . Water-sorted deposits overlying Stonehaven till.
Dominant Series . Imperfectly drained.

Profile :

Horizon	Depth	
S	0–10 in.	Brown loam ; nutty structure.
	10–13 in.	Red loamy sand ; weak nutty structure. Merging into B–G.
B–G	13–23 in.	Pale-reddish-brown sandy loam ; slightly grey and ochreous mottling.

The B–G horizon merges into a clay loam till.

The topography is gently sloping.

The Craigo and Stonehaven Associations form a complex in these areas, but it has been possible to delineate them.

Undifferentiated Alluvium

A small strip of alluvium occurs near Stracathro Hospital. It is imperfectly drained, and a typical profile is :

Horizon	Depth	
S	0–15 in.	Reddish-brown loam ; cloddy, breaking into crumb structure.
	15–23 in.	Grey-brown, fine sandy loam ; faint-orange mottling ; cloddy structure.
	23–28 in.	Brownish-red, fine sandy loam ; faint-orange mottling ; cloddy structure.
	28 in.+	Red, stony, loamy coarse sand.

SKELETAL SOILS

GRANITE

Distribution . . Extensively in the mountainous area north of the Hill of Saughs and Rough Bank.

Parent Material . Weathered granite and granite gravel.

Profile :

Horizon	Depth	
A_0L	0–1 in.	Undecomposed litter.
A_0F	1–5 in.	Partially decomposed, very dark-brown fibrous mor.
A_2	5–15 in.	Grey fine gravel : no structure.

The A_2 horizon merges into very compact, grey, rotten granite.

The humus horizon is very variable in depth. The topography is mountainous, and the soils can be either excessively wet or dry.

HILL PEAT

Hill peat occurs extensively on the upper slopes of the mountainous area. The summits are usually bare.

SOUTH-EAST SCOTLAND

Roxburghshire (Geological Survey Sheet 17)

In Roxburghshire, surveying has been continued in a south-westerly direction with the National Boundary as the south-east limit of the area surveyed. The River Teviot from Eckford westwards to the River Rule is the northern boundary of the area, whilst the River Rule itself forms the western boundary. Approximately 100 square miles have been surveyed.

The topography of the area is closely related to its geology. The area as a whole is hilly, but while few of the hills in the centre and west are over 750 ft., those of the east and south range from 1,000 ft. to 2,000 ft. The hills in the centre and west, except for a few volcanic necks, are composed of sediments of Old Red Sandstone age and are well-rounded and smooth. Streams have cut deep channels through the sandstone strata exposing large rock faces. Lava is predominant in the east and the hills are steep-sided and rugged. Here the valleys tend to be wider and the streams have made little impression on the underlying rock. In the south of the area the sediments are of Lower Carboniferous age, and a prominent topographical feature is a long ridge, about 1,800 ft. high, from which several lower ridges branch out to divide the country into relatively wide basins. Glacial till covers most of the area, but tends to be thin over the area of the Hindhope Association. Extensive spreads of fluvio-glacial gravel occur along the banks of the River Teviot.

The farms in the area are usually large, often exceeding 1,000 acres, and are primarily concerned with the rearing of sheep and, to a lesser extent, of cattle. Cultivation plays only a minor part in the economy of the typical hill farm, but on the lower ground it is more important though still secondary to livestock production.

Soil Associations

The Associations encountered during the season are

1. Sourhope *see* Annual Report, 1948–1949.
2. Bowmont *see* Annual Report, 1948–1949.
3. Eckford *see* Annual Report, 1948–1949.
4. Martinlee New Association.
5. Hindhope New Association.

Sourhope Association

Distribution . . Eastern part of the area.
Parent Material . Till derived from porphyritic lava.
Dominant Series . Imperfectly drained (semi-natural).

Profile :

Horizon	Depth	
A_0L	0–1 in.	Undecomposed grass litter.
A_1	1–7 in.	Darkish-brown, gritty loam ; soft cloddy structure ; high organic matter ; very slight ochreous mottling. Sharp change into B_1.
B_1	7–8 in.	Dark-reddish-brown, gritty sandy loam ; soft nutty structure ; enriched in humus. Relatively sharp change into B_2.
B_2	8–14 in.	Light-reddish-brown, gritty, coarse loamy sand ; very indurated ; few roots penetrate ; slight ochreous mottling. Merging into C–G.
C–G	14–42 in.	Light-reddish-brown, gritty, clay loam ; cloddy to laminated ; ochreous mottling.

The topography is hilly to mountainous.

Bowmont Association

Distribution . . The central and western parts of the area.
Parent Material . Shallow till derived from arenaceous Old Red Sandstone.
Dominant Series . Imperfectly drained.

Profile :

Horizon	Depth	
S	0–9 in.	Light-brown loam ; soft cloddy structure. Relatively sharp change into B_2.
B_2	9–18 in.	Reddish-brown, sandy clay loam ; slight ochreous mottling ; cloddy structure.

The B_2 horizon changes sharply into rotten sandstone, reddish-brown, with patches of grey.

The topography is strongly rolling to hilly.

Eckford Association

Distribution . . Along the southern bank of the River Teviot.
Parent Material . Fluvio-glacial sands and gravels.
Dominant Series . Freely drained (immature).

Profile :

Horizon	Depth	
S	0–10 in.	Brown, gravelly sandy loam ; loose crumb structure. Sharp change into B.
B	10–15 in.	Reddish-brown, gravelly, loamy sand ; very little structure. Merging into C.
C	15 in.+	Reddish-brown, gravelly sand ; single-grain structure.

The topography is undulating to moundy.

Martinlee Association

Distribution . . The southern part of the area.
Parent Material . Till derived from sandstone of the Lower Carboniferous formation
Dominant Series . Poorly drained.

Profile :

Horizon	Depth	
A_0L	0–1 in.	Undecomposed grass litter (mainly *Molinia*).
A_0F	1–8 in.	Dark-reddish-brown mealy humus. Sharp change into A_1.
A_1	8–17 in.	Pale-yellow, fine sandy clay loam ; cloddy structure ; grey and ochreous mottling ; dark-brown, organic staining. Merging into A_2.
A_2	17–24 in.	Pale-yellow clay ; strong, cloddy to prismatic structure ; grey faces to structural units ; strong ochreous mottling. Merging into G–C.
G–C	24–32 in.	Pale-olive, fine sandy clay ; massive structure ; ochreous mottling.

The area consists for the most part of gently sloping basins bounded by steep-sided ridges.

Hindhope Association

Distribution . . Two small areas, one near Hindhope Farm and the other near Camptown.
Parent Material . Shallow till derived from shaly sediments of the Upper Silurian formation.
Dominant Series . Imperfectly drained.

Profile :

Horizon	Depth	
A_0	0–1 in.	Undecomposed grass litter.
A_1	1–3 in.	Dark-brown, fine sandy, silty clay loam ; crumb structure. Merging into A_2.
A_2	3–9 in.	Grey-brown, fine sandy, silty clay loam ; crumb structure. Sharp change into B_2.
B_2	9–13 in.	Pale-yellow, fine sandy, silty clay loam ; cloddy structure breaking into nuts. Merging into B_3.
B_3	13–20 in.	Pale-yellow, fine sandy, silty clay loam ; cloddy structure ; many small flat stones ; slight ochreous mottling. Merging into C.

C 20–26 in. Pale-olive, very stony, fine sandy, silty clay loam ; slight ochreous mottling.

Below 26 in. shattered rock is found.

The topography near Hindhope Farm is hilly but near Camptown it is gently sloping.

Hill Peat

Hill peat occurs at about 1,500 ft. where the topography is slightly convex, flat, or concave. The depth of peat is variable, but is usually over 2 ft.

SOUTH-WEST SCOTLAND

Ayrshire (Geological Survey Sheet 22)

An area of approximately 120 square miles has been surveyed, the southern boundary running from Irvine along the Irvine valley to Darvel, and the northern from West Kilbride due east through Stewarton to a point roughly 6 miles north of Darvel.

The country is mainly undulating, with drumlins scattered throughout the central part ; the hilly ground is confined to the north-east (Rough Hill, 906 ft.) and the north-west (Hinglie Hill, 700 ft.).

The main drainage channels are those of the Irvine Water, which flows due west, and the Garnock, which flows a southerly course to join the former at Irvine. The subsidiary drainage, as indicated by the Dusk, Lugton, Annick, Fenwick and Craufurdland Waters, has a decided north-east to south-west trend.

There is a progressive increase in rainfall over the area, from 37 in. at the coast to 48 in. in the northern parts.

Carboniferous sediments, with igneous rocks, underlie the greater part of the area, but lavas predominate in the north-east and sandstone of the Old Red Sandstone formation in the north-west corner.

The area is extensively covered by superficial deposits consisting of glacial drifts, raised beach deposits, alluvium, blown sand and peat. The glacial drifts comprise boulder clays, some of which are shelly, and fluvio-glacial sands and gravels.

Two types of farming are practised in this area. The whole of the Kilmarnock Basin is devoted to intensive dairy farming, usually on farms of rather more than 100 acres. From West Kilbride to Ardrossan early potato production is an important secondary activity. On the uplands to the north, north-east and east, stock raising—sheep and, to a lesser extent, cattle—is practised. The farms here are usually about 500 acres with a small proportion arable and the remainder in rough pasture.

Soil Associations

Seven soil Associations have been established in this area :

1. Kilmarnock.
2. Ashgrove.
3. Kirkland.
4. Dreghorn.

5. Glenmount.
6. Darlieth.
7. Eglington.

Kilmarnock Association

Distribution . . A belt of 6 miles wide extending from the uplands to the vicinity of Stewarton and Dreghorn.

Parent Material . Mixed till derived mainly from basalt, with varying sedimentary rock content of sandstone, limestone, shale, etc.

Dominant Series . Poorly drained.

Profile :

Horizon	Depth	
S	0–9 in.	Strong-brown clay loam ; cloddy structure. Sharp change into G_1.
G_1	9–27 in.	Red-brown clay loam ; large prismatic structure ; strongly mottled with ochre and grey. Merging into G–C.
G–C	27–48 in.	Yellow-brown, clay till ; faintly prismatic to massive structure.

The topography is undulating with drumlins having a general north-east to south-west orientation.

Ashgrove Association

Distribution . . An area bounded on the east and south by the Kilmarnock Association and extending north-west to Garnock Water.

Parent Material . Mixed till of sedimentary rocks, sandstone, limestone, shales, etc., of Carboniferous formation.

Dominant Series . Poorly drained.

Profile :

Horizon	Depth	
S	0–9 in.	Brown, heavy clay loam ; strong, cloddy structure. Sharp change into G_1.
G_1	9–23 in.	Yellow and grey-brown clay ; large columnar structure ; strong ochreous and grey mottling.
G–C	23–48 in.	Grey-brown clay ; many decomposed stones ; massive structure ; strong-grey coating round stones.

Kirkland Association

Distribution . . Area lying between the Ardrossan-Dalry Road in the east and the coastal strip from Ardrossan to West Kilbride.

Parent Material . Till derived from sandstone of the Old Red Sandstone formation, with some quartz pebbles and basaltic stones.

Dominant Series . Freely drained.

Profile :

Horizon	Depth	
S	0–9 in.	Reddish-brown sandy loam ; weak, cloddy structure. Sharp change into B_2.
B_2	9–24 in.	Light-reddish-brown, sandy, clay loam ; soft cloddy structure. Merging into C.
C	24 in.+	Reddish-brown, sandy, clay loam till.

The topography of the area is hilly.

Dreghorn Association

Distribution . . A broad fringe adjoining the coast from Ardrossan to Irvine ; up the Irvine Valley as far as Springside ; a very narrow belt from Ardrossan north to West Kilbride.

Parent Material . Raised-beach sand.

Dominant Series . Freely drained.

Profile :

Horizon	Depth	
S	0–8 in.	Dark-brown loamy sand ; soft cloddy structure. Sharp change into B–C.
B–C	8–48 in.	Brownish-yellow sand ; single-grain structure.

The topography is relatively flat. In certain areas of depressed microrelief the permanent water-table is high and drainage is difficult.

Glen Mount Association

Distribution . . Immediately east of the Stevenston-Dalry road, forming a strip about 3 miles long and from a half to 1 mile broad.

Parent Material . Mixed till derived largely from shales and limestones of the Carboniferous formation.

Dominant Series . Poorly drained.

Profile :

Horizon	Depth	
S	0–9 in.	Dark-brown heavy loam ; strong cloddy structure. Sharp change into G_1.
G_1	9–27 in.	Bluish-grey clay ; cloddy structure mottled with grey and a little ochre. Merging into G–C.
G–C	27 in.+	Brown clay ; massive structure ; strong grey mottling and a little ochre ; high content of weathered shale chips.

The topography is sharply rolling.

Darlieth Association

Distribution . . A narrow strip between the Kirkland and Glen Mount Associations.

Parent Material . Thin basaltic till over shattered basalt.

Dominant Series . Imperfectly drained.

Profile :

Horizon	Depth	
S	0–7 in.	Brown, stony loam; nutty structure. Sharp change into B_2–G.
B_2–G	7–14 in.	Red-brown clay loam; cloddy structure; slight ochreous staining.

The B_2–G horizon merges into shattered rock.

The topography is hilly with many outcrops of rock.

Eglington Association

Distribution . . From Kildrummy south-east to Dreghorn.
Parent Material . Fluvio-glacial sand and gravel.
Dominant Series . Freely drained.

Profile :

Horizon	Depth	
S	0–7 in.	Dark-brown, gravelly loamy sand; incoherent structure. Sharp change into B_1.
B_1	7–10 in.	Light-brown gravelly sand; slightly compact. Sharp change into C.
C	10 in.+	Light-brown, stratified sand and gravel; single-grain structure.

The topography is moundy.

Skeletal Soils

Dune Sand

Distribution . . South-east of Stevenston between the coast and Garnock Water; in small areas throughout the western part of the Dreghorn Association.
Parent Material . Wind-blown sand.

The profile, where developed, consists of a succession of shallow A_1 horizons, separated by layers of sand. The major part of the area is bare sand.

Hill and Basin Peat

Hill and basin peat of considerable depth is scattered throughout the country mapped, the most extensive belt being that of the north-east region, consisting of Flow Moss, Cameron Moss, and Wallacegill Muir, the total area of which is approximately 12 square miles. *Eriophorum* is the dominant vegetation type. The area is grazed by a few sheep and store cattle.

LABORATORY INVESTIGATIONS AND COLLABORATIVE WORK

The hydrologic sequence of soils with natural drainage varying from free to very poor have been investigated with reference to (i) pore space distribution within the various profiles, (ii) the amount of decomposed stone fragments, (iii) the fractionation of the phosphate content. Further work has also been done on methods of estimating free sesquioxides, and a collection of rock specimens characteristic of the soil associations is being made.

Collaboration with the X-ray and Physico-Chemical Sections and with the Department of Spectrochemistry has been continued, while assistance has been given to the Department of Soil Fertility in the selection of sites for field trials.

Surveys have been carried out in the following areas :

1. Glenrothes, Fife (development area).
2. Loch Challium Chille, Skye (drainage).
3. Orkney Mainland (deep ploughing).
4. Carse of Stirling (corrosion of water pipes).

and, after examination of samples, *ad hoc* reports were issued.

The Third Soil Survey Conference between officers of the Soil Surveys of England and Wales and of Scotland was held in Somerset in April, 1950.

Students from University Departments of Botany, Geography, Soil Science and Agriculture have been given instruction and information, while during the year twelve visitors, including Dominion and foreign research workers, have been shown typical soils of north-east Scotland.

ANALYTICAL SECTION

The samples taken by the soil surveyors—some 400, representing 80 profiles—have been examined for moisture, loss on ignition, *p*H value, total carbon, total nitrogen, and total and soluble phosphorus, while the determinations of exchangeable calcium, magnesium, sodium and potassium have been completed for 60 of the profiles received. Mechanical analyses are in progress. An analysis of a sample of vermiculite received from Kenya has been made at the request of the X-ray Section.

Special Investigations. (1) Twelve profiles—64 samples—have been examined for determination of *p*H value, total water-soluble salts, sulphur and chlorine, in connection with the investigation of the corrosion of a water pipe line in the Carse of Stirling to which reference has been made in the report of the Soil Survey Section.

(2) Routine analyses have been made of 7 profiles—37 samples—from Scare Hill, Monymusk, on behalf of the Department of Botany, University of Aberdeen in connection with an ecological survey of the area.

SOIL GEOLOGY AND MINEROLOGY

The mineralogical study of soils and their parent materials has been continued to determine the nature of the fine sand fractions, in order to characterize the soil associations already delineated. The materials examined were mainly glacial drifts of mixed lithological composition.

North-east Scotland. In the areas being surveyed in north-east Scotland the soils have been examined in the field in order to determine the nature of their parent materials. These areas are underlain by sedimentary, igneous and metamorphic rocks but the soils are generally developed on overlying superficial deposits, mainly glacial drifts of mixed lithological composition.

South-west Scotland. Various districts in north Ayrshire, where a soil survey is being conducted, have been visited for co-operation in the determination of the soil parent materials. In this area of complex solid geology,

the glacial drifts (mainly boulder clays) on which most of the soils are dedeloped are of mixed rock origin, being derived from a variety of sedimentary and igneous rock types. A classification based on the predominant rock types in the drifts has been devised.

South Scotland. Field work in connection with the sheep pining investigation has been continued, mainly in Selkirkshire and Dumfriesshire, with visits to neighbouring districts in Kirkcudbrightshire. The main areas investigated lie around the head waters of the Esk and Ettrick. These lie in a belt of Silurian rocks, mainly shales, sandstones and greywackes. Traverses have been made throughout the district and the soils and herbage sampled for laboratory investigation as a preliminary to further experimental work being carried out in the area.

Other Investigations. Field work has also been carried out in connection with the field trials being made by other departments, while co-operation with the Department of Soil Fertility has been maintained in the examination of materials submitted for investigation.

X-RAY INVESTIGATIONS

Soil-clays from a large number of different parent material types have now been studied by X-ray diffraction methods. The parent material groups (associations) which have been investigated are Insch, Tarves, Countesswells, Durnhill, Foudland, Leslie, Ordley, Corby, Kemnay, Gartly, Strathfinella, Cruden, Stonehaven, and Laurencekirk, representing soils developed on glacial till derived from igneous rocks of all types, from gneisses quartzites, sandstones, sands and gravels, slates, and red clays, as well as some residual soils. It is evident that this diversity is not reproduced in the mineralogy of the soil-clays, which is remarkably constant. It is not certain, however, that the effect of the parent material is altogether negligible, and the slight differences which appear to exist are being investigated more fully. Any real differences are, of course, made more difficult to detect by the considerable intermixing by ice action which the parent materials of these soils have undergone. In general, the influence of drainage is also slight, except in the case of soils developed on the more basic rock types.

The genesis and subsequent breakdown of certain minerals can be followed in the soil profiles. For example, a clay mineral similar to biotite, formed in the parent till, breaks down to vermiculate or montmorillonite when exposed to weathering in the soil itself ; hematite is similarly broken down and replaced by amorphous iron oxide or sometimes by goethite ; and kaolinite may also be produced in the soil profile at the expense of the mica-type minerals.

Soils from other parts of the world are also examined from time to time, and recently a detailed study has been made of selected soils from Zanzibar and Pemba. The clay mineral composition of these soils, worked out from their diffraction patterns, shows that they are mainly kaolinite-bearing, with montmorillonite assuming the dominant role in a few cases, and vermiculite minerals occasionally occurring in minor quantity. Amorphous sesquioxides, which have been determined chemically, in some cases make up as much as 50 per cent. of the clay fractions.

The γ-iron hydroxide, lepidocrocite, has been found in samples of weathered rocks from various localities in Scotland. This mineral appears to be commonly formed at an early stage in the weathering process. It was also found to be a prominent constituent of certain lateritic soils from Natal, which have recently been studied.

As in previous years, considerable attention has been focussed on the mineral vermiculite, because of its widespread occurrence in Scottish soil-clays. During the year a paper dealing with the effect of the exchangeable cation on the hydration characteristics of this mineral was read to the Clay Minerals Section of the Fourth International Congress of Soil Science in Amsterdam.[4] A review of the present state of knowledge on vermiculite is in the press.[31]

The detailed structure of vermiculite is being investigated by means of single-crystal X-ray photographs and unidimensional Fourier syntheses based on the basal-plane reflections. An interim report on this work was given at a meeting of the Clay Minerals Group of the Mineralogical Society.[32]

The ability of vermiculite to form organic complexes like those of montmorillonite has been demonstrated. Both organic cation complexes and van der Waals adsorption complexes can be formed, although less rapidly than with montmorillonite.[30]

PHYSICO–CHEMICAL INVESTIGATIONS

Differential Thermal Analysis. The new apparatus envisaged in last year's report has now been constructed and is working satisfactorily, although further developments are planned. The construction of this apparatus has necessitated a considerable amount of development work, calibration, etc., so that the output of results during the year has suffered although the increase in output now possible should more than compensate for this in a short time.

A brief description of the new apparatus may not be out of place here. It is at present operating with the two original furnaces, but other three are in the course or construction. The rate of temperature increase of the furnace is controlled by a Kent " Multelec " Programme Controller, operating from a thermocouple outside the specimen holder block, in such a way that the temperature at the centre of the inert material increases at a uniform rate of 10° C. per minute. The actual temperature at the centre of the inert material is recorded on a Kent " Multelec " Recorder, while the differential temperature is recorded on a Cambridge Model B, 0–1 mv. Recorder. This recorder is not sufficiently sensitive for the detection and determination of substances, such as quartz, which give a small reaction, but a compact adaptation to make this possible is now almost complete.

The thermocouple system and specimen holder are the same as those used in the original apparatus, although modification of the specimen holder is contemplated. A reasonably reproducible uniform rate of heating at the centre of the inert material has now been obtained over the whole range 0–1,000° C., although considerable difficulty in obtaining this reproducible linear control was experienced originally, especially in the region below 250° C., on account of the controlling thermocouple being outside the specimen-holder block.

Curves for a number of pure materials and artificial mixtures have been determined on the new apparatus to provide standard data for interpretation of results. These curves are very similar to those obtained on the original apparatus, although, owing to the different heating rates, the peak areas are different. A much better proportionality between the peak areas and amounts of reacting material is now obtainable and reproducibility appears to be good.

The mineralogy of Scottish soil-clays has been further investigated. Some proportion of halloysite or kaolinite has again been found in most of the soil-clays examined, although some have shown the presence of illite and montmorillonite, the last being noted particularly in the fine fraction ($> 0{\cdot}4\mu$, e.s.d.) of a poorly drained soil in the Stonehaven Association.

The widespread occurrence of the " cold-precipitated " type of hydrated ferric oxide has been confirmed. In view of the fact that it has been found in excessively drained, freely drained and poorly drained soils, its occurrence does not seem to be related to drainage type, although further work on wet and excessively wet soils is needed to substantiate this. Whether its occurrence can be related to any particular parent material is not yet clear. Only a very small proportion of the " cold-precipitated " material has been found in the $1{\cdot}4$–$0{\cdot}4\mu$ e.s.d. fraction of a sample of *terra rossa* from the Mediterranean coast of France, while none was detected in some soil-clays from Denmark. No goethite was observed in the *terra rossa* or the Danish clays.

In continuance of the work on the weathering products formed *in situ* from different rock types, a quartz schist has been examined. The clay formed consisted to a large extent of kaolinite, but the quartz content of this clay has not yet been checked.

Further work has been carried out on the pure, laboratory-prepared ferric oxides. Ammonium hydroxide is the only precipitant which, so far, has given material with the characteristic 350° C. exothermic peak. That the peak is not due to incomplete removal of NH_4^+ or to contamination with impurities has been shown by chemical analysis. The sensitivity to precipitation conditions is being further investigated.

During the year a scheme for the international standardization of different thermal analysis apparatus by means of "standard" * minerals has been inaugurated by the Differential Thermal Analysis Sub-Committee of the Comité International pour l'Etude des Argiles (C.I.P.E.A.). This laboratory has been in charge of distribution of these minerals to laboratories in Great Britain, Europe, South Africa and Australia, and a preliminary correlation of about 20 results received from these—and from laboratories in America—is at present being carried out. The results so far have abundantly demonstrated the need for some standardization.

A review of the differential thermal analysis method for the investigation of clays and of the work of the Differential Thermal Analysis Sub-Committee of C.I.P.E.A. was presented at the Fourth International Congress of Soil Science in Amsterdam.[2]

Other Studies. In addition to the chemical analysis of iron oxides

* Although their mineralogical purity is generally high, these minerals are "standard" only in the sense that the samples distributed to the various laboratories were from the same stock.

carried out during the year, the "standard" minerals distributed under the C.I.P.E.A. scheme have been analysed, as well as some clays derived from weathered rocks. From chemical data the "standard" clays appear to be relatively pure, kaolinite, for example, giving the formula

$$K_{0\cdot13}\,(Al_{7\cdot82}\,Ti_{0\cdot01}\,Fe^{+3}_{0\cdot02}\,Fe^{+2}_{0\cdot02}\,Ca_{0\cdot07})\,(Si_{7\cdot63}\,Al_{0\cdot37})\,O_{20\cdot82}\,(OH)_{15\cdot18}$$

as compared with the theoretical

$$Al_8\,Si_8\,O_{20}\,(OH)_{16}.$$

A clay derived from weathered rock (originally thought to be limestone) previously identified by differential thermal analysis as a relatively pure halloysite with some iron oxide contamination was found to have 10·5 per cent. free iron oxide, and gave the formula

$$(K_{0\cdot09}\,Na_{0\cdot08})\,(Al_{5\cdot79}\,Ti_{0\cdot67}\,Fe^{+3}_{0\cdot84}\,Fe^{+2}_{0\cdot27}\,Ca_{0\cdot18}\,Mg_{0\cdot23}\,Mn_{0\cdot01})\,(Si_{7\cdot41}\,Al_{0\cdot59})\,O_{19\cdot51}\,(OH)_{16\cdot49}$$

which compares reasonably well with the theoretical for halloysite

$$Al_8\,Si_8\,O_{20}(OH)_{16}.$$

The change in cation exchange capacities of muscovite and vermiculite with time of grinding have been examined, using a micro cation-exchange capacity method. This method, which has recently been developed, is a modification of the macro method using ammonium acetate, and can be used with samples of 10–50 mg. of clay. Where the amount of the material allows, the changes induced in muscovite and vermiculite are being further investigated by differential thermal analysis and in collaboration with the X-ray Section.

In view of the complex mixture of minerals occurring in soil-clays a method for separating these minerals even partially, would be of considerable value. Separation of artificial mixtures of clay minerals by electrophoresis is now being attempted, in collaboration with the X-ray Section, but it is too early yet to assess the value of the method.

A paper dealing with the theoretical aspects of the hydration of montmorillonite is in the press.[21]

SPECTROCHEMISTRY

The function of the Department of Spectrochemistry is to develop and apply spectrochemical and allied physical methods for the analysis of soils, plant materials and related substances, such as rocks, minerals, fertilizers, waters, animal organs and other biological materials. The chief emphasis has in the past been on inorganic and particularly trace metal constituents, using the methods of emission spectrography, but the adoption also of absorption spectroscopy is leading to the investigation of organic materials and further work along these lines, including infra-red absorption spectrometry is projected.

In addition to their application to investigations initiated within the Department, the analytical services are available to other departments of the Institute, to allied Institutions, particularly those in Scotland, and to agricultural workers in the Commonwealth. The demands for such analyses are increasing and unfortunately the scope of such work must often be restricted in order to ensure that the total number of samples received lies within the compass of the Department. It is not always realized that most soil, plant and biological samples require extensive chemical pre-treatment, and that quick methods similar to those applicable to metals and alloys are not feasible with such samples if accurate results are required. Frequently the requisite care is not exercised in the taking and packaging of samples for trace element analysis. Samples are still being received in unsuitable containers such as bottles with metal lids which render the source of the metallic constituents found in any subsequent analysis subject to doubt.

It has been possible only towards the end of the year to make an appointment of an officer to take charge of the workshop for the construction of precision equipment, for the design and equipping of which the Department has been responsible. The workshop has therefore not been available during the year under review.

The facilities provided for the training of approved applicants in spectrochemical methods have been fully utilized during the year. Workers from Australia, Jamaica, Kenya, South Africa, Switzerland and Belgium have spent extended periods in the Department, whilst there have been numerous short period visitors.

Liaison with other workers engaged in spectrochemistry and its application to agriculture has been maintained through the Consultative Committee for the Development of Spectrographic Work, sponsored by the Department of Agriculture for Scotland, the Spectrographic Discussion Group in Glasgow, the Interservices D.S.I.R. Panel for emission spectrophotometry, and in other groups, and by representation at conferences such as the International Congress of Soil Science in Amsterdam and the International Microchemical Congress in Graz.

Flame Emission Methods

The flame photometer employing photomultiplier tubes and an infra-red image converter, which was described briefly in last year's report, has been in regular operation throughout the year. In soil or plant extracts routine

determinations of potassium, sodium and calcium simultaneously can be made at the rate of 40 per hour with this instrument, a short description of which has been published.[5]

The development of electronic methods for flame photometry is being continued. In particular the applications of image converter tubes and interference filters are being studied.

Flame emission employing the Lundegardh type air-acetylene flame with a solution spray introduction of the sample is employed for the analysis of soil extracts and solutions of plant materials both by flame photometric and spectographic methods. By the former, potassium, sodium and calcium results are obtained whilst the latter gives determinations also for magnesium, manganese and strontium. Analyses carried out on a large scale have included exchangeable cations in soil profiles for the Department of Pedology, and cations in extracts of plant tissues for the Department of Plant Physiology, in addition to the normal requirements of the Department of Soil Fertility for potassium determinations in acetic acid extracts of soils for advisory purposes, amounting to some 10,000 determinations per year.

Arc Emission Methods

The determination of trace elements in soil extracts, plant materials, ashes of animal organs, bacterial products and similar materials by the cathode layer arc technique, generally combined with chemical concentration by means of mixed organic reagents, has been continued. The elements sought in a comprehensive investigation include cobalt, nickel, molybdenum, zinc, tin, lead, vanadium, chromium, titanium, silver, copper, manganese, magnesium, barium, strontium and, if required, sodium and calcium, although these are better determined in the flame. Several other elements, such as, for instance, certain of the rare earths and beryllium, recently observed in samples of sisal leaves, can also be detected should they be present. The investigation of the effect of alterations in carbon electrode dimensions and other variable factors in the cathode layer arc has been completed and the results published.[7]

A description of the technique adopted for copper and certain other elements in plant materials is also being published.[18] The determination of soluble copper in soils is being studied.

The cathode layer direct current arc is the standard source employed, but for certain purposes a cooler arc is desirable, and a versatile source unit, combining direct current arc, alternating current arcs (full and half-wave) triggered by secondary spark gap or trigatron pulses, and Hilger-type spark excitation, has been constructed. Preliminary results suggest that this unit will prove of particular value for the determination of the more volatile metals such as zinc.

A brief account of the methods applied in the Department, presented to the First International Congress of Microchemistry in Graz, will be published shortly.[23]

Trace Constituents in Soils, Plant and Biological Materials

The results of the geochemical investigations of rocks and their constituent minerals, made in collaboration with Professor L. R. Wager, now

of Oxford, are awaiting publication.[29] A preliminary note dealing with chromium, vanadium, nickel, cobalt and copper in a few of the rocks has been published.[8] The interest taken in this work is shown by the number of enquiries regarding the technique, and the number of applications for training, some of which have unfortunately to be refused because of lack of accommodation. The Institute has taken part in a collaborative analysis of rocks sponsored by the Massachusetts Institute of Technology and the United States Geological Survey. The results have not yet been published but the initial reports indicate that the results of the different institutions are in reasonable agreement.

A study of the movement of trace constituents in soil profiles is in progress. Data have been obtained for the total contents in different horizons, and analyses of the amounts extracted by solvents of different *p*H-values are now being made.

The trace element contents of soils and produce have been investigated in areas where disorders of plants and animals possibly due to trace elements are found. Areas in Caithness and the south of Scotland have received particular attention in view of certain animal disorders prevalent there. Much of this work is done in collaboration with the Animal Diseases Research Association. The Moredun Institute has also submitted a considerable number of sheep liver ashes with the object of obtaining data on the range of contents to be expected in healthy animals. Animal organs and products have also been received from the Rowett Research Institute in connection with a study of the locus of cobalt deficiency in sheep. The analysis of dried grass samples for the Hannah Dairy Research Institute has continued, as has the investigation of samples of seaweed and seawater from the Scottish Seaweed Research Association. Numerous samples of soil, herbage, produce and water have been received from overseas. A brief account of the importance of trace elements in agricultural practice has been published.[6]

Absorption Spectrometry of Soil Organic Matter

The equipment available for this work includes Beckman DU and Hilger Uvispek Spectrophotometers and a Leeds-Northrup recording microphotometer. The initial investigations are being made on the lignins of peat-forming plants, as lignin may play an important part in the composition of peat. Lignin from phragmites appears to be closely related to hard-wood lignins, but that from sphagnum differs significantly from any lignin previously described. It appears unlikely that vanillyl and syringyl nuclei, the principal aromatic components of wood lignins, play the same part in sphagnum lignin.

Ethanolysis of phragmites peat yields phenolic products with considerably stronger absorption than is obtained from the original phragmites. These products may arise from the oxidation of the original phenolic lignin compounds but it is questionable whether the term *lignin* can be applied to them, or to the fraction of peat insoluble in 72 per cent. sulphuric acid.

SOIL ORGANIC MATTER

The work of this department has continued along the lines indicated in previous reports. Two papers dealing with the constitution of the polysaccharide isolated from soil [12] and with the reducing sugars liberated from sucrose during the synthesis of polysaccharides by bacteria,[13] for which the work was carried out in previous years, have been published during the year.

Chemical Investigations

Carbohydrates. Work on the soluble carbohydrate fraction isolated from soil has been continued and evidence obtained that the material is more complex than indicated in the original investigations.

Using an improved method of extraction a polysaccharide complex has been obtained containing the constituents recorded previously, but with the addition of significant amounts of rhamnose and traces of two unknown sugars distinguished by their high mobility on the paper chomatogram.

The detection of rhamnose in the soil polysaccharide is of interest in that Forsyth and Webley (*J. Gen. Microbiol.*, **3**, 395, 1949) succeeded in isolating from soils, bacteria capable of synthesizing a rhamnose containing polysaccharide from sucrose media.

That more than one polysaccharide is present in the complex has been shown by fractionation into two portions in which the ratio of the constituent sugars differs considerably.

Similar polysaccharides have been obtained from the upper layers of a soil profile, Dunottar brown earth soil.

The isolation of the soil polysaccharide on a fairly large scale is in progress and the material is being examined by the usual methods. In connection with this work an automatic fraction-cutter has been constructed after that described by Hough, Jones and Wadman (*J. Chem. Soc.*, 2511, 1949) but with improvement in detail. No suitable machine is available commercially.

Work on the carbohydrate metabolism of the fungus *Chaetomium globosum* has been carried on in collaboration with the microbiological section. A reasonably rapid and reliable method of estimating the small quantities of various sugars separated on the paper chromatogram was required and Nelson's arsenomolybdate-Somogyi colorimetric reagent (*J. Biol. Chem.*, **153**, 375, 1944) was found to be suitable. A preliminary note has been published [9] giving details of the method as applied to the determination of glucose, fructose and sucrose as found in the sucrose media at various stages of growth of the fungus. The method is considered to be better suited to routine work than the titrimetric methods used previously (Hough, Hirst and Jones, *J. Chem. Soc.*, 928, 1949).

Nitrogenous Compounds. Investigation of the amino-acid content of soils and organic soil constituents has been continued and satisfactory techniques have been developed for the preparation of both acid and alkaline hydrolysates of soils for the separation and identification of amino-acids by the method of paper chromatography.

A survey is in progress of natural and agricultural soil types with reference to the content and distribution of amino-acids in them, but no significant trends can yet be reported.

The following amino-acids have been detected in varying, though small, amounts in hydrolysates of various types of soil: aspartic acid, glutamic acid, serine, glycine, threonine, α-alanine, β-alanine, λ-amino-*n*-butyric acid, proline, hydroxyproline, valine, leucine, tryosine, phenyl-alanine, lysine. arginine and histidine.

The search continues for a thoroughly satisfactory method for the determination of individual amino-acids in the minute amounts separated by paper chromatography. From the results of approximate methods of determination, however, it seems evident that the amino-acid content of soils is not high. The total amino-acid content of the acid hydrolysate of a sample of cultivated soil amounted to 0·3 per cent. of the total organic matter in the sample.

Most of the amino-acids in soil are chemically fairly firmly bound. Only small amounts of amino-acids can be extracted with water, and there is a progressive increase in the amount extracted as the concentration of acid used in the extraction is increased. Aspartic and glutamic acids, serine, glycine and λ-alanine are most readily extracted by water and dilute acids (up to 0·5 N HCl). Basic amino-acids such as lysine, histidine and arginine require 3–6 N hydrochloric acid to bring them into solution.

The Humus Complex. Work of a preparative and exploratory nature continues on this important fraction of soil organic matter.

Microbiological Investigations. The main emphasis this year has again been on the physiology of the fungi and bacteria isolated from soils and composts. A considerable amount of work has been carried out on the microbiology of the rhizosphere. In this the general plan is to start from simpler soil-plant ecological systems (for example, sand dune) and extend the work to more complex systems; progress is being made in this initial phase of the work.

Composting. A paper entitled "Observations on the fungus flora of composts" has been accepted for publication.[17] This is the third paper on the microbiology of composting and covers the fungal succession in the process of composting.

Physiology of Micro-organisms isolated from Soils and Composts. Using *Leuconostic mesenteroides* and an enzyme preparation from this organism, strains of *B. megatherium*, *B. circulans* (= *B. krzemieniewski*) and a strain of *Rhizobium*, namely *R. radicicolum No.* 317, it was shown that only glucose and fructose could be detected, the amounts liberated varying with the organism and type of polysaccharide synthesized. Of special interest is the observation that the enzyme preparation from *L. mesenteroides* produces glucose as well as fructose, although in very small amounts. This discovery suggests the presence of a hydrolytic as well as a polymerizing enzyme in the preparation. In fact, the finding that both dextran and levan producers liberate both glucose and fructose suggests that the hydrolytic part of the enzyme systems of these organisms is of some importance in the synthesis of polysaccharides from sucrose. Previous workers in this field have tended to minimize the part played by hydrolytic enzymes. During the utilization of sucrose by fungi also (for example, *Chaetomium globosum*)

glucose and fructose are liberated in increasing amounts. Fructose appears in quantities up to some 50 per cent. greater than the amount of glucose produced. A published note [9] on this work has been referred to above; the work is being continued.

The work reported in last year's Annual Report on the fruiting of *Coprinus lagopus* in pure culture has been continued, and a short preliminary note on this has been published [10]; this phase of the study is nearing completion and the results are being prepared for publication.

Field and Glasshouse Experimental Work. In the field experiment on the effects of peat as a source of organic matter the same trend has been noted as in previous years, namely that differences in growth and yield tend to become less as time goes on. Extended studies have been carried out on the effects of organic manures (composts) and of various carbohydrates on the rate of growth of crops under glass. In detail the effects produced appear to be more complex than was at first suspected.

Forestry Investigations. The work reported last year on the effect of tree canopy on soil conditions at Culbin has been written up in a paper now accepted for publication.[24] Corresponding work at Tentsmuir has been in abeyance for most of the forest season.

Reference may be made to a short note [11] on the microbiological factor in relation to the afforestation of marine sands. Here a very striking increase was observed in the numbers of bacteria and fungi in the upper few inches of "soil" under the twenty years old forest crop as compared with the open sand. The results provide an excellent demonstration of the importance of micro-organisms in relation to the decomposition of soil organic matter and profile development.

Peat Investigations. Routine vegetational surveys of Flanders and Altnabreac mosses have been or are being carried out in connection with the Department of Agriculture for Scotland survey of the peat deposits of Scotland. Routine examination and analyses of some 750 samples from these mosses have been made during the season.

A beginning has been made on the pollen-analysis of Scottish peat deposits.

PLANT PHYSIOLOGY

The nutritional relationship of soil and plant has been investigated as in previous years, particular attention being given to the problem of antagonism between nutrient ions in soil and sand cultures. Experiments have been carried out with several potassium-magnesium ratios, under varied growing conditions, and with varying concentrations of nickel and boron to determine their effect on plants and nutrient uptake. Preliminary work has been done in establishing experiments designed to investigate the influence of water, temperature and light on nutrient assimilation and ion antagonism.

Yield data from the field experiments on the nutrition of raspberries, strawberries and gooseberries have been recorded, and progress has been made with the laboratory investigations.

Investigations on the composition of bracken have been completed, further samples having been collected and examined.

Field investigations have indicated that the plant analysis technique is effective both in establishing the nutrient status of healthy plants and in diagnosing nutritional disorders responsible for crop failures.

The chemical methods of analysis used in the plant-analysis technique have been re-examined and the chloranilic acid method for determining calcium replaced by a turbidimetric method based on the formation of calcium stearate and oleate. An account of the absorptiometric method developed for the routine determination of magnesium in plant tissues has been published.[14] This method is also proving satisfactory for soil magnesium determinations.

The experimental glasshouse has been partially fitted with artificial illumination equipment which will extend its usefulness into the winter months and enable experiments to be carried out under conditions of controlled light intensity.

Instruction in the methods used in the Department has been given to several visiting research workers, one of whom has undertaken the research on the effect on plant metabolism of the absorption of nickel from soil.

Radioactive Studies

A sub-section has been formed in the Plant Physiology Department to specialize in the use of radioactive isotopes as tracers. The primary object of the radioactive studies is the investigation of the mineral nutrition and the physiological processes of the plant, but the section will collaborate with other departments of the Institute in any research problem where the special technique of radioactive indicators is likely to be of value.

A new building has been completed for the radioactive tracer work. It comprises two laboratories for chemical work, one laboratory for the assay of the radioactive isotopes, a balance room and an office. Because of their dangerous nature a small store has been built outdoors for the supplies of radioisotopes. Tanks have also been constructed to hold the wastes from the radioactive tracer work until the activity has decayed sufficiently to make disposal safe by the normal means. The laboratories have been

equipped and the electronic apparatus necessary for routine counting of large numbers of radioactive samples has been assembled.

The rate of absorption of phosphates by oats grown in water culture is being investigated, utilizing radioactive phosphorus as a tracer element. Preliminary investigations have also been made on the possibility of the use of radioactive nickel in the study of the toxic effect of nickel on plants.

Samples of peat ash, obtained in the course of the Peat Survey of Scotland, are being tested in order to determine whether radioactive minerals occur in proximity to the peat moss.

SOIL FERTILITY—CHEMISTRY AND FIELD EXPERIMENTATION

Soil Fertility Investigations

The main aims and scope of the work on soil fertility have been summarized in previous reports, and experimental work has been continued and extended along the general lines indicated below. Reviews of the present position regarding supplies and utilization of fertilizers and lime in Scotland have been prepared with special reference to future needs and policy [25, 26, 27]. In these, the case has been argued for meeting the lime and fertilizer needs of (*a*) arable land, (*b*) permanent grassland, and (*c*) other land in that order. The over-all gap between 1948–49 consumption of fertilizers and the total estimated requirement of land under crops and grass in Scotland amounts to about 8,000 tons N, 9,000 tons P_2O_5 and 8,000 tons K_2O, and it has been stressed that the main need at present is to attempt to fill the gap in nitrogen supplies. Much more liming is also needed; even the increased liming done in recent years is barely sufficient to meet annual maintenance requirements with nothing to spare for the correction of major deficiencies.

General Manurial and Liming Experiments. Under this heading come mainly long-term and short-term field experiments with fertilizers, lime and organic manures with different crops on the various soil types distinguished in the Soil Survey. Their main function is to provide the basic characterization of the field behaviour of the soils which is essential for the systematic investigation of the various factors determining their fertility. Several new experiments of this type were started during the year and existing long-term experiments have been continued. At present, the experiments are distributed mainly over the Laurencekirk, Stonehaven, Countesswells, Insch and Foudland Soil Associations. The soil-substitution experiments at Craigiebuckler, referred to in the 1947–48 and 1948–49 reports, and the corresponding experiments in the fields from which the bulk samples of soil were taken are being continued, and it would be premature to draw conclusions from the results at this stage.

The results of the experiments with various liming materials summarized in last year's report have now been published.[15] These experiments and others on the effect of magnesian limestone are also being continued.

Fertilizer Placement. The study of methods of fertilizer application has been continued and extended, and the work to-date on this problem by J. W. S. Reith has been the subject of a thesis accepted by the University of Aberdeen for the Degree of Doctor of Philosophy. The results of the 1949 experiments have been given in a report to the Agricultural Research Council and are briefly as follows :

The cereal experiments provided further evidence that there are no outstanding differences between broadcast and combine-drill applications of sulphate of ammonia at a rate supplying 20 lb. N. per acre, and that superphosphate is more effective combine-drilled than broadcast. There were no differences between broadcast and combine-drill applications of muriate of potash at a rate supplying 45 lb. K_2O per acre, either alone or in combination with sulphate of ammonia and superphosphate. Potash

salts (40 per cent. K_2O) gave similar results to muriate of potash when drilled alone or in combination with superphosphate, but reduced the yields of both oat and barley grain when combine-drilled with sulphate of ammonia, indicating that there may be some risk in combine-drilling a mixture of these two fertilizers. The results of four experiments laid down with the National Institute of Agricultural Engineering experimental root drill showed that about 2 cwt. sulphate of ammonia, 2 cwt. superphosphate and 1 cwt. muriate of potash can be placed quite near swede seed without any harmful effects on germination and yield.

During the winter months the root drill was adapted for ridge work and experiments are meantime in hand to compare broadcast and placed additions of fertilizers on turnips and swedes grown in ridges. The ploughing down of superphosphate is also being investigated.

Statistical Work. All the field experiments conform to modern statistical designs so that the data can be analysed to determine the statistical significance of the results. Present designs, depending on the nature and aim of the individual experiments, include randomized blocks, latin squares, split-plot latin squares, factorial arrangements, and lattice squares. Meantime, the work is being carried out in the Statistics Department in the University of Aberdeen and we are indebted to Mr. Quenouille and his staff for facilities, advice and assistance. For computing work a Marchant Model 10 M calculating machine has been purchased.

Phosphate Relationship of Soils. The experimental work in progress on this subject includes :

(1) *Long-term field experiments* on the residual effects of phosphates, the interactions of phosphate with lime, the effectiveness of light annual applications compared with occasional heavy dressings, and the rate of penetration of phosphate into grassland.

(2) *Short-term field experiments* on the effectiveness of dung-superphosphate mixtures compared with the same materials applied separately, the relative effectiveness of phosphates in powder and granular forms, the comparison of autumn and spring applications, and the effect of ploughed-down phosphate with special reference to its influence on the subsequent response to broadcast phosphate.

(3) *Pot experiments* on the availability of phosphate residues of varying age, from cropped and uncropped soils, and on the response to phosphate in different soils.

(4) *Laboratory work* covering analyses of crops and investigations on soil samples from field experiment areas. The latter cover such points as : fractionation of the phosphate in different soil types, solubility of phosphate residues, nature of the fixation in different soils, effect of calcium on phosphate retention, rate of fixation of different phosphates, and assessment of the phosphate status of soils.

A preliminary assessment has been made of the relation between phosphate fixation and availability in the case of superphosphate applied to some typical acid soils. This is based on field and pot measurements of the availability of superphosphate residues and solubility data on the rate of fixation. There appear to be two stages in the fixation. In the first stage the superphosphate very rapidly loses its identity and, under the normal field moisture conditions in N.E. Scotland, it seems unlikely that it persists

as such to any appreciable extent after a few weeks. In this sense, therefore, the superphosphate can be said to be completely fixed at this stage ; and the dominant reaction is probably an adsorption. But this adsorbed phosphate is still highly available, and, in the absence of a crop and cultivations, it seems to remain so for a considerable period because field and pot results indicate that there is little or no decrease in the effectiveness of superphosphate during about three months in the moist, bare, undisturbed soils. Probably the main reason for this is that the phosphate is loosely held on the external surfaces of a limited number of particles and aggregates, and exists in minute pockets of highly-saturated soil. Further, these pockets are usually favourably positioned and to some extent (depending on the method of application and the nature and extent of the cultivations) concentrated in the root zone. The concentration of phosphate in the soil solution necessary for satisfactory growth is, of course, low. During the period of one year in the cropped soils, however, the phosphate residues undergo further changes which reduce their inherent availability by 50–75 per cent. These relatively slow secondary changes represent the second stage of the transformation and constitute the true fixation. The nature of these changes has not yet been determined, and it is not known to what extent they are influenced by the intervening crop. Comparison of the field and pot results, however, suggests that the very low residual effects of superphosphate found in the field are not entirely attributable to fixation. This is undoubtedly the main factor, but reduction in the positional availability and concentration of the residues, brought about by ploughing and cultivations, may also be of considerable importance. A paper on the subject has now been published.[16]

A paper on the effect of acid treatment of soils on phosphate availability and solubility has also been accepted for publication.[33] In this investigation it was found that extraction with dilute acetic or sulphuric acid, followed by restoration of the cation content and *p*H, increased greatly the availability of the phosphate remaining in the soils, and produced parallel increases in water-soluble phosphate. The effect is attributed to a combination of factors, such as : deactivation of fixing agents, partial hydrolysis of difficultly soluble phosphates, and redistribution of phosphate in the soils. Although the treatments used are much more drastic than any treatment encountered in practice, the results are of interest from the point of view of their implications regarding the changes to be expected in soil phosphate with increasing acidity in the field, the low availability of phosphate in acid soils, and the beneficial effects of liming.

Advisory Work

Advisory work carried out in collaboration with the North of Scotland College of Agriculture has been continued along the lines indicated in previous reports. About 8,500 soil samples and numerous samples of liming materials and industrial by-products and wastes have been examined during the year.

The grouping of advisory soil samples according to their soil associations has been continued and the data are recorded in the accompanying table. Some allowance must of course be made for the likelihood that a high proportion of the advisory samples may come from the poorer fields, but

GROUPING OF ADVISORY SOIL SAMPLES FROM ROTATION LAND IN ABERDEENSHIRE AND KINCARDINESHIRE ACCORDING TO THEIR CONTENTS OF LIME, PHOSPHATE AND POTASH

The figures under the various heads are percentages of the samples examined

Parent Material Group	*Soil Association*	*No. of Samples examined*	*Lime*			*Phosphate*			*Potash*		
			*S.	S.L.	L.	S.	S.L.	L.	S.	S.L.	L.
All Groups		12,116	3	48	49	8	45	47	14	71	15
A. Acid Igneous Boulder Clays	All Associations	2927	2	43	55	9	55	36	8	70	22
	Countesswells	2425	2	45	53	10	59	31	7	69	24
	Strichen	443	2	35	63	2	35	63	14	76	10
B. Intermediate and Basic Igneous Boulder Clays	All Associations	3665	2	55	43	8	51	41	14	73	13
	Insch	790	2	66	32	15	54	31	11	67	22
	Tarves	2388	3	52	45	7	51	42	14	75	11
	Maud-Arnage	364	1	56	43	4	44	52	17	77	6
C. Old Red Sandstone Boulder Clay	All Associations	954	9	58	33	18	46	36	34	59	7
	Cruden	583	5	66	29	7	45	48	37	57	6
	Stonehaven	260	16	45	39	36	47	17	30	63	7
	Laurencekirk	111	14	48	38	36	50	14	32	58	10
D. Slate Boulder Clay	All Associations	2590	2	42	56	3	27	70	18	72	10
	Foudland	2510	2	42	56	3	27	70	18	73	9
E. Water Sorted Sediments	All Associations	1385	4	49	47	14	51	35	9	69	22
	Corby	1018	2	47	51	9	57	34	7	70	23
	Kemnay	172	5	61	34	33	20	47	14	67	19
	Memsie	140	10	52	38	33	36	31	22	64	14
F. Old Red Sandstone Boulder Clays—Medium and Light Textured	All Associations	431	1	41	58	2	29	69	9	73	18
	Haddo	428	1	41	58	2	29	69	9	73	18
G. Siliceous Deposits	All Associations	162	1	23	76	3	26	71	3	89	8
	Skelmuir	156	1	22	77	3	25	72	2	90	8

*S.—satisfactory S.L.—slightly low L.—low

even so the table shows that deficiencies of lime and phosphate are still widespread and that the large majority of soils are slightly low in potash. There is a higher proportion of soils with a satisfactory lime status in the Stonehaven, Laurencekirk and Memsie Associations than in the others. Phosphate deficiency appears to be more pronounced on the Countesswells, Strichen, Tarves, Maud-Arnage, Cruden, Foudland, Corby, Haddo and Skelmuir Associations than on Stonehaven, Laurencekirk, Kemnay and Memsie, with the Insch soils intermediate between these two groups. The soils of the Cruden, Stonehaven and Laurencekirk Associations are higher in potash than the others, while the Countesswells and Corby Associations appear to be the lowest in potash.

COLLABORATIVE WORK

The Animal Diseases Research Association

Collaboration has been continued on problems of the interrelationships of soil and herbage upon animal health. Spectrographic determinations have been made on samples of soils, plant materials and animal organs in connection with joint investigations on various animal diseases.

The Rowett Research Institute

Analyses of soils, pasture herbages, animal organs and other related materials, such as constituents of animal diets, have been examined for trace constituents.

The Hannah Dairy Research Institute

Problems arising in the manuring of grass have been studied and the necessary experimental work undertaken. The trace elements present in samples of dried grass have been determined.

The Scottish Colleges of Agriculture

The Macaulay Institute and the Colleges of Agriculture have collaborated in the application of experimental findings to practical agriculture and in the development of spectrographic work.

Forestry Commission (Research Branch)

Co-operative work with the Research Branch of the Forestry Commission on various aspects of the nutrition of forest tree seedlings has been continued.

Scottish Raspberry Investigation and Strawberry Disease Investigation

Experiments on strawberries, raspberries and gooseberries to correlate soil treatments with vegetative development, fruit yield, tissue composition and disease resistance, have been established in collaboration with the workers on Strawberry Disease Investigations (Department of Agriculture for Scotland) and on Small Fruit Diseases in Scotland (East Malling Research Station).

The Department of Agriculture for Scotland

Samples of peat obtained during the Survey of Peat Mosses in Scotland have been examined, and reports furnished in connection with the investigations of the Scottish Peat Committee.

Consultative Committee on the Development of Spectrographic Work

The Consultative Committee—constituted by the Agricultural Research Council and the Department of Agriculture for Scotland, with the Director of the Macaulay Institute as Convener—represents all the Research Institutes in Scotland, the Scottish Colleges of Agriculture and the Research Division of the Ministry of Agriculture for Northern Ireland. The parent committee reviews the various aspects of pure and applied spectrochemistry, while a technical sub-committee representative of the active workers in this field of investigation has been appointed to deal with detail.

PUBLICATIONS

(A) *Published during the year—*

1. " The Colorimetric Determination of Aluminium in Silicate Materials." By G. Robertson. (*J. Sci. Food & Agric.*, **1**, 59-63, 1950.)

Two methods are outlined for the colorimetric determination of aluminium in the presence of iron. They differ only in the reagent used to inhibit the iron colour, the final *p*H of the lake and the amount of iron that can be present. Thioglycollic acid and hydroxylamine hydrochloride are used to prevent the formation of the colour due to iron, thioglycollic acid being the more effective. As the solubility of the lake increases with increasing alkalinity the *p*H in the alkaline method is carefully controlled at $7{\cdot}5 \pm 0{\cdot}2$ by means of ammonium borate solution. Other factors influencing colour development are discussed. The limits of tolerance of elements that interfere in colour production are given, and the application of the methods used to the determination of aluminium in soil extracts, soils and clays is described.

2. " Differential Thermal Analysis of Clay Materials." By R. C. Mackenzie. (*Trans. 4th Int. Cong. Soil Sci., Amsterdam*, II, 55-59, 1950.)

The differential thermal analysis method for the mineralogical examination of clays is briefly reviewed, outlining the history and the general advantages and limitations of the method. The work of the Differential Thermal Analysis Sub-Committee of the Comité International pour l'Etude des Argiles is discussed, and the need for further standardization stressed.

3. " Trioctahedral Minerals in the Soil-clays of North-east Scotland." By G. F. Walker. (*Min. Mag.*, **29**, 72-84, 1950.)

A clay mineral similar to biotite is formed in the parent till of north-east soils under the action of weathering in the soil profile. This mineral breaks down in most cases to vermiculite. If the parent material of the soil, however, is derived from basic or ultra basic rocks, and if leaching is not active, the product of weathering of the " clay biotite " is montmorillonite. This series of trioctahedral minerals constitutes the major portion of the crystalline component of the soil clays of the area.

4. " Hydration of Vermiculite Saturated with Various Cations." By G. F. Walker and A. A. Milne. (*Trans. 4th Int. Cong. Soil. Sci., Amsterdam*, II, 62-67, 1950.)

The organization of the water layers in vermiculite is largely dependent on the type of exchangeable cation present. In general, the layers of water molecules exist interleaved with the mica-like alumino-silicate layers. Humidity changes also affect the interlamellar water but not to the same extent as in montmorillonite.

5. " Flame Photometry." By R. L. Mitchell. (*Spectrochim. Acta*, **4**, 62-63, 1950.)

Describes briefly a flame photometer recently constructed at the Macaulay Institute for the determination of sodium, calcium and potassium.

6. " The Importance of Trace Elements in Agriculture." By R. L. Mitchell. (*Guernsey Breeders Journal*, **4**, No. 1 (n.s.), 43-44, 48, 1950.)

A short popular account of the effects of certain trace elements on the growth of plants and animals.

7. " The Effect of Electrode Dimensions on Spectral Line Intensity in the Carbon Arc." By R. O. Scott. (*Spectrochim. Acta*, **4**, 73-84, 1950.)

Results for the spectrographic determination of trace elements in an alumina matrix, obtained by carbon arc excitation, are given for the variations in both trace element and internal standard line intensities, and in the intensity ratios caused by relatively small variations of the cathode dimensions from the normal size of 2·8 mm. outside diameter and a boring 8 mm. deep and of 0·8 mm. diameter. The elements considered are Co, Zr, Zn, Ti, V, Mo, Sn and Pb, with Fe as the internal standard, and also Zn with Cd, and Pb with Bi as internal standards. It is shown that variation of the electrode dimensions can alter not only the line intensities but also the intensity ratios. Accurate determinations of trace elements will only be obtained if the electrode dimensions and especially that of the electrode boring depth are kept constant.

8. " The Distribution of Cr, V, Ni, Co and Cu during the Fractional Crystallization of a Basic Magma." By L. R. Wager (University of Durham) and R. L. Mitchell. (*Rept. 18th Sess. Int. Geol. Cong., Great Britain*, 1948, II, 140-150, 1950.)

The amounts of certain trace elements have been determined by optical spectographic methods in minerals separated from the Skaergaard intrusion. The minerals were formed successively as a primary precipitate from a convecting mass of basic magma. The amounts of trace elements in the original magma have been obtained from analysis of the chilled marginal gabbro and sufficient later rocks have been analysed to allow estimates to be made of the trace element composition of successive residual magmas. By comparing the amounts of the trace elements in the crystal phases and the amounts in the corresponding magma an appropriate distribution ratio between liquid and crystal phases has been obtained.

In the case of Cr, Ni, and Co the amounts precipitated in chromite and in early pyroxenes and olivines are greater than the amounts in the magma. Thus the amounts of these elements in successive residual magmas decline—Cr and Ni rapidly, and Co slowly. On the other hand the amounts of V and Cu precipitated in the early minerals are less than the amounts of these elements in the original magma, and the amounts of these elements increase for a time in successive residual magmas and then also decline rapidly. In the later rocks Cu enters with about equal case into the feldspar, pyroxene, olivine, and iron ores ; so far no convincing crystal chemical explanation of this has been found.

The trace element composition of the iron ores has been investigated ; early primary precipitates of iron ores have a trace element composition comparable with average values for titaniferous iron ores as found by Landergren, while later iron ores have a composition comparable with Landergren's average values for the apatite iron ores.

9. " Use of the Arsenomolybdate-Somogyi Reagent in Quantitative Paper Chromatography and its Application to the Study of Sucrose Utilization by a Fungus." By. R. B. Duff and D. J. Eastwood. (*Nature*, **165,** 848, 1950.)

The fungus *Chaetomium globosum* was cultured on a medium containing inorganic salts and sucrose. Sucrose, glucose and fructose were estimated in samples removed from time to time. The disappearance of sucrose was found to be accompanied by the appearance of increasing amounts of glucose and fructose, the latter in amounts some 50 per cent. greater than the former. This is of interest with regard to the carbohydrate metabolism of the fungus. The sugars were separated on a paper chromatogram and estimated by the arsenomolybdate-Somogyi reagent of Nelson (*J. Biol. Chem.*, **153,** 375, 1944). This method is considered to be as accurate as the titrimetric procedure and is considerably more convenient for routine use.

10. " The Fruiting of *Coprinus lagopus* in Pure Culture." By D. J. Eastwood. (*Nature*, **165,** 324, 1950.)

An isolate of *Coprinus lagopus* from a compost of barley straw was observed to produce sporophores on slants of cellulose agar which may supply growth substances. In liquid media growth was poor on cellulose, but fruit was produced on straw, or on cellulose with straw extract. It is considered that the extract provides the necessary growth substance. Investigations on this point are being continued.

11. " Microbiological Factor in the Culbin Sands Afforestation Scheme." By D. J. Eastwood, G. K. Fraser and D. M. Webley. (*Nature*, **165,** 980, 1950.)

Attention is drawn to the importance of the microbiological factor in the afforestation schemes carried out in such areas as the Culbin Sands. Investigations in this area revealed an enormous increase in microbial numbers due to the planting and growth of trees.

12. " Studies on the more Soluble Complexes of Soil Organic Matter. 2. The Composition of the Soluble Polysaccharide Fraction." By W. G. C. Forsyth. (*Biochem. J.*, 141–146, 1950.)

Ash-free polysaccharide complexes have been obtained from widely different pedological, vegetational and climatic types of soil.

All the polysaccharide preparations have very similar properties. They all contain the same sugars, galactose, glucose, mannose, arabinose, xylose, and

glucuronic acid, although the proportions, especially of the pentoses, vary to some extent in the different samples. They all contain small amounts of nitrogen and ribose, presumably as ribonucleic acid, suggestive of a microbial origin.

From a humus-rich agricultural soil a polysaccharide complex has been isolated in relatively large quantity and the constituent sugars determined both by paper chromatography and by specific precipitants. The results agree well with a repeating unit containing galactose (2 mol.) ; glucose (2 mol.) ; mannose (2 mol.) ; arabinose (1 mol.) ; xylose (3 mol.) ; 2 mol. of an aldobionic acid consisting of glucose and glucuronic acid.

Mild hydrolysis of the polysaccharide gives an arabinose-free polysaccharide containing galactose (2 mol.) ; glucose (2 mol.) ; mannose (2 mol.) ; xylose (3 mol.) ; the aldobionic fraction as before.

The oxidation of both the original and the degraded polysaccharides with potassium metaperiodate has been studied.

13. "The Reducing Sugars Liberated during the Bacterial Synthesis of Polysaccharides from Sucrose." By W. G. C. Forsyth and D. M. Webley. (*J. Gen. Microbiol.*, **4**, 87–91, 1950.)

Paper chromatography was used for studying qualitatively and quantitatively the reducing sugars liberated from sucrose during the synthesis of polysaccharides by certain bacteria. Glucose and fructose were the only sugars detected, varying in amount with the bacteria and with the type of polysaccharide synthesized. The results suggest that both polymerizing and hydrolytic enzymes were present.

14. "An Absorptiometric Method for the Determination of Magnesium." By J. G. Hunter. (*Analyst*, **75**, 91–99, 1950.)

The method is based on the formation of coloured complexes of magnesium hydroxide with certain dyes of the Thiazol Yellow class. A constant quantity of the dye, more than is necessary for the formation of the complex, is taken, and the quantity of magnesium present is ascertained from the excess of unused dye, which is extracted from the reaction mixture by means of *n*-butyl alcohol and read as a solution in that solvent, on a Spekker absorptiometer. A calibration curve relates quantities of magnesium directly with drum readings of the unused dye solution.

The method was developed for the determination of magnesium in plant tissues and soil extracts, and can be adapted also to trichloroacetic acid filtrates of milk and blood serum. It determines from 0·02 to 0·20 mg. of magnesium with an accuracy satisfactory for this type of determination. Permissible concentration limits of certain interfering ions and means for controlling their interference are given where necessary. Data on the concentration of magnesium, iron, calcium, manganese and aluminium in extracts of a number of soils, prepared with (*a*) N ammonium acetate solution, (*b*) Morgan's solution, and (*c*) 0·5 N acetic acid, are tabulated.

15. "The Effectiveness of Various Liming Materials." By J. W. S. Reith and E. G. Williams. (*Emp. J. Expt. Agric.*, **17**, 265–276, 1949.)

Effectiveness of ground burnt lime, ground burnt magnesian lime, ground magnesian limestone, dried paper-works lime, calcareous shell sand, blast furnace slag and various sizes of ground limestone was tested in field experiments carried out over four years. All forms produced large crop responses and marked increases in soil *p*H and acetic soluble CaO. Except where yield response was very high, percentage CaO in crops was also increased, and there were greatly increased removals of other nutrients, especially phosphate. Compared with the general effect of lime, differences between forms were unimportant, but blast-furnace slag was slightly inferior to the others and shell sand appreciably slower-acting in the first year. The 20–40 mesh limestone was highly effective throughout and results provide no support for fine grinding. Burnt magnesian lime markedly increased the magnesium-content of the crops but low-grade magnesian limestone did not. Both were equally as effective as other forms in correcting acidity and increasing yields. Results support normal practice of liming ordinary mineral soils to a *p*H of 6·0–6·2 corresponding to an acetic-soluble CaO of about 0·25 per cent. for a common rotation of oats, roots, hay, and pasture. They also illustrate clearly benefits of liming and need for adequate supplementary manuring.

16. " Phosphate Fixation and Availability." By E. G. Williams. (*J. Sci. Food & Agric.*, **1**, 244–248, 1950.)

Factors that may affect the relation of fixation to availability are briefly reviewed. A preliminary assessment of this relationship for superphosphate added to some typical acid soils in north-east Scotland is made from solubility data on the rate of fixation, the effect of time of application, and the residual value of phosphate dressings as measured by field and pot experiments.

(B) *Submitted for publication—*

17. " Observations on the Fungus Flora of Composts." By D. J. Eastwood. (To appear in *Trans. Brit. Mycol. Soc.*)
18. " The Spectrographic Analysis of Plant Ash in the Carbon Arc." By V. C. Farmer. (*Spectrochim. Acta.* **4**, 224–228, 1950.)
19. " The Macaulay Institute for Soil Research." By D. N. McArthur. (To appear in *British Agricultural Bulletin*, published by the British Council.)
20. " Recent Advances in Soil Research at the Macaulay Institute." By D. N. McArthur. (To appear in *Proc. Roy. Philos. Soc. Glasgow.*)
21. " Some Notes on the Hydration of Montmorillonite." By R. C. Mackenzie. (*Clay Min. Bull., No.* 4, 115–119, 1950.)
22. " The Trace Constituents of the Soil." By R. L. Mitchell. (To appear in *Trans. XIth Int. Cong. Pure and Appl. Chem.*)
23. " The Spectrographic Determination of Trace Elements in Rocks, Minerals and Soils." By R. L. Mitchell. (To appear in *Mikrochemie.*)
24. " Some Aspects of Afforestation in the Culbin Sands." By J. D. Ovington. (To appear in *J. Ecol.*)
25. " Fertilizers and Crop Production." By A. B. Stewart. (To be published as *Department of Agriculture for Scotland Advisory Series Leaflet.*)
26. " Fertilizers and Lime in Scotland. 1. Fertilizers and Crop Production." By. A. B. Stewart. (*Scot. Agric.*, **30**, 107-111, 1950.)
27. " Fertilizers and Lime in Scotland. 2. Lime and Soil Fertility." By A. B. Stewart. (To appear in *Scot. Agric.*)
28. " Placement of Mineral Nutrients in Soils." By A. B. Stewart. (To appear in *Trans. XIth Int. Cong. Pure and Appl. Chem.*)
29. " The Distribution of Trace Elements in a Strongly Differentiated Basic Magma—a Further Study of the Skaergaard Intrusion, East Greenland." By L. R. Wager (University of Oxford) and R. L. Mitchell. (To appear in *Geochim. Acta.*)
30. " Vermiculite-Organic Complexes." By G. F. Walker. (*Nature*, **166**, 695-696, 1950.)
31. " Vermiculites and Some Related Mixed-layer Minerals." By G. F. Walker. (*Monograph on Clay Minerals*, Chap. 7. To be published by the Oxford University Press, Spring, 1951.)
32. " Unidimensional Fourier Synthesis of Vermiculite." By G. F. Walker and A. A. Milne. (To appear in *Clay Minerals Bulletin No.* 5.)
33. " Effect of Acid Treatment of Soils on Phosphate Availability and Solubility." By E. G. Williams. (To appear in *J. Soil Sci.*)

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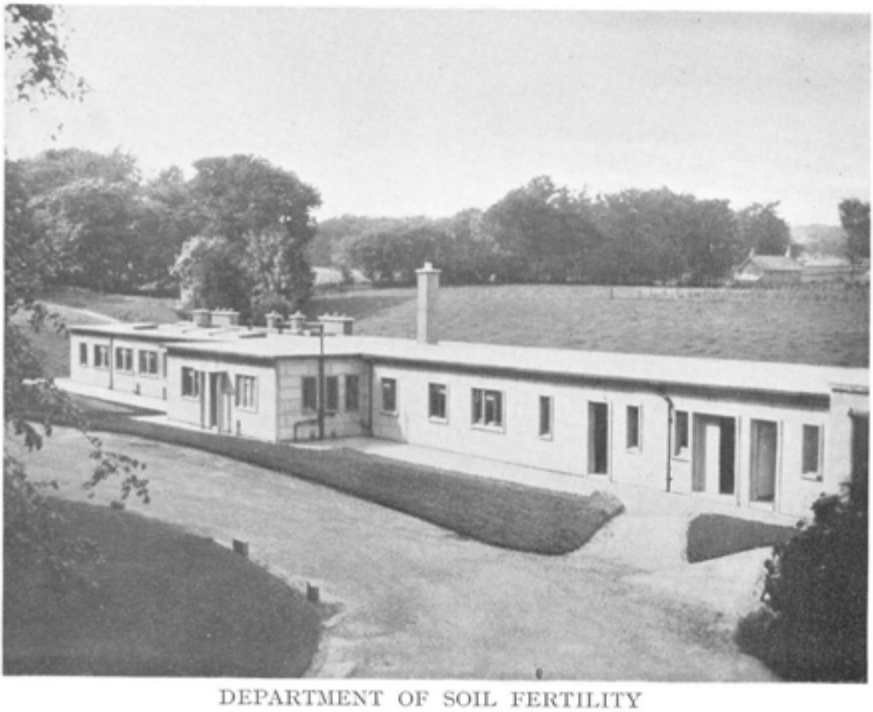

DEPARTMENT OF SOIL FERTILITY

EXPERIMENTAL GREENHOUSE