THE MACAULAY INSTITUTE FOR SOIL RESEARCH

FOUNDED 1930

ANNUAL REPORT 1954-1955

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.

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

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CRAIGIEBUCKLER, ABERDEEN

(Founded 1930)

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Radioactivity . . .	A. H. KNIGHT, B.Sc., A.R.I.C.

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POST-GRADUATE RESEARCH WORKERS

F. C. ARCHER (Department of Agricultural Chemistry, University College of North Wales, Bangor).

R. du T. BURGER (Stellenbosch-Elsenburg College of Agriculture, Stellenbosch, South Africa).

J. D. COLWELL (New South Wales Department of Agriculture, Sydney, Australia).

B. G. DAVEY (Soil Survey Unit, New South Wales Department of Agriculture, Sydney, Australia).

D. J. GREENLAND (Agricultural Research Council Training Grant).

F. GÜLCÜR (Orman Fakültesi, Istanbul Üniversitesi, Büyükdere, Istanbul, Turkey).

R. G. HUTTON (University College of the Gold Coast, Achimota, Gold Coast).

R. S. KOESOEMO (Balai Penjelidikan Kimia, Bogor, Indonesia).

C. G. LAMM (Statens Planteavls Laboratorium, Lyngby, Denmark).

S. LARSEN (Blangstedgaard Experimental Station, Denmark).

I. R. MACDONALD (Agricultural Research Council Training Grant).

A. PINKERTON (Colonial Office, London).

M. H. POTTERAT (Service fédèral de l'hygiene publique, Berne, Switzerland).

B. RAMAMOORTHY (Indian Agricultural Research Institute, New Delhi, India).

A. D. ROVIRA (C.S.I.R.O. Division of Soils, Waite Institute, Adelaide, Australia).

C. H. WILLIAMS (C.S.I.R.O. Division of Plant Industry, Canberra, Australia).

*Appointed 1954-5 †Deceased 1954. ‡Seconded from Colonial Pool of Soil Surveyors.

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INTRODUCTION

The work of the Institute is designed to further the study of the soil in all its aspects with a view to the maintenance and improvement of soil fertility. This report briefly reviews the research and experimental work carried out during the year and gives some indication of the progress being made on the various problems under investigation. Many special investigations are undertaken in collaboration with other research organizations, the Colleges of Agriculture in Scotland, the Forestry Commission, and the Department of Agriculture for Scotland, and facilities are offered for training in the methods of soil research and for post-graduate study.

The generous financial support given by the Department of Agriculture for Scotland, the Agricultural Research Council, and the Forestry Commission is of vital importance in the development and extension of the research programme; grateful acknowledgement is again made to these bodies and to other benefactors.

STAFF

The Council of the Institute records with deep regret the sudden death of Dr G. K. Fraser on 22nd December, 1954.

Dr Fraser—a distinguished graduate of the University of Aberdeen—was appointed to the staff as Head of the Department of Soil Organic Matter in 1937 after a period, following service in World War I, as lecturer in Forestry in the University of Aberdeen. His wide counsel and catholic interests in all matters pertaining to soil research, particularly on organic soils, were greatly appreciated.

The following appointments have been made:

Pedology

C. J. Bown, B.Sc. (Soil Survey Section).
W. G. Jardine, M.Sc. (Soil Survey Section).

Forest Soils

W. O. Binns, M.A. (Cantab.), B.Sc. (For.).

Statistics

Mrs M. J. McDonald, B.Sc.

The Director continued to serve on the Scottish Peat Committee (of which Sir Edward Appleton, K.B.E., K.C.B., F.R.S., is Chairman) and to act as Chairman of the Scottish Moss Survey Group. Dr V. C. Farmer attended the Conference on Molecular Spectroscopy organized by the Institute of Petroleum Hydrocarbon Research Group in London. At the January meeting of the Society of Experimental Biology in London Dr P. C. de Kock

presented a paper on iron nutrition and, in collaboration with Mr I. R. Macdonald, a paper on phosphate balance. He also contributed a paper on iron nutrition to the Conference of the International Congress on Biochemistry, held in Brussels. Mr J. R. Devine was present at the Fifth National Power Farming Conference in Harrogate, and Dr E. G. Williams and Mr A. H. Knight attended the Easter meeting of the British Society of Soil Science, to which Dr Williams contributed two papers written in collaboration with Dr W. M. H. Saunders. Dr R. L. Mitchell went by invitation to the Vatican City to take part in a Study Week on Trace Elements organized by the Pontifical Academy of Sciences. Mr S. E. Durno and Mr R. A. Robertson attended the July meeting of the British Ecological Society in Aberdeen and Mr Robertson read papers at this meeting and at the September meeting in London. On the invitation of the International Potash Institute, Berne, Dr R. C. Mackenzie presented a paper at the Rome Conference on The Potassium in the Soil. Several members of staff were present at the meeting of the British Society of Soil Science held in Aberdeen; Dr Glentworth addressed the meeting and made arrangements for the party to see something of the soils of Aberdeenshire.

HIGHER DEGREES

The following theses were accepted by

(1) University of Aberdeen (Degree of Ph.D.).

(*a*) *A study of the potassium relationships in selected South African and Scottish soils.* By R. du T. Burger.

(*b*) *An investigation of factors affecting phosphate solubility and retention in some Krasnozem soils of Eastern Australia.* By J. D. Colwell.

(*c*) *Physiological studies of fungi concerned in the decomposition of lignin and related substances.* By Moira E. K. Henderson.

(*d*) *The starvation metabolism of sugar beet tissue (Beta vulgaris var. Saccharifera) with particular reference to phosphate absorption.* By I. R. MacDonald. (A.R.C. Scholar).

(2) University of Oxford (Degree of D.Phil.).

The interaction of montmorillonite with some organic compounds. By D. J. Greenland. (A.R.C. Scholarship).

(3) University of Edinburgh (Degree of Ph.D.).

Nickel toxicity in plants: the physiological relationship existing between plants and the serpentine soils on which they grow. By W. M. Crooke.

PUBLICATIONS

Thirty-five papers were issued during the year and are summarized in this report. Reprints can be obtained from the Librarian.

VISITORS

The widespread interest in the work of the Institute is reflected in the increasing number of research workers from both this country and overseas who make the journey north to visit the laboratories. Overseas visitors this year have included representatives from research stations in Argentina, Australia, Austria, Canada, Denmark, Egypt, Gold Coast, India, Israel, Italy, Japan, Malaya, New Zealand, Norway, South Africa, Southern Rhodesia, Sweden, Switzerland, Trinidad, U.S.A., and Yugoslavia. Amongst the many organized parties welcomed to the Institute during the year were members of the Biochemical and Nutrition Societies, The British Society of Soil Science Conference, and the National Agricultural Advisory Service Conference of Provincial Soil Chemists.

POST-GRADUATE RESEARCH WORKERS

The following research workers were associated in the work of the Institute during the year —

Department of Pedology:

F. Gülcür (Orman Fakultesi, Istanbul Üniversitesi, Büyükdere, Istanbul, Turkey).

Soil Survey—

A. Pinkerton (Colonial Office, London).

Soil Geology and Mineralogy—

D. J. Greenland (Agricultural Research Council Scholarship).

Department of Plant Physiology:

I. R. MacDonald (Agricultural Research Council Training Grant).

Department of Soil Fertility:

R. du T. Burger (Stellenbosch-Elsenburg College of Agriculture, Stellenbosch, South Africa).

J. D. Colwell (New South Wales Department of Agriculture, Sydney, Australia).

C. G. Lamm (Statens Planteavls Laboratorium, Lyngby, Denmark).

S. Larsen (Blangstedgaard Experimental Station, Denmark).

C. H. Williams (C.S.I.R.O. Division of Plant Industry, Canberra, Australia).

Department of Soil Organic Matter:

Chemistry—

R. G. Hutton (University College of the Gold Coast, Achimota, Gold Coast).

Microbiology—

A. D. Rovira (C.S.I.R.O. Division of Soils, Waite Institute, Adelaide, Australia).

Department of Spectrochemistry:

F. C. Archer (Department of Agricultural Chemistry, University College of North Wales, Bangor).
B. G. Davey (Soil Survey Unit, New South Wales Department of Agriculture, Sydney, Australia).
R. S. Koesoemo (Balai Penjelidikan Kimia, Bogor, Indonesia).
M. H. Potterat (Service fédèral de l'hygiene publique, Berne, Switzerland).
B. Ramamoorthy (Indian Agricultural Research Institute, New Delhi, India).

Other workers who spent short periods studying the methods in use in the laboratories were—

I. Carmichael (Mineral Search of Africa (Private) Ltd., Northern Rhodesia).
K. Ellitsgaard-Rasmussen (Mineralogisk-geologisk Institut, Copenhagen, Denmark).
S. M. Feillafe (Sugar Industry Research Institute, Mauritius).
T. Hay (Ministry of Food Research Station, Torry, Aberdeen).
J. A. Pask (Division of Mineral Technology, University of California, Berkeley, Calif., U.S.A.).
P. Ryan (Johnstown Castle Research Station, Wexford, Ireland).
Miss J. Tivy (Department of Geography, University of Edinburgh).
B. Vovk (University of Ljubljana, Yugoslavia).
R. H. Wallace (Macdonald College, Quebec, Canada).
S. G. Willimott (Ministry of Agriculture Research Division, Yambio Experimental Farm, Sudan).
H. R. Wynne-Edwards (University of Aberdeen).

REPRESENTATION ON COMMITTEES

The Institute was represented on the following committees, appointed by—

(1) *Secretary of State for Scotland*:

(*a*) The Scottish Standing Committee for the Calculation of Residual Values of Fertilizers and Feeding Stuffs.
(*b*) The Scottish Peat Committee and the Sub-Committee on the Survey of Peat Deposits in Scotland.
(*c*) The Standing Advisory Committee, Fertilizers and Feeding Stuffs Act, 1926.

(2) *Department of Agriculture for Scotland*:

(*a*) Scottish Agricultural Improvement Council.
(*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) *Agricultural Research Council*:

(*a*) Conference on Fertilizers.

(*b*) Conference on Mineral Deficiencies in Agricultural and Horticultural Crops.

(*c*) Group for Mineral Deficiencies and Excesses in Animals.

(*d*) Land Drainage Conference.

(*e*) Soil Survey Research Board.

(4) *Forestry Commission*:

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

(5) *Colonial Office*:

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

30th September, 1955.

PEDOLOGY

SOIL SURVEY (SCOTLAND)

The soil surveys of Roxburghshire (Sheet 17: Jedburgh and Sheet 18: Morebattle) and North Ayrshire (Sheet 22: Kilmarnock) have been completed. The Soil Survey memoir for Roxburghshire will be published shortly and the maps for North Ayrshire are in process of production. Sheets 76 (Inverurie), 87 (Peterhead) and 57 (Brechin) have been revised and checked. The survey of Sheet 95 (Elgin) has been completed. Field work has continued in Berwickshire (Sheets 25 and 26) and Central Ayrshire (Sheet 14), and surveying has commenced near Stirling (Sheet 39).

Some 300 square miles of new territory have been surveyed on a scale of 2·5 inches to 1 mile on the Berwickshire, Ayrshire, Stirling and Brechin sheets, whilst an area of about 300 square miles on the Inverurie and Peterhead sheets has been mapped and checked in the requisite detail for the 2·5 inches to 1 mile field maps.

This year arrangements were made for the ecologist member of the Survey staff to study the vegetation of the sheets under survey, with a view to compiling for the Soil Survey memoirs an account of the vegetation in relation to the soil series.

The joint field meeting of the Soil Survey of England and Wales and the Soil Survey of Scotland was held in Cambridge in March and the soils of Sheet 188 (Cambridge) were inspected. This meeting provided an opportunity for discussions concerning the revised version of the handbook of survey methods and definitions which has been compiled by a committee representative of both Survey teams.

Arrangements were made in co-operation with the Department of Soil Science of the University of Aberdeen for the meeting of the British Society of Soil Science held in Aberdeen in September.

NORTH-EAST SCOTLAND

Aberdeenshire (*Soil Survey Sheets* 76 *and* 87)

The revision of Sheet 76 has now been completed. The soils of the area have previously been reported on.

The main part of the area surveyed this year covers the northern part of the sheet; it stretches westwards from the Rhynie-Kildrummy Old Red Sandstone outlier, extending through the Correen Hills and Bennachie to Inverurie and Kintore near the eastern edge of the sheet. The Hills of Cairn William, Tillyfourie and Corrennie Forest were examined, together with the lower ground to the east of them. Approximately 200 square miles of the previous reconnaissance survey were implemented with detail requisite for the survey on a scale of mapping of 2·5 inches to 1 mile.

The Countesswells Association on granite and granitic gneiss till was the most extensive, with representative areas of the Tarves, Foudland, Insch, Boyndie, Corby, and Cuminestown Associations less extensive. The Boyndie Association on fluvio-glacial sand was separated this year from the previously mapped Corby Association.

In the Rhynie-Kildrummy basin, underlain by rocks of Old Red Sandstone age, two associations have now been distinguished —(i) soils developed on heavy textured (clay loam) till, derived from sandstone and conglomerate, with an admixture of slate and schist fragments, and (ii) a light textured association of soils developed on sandy loam till, derived from arenaceous Old Red Sandstone. The former (previously called the Mossat Association) has been correlated with the Ordley Association, and the latter with the Cuminestown Association.

Passing eastward, the Correen Hills (1698 ft) lying to the north-west of Alford form a smooth range running east to west. Composed mainly of andalusite and argillaceous schist, with a till covering, they give rise to predominantly freely drained soils of the Foudland Association.

The Correen range is continued and passes into the granite mass of Bennachie with its several sharp craggy peaks—the Mither Tap and the highest point, Oxen Craig (1733 ft). Rock outcrops and skeletal soils occur on and around the summit areas and there are several areas of hill peat in the troughs between. The upper slopes support freely drained podzol soils under a dry heath vegetation of the Countesswells Association. Extensive areas of poorly drained soils occur over the lower slopes, particularly on the northern side, and certain areas have been or are being prepared for planting by the Forestry Commission. The Countesswells Association also extends southwards across the River Don over the granite masses of Cairn William (1468 ft) and Tillyfourie Hill (1180 ft) to the Corrennie Forest. This latter hill mass is composed largely of granitic gneiss and the Countesswells Association is found to occur over the lower eastern and southern slopes. The upper part of the hill is capped by a schist till and has been mapped as the Foudland Association. On both the Foudland and the Countesswells Associations freely drained podzol soils predominate; local areas of brown podzolic soils also occur. Poorly drained soils are associated with depressed areas adjacent to the drainage channels and there are several inextensive areas of hill peat.

Areas of till with a mixed stone content, giving rise to soils of the Tarves Association, flank the lower western slopes of Cairn William, the Tillyfourie and the Corrennie Forest Hills. A belt of this soil association has been mapped passing through the saddle between Cairn William and Tillyfourie Hill.

Mounds of roughly stratified sand and gravel—kames—are extensive about Kemnay and Kintore and are representative of the Corby Association. The fluvio- glacial terrace of the Don, which occurs between the 350 and 200 ft contour is essentially of gravel with freely drained soils, markedly affected by drought this season. Areas of the Boyndie Association on fluvio-glacial sand have been separated from the Corby Association on gravel.

Eastwards from the eastern foot slopes of Bennachie and extending as far south and east as Inverurie, till from the Insch mass has been transported for a distance of two miles to overlie the gneiss of the Oldmeldrum series of the Highland schists. The Insch Association therefore occupies the north-east corner of the map.

In the main the soils are, or have been derived from, podzols under naturally free drainage conditions. The texture most common to the soils of this region is sandy loam of varying degrees of coarseness and stoniness.

Mixed farming with stock fattening is practised on the more favourable lower ground farms, and stock rearing on the high lying holdings. The extensive hilly areas are given over to sheep farming and forestry.

The following soil associations are found in these areas and are described in the appendix. Descriptions of the soil series of the associations are given more fully in the Soil Survey (Scotland) memoir *The soils of the country around Banff, Huntly and Turiff* (H.M.S.O., 1954. 17/6).

1. Countesswells — *see* Annual Reports 1943-44 and 1950-51.
2. Tarves — *see* Annual Reports 1945-46 and 1949-50.
3. Foudland — *see* Annual Reports 1940-41 and 1945-46.
4. Insch — *see* Annual Reports 1939-40 and 1945-46.
5. Boyndie — *see* Annual Report 1942-43.
6. Corby — *see* Annual Reports 1944-45 and 1945-46.
7. Cuminestown — *see* Annual Report 1944-45.
8. Ordley — *see* Annual Reports 1941-42 and 1953-54.

The revision of Sheet 87 (Peterhead) was conducted mainly on the coastal area from Collieston northwards to Crimond, extending inland for a distance of twelve to fourteen miles. Over 100 square miles of the region were re-examined.

An assortment of deposits foreign to the area overlie the solid rock, and it is everywhere apparent that these are far travelled.

Of the associations distinguished and previously reported on, the Cruden on red clay deposits is the most extensive. It is proposed to separate it into three associations. Originating from rocks of Old Red Sandstone in the Howe of the Mearns and transported by the Strathmore ice in the Second Ice Age, this deposit is, at Hatton of Cruden, over 70 ft thick. Extensive areas are water sorted and are best described as a brick earth. Elsewhere the deposit is a clay-loam to clay textured till, while along the western margin of its occurrence, it is impinged upon by till deposits coming from the west. In this area of mixed Cruden till, western till may overlie the red clay, or the red clay may be partially commingled and incorporated in the western till.

The flint and quartzite till of the Skelmuir Association has been more precisely defined as to its boundaries. It occurs south-west of Peterhead and extends to Kinknockie and beyond to Skelmuir Hill. Hill peat of the Moss of Cruden covers a great deal of the deposit, and it is apparent that most of the farmland of this association has been derived from peaty gleyed podzols with iron pan.

The Tarves Association on a till of mixed stone content encircles the red till areas of the former Cruden Association and also the Skelmuir flint drift association. North of the Moss of Cruden, about and to the north of Lenabo, the Tarves Association consists mainly of poorly drained soils of sandy clay loam or heavier textures. Quartz-mica-schist contributes largely to the till, but is not sufficiently dominant over the flint, granite, gneiss and basic rock constituents to classify it as the Strichen Association.

The Countesswells Asssociation is distinguished south of Peterhead and north of Longside in small areas.

The raised beach deposits north of Peterhead and extending up through St Fergus to Crimond have been examined. The greater part of this flat shelf consists of the Boyndie Association on fluvio-glacial sand. Some peat occurs over the sand at St Fergus and northwards to Rattray. At Blackwater a heavy dark grey clay occurs, not unlike the Carse clays of Stirling; this clay is in places overlain by sand and is sufficiently thin in parts to be observed to overlie sand.

The kame belt which occurs extensively between the Potterton Burn and the River Don is discernible northwards to Cruden Bay and beyond in isolated and sometimes extensive mounds. Where the gravel forms the parent material of soils it is classified as the Corby Association, but south of Cruden Bay and extending to Slains it is extensively capped by red brick-earth deposits and the gravel protrudes only in isolated prominent mounds.

The following associations are found in the area surveyed this year and are described in the appendix:

1. Cruden — *see* Annual Reports 1942-43 and 1943-44.
2. Skelmuir — *see* Annual Report 1942-43.
3. Countesswells — *see* Annual Report 1944-45.
4. Tarves — *see* Annual Report 1944-45.
5. Boyndie — *see* Annual Report 1949-50.
6. Corby — *see* Annual Report 1944-45.
7. Blackwater — New Association: may be correlated with the Carse.

EAST SCOTLAND

Angus and Kincardineshire (*Soil Survey Sheets* 57, 57*a and* 66)

Mapping and revision of Sheets 57 and 57a have been completed. This has involved about 24 square miles of new mapping, mainly in the Aberlemno area between Forfar and Brechin. In addition about 40 square miles of remapping and major adjustment of association boundaries has been carried out between Laurencekirk, Edzell, Brechin, and St. Cyrus. Extensive minor revisions of drainage and association boundaries have been made throughout the sheets. No new associations have been defined, but as a result of the revision much ground previously assigned to the Craigo Association has been transferred to the Balrownie Association, together with minor patches previously included within the Laurencekirk and Stonehaven Associations. Some light textured soils not previously separated have been included within the Drumgley Association.

The following soils are found in the area about Aberlemno and are described in the appendix:

Associations

1. Auchinblae — *see* Annual Report 1950-51.
2. Corby — *see* Annual Report 1950-51.
3. Balrownie — *see* Annual Report 1950-51.
4. Turin — *see* Annual Report 1952-53.
5. Drumgley — *see* Annual Report 1952-53.

Alluvium (*undifferentiated*)
Lacustrine Alluvium
Basin Peat

CENTRAL SCOTLAND

Stirling (*Soil Survey Sheet* 39)

A soil survey has commenced in this area which is bounded to the east by a line from Auchterarder, Perthshire, through the Ochil Hills and across western Fife to Culross on the Forth; to the south from Culross *via* Denny to Fintry in Stirlingshire; to the west across west Flanders Moss to Ben Vorlich, near Callander, Perthshire; and to the north from Ben Vorlich, *via* Muthill to Auchterarder. Portions of the counties of Perth, Stirling, Clackmannan, Fife and Kinross are included.

Represented within the sheet area are two major geological regions of Scotland—the Highlands and the Midland Valley—and three landscape units within the Midland Valley—the Helensburgh-Stonehaven trough, the lava hills to the south which confine the trough, and the Carboniferous lowlands. Thus, with the exception of the Southern Uplands, Scotland is to some extent epitomized in the area. Furthermore, the Pleistocene Epoch has contributed a variety of distinctive soil parent materials, namely glacial tills and moraines and fluvio-glacial gravels (all of varying composition), together with estuarine deposits and large accumulations of basin and hill peat. This diverse and representative pattern of parent materials, with wide variations of slope and climate, gives rise to the hope that in this district useful correlation may be achieved among Scottish soils which until now have been recognized only in widely separated areas.

During an initial reconnaissance the following soils were recognized:

(1) In the northwestern hills traversed by the Highland Boundary Fault:—Soils similar to those noted at Lephinmore, Argyll, and to the Strathfinella and Strichen Associations of Kincardineshire and Aberdeenshire.

(2) In Strathallan and the upper Forth Valley:—The Corby and Carse Associations together with Old Red Sandstone soils similar to those found in Angus.

(3) On the Campsie Plateau:—The Darleith and Kirktonmoor Associations as found in North Ayrshire.

(4) On the Ochil Hills:—The Sourhope Association of Roxburghshire.

(5) On the Carboniferous lowlands on both sides of the Forth between Stirling and Grangemouth:—The Carse Association, together with soils on Millstone Grit (local till) and on medium till derived from Carboniferous Limestone and Coal Measures sediments, much of these being influenced by the Upper Raised Beach.

Detailed surveying has been started in three areas and a total area of approximately 45 square miles has been mapped.

Area 1 is an area of the Ochil Hills contained within a line joining Blackford, Dunning. Glendevon, and Frandy Reservoir. Altitudes range from 250 feet to 1,647 feet above sea-level and the area is dissected with undulating summits and ridges and steep valleys. The whole region is covered with glacial till derived mainly from the local andesitic lava and associated tuff, though erratics of Old Red Sandstone and Highland schists are common. On the hills the till is shallow and coarse textured, whereas in the valleys it is deep and finer textured. Sheep farming is the main agricultural occupation.

The following soils are found in this area:

Associations

Sourhope *see* Annual Report 1949-50, and Appendix.

Undifferentiated Alluvium

Skeletal Soils

Hill and Basin Peat

Area 2 consists of three units of land underlain by Old Red Sandstone—(i) Tullibardine Muir, (ii) Kippenross Estate, Dunblane, and (iii) part of Kippen parish. In the first two there is a shallow covering of till and the surface exhibits the form of the concealed bedrock. Tullibardine Muir is a heather-covered sheep run, whilst Kippenross Estate is in cultivation. The Kippen unit is on deeper till formed into drumlins and it receives a higher rainfall. Pastoral farming is more important here than at Dunblane. Altitudes range between 200 and 850 feet above sea level.

Pending correlation with similar soils in other parts of Scotland, no associations have been established.

Area 3 is an area of carse land south-east of Stirling. The surface of this estuarine alluvium of the Lower Raised Beach is level except where the Forth and its tributary streams are entrenched at about 20 feet above sea-level. The streams are flanked by haughland similar in composition to the carse but wetter, owing to periodical flooding by tides. A gentle slope divides the two land forms—the only incline in an otherwise flat countryside. At one time a morass, the carse is now the most fertile district within the sheet area and its speciality is the growing of timothy. A few relict peat mosses serve as a reminder of its former state.

The following soils are found in the area, the association being described in more detail in the appendix:

Associations

Carse New Association.

Undifferentiated Alluvium

Basin Peat

SOUTH-EAST SCOTLAND

Berwickshire, Midlothian, Peeblesshire, Roxburghshire, and Selkirkshire
(Soil Survey Sheets 25 and 26)

A further 170 square miles were mapped during 1955. This is an area considerably larger than is usually covered in one season, due in part to increase in experience and also to exceptionally good weather. The area was also all easily accessible.

Sheet 26 (Berwick-upon-Tweed) has been completed. Sheet 25 (Kelso) has been mapped as far north as easting 400 and also to the west of northing 700.

Almost the whole of Sheet 26 north of the Tweed is underlain by Lower Carboniferous Ballagan type sediments of the Cementstone Group. These consist of rapidly recurring sandstone shales, cementstones, and impure limestones, which vary considerably in colour from pure white to dark reddish brown. Shales and sandstones are the most common facies, the former being the dominant and usually reddish brown in colour and the latter usually of a cream or brown colour. The conditions of deposition of these rocks were estuarine and semi-terrestial, giving them an intermediate character between the Upper Old Red Sandstones to the west and the marine and lagoonal beds of the later Carboniferous sediments which contribute to many of the tills encountered in south-west Scotland.

Overlying these rocks is a mixed till, derived from them and from other rocks in the west, mainly Lower Carboniferous olivine basalts, Upper Old Red sandstones and Silurian greywackes. The Whitsome Association is developed upon this mixed till. During the glacial retreat, what had been an ice sheet covering the whole area shrank gradually towards the Tweed. Melt waters at this time confined to the margin of the ice reworked some of the till described above and deposited much sandy and gravelly material in patches and long interdigitating strips. Areas thus modified give rise to soils of such an intricate pattern that they have had to be placed within a soil complex—the Coldstream Complex. The topography in this district is rolling, becoming more gentle towards the north-east. As the annual rainfall is only about 25 inches, the light soils of the Coldstream Complex suffer very badly from drought in a dry summer. The heavy soils of the Whitsome Association, however, have a high moisture retention capacity and are more suited to a dry summer. As their natural potential of fertility is high, these soils are eminently suitable for the culture of barley and wheat, the former being the main arable crop. Most of the soils in the area are or have been subject to podzolisation and the heavy soils of the Whitsome Association correspond very closely to the grey brown podzolic soils described in the U.S.A.

On Sheet 25 an area between Kelso and Duns and the eastern edge of the map is also underlain by similar rocks of the Cementstone Series, and the descriptions above for Sheet 26 are equally applicable to this area. To the west, as far as the lower reaches of the Leader Water, the underlying solid geology comprises sandstones, marls and shales of Upper Old Red Sandstone age and trachytic and basaltic intrusions and basalt lavas of Lower Carboniferous age. These rocks are covered by tills derived from them and give rise

to soils of light texture. The topography is rolling with occasional craggy hills. The annual rainfall is about 30 inches. Mixed arable farming and stock rearing are the main agricultural practices. On the Hobkirk Association between Greenlaw and Duns where the natural *Callunetum* has been allowed to remain, a shallow peaty podzol with or without iron pan is the dominant soil series; cultivation has modified similar soils elsewhere. No such signs of definite podzolisation are to be found on the Hobkirk Association to the south where there is contamination from basic material such as olivine basalt lavas. The trachytic rocks of the Dirrington Laws are acid enough to give rise to poorly developed peaty podzols.

To the west of the Leader Water is a large hilly area where the solid geology is of isoclinally folded Silurian greywackes and shales and here the annual rainfall ranges from 30 to 50 inches. True tills in this area are not common and the parent material of the Ettrick Association on the hills is merely rock rubble which may in part be ablation moraine but is probably mostly soliflucted material. Freely drained soils develop upon this material and are brown podzolic soils or humus podzols; the latter occur where the rainfall exceeds 35-40 inches per annum. Where, in the valleys or in pockets in the hills, till of heavy texture occurs, low humic and peaty gley soils are found. Sheep farming and forestry are the only forms of agriculture in this area.

Forty-two profiles have been sampled this season to enable analytical records to be compiled for areas described above.

Soil series within the following associations were found in the areas surveyed this year and are described in the appendix.

Associations

1. Ettrick	*see* Annual Reports 1949-54.
2. Hobkirk	*see* Annual Reports 1949-51.
3. Minto	*see* Annual Reports 1950-51 and 1952-53.
4. Eckford	*see* Annual Report 1949-50.
5. Darleith	*see* Annual Reports 1949-51 and 1952-54.
6. Whitsome	*see* Annual Reports 1948-49 and 1953-54.
7. Coldstream Complex	New Soil Complex.
8. Bemersyde	New Association.
9. Smailholm	New Association.
10. Yarrow	New Association.

Hill Peat
Basin Peat
Peat-Alluvium Complex
Alluvium

SOUTH-WEST SCOTLAND

Ayrshire (*Soil Survey Sheet* 14)

Approximately 75 square miles have been surveyed on Sheet 14 during the current season. Mapping has been continued in the main areas to complete a north to south cross-section of the sheet, in an attempt to assess the complicated glaciation pattern of the region.

The first of these areas lies south-east of a line from Coylton to Maybole, to beyond Straiton, and includes sections of the valleys of the River Doon and

the Girvan Water. The topography here is dominated by an extensive series of drumlins which are particularly prominent north of Kirkmichael. Southwards the land rises to over 1,000 feet at Keir's Hill, and at Straiton an important fault line marks an abrupt change to rugged, hilly country formed of Lower Old Red Sandstone sandstones and lavas. The dominant rocks of the rest of the area are sediments of Upper Old Red Sandstone and Calciferous Sandstone age, mainly sandstones but with marls, shales and cornstones fairly common. The soils are almost everywhere developed on till, usually of heavy texture, and are dominantly imperfectly or poorly drained. Fluvio-glacial and moraine deposits occur in small areas along the Girvan valley from Maybole to Straiton. The main agricultural activity is dairy farming but many farms carry sheep in addition, especially in the south where there is access to hill grazings.

The second area, in the north-west of the sheet, includes all the land between the Ayr-Coylton road and the northern margin. The wide raised beach between Alloway and Troon is the outstanding topographic feature. It is now largely given over to airfields and golf courses, where it has not been built over. Inland the topography rapidly changes to rolling, and again drumlins occur frequently. The Ayr is the only important river, but the Pow, Raith, and Ladykirk Burns also contribute to the drainage of the area.

The underlying rocks are mainly sediments of the Coal Measures including, in the north, a wide outcrop of Barren Red Measures. Igneous rocks are represented by a teschenite sill which extends from Annbank to the coast at Prestwick, and olivine-basalt lavas in the Tarbolton area, both of Permian age. Most the area beyond the raised beaches is till covered, and the only other important superficial deposit is a spread of dune sand on the seaward side of the raised beach from Prestwick northwards. Again dairy farming is the chief practice, but on the lighter and better drained soils near the coast cash crops such as wheat and potatoes are grown. Market gardening is an important subsidiary activity on the alluvial soils in the vicinity of Ayr.

The following soils have been distinguished in the areas mapped and are described in the appendix.

Associations

1. Darleith	*see* Annual Reports 1950-51 and 1953-54.
2. Dreghorn	*see* Annual Report 1950-51.
3. Rowanhill	*see* Annual Report 1950-51.
4. Bargour	*see* Annual Report 1950-51.
5. Darvel	*see* Annual Report 1951-52.
6. Lanfine	*see* Annual Report 1951-52.
7. Glenalmond	*see* Annual Report 1953-54.
8. Ettrick	*see* Annual Report 1953-54.
9. Braston	New Association.
10. Glenpark	New Association.
11. Tranew	New Association.

Links

Alluvium

Hill and Basin Peat

In addition, three other associations have been tentatively named, but their description is deferred pending probable correlation with associations already described from Sheet 22 (North Ayrshire).

MAPS AND REPORTS

The second memoir of the Soil Survey of Great Britain (Scotland), dealing with the soils of the country round Jedburgh and Morebattle, with accompanying maps (Sheets 17 and 18), will be published shortly[36]. The third memoir, which deals with the soils of the Kilmarnock area, is almost ready for submission to the printers. Some delay in the processing of the map by the Ordnance Survey has been caused by the need to bring the topography of their base map up to date in the delineation of new reservoirs and roads, but the line proof of the map (Sheet 22) will soon be available.

The 1 inch to 1 mile maps of Brechin (Sheet 57), Inverurie (Sheet 76), Peterhead (Sheet 87) and Elgin (Sheet 95) have been compiled by the surveyors preparatory to the drafting of fair copies for submission to the Ordnance Survey.

Reports have been completed on the work done by the sub-committees on the revision of the Soil Survey Handbook.

Two visits have been made by staff of the Department of Pedology to Altnabreac, Caithness, where it is proposed to utilize 20 square miles of peat for the generation of electricity. The material under the peat has been examined where possible, in order to assess its suitability for reclamation. The 300 acre pilot scheme has been examined and sampled in more detail.

LABORATORY INVESTIGATIONS AND COLLABORATIVE WORK

Work has continued on samples of horizons from selected profiles for air-air-space determinations, on clay analyses of indurated B_3 layers, and on the total analyses of selected genetic type profiles.

Soil monoliths have been collected, treated with vinylite resin and prepared for demonstration.

Selected soil profile samples have been submitted for examination of the clay fraction by X-ray and differential thermal analysis, and selected soil profiles have also been supplied to the Department of Spectrochemistry for trace element analyses.

Assistance has been given in the selection and characterization of sites for field trials conducted by the Institute and by the Scottish Colleges of Agriculture. Assistance has also been given to Agricultural Advisory Officers in the planning of land drainage schemes. Dr E. C. Childs, School of Agriculture, University of Cambridge, was shown soil types and drainage schemes in north-east and south-west Scotland in connection with studies on soil water percolation.

VEGETATION SURVEYS

The different types of vegetation occurring in the North Ayrshire sheet were recorded during early summer 1955. The soil map which had already been prepared was used as the base for mapping, and species lists giving estimated frequency of occurrence were made on each soil series. On the

more important soil series several types of vegetation were recorded, ranging from temporary pasture to woodland; series of limited area were treated less intensively.

A comparison of the vegetation occurring on different Major Soil Groups is to be made and is likely to be of more significance than the comparison of series falling approximately within the same Major Soil Group.

The Brown Blanquet Plant Sociological analysis was applied to various communities of the more stable hill peat and heath vegetation.

The vegetation of Angus is being recorded in a similar manner. Work began in August, 1955, and will continue until the end of the current survey season.

The major species growing on Beauty Hill, near Udny, Aberdeenshire, have been sampled for inorganic analysis. The soil on this hill is derived largely from the underlying serpentine rock, and samples of the same species have been collected from non-serpentine soils in the neighbourhood so that a comparison can be made.

At the request of the Forest Soils Section a visit was made to Bowmont Forest, near Kelso, Roxburghshire, for the purpose of recording the ground vegetation under varying degrees of thinning of Norway Spruce.

More than 250 specimens have been collected in duplicate for the herbarium. Of these about 160 are common species not previously collected and the remainder less common species and abnormal forms or better specimens of species already collected.

HEATHER SURVEY

Field examination of upland grazings has been extended to Peeblesshire, Selkirkshire, Argyllshire and Inverness-shire. The factors controlling the distribution and botanical composition of heather communities have been investigated, special attention being directed towards management practices and behaviour of stock. A paper on some of the main ecological features of this work was read at the autumn meeting of the British Ecological Society.

More detailed investigations have been continued at selected centres. In collaboration with Mr I. A. Nicholson of the North of Scotland College of Agriculture, a paper dealing with the ecology of an area of hill grazing in north-east Scotland is being prepared for publication. In this paper a method is suggested for the characterization of *Calluneta* and it is intended to extend this work to other areas in Scotland. An account of this work was given at the summer meeting of the British Ecological Society in Aberdeen.

Many interesting problems have come to light during the course of the work and these are being investigated experimentally. For instance, the immediate and long term effects of heather burning on soil fertility are being studied and heather cutting experiments, transplant experiments, and a study of the effect of fertilizers are contemplated.

Co-operation with other departments and research institutes has continued. Further analytical work has been undertaken on behalf of the Department of Soil Fertility, while observations on the heather grazing experiment at the Rowett Institute are still in progress. In collaboration with the North of

Scotland College of Agriculture, a report on the effect of top dressing four types of hill pasture with various combinations of lime and phosphate has been completed. The effect of these treatments in terms of soil fertility, botanical composition of the sward, and nutrient content of the herbage is recorded and the practical application of the results is discussed.

A broad survey of the vegetation and peat deposits of North Ayrshire has been completed in collaboration with the Survey ecologist.

PEAT ECOLOGY

As in previous years, routine work has continued mostly in conjunction with the Department of Agriculture for Scotland (Peat Division). During the year some 500 samples have been received from the following areas:

Moss of Cree, Wigtownshire
Mark of Luce, Wigtownshire
Dava Moor, Morayshire

Additional samples from these deposits were dealt with for the estimation of fibre content.

Further samples for spectrochemical and carbohydrate chemistry investigations have been taken from various mosses and submitted to the departments concerned. The Altnabreac peat scheme of the North of Scotland Hydro Electric Board was also examined.

Pollen Analysis

A pollen analysis diagram from the buried peat exposed during excavation in Nelson Street, Aberdeen, has been submitted to the Department of Geography of the University of Aberdeen.

Contact was again made with Dr McVean of the Nature Conservancy in the Beinn Eighe Nature Reserve. Peat samples representing two profiles were taken from specially selected sites, one at high elevation and the other at low. It is hoped that the pollen analyses of these samples will result in a better understanding of the forest history of this area.

St. Fergus Moss, Aberdeenshire, has been the subject of more intensive study from the stratigraphical and palynological angle. At present the first stage, consisting of a repeated pollen analysis and profile transect, has been completed.

In collaboration with the Soil Survey Section samples from Restenneth Moss near Forfar have been taken with a view to assisting the dating of a marl layer which occurs in the peat of that deposit and elsewhere in the district.

SOIL GEOLOGY AND MINERALOGY

Scottish Soils

Mineralogical analysis of the clay and sand fractions of Scottish soils has continued with the examination of profiles sampled by the Soil Survey Section in Roxburghshire, Ayrshire, Kincardineshire and Angus. The clays have been investigated by X-ray diffraction methods and the results compared with those obtained by differential thermal analysis in the Physical Chemistry

Section. In general the findings are similar to those for other Scottish soil clays and differences between associations are usually not marked, illite being the commonest clay mineral with kaolin invariably present. An exception was found in the soils from Roxburghshire derived from glacial drifts containing chloritic rocks of Ordovician and Silurian age. These contained considerable amounts of chlorite in the clay fraction, a mineral seldom found in soil clays except in very small quantities. A paper[2] on the distribution of clay minerals in Scottish soils has been published in which a correlation is made between the clay mineral suites and the parent rocks, and the origin of the clay minerals is discussed.

The sand fractions of these soils were investigated by optical methods, and differences in the contents of ferromagnesian silicates and iron oxides were found in soils from Roxburghshire derived from glacial drifts overlying various rock types, both igneous and sedimentary, belonging to Ordovician, Silurian, Old Red Sandstone, and Carboniferous formations. Differences in the mineralogy of the sand fractions were also found in samples from Ayrshire, Kincardine and Angus.

The variations in the mineralogy of the clay and sand fractions have served to characterize the soil associations.

Rock Weathering

An investigation by optical and X-ray diffraction methods into the weathering of ferromagnesian minerals in soils derived from basic igneous rocks has been started.

Peat Subsoils

Collaborating with the Soil Analysis Section, chemical and mineralogical analyses of subsoil samples from the Altnabreac Moss in Caithness have been carried out in connection with the scheme to reclaim the land for agriculture or forestry after the removal of peat. The results showed a very low degree of base saturation, but the mineralogical composition indicated that the material could be converted to arable land if suitably drained, fertilized, and cleared of boulders.

The clay fractions of subsoils from the Moss of Cree in Wigtownshire have also been examined in collaboration with the Physical Chemistry Section.

Quantitative Analysis

Considerable progress has been made in the development of the internal standard method for quantitative analysis by X-ray powder diffraction, particularly in the case of the non-clay minerals in soils. The main difficulties in estimating the clay minerals arise from the variations in chemical composition and irregularities in crystal structure.

Clay-Organic Complexes

The investigation of the complexes formed with montmorillonite and organic molecules (simple sugars and polysaccharides) by an Agricultural Research Council student, Mr D. J. Greenland, has been completed with the award of the degree of Doctor of Philosophy from the University of Oxford. Further work on clay organic-complexes is proposed.

Foreign Soils

The sand and clay fractions of some Italian soils developed on calcareous parent materials have been examined in collaboration with the Physical Chemistry Section, and a joint paper[38] on these soils is in press.

Mineralogical analyses of laterite profiles from Africa by Dr S. G. Willimott of the Yambio Experimental Station, Equatoria, Sudan, and of Turkish soil clays by Dr F. Gülcur from Istanbul have enabled these visitors to be given a training in the use of X-ray diffraction methods.

Lamb Stiffness and Sheep Pining Surveys

A survey was carried out on the soils and their parent materials in the Leadhills district of upper Lanarkshire and Dumfriesshire as part of a joint investigation with the Animal Diseases Research Association and the West of Scotland College of Agriculture into lamb stiffness. The affected area is underlain by rocks of Ordovician age, consisting mainly of shales, sandstones, and greywackes with some igneous intrusions. Associated with these rocks are metalliferous veins, principally of lead and zinc. There are many waste heaps from the former mines and mills about the hillsides. Samples of soil and herbage were collected from the affected and adjacent unaffected areas for further laboratory examination.

Field work in connection with the sheep pining investigation on hill farms was continued in Selkirkshire in the district of the lower Yarrow and Ettrick Waters. The rocks of this area are shales, grits, and greywackes of Silurian age and are covered on the lower ground by a compact boulder clay, formed largely from the local rocks. Samples of typical soils were collected for laboratory examination.

PHYSICAL CHEMISTRY

Differential Thermal Analysis

During the year there has been a gratifying increase in the number of soil clays handled in a routine manner, and the apparatus is now working at capacity (four samples in all, per day). Scottish soils clays from Aberdeenshire, Ayrshire and Roxburghshire showed the usual clay mineral associations, with the addition of chlorite in some of the Roxburghshire soils. It has again been noted that Ayrshire soil clays derived from Carboniferous parent material generally have higher kaolin content than Roxburghshire soil clays derived from Ordovician and Silurian sediments. Irrespective of locality, all soil clays derived from Old Red Sandstone deposits showed the unusual type of hydrous mica previously found to be present in such clays in Aberdeenshire and Kincardineshire. Samples from under peat at the Moss of Cree, Wigtownshire, have been examined in connection with the peat survey. A series of soil clays from Turkey are at present under investigation.

Minerals examined during the year included natural and synthetic aluminium oxides, manganese oxides, antigorites, hydrous micas, montmorillonoids, dolomites, palygorskites, and ground samples of micas. The differential thermal apparatus has also been calibrated for the quantitative determination of small amounts of quartz (1-10 per cent.).

The effect of wetting and drying upon the differential thermal curves of various *normal* and *abnormal* montmorillonites (those with peaks at 700°C and those with peaks at 650-700°C and/or 550-600°C, respectively) has been investigated and the observation correlated with chemical data for potassium fixation, etc. The effect of treatment with sodium hydroxide upon the curves for some soil clays suspected to contain free aluminium oxides has also been checked.

The note upon the comparative performance of nickel and porous alumina specimen holders has now appeared[5], and a paper upon the mineralogy of some Italian soils, in collaboration with the Section for Soil Geology and Mineralogy and with Conte Prof. C. Lippi-Boncambi, Perugia, is in press[38].

Chemical Studies

A considerable number of semi-micro chemical analyses have been carried out, mainly in connection with the wet-grinding of muscovite and the potassium contents and cation-exchange capacities of treated montmorillonites. The free iron and aluminium oxide contents of a series of samples of Turkish soil-clays have been determined.

Other Studies

The infra-red spectra of a series of samples of ground micas have been determined by the Department of Spectrochemistry, and an attempt has been made to correlate the results with other available data. Other clay samples have been supplied for infra-red examination, and present results indicate that in many instances the method should form an extremely useful addition to the normal X-ray and differential thermal techniques at present in use. Much more work on the interpretation of spectra is, however, necessary.

A paper[37] on potassium in clay minerals was read at the Symposium on *Potassium in the Soil* held by the International Potassium Institute in Rome in September 1955.

SOIL ANALYSIS

Routine analyses have been completed on samples taken by the Soil Survey officers during 1953 (650 samples representing 131 profiles). During 1954, 417 samples (93 profiles) were taken and with the exception of total nitrogen determinations, routine analyses have also been completed on these. Ultimate analyses of seven selected profiles (34 samples) from Roxburghshire have been completed. Total silica, iron, and aluminium determinations have been carried out on 71 clay samples (16 profiles) separated from selected soils from Ayrshire.

In addition, 237 samples of soils and similar materials were analysed for (a) the Departments of Plant Physiology and Soil Fertility, (b) the Midge Control Unit, University of Edinburgh (investigation on breeding grounds of midge), and (c) the Department of Agriculture for Scotland: Peat Survey (basal material below peat).

SPECTROCHEMISTRY

There have been no major changes in the staffing or equipment of the Department in the course of the year, during which the main efforts have been directed towards the application of existing techniques of analysis to field problems, in collaboration chiefly with the Departments of Soil Fertility and Pedology. The principal investigations have involved studies of the effects of fertilizer treatments on trace element uptake, of the relative uptakes of different plant species, and of the influence of pedological processes on the distribution of trace elements in the soil profile.

The application of absorption spectroscopy to problems related to the organic constituents of the soil has been extended, largely in collaboration with the Department of Soil Organic Matter.

Samples for examination have been received from numerous outside sources, including other research institutes in Scotland, the National Agricultural Advisory Service of England and Wales, and various overseas organizations including the Colonial Products Advisory Bureau.

The facilities available for training visiting workers have been employed to their full capacity throughout the year. Among those spending appreciable periods in the Department were Dr B. Ramamoorthy, Indian Agricultural Research Institute, New Delhi, Mr B. G. Davey, New South Wales Department of Agriculture, Sydney, Mr F. C. Archer, University College of North Wales, Mr R. Sunarto Koesoemo, Bogor, Indonesia, Mr M. H. Potterat, Federal Board of Public Health, Berne, Switzerland and Mr K. Ellitsgaard-Rasmussen, Mineralogisk Museum, Copenhagen.

Meetings of the Consultative Committee for the Development of Spectrographic Work, the Interservices-D.S.I.R. Panel on Emission Spectroscopy, the Agricultural Research Council Group on Mineral Deficiences and Excesses in Animals, the A.R.C. Sub-Committee for Comparison of Methods for Diagnosis and Analysis and the Spectrographic Discussion Group (Glasgow), in addition to a conference on Molecular Spectroscopy in London, were attended by members of staff. A paper on the geochemical and pedological distribution of trace elements in soils was presented to a Study Week on Trace Elements organised by the Pontifical Academy of Sciences in Rome. The bibliography of references to trace elements in soils[39] mentioned in the previous report is on the point of publication.

TRACE ELEMENTS IN SOILS, PLANTS AND BIOLOGICAL MATERIALS

Soil Status and Plant Uptake

During the past eight years a survey of the cobalt status of soils from the sheep rearing areas of southern Scotland has been in progress. Samples

have been taken by the Department of Pedology and submitted for determinations of extractable cobalt. More than one thousand samples have now been analysed and the results passed to the Animal Diseases Research Association and to the county representatives of the Colleges of Agriculture. The results have led to the identification of several cobalt deficient areas where treatment has proved beneficial, and indicate that, for cobalt, soil analysis is a valuable diagnostic approach, although lack of controlled animal experiments still renders difficult the interpretation of the results from certain types of soils, notably hill grazings. In addition to this systematic survey, numerous soils from the north and north-east of Scotland have been examined on an advisory basis for cobalt, and the existence of areas of low cobalt content, particularly on certain Old Red Sandstone and Granitic soils has been established. In this connection, samples of pasture herbage and of animal organs, principally livers, have been examined, the latter reaching us from Veterinary Investigation Officers through the Animal Diseases Research Association where facilities, provided on the recommendation of the Consultative Committee for the Development of Spectrographic Work, are now available for the pretreatment of animal organs prior to trace element analysis.

The effects of fertilizer treatment on trace element content of mixed herbage have been studied on a number of soils. On a soil on a parent material derived from slate, the effect of additions of copper, molybdenum, zinc and vanadium have been studied on limed and unlimed plots. The greatest variation in uptake is observed with molybdenum; so far no increase in the above-ground plant content of vanadium has been found as a result of addition of this element to the soil at the same rate as molybdenum. The increased uptakes of copper and zinc, despite much higher dressings, (20 lb. sulphate per acre) are relatively much smaller than for molybdenum (1 lb. sodium molybdate per acre). Liming increased the uptake of molybdenum and strontium (probably contained in the lime) and reduced that of manganese, cobalt, nickel and possibly zinc, but these results have not yet been examined statistically and may not be significant in the case of zinc.

The application of copper to a light Old Red Sandstone soil has been studied. Here an interesting difference between the clovers and grasses of a mixed pasture herbage has been observed, the former showing considerably greater variation in copper uptake.

Effects of N.P.K. fertilizers on trace element uptake are not generally very marked and can probably be ascribed to species variation in many instances. For example, in one set of plots there appears to be an inverse relationship between nitrogen addition and strontium content.

The relationship between trace element uptake of individual species and soil content has been investigated further, and in continuance of this line of research, a set of four mixed herbage plots are being sampled regularly at short intervals and the plants subdivided into their constituent parts in order to trace the distribution of trace elements in different parts at different stages of growth. It is considered necessary to have this information in view of occasional discrepant values obtained, for instance, for cobalt, from a pasture herbage grown on a soil whose cobalt status is known.

An account[6] has been published of an investigation of the trace element contents of the constituent species of hill grazings from Sutherland, with analyses of samples taken several times per year over a period of three years in the course of an animal disease investigation carried out in collaboration with the Animal Diseases Research Association.

The effect of lime on trace element uptake is of considerable practical agricultural significance and a summary[7] of the present position as it affects this aspect has been presented.

Soils and Soil Parent Materials

Geochemical investigations into the contents of rocks and related materials have been continued. Analyses have been made of granitic and gneissic rocks from north-west Scotland, and of basalts from Northern Ireland; details of the findings regarding the latter are in course of publication[40].

The study of profiles of typical soils from areas surveyed by the Soil Survey Section of the Department of Pedology have continued, particular attention having been given to soils from south and south-west Scotland. Generally the findings have confirmed results obtained from profiles from the north-east of Scotland, although the parent materials involved are of a different character, being chiefly argillaceous sediments and intermediate or basaltic lavas rather than the granites, gabbros, gneisses, schists and sandstones of the north-east. A summary[8] of the present state of knowledge regarding the distribution of trace elements in soils has been contributed to an American Chemical Society Monograph.

The distribution of trace elements in peats is a line of investigation which has not been widely studied. Results of analyses of a few Scottish peat profiles were presented to the International Peat Symposium in Dublin in 1954[9], and further work is in progress.

Other Types of Sample

Among the miscellaneous samples examined during the year may be mentioned further samples of drinking water from Shetland in connection with the disseminated sclerosis investigation being carried out in collaboration with Dr J. M. Sutherland of Inverness, samples of seaweed from the Seaweed Research Institute, power station ash and similar materials from various sources, and casein products from the National Institute for Research in Dairying. The findings of the investigation into depigmentation of rats' teeth have been published[10].

SPECTROCHEMICAL METHODS OF ANALYSIS

As already mentioned, no significant changes in technique or equipment have been made. A review[11] of methods applicable to plant materials has been published.

Flame Emission

A modified version of the flame photometer which has been in use for over five years is in course of construction. Limitations of space have delayed further development of the integrating flame photometer mentioned in the preceding report.

The standard Lundegårdh flame technique is proving valuable for the determination of lead and copper in acetic acid extracts of soils from certain areas in the neighbourhood of old mine workings where animal disorders are reported.

Arc Emission and Chemical Pretreatment

No modifications in methods have to be reported. The experimental hotplates in MG5 aluminium alloy have proved very successful in practical use, showing little or no corrosion in the presence of fumes of acetic, nitric and hydrochloric acids and of ammonia, provided they are kept slightly warm when not actually in use.

Spark Emission

Further studies into the application of the porous cup solution spark technique to various problems have been made. It is used on a routine scale for the determination of magnesium in acetic acid soil extracts without previous concentrations, and for the determinations of copper and zinc in various types of extract.

ABSORPTION SPECTROMETRY OF SOIL CONSTITUENTS

From their infra-red spectra, a number of organic compounds isolated in the Department of Soil Organic Matter have been identified with certainty during the year. As the infra-red spectrum is a specific property of a compound, and as it can be obtained from half a milligram of material, this technique has many advantages. Sufficient material can be isolated by paper chromatography, but it has been found that its purity is often too low for satisfactory identification. Provided the material can be purified by crystallization it can generally be identified.

The mould and press constructed for the preparation of alkali halide disks, as reported last year, has proved completely satisfactory. The pressed disk technique is of great value in obtaining the spectra of solid materials. Clays and finely ground minerals give excellent spectra by this method, and preliminary work indicates that infra-red spectrometry will give information, particularly about hydroxyl groups, supplementary to that given by X-ray and differential thermal analysis.

It has been found that caution must be exercised in applying the pressed disk technique to polar organic compounds. It appears that the molecules of such compounds may become adsorbed at polar sites on the surfaces of the finely ground alkali halides. The spectra of the adsorbed molecules often differ markedly from those in the normal crystalline state. This effect has been observed with compounds containing hydroxyl, amino, or amide groups. It is most marked with acids, where there is evidence that at least in some cases the acid is adsorbed in the monomeric form. Fortunately it now seems clear that under suitable conditions the effect can be reduced to negligible proportions. A note[12] on these observations has been published.

Ultraviolet spectrometry, although limited to aromatic and other unsaturated compounds, nevertheless has many advantages in its own field. Such compounds can be detected and determined quantitatively at the micro-

gram level in the presence of large quantities of weakly absorbing material. The choice of phenyl-substituted fatty acids has permitted the use of this technique in a study of the metabolism of fatty acids by the micro-organism *Nocardia opaca*, in co-operative work with the Microbiological and Chemical sections of the Department of Soil Organic Matter. The formation of benzoic and cinnamic acids was readily observed from acids of the general formulae $C_6H_5.(CH_2)_{2n}COOH$. Acids containing an odd number of methylene groups have been shown to yield phenols and this has led to the chromatographic identification of *o*-hydroxyphenylacetic acid as a metabolic product common to these acids. A joint paper[41] on this work has been accepted for publication.

The work of the Department of Soil Organic Matter on the oxidation of organic matter from soils and peats has made considerable use of ultraviolet spectrometry. Over 250 determinations of phenolic aldehydes have been made. The sensitivity of the method permits the analysis to be carried out on the small amounts of these aldehydes isolated by paper chromatography after oxidising 100 mg. or less of material. A joint paper[13] has been published on the identification of anisic acid as a product of the oxidation of methylated sphagnum, as has the account[14] of the work on the utilization of *p*-hydroxybenzaldehyde and other aldehydes by soil fungi.

SOIL ORGANIC MATTER

CHEMISTRY

Nitrogenous and Cyclic Compounds

The basic work of the section has been the chemical investigation of the nature and transformations of the nitrogenous organic compounds in soil, and also of the nature of the organic soil complex usually known as humic acid. During the past year, however, considerable time has been devoted to the application of chromatographic techniques to problems originating in other departments.

(*a*) *Alkali-Nitrobenzene Oxidation of Soil Organic Matter.* The relationship between the lignin of plant residues and the organic matter of the soil is still far from clear, for although it is obvious that lignin, in common with other plant residues, must eventually be completely oxidized in the soil, it has generally been believed that it is decomposed much more slowly than, for example, plant carbohydrates; but there is no convincing evidence of this. By the method of proximate analysis, originally developed for plant materials and later extended to soil organic matter, a fraction can be obtained which is recorded as lignin, but it has not been shown that this necessarily bears any relation to plant lignin. The oxidation of lignin with nitrobenzene in an alkaline medium, whereby vanillin and other aromatic compounds with a carbon side chain are obtained, has proved to be of great significance in the determination of the structure of lignin, and it has seemed that the application of this reaction to soil organic matter might provide some criterion of the extent to which lignin persists in the soil. Gottlieb and Hendricks (*Soil Sci. Soc. Amer. Proc.*, **10**, 117, 1945) applied the reaction to a few soils and soil extracts, and although indications were found of the presence of traces of vanillin in the reaction products, only in one experiment was vanillin isolated and in very low yield (0·31 per cent.). A more extensive examination of the application of this reaction to soil organic matter seemed, however, to be warranted, with the use of more sensitive methods for the examination of the products. Preliminary results of such an investigation, already briefly reported (*Ann. Rep.*, 1953-4), have shown that appreciable yields of vanillin, syringaldehyde and *p*-hydroxybenzaldehyde can be obtained from certain types of soils, and a quantitative micro-technique, based on separation by paper chromatography and measurement of the UV absorption, has now been developed for the determination of these products. Results have been accumulating during the past year, but the examination of a wider range of soil types is required before a general statement of conclusions can be made.

(*b*) *Nitrogenous Compounds.* Attempts to isolate from soil a protein fraction virtually free from other material, continue to be unsuccessful. The polysaccharide-protein complex previously isolated and described (*Ann. Rep.*,

1953-54) has been fractionated by adsorption on charcoal and elution with various solvents. No useful fractionation was, however, achieved and a major part of the material, containing about 75 per cent. of the total nitrogen was irreversibly adsorbed on the charcoal. Although the proportion of nitrogen in the eluted fractions showed some variation, only one fraction, eluted by acetone and insignificant in quantity, had a higher nitrogen content than the original material. Other methods of fractionation are being investigated.

(*c*) *Lignin of Sphagnum.* The investigation of the lignin of *Sphagnum*, performed jointly with the Department of Spectrochemistry, has continued, and a note[13] has been published dealing with the isolation of anisic acid in 4 per cent. yield from the oxidation products of methylated sphagnum. Studies of the products of acid alcoholysis and of alkaline hydrolysis of sphagnum have been made and are continuing. Alcoholysis appears to produce a rather large number of aromatic products, many of which have not yet been identified, but they include *p*-hydroxyacetophenone, *p*-hydroxybenzoic acid and *p*-hydroxycinnamic acid, the last representing the first isolation from sphagnum of a benzene derivative with a three-carbon side chain. The precise yields of these products have still to be determined. Alkaline hydrolysis produces low yields of the above compounds along with *p*-hydroxybenzaldehyde and an unidentified acid apparently related to *p*-hydroxycinnamic acid.

(*d*) *Organic Acids and Amino-acids in Plants.* A considerable amount of effort has been directed to the examination of the organic acids and free amino-acids of plants in connection with the investigation of the metabolism of chlorosis in plants at present being undertaken by the Department of Plant Physiology.

A suitable technique has been established for the separation of plant organic acids by means of partition chromatography on columns of silica gel using gradient elution, and good separations of synthetic mixtures of acids have been obtained. Only a few separations with plant extracts have yet been made, but good results have been obtained and well defined differences in the organic acids content of green and chlorotic bracken plants have been detected.

The results of examination of the free amino-acids content of a large number of plant extracts indicate that there exists here a wide field for investigation. It would appear that not only does the content of free amino-acids vary with the species of plant, but also that notable variations are associated with the stage of development of the individual plant. From the results so far obtained it seems that an enhanced content of free amino-acids is associated with toxicity-induced chlorosis in plants.

Several unidentified amino-acids and one unidentified organic acid have been encountered in the course of this work, and it is hoped to isolate and identify these when a sufficient quantity of suitable material becomes available.

Carbohydrates

(*a*) *The Soluble Polysaccharides from Soil and Peat.* A paper describing the partial identification of O-methyl sugars occurring in soil peat and compost

has now been published[18]. As mentioned, it seemed likely that the sugars were of microbial origin. In conjunction with the Microbiological Section a short survey has been made of various soil bacteria and fungi with this point in view. It was found that eleven out of twelve bacterial species produced one of the methylated sugars, although only in two cases were appreciable quantities involved.

While this work was in progress Forsyth (*Trans. Vth Intern. Cong. Soil Sci. Leopoldville*, **3**, 119, 1954) indicated that a strain of *B. megatherium* was a good source of an O-methyl sugar and subsequent work here using a culture of the organism, kindly supplied by Dr Forsyth, has confirmed that the substance concerned was identical chromatographically with one of the soil sugars.

Other workers (Dzulynska and Mikulaszek, *Bull. Acad. Polon. Sci., Class II.*, **11**, 101, 1954), have examined polysaccharides from (mostly) pathogenic bacteria and have obtained indications of the presence of O-methyl sugar units.

As mentioned previously, there are difficulties involved in the preparation of the rather large quantities required for a systematic chemical study of the O-methyl sugars. However, it is hoped that an investigation of the mechanism of their production may throw some light on the problem. It may be that the sugars are of some importance in bacterial metabolism generally since they are produced by a wide range of organisms.

(*b*) *Fungus Cellulose* (*Betulan*). The investigation is being continued. It was found that the fully methylated polysaccharide is very resistant to hydrolysis and there have been some technical difficulties due to the small scale on which it has been necessary to conduct experiments designed to hydrolyse the material completely and yet avoid any considerable decomposition of the constituent units.

A method of determining molecular weights of polysaccharides involving the use of radioactive carbon (^{14}C) as potassium cyanide has been investigated in collaboration with the section for Radioactive Studies. Preliminary work indicates that there may be serious difficulties in the application of the method. A paper[42] describing a simple apparatus for handling radioactive barium carbonate has been submitted for publication.

(*c*) *The Chemical Investigation of Peat.* Several peat profiles are being studied and the various constituents, *e.g.*, holocellulose, pentose, uronic acid, alcohol-benzene solubles, etc., determined by established methods. In some cases the presence of the substance concerned was confirmed by qualitative paper chromatography. This technique was found to be of particular value where the method of determination was relatively unspecific as in the cases of uronic acid and fructose. Uronic acid could be readily demonstrated on the paper chromatogram but only traces of fructose were found and these were confined to the upper layers of the peat. This agrees with the results obtained by other workers (cf., e.g., Black *et al, Institute of Seaweed Research, Report No.* 180), but does not agree with the amounts obtained by the quantitative methods (1·3 per cent. decreasing to 0·6 per cent. in the lowest layer of the peat).

Other determinations agreed well with the conventional views of increased humification in the deeper layers of the peat. A holocellulose content of about 50 per cent. in the upper layers drops regularly to 20 per cent. in the lower layers. A pentose content of 6 per cent. drops to 2 per cent. The more resistant polyuronides do not decrease to the same degree, but some decomposition is apparent as an initial value of 10 per cent. drops to 6 per cent.

In some cases humic acid was quantitatively isolated from certain layers of the peat and the cation exchange capacity determined by the method of Mackenzie (*J. Colloid Sci.*, **6**, 219, 1951) with slight modifications. Preliminary work in one case indicates that that portion of the exchange capacity of the peat due to humic acid is greater in the lower than in the upper layers, although the total exchange capacity of the peat falls off slightly with increasing depth. Other peats are being examined to discover if this is a general phenomenon.

(*d*) *Other Work.* Methods of chromatography of phenols, phenolic acids, keto acids, and saturated and unsaturated acids have been instituted on behalf of the Microbiological Section for use in the investigation of the metabolism of soil organisms.

Certain routine analytical work on the carbohydrates of potatoes is being developed on behalf of the Department of Soil Fertility.

MICROBIOLOGY

The main work of the section continues to be the study of actinomycetes and fungi concerned in the decomposition of organic matter in soils and composts.

The lines of work under investigation are:—

1. The morphology and physiology of paraffin and fat-decomposing soil nocardias.
2. The nutritional requirements and metabolism of thermophilic actinomycetes from composts.
3. The physiology of fungi which attack lignin-related substances.

The work on the physiology of the soil nocardias and part of the work on the thermophilic actinomycetes have been undertaken in collaboration with colleagues in other sections.

It was also possible to take up once again work on the rhizosphere through the collaboration of a visiting research worker from Australia.

Paraffin and Fat-Decomposing Soil Nocardias

A paper[19] has been published on the morphology of *Nocardia opaca* Waksman and Henrici when grown on hydrocarbons, vegetable oils, fatty acids and related substances.

Much progress has been made during the year in our understanding of the mechanism by which this organism attacks fatty acids. For this part of the investigation ω phenyl substituted fatty acids were used. It was found that *N. opaca* would not grow on benzoic acid as carbon source. Similarly very

little growth was obtained on phenyl propionic (PhC-3) phenyl valeric (PhC-5) and phenyl heptylic (PhC-7) acids. However, washed suspensions of *N. opaca* showed no increased oxygen uptake in the presence of benzoic but gave marked increases with the other compounds. The manometric experiments suggested the possibility that the side chain of PhC-3, PhC-5 and PhC-7 was oxidized to benzoic acid, as would be expected for β-oxidation. This was confirmed by spectrochemical and chromatographic methods. In contrast to its behaviour with benzoic acid and the odd numbered phenyl substituted fatty acids, *N. opaca* grew well on phenyl acetic (PhC-2), phenyl butyric (PhC-4) and phenyl caproic (PhC-6) acids. Washed suspensions gave increased oxygen uptake in the presence of all these compounds. Exposure of glucose grown cells to PhC-4, PhC-6 and PhC-8 completely adapted them to the oxidation of phenylacetate but exposure to the odd numbered members (PhC-3, PhC-5, PhC-7) did not do so. This supports the view that the oxidation of phenylbutyrate, phenylcaproate and phenylcaprylate proceeds *via* phenylacetic, as would be expected for β-oxidation. In addition, during the breakdown of these even numbered phenyl substituted fatty acids evidence was obtained of the production of phenols (spectrochemically) and a phenol (O-hydroxy phenylacetic acid) was identified chromatographically as a common product of PhC-2, PhC-4, PhC-6 and PhC-8 metabolism. These results are in favour of β-oxidation as a mechanism of breakdown of fatty acids by this organism. A paper[41] has been accepted for publication and the work is being continued and extended. Contact has been made with Professor R. L. Wain (A.R.C. Plant Growth Substance and Systematic Fungicide Unit) in this connection.

Evidence has also been obtained of the presence of some of the reactions of the Krebs citric acid cycle using crude extracts of *N. opaca*.

Thermophilic Actinomycetes from Composts

A defined medium has now been established for the growth of the aerobic thermophilic actinomycete *Micromonospora vulgaris*. However, the growth obtained on this medium is inferior to that obtained with the complex C.P.S. medium used in the past for the growth of this organism (Erikson, *J. gen. Microbiol.*, **6**, 286-294, 1952). Last year it was shown that growth would not take place in a vitamin free amino acid mixture (Difco vitamin free casamino acids) unless yeast extract is present. It has now been shown that biotin will largely replace yeast extract. It has further been established that the Difco vitamin free casamino acids can be replaced by a mixture containing all the known amino acids in the proportions in which they are present in the acid hydrolysized material. Chromatographic analysis of this synthetic medium after growth revealed a selective utilization of amino acids similar to that reported last year. Attempts to simplify this synthetic medium further by using the preferentially selective amino acids and biotin were unsuccessful.

In addition the role of *M. vulgaris* during the high temperature phase in composts has been partly elucidated. It appears that the amino acids liberated by the proteolytic activities of the thermophile are further broken down with the liberation of ammonia. It has been found that the ammonia is

released into the gaseous phase above the culture medium as well as in the medium itself during the growth of the organism at 60°C. It is thought that this organism plays an important part in the losses of ammonia-nitrogen which occur from composts rich in organic nitrogenous matter during the high temperature phase (Forsyth and Webley, *Proc. Soc. appl. Bact.*, 34-39, 1948).

Mycological Studies

(*a*) *Lignin Decomposition.* A paper[14] has been published on the utilization of the lignin-related phenolic compounds *p*-hydroxybenzaldehyde, ferulic acid, syringaldehyde, and vanillin, as sole sources of carbon, by a number of soil micro-fungi.

The release of such molecules from lignin has been demonstrated. Two white-rot fungi, *Polystictus versicolor* and *Trametes pini*, were grown on spruce and birch sawdusts, to which a mineral salts medium containing glucose and peptone had been added. After six months incubation, samples of the residual sawdust were extracted with sodium hydroxide and the extracts examined by paper chromatography. Vanillin and vanillic acid were found to be present in the spruce extracts, while syringic and vanillic acids, syringaldehyde and vanillin were present in the birch extracts. These results agree with chemical analyses of lignins, which show the occurrence of guaiacyl groups only in softwood lignins and of guaiacyl and syringyl groups in hardwood lignins. A note[20] on this work has been published.

A combination of the different types of attack of the wood-rotting and soil micro-fungi may be responsible for the breakdown of lignin in nature, the former releasing the constituent molecules and the latter decomposing them.

(*b*) *Warburg Studies.* The technique previously developed for studying the metabolism of fungi in the Warburg apparatus by means of spore suspensions has been used extensively.

A close relationship was found to exist between the pH of the substrata from which fungi were isolated and their optimum pH for respiration. The respiration of a few fungi on the lignin-related phenolic compounds was studied, the results corresponding closely to those previously obtained from growth experiments. This was indicated by the more rapid oxygen uptakes by the fungi which had been shown to be most active in decomposing the phenolic compounds and by the more rapid uptakes in the presence of the most readily decomposable compounds. Oxidation of intermediate products, detected in the culture media of growth experiments, was also studied. These were found to be more slowly attacked than the original compounds, which probably explains the tendency for them to accumulate in the media. A brief study of the action of enzyme inhibitors revealed marked differences in sensitivity of different fungi.

Rhizosphere

A study has been made of the course of development of the root surface flora of oats and tomato from the seed stage. It was shown that the micro-organisms originally present on the seed coat multiply rapidly during germination. The organisms establish themselves immediately after the root has

completely emerged and extremely rapid multiplication occurs during the subsequent 24 hours. At these early stages of development the roots selectively stimulated short gram negative rods and chromogenic organisms while the gram positive spore forming organisms which were particularly dominant on the dried tomato seed coat failed to become established.

A staining method developed for the direct examination of the micro-organisms on the root surface confirmed the above findings and supplied information on the distribution of the micro-organisms. With the tomato the micro-organisms which were almost entirely bacteria were mainly confined to the root itself, with the root tip and root hairs almost invariably free. The occurrence of bacteria on the root hairs of oats as well as on the main root may be due to the mucilaginous material occurring on the roots. As in the tomato, the root tip of the oats was free of organisms. A paper on this work is in the course of preparation.

General

A paper[21] describing the shaking machine for the production of uniform cell material of *N. opaca* has been published. The mechanical side of the machine has been considerably improved by the workshop staff and expanded to accommodate more culture flasks.

Growth experiments with soil bacteria and fungi have been carried out in connection with the production of a O-methylated sugar by these organisms.

PLANT PHYSIOLOGY

During the past year investigation has been extended to all forms of chlorosis in plants, whether caused by deficiency or excess of certain elements or oligo-elements, or of genetical or virological origin. To obtain further insight into the biochemical background of chlorosis, studies of the amino acids, organic acids and certain enzymes have been made. The full investigation of every form of chlorosis will necessarily take some time, but this project will be actively pursued in the coming year. However, results obtained so far indicate that certain ratios of elements are characteristic for chlorotic tissues, irrespective of the cause. At the same time an insight has been obtained into the iron nutrition of plants and the translocation of iron from the roots. The study of the influence of chelates on the movement of iron in the plant has further brought to light a possible direct influence of soil organic matter on plant growth.

The Phosphorus-Iron and Potassium-Calcium Ratios

Chlorotic plants have been found to have ratios of total phosphorus to total iron either (usually) higher or (less commonly) lower than those of normal plants grown under the same conditions[22].

The ratio of total potassium to total calcium in the leaf can similarly serve as an index of chlorosis and appears to be directly correlated with the phosphorus-iron ratio, increase or decrease in one ratio being accompanied by a corresponding increase or decrease in the other[23]. In this connection the sodium content of leaves does not appear to be of great consequence in crop plants while magnesium in many instances varies inversely with potassium also.

The Citric Acid-Malic Acid Ratio

Detailed studies of the organic acid composition of healthy and chlorotic plants are being made by paper and column chromatography in conjunction with the Department of Soil Organic Matter. Progress is necessarily slow. By these methods and by colorimetric tests it has been found that in accordance with the work of other authors, the amount of citric acid is higher in a chlorotic leaf than in a green leaf, whereas malic acid tends to be higher in the green leaf.

The Metabolic Control of the Mineral Elements

As the above ratios are seen to be correlated, change in any one ratio implying a change in the others, they must be part of some overall metabolic pattern. A scheme[24] which takes the above facts into account is the following: The major part of the iron in a plant cell is found to be attached to phosphoproteins and iron so attached is in the ferric form. The iron which is free in the cell is in the ferrous form and is physiologically active. In the metabolic

cycle of the organic acids, citric acid is converted to *cis*-aconitic and *iso*-citric acid by the enzyme aconitase which requires ferrous ions for its activity. If ferrous ions are lacking, citric acid will accumulate. There can be little doubt that the balance of potassium and calcium in a cell depends upon the balance of citric and malic acids or some similar balance between organic acids.

The Amino-acid Pattern and the Translocation of Iron

It has been found that in chlorotic leaves the free amino-acids are present in greater amounts than in green leaves. Also more free amino-acids are present in the roots of iron deficient mustard plants and amino-acids such as proline and pipecolinic acid, which may be involved in the chelation and transport of iron, appear in greater amounts.

Roots of chlorotic plants have been found to contain considerable amounts of iron, the translocation of which must be prevented in some way. Studies with the synthetic chelates such as ethylenediamine tetra-acetic acid (EDTA) have shown that iron is most probably transported as a nitrogenous organic chelate. Different species may have different chelating abilities in their roots, thus accounting for the ecological distinctions between "calciphobes" and "calciphiles." A study of chlorosis caused by toxic concentrations of heavy metals has similarly indicated that iron is transported as an organic chelate. Organic matter in the soil may contribute to the chelation and transport of iron[25] as shown by experiments with tomato plants, utilizing a "split-root" technique.

Types of Chlorosis

According to the above theory, chlorosis is essentially of two types depending on whether the phosphorus-iron ratio is higher or lower than in the normal green leaf.

(*a*) *Iron Deficiency Chlorosis.* This type of chlorosis, characterised by high phosphorus-iron, high potassium-calcium or potassium-magnesium ratios, would include iron deficiency, lime-induced chlorosis[26], calcium deficiency, and magnesium deficiency as well as phosphorus toxicity and potassium toxicity. Potassium deficiency in the soil is included here also as lack of potassium leads to an impeded transport of iron from the roots. It is thus well-known that plants suffering from potassium deficiency frequently have a high potassium content of the chlorotic leaves. Heavy metal toxicity[43] for example, due to excess of manganese, is similarly an iron deficiency chlorosis, as the heavy metal appears to interfere with the transport of iron. Nitrogen deficiency implies failure of formation of the nitrogenous chelate involved in iron transport. Plants suffering from chlorosis due to virus infection, as also variegated plants, have an iron-deficiency type of chlorosis, apparently dependent on the oxidation state of iron, possibly *via* manganese and some oxidising enzyme[23].

(*b*) *Iron Toxicity Chlorosis.* This form of chlorosis can be experimentally induced by supplying plants with excess of chelated iron. It is also met with in acid peat soils, in phosphorus deficiency, and in autumn coloration. It

also is typical of manganese deficiency, thus indicating that manganese controls the oxidation state of iron which in turn determines the amount of free organic acids and thus the amount of phosphorus in the cell. Thus manganese deficiency results in an excess of ferrous iron and very low phosphorus-iron values, while with manganese excess the converse becomes true.

The Concept of a Balanced Mineral Nutrition

As the above ratios of mineral elements are interconnected, there will be one particular state in which these elements are in optimal balance for production of chlorophyll. Each crop will have its own particular balance of elements, departure from these values implying that a particular element will become either deficient or toxic. A balanced fertilizer giving optimal yields can thus be devised for each crop.

From the above studies it would appear that synthesis of chlorophyll is governed by the oxidation state of iron. The relative amounts of catalase and peroxidase are concomitants of this oxidation state.

Nickel Toxicity

Studies in this field have progressed satisfactorily and three papers [27, 28, 29] have been published.

Metabolism of Sugar Beet Disks

From the time of their excision, and depending on the nature of the after-treatment, sugar beet disks show a characteristic absorption pattern for phosphate uptake. Since the phosphate absorption pattern must be influenced by the associated biochemical changes in the tissue, the primary object of the present investigation has been to relate the altered capacity for phosphate absorption to the other physiological and anatomical changes occurring in the disks with a view to elucidating the nature of the absorption mechanism.

The details of changes in the respiration, phosphatase activity, sugar content, mineral ion content, and organic acid content and variations in fractions containing organically bound nitrogen and phosphorus have been worked out. While this study has provided another illustration of the dynamic equilibrium between the several interlocking metabolic systems on which devolves the maintenance of vital activities in living plant tissue, so far no exact parallelism has been demonstrated between the rate of phosphate uptake and any one of the metabolic patterns studied.

The evidence, however, does suggest that phosphate absorption is related to the availability of certain organic compounds, possibly of a nucleosidic nature, the concentration of which is determined by synthetic processes dependent on respiration.

RADIOACTIVE STUDIES

The radioactive method of estimating plant available phosphate has been extended by the use of radioactive superphosphate. An extensive comparison has been made in pot experiments between this fertilizer and the labelled potassium dihydrogen phosphate used formerly. It has also been possible

for the first time to perform a number of small field experiments with different crops. Radioactive superphosphate has also been used in a small field experiment to determine the fraction of the phosphate in swedes derived from the fertilizer at different placements. In pot experiments the radioactive method has been employed to assess the phosphate status of a series of calcareous soils and to investigate the availability to plants of a number of forms of phosphate. Complementary laboratory studies on the determination of solid phase phospate have been continued. This work is in collaboration with the Department of Soil Fertility.

As part of an ecological investigation, a method of tracing the root systems of plants has been developed. Radiophosphorus was placed at various depths between 3 and 36 inches, placement for each depth being made to cover an area of approximately one square foot. After a suitable period of growth, the vegetation over each area was harvested and the plants separated according to species. Measurement of the radioactivity in the plant material indicated the size of the root system of the particular species at the depth of placement. From the satisfactory agreement between replicates and previous knowledge of root systems the method appears to be quite reliable. Excavation of sites with soil sampling has shown the method of placement to be effective.

Autoradiography has been used in several studies of the distribution of mineral elements in plants. A paper has been published in which it is shown that the concentration of iron is low in necrotic and chlorotic areas of nickel toxic oat plants[29].

The description of a simple method of preparation of radiocarbon for counting has been submitted for publication[42].

SOIL FERTILITY

Investigations covering the main soil types and agricultural crops have been continued and extended in accordance with the approved programme of work, and collaboration with other departments of the Institute and other research organisations and technical bodies has been maintained. Advisory work, with attendant lectures and illustrations covering the practical implications of recent results, has been continued in collaboration with the North of Scotland College of Agriculture. The department also continues to be represented on the Agricultural Research Council's Technical Conference on Fertilizers and on Technical Committees of the Department of Agriculture for Scotland.

Papers covering work on organic phosphorus in soils[31, 32], the fertilizer responses of cereals[33], and the effects of calcic and magnesium liming materials on the composition of crops[34] have appeared during the year. Two papers on the distribution and significance of phosphorus in soils and particle size fractions were presented and circulated in summary form at the Easter, 1955, meeting of the British Society of Soil Science in London, and fuller accounts have been accepted for publication[44, 45]. An account of co-operative work with the Animal Diseases Research Association on the effects of magnesian limestone on the magnesium content of pastures in relation to the magnesium level of the blood of cows consuming the herbage is also due to appear[46]; and revised versions of the Advisory Leaflets issued by the Department of Agriculture for Scotland entitled *Fertilizer Placement for Arable Crops* and *Improving Marginal Land* (Nos. 3 and 4, New Series, by A. B. Stewart, revised by J. W. S. Reith) have been prepared.

During the year, two visiting workers, Mr J. D. Colwell, from the Department of Agriculture, New South Wales, Australia, and Mr R. DuToit Burger, Stellenbosch-Elsenburg College of Agriculture, South Africa, completed post-graduate studies on phosphorus and potassium relationships of soils. References to these investigations have been made in previous reports and accounts of the main results will be published in due course.

In the experimental programme stress continues to be laid on the concurrent development and integration of field, pot and laboratory studies, and the main subjects under investigation are reviewed below.

FIELD EXPERIMENTS

The field programme is designed with two ends in view. The first of these is to establish the behaviour of the different soils and crops to provide the basis for: (a) assessing the significance of soil properties and pedological and environmental factors in relation to crop production, and (b) developing methods for evaluating nutrient status and fertilizer requirements. At the same time importance continues to be attached to improving fertilizer practice by the

practical application, through the medium of the advisory work, of information on the effects of lime, fertilizers, farmyard manure and trace elements on the yield and composition of crops, with particular reference to the factors of rate, frequency, time and method of application. To these ends, the policy of distributing experiments over recognised soil types at centres chosen in consultation with the Soil Survey Section has been continued. In the past, attention has been concentrated mainly on the Countesswells, Insch, Foudland, Stonehaven and Laurencekirk soils, but detailed work has now been started on the Tarves Association.

In addition to the work on phosphate and methods of applying fertilizers noted below, the 1955 programme covered: (a) the residual effects of various liming materials, (b) the effects of magnesium sulphate and trace elements on crop yield, and (c) the responses of different crops to, and the interactions of, nitrogen, phosphate and potassium. In the latter connection, increasing use is being made of an NPK factorial design with four levels of each nutrient, adjusted according to the crop. As with other classes of experiments, a number of these experiments is being laid down each year to cover seasonal effects.

Phosphate Relationships of Soils

Experiments on the residual effects of heavy dressings of superphosphate in limed and unlimed soils, and on the related questions of the significance of rate and frequency of application of phosphate for different crops, have been continued and extended. Further experiments on the effectiveness of different forms of phosphate, ranging from superphosphate through dicalcium phosphate and different mineral phosphates to compounds of iron and aluminium, have also been laid down. In these experiments particular attention is being paid to the nature of the response curves and to relative effectiveness at different rates of application. In addition, a new series of experiments has been started to test the long-term effects of heavy dressings of mineral phosphate. The 1955 programme also included a series of small-scale experiments with radioactive superphosphate, carried out in collaboration with the Section for Radioactive Studies to supplement the pot work on this subject.

Methods of Fertilizer Application

Examination of the results from experiments laid down in 1954 to obtain further data on the effects of placing fertilizers for swedes grown in ridges has been completed and a report is being prepared for the Agricultural Research Council. The findings confirm the conclusions noted in last year's report. With superphosphate alone placement directly below the seed is normally clearly superior to broadcasting, but it is only on soils showing a very large superiority of placed over broadcast phosphate that placing of NPK fertilizers is superior to the normal method of broadcasting on the flat before raising the ridges.

Four experiments carried out in collaboration with the North of Scotland College of Agriculture have indicated that where potatoes are planted in a single operation by one implement, placing of NPK fertilizer either in contact

with or to the side of the sets is generally superior to broadcasting. In the case of oats, comparisons with superphosphate have shown little difference between broadcasting: (a) on the ploughed surface immediately before preparing the seedbed, (b) on the seedbed, or (c) after drilling the seed, but all three methods were clearly inferior to combine-drilling; with potash, the method of application had no clear effects.

As indicated above, the main effects of placing fertilizers near the seed of swedes and turnips have now been established. In all the past work, however, the source of phosphate has been superphosphate. To cover this point, further experiments have been laid down to examine the effects of placing less soluble forms. Other features of the 1955 programme are: (a) additional tests on times of application of nitrogen for cereals, including comparisons of spray and solid applications of urea, and (b) extension of placement techniques to trace element problems with particular reference to the effectiveness of combine-drilled dressings and spray applications of manganese and copper sulphate on oats in deficient areas.

POT EXPERIMENTS

The pot tests continue to provide the essential link between the field and laboratory studies. Most of the 1955 programme has been devoted to further collaborative work with the Section for Radioactive Studies on the use of P^{32} to investigate the phosphate relationships of soils from field experiment areas, with particular reference to the evaluation of phosphorus status. The main feature of the current experiments is that it has been possible for the first time to obtain a supply of radioactive superphosphate. As already mentioned, this has enabled small-scale field experiments to be carried out to give a direct link with the pot tests, thereby broadening the examination of the usefulness and validity of the P^{32} approach. The scope of this investigation has also been extended by the inclusion of five different indicator crops and a range of calcareous soils.

Preliminary tests in 1954 showed that marked fixation of added phosphate can be induced by over-drying treatment of the soil, and further, more detailed experiments of this type have been carried out to study the extent and significance of phosphate fixation in different soil types. Other points being covered are the responses to manganese and copper on soils from problem areas, and further tests on the effectiveness of different organic and inorganic forms of phosphate, including a supplementary evaluation with the aid of P^{32}.

LABORATORY WORK

Examination of soil and produce samples from field and pot experiments, amounting to a total of about 5,000 samples a year, continues to be a major item in the laboratory. In addition to this and advisory soil analyses, attention has been focussed mainly on the following subjects.

Characterization of Soils

Soil samples from field experiment areas before treatments are applied form the main basis for the ultimate evaluation of the significance of soil properties

in relation to crop production. The characterization of these samples is therefore of particular importance and an examination of this question is in progress using forty soils representing ten experiment areas on each of the four main soil associations in north-east Scotland. These samples are being subjected to a wide chemical characterization and are also being examined by the Sections for Soil Geology and Mineralogy and Physical Chemistry to provide trial evaluations of the significance of various properties in relation to crop data from field and pot experiments.

Phosphate Investigations

Chromatographic work on the organic phosphorus fraction in soils has been continued. As mentioned in a preliminary note[31], upward development of phytin hydrolysates with a methanol/ammonium hydroxide solvent on specially purified paper yields four spots containing inositol phosphates. With the aid of authentic specimens these have now been identified, enabling the method to be used for estimating very small quantities of the various inositol phosphates. In this way the hydrolysis of phytin and its derivatives can be followed, and the method should also be applicable to the study of inositol phosphates in plant material. A procedure for macro-separation of the phytate fraction from soils has also been established. Used in conjunction with chromatographic analysis of the product this provides a method for quantitative estimation of inositol phosphates in soils. This method is being applied to study the distribution in different soil types and an account of the experimental procedure is being prepared for publication.

During a stay of some months in the department, Mr C. H. Williams, Division of Plant Industry, C.S.I.R.O., Canberra, Australia, collaborated in further work on the determination of total organic phosphorus in soils. An account of earlier work on this subject has been published[32] and was summarized in last year's report. The subsequent work covers comparisons between two versions of the ignition method, using extraction with 0·2N or 2N H_2SO_4, and the hot 0·1N HCl-cold 0·1N NaOH extraction method on a range of surface soils from different associations. The results confirm the validity of the ignition method for acid soils and will be presented in a forthcoming publication.

Work on the distribution, solubility and retention of inorganic phosphorus in different soil types, including experiments in collaboration with the Section for Radioactive Studies, has also been continued. In this connection, examination of the distribution and solubility of phosphorus in particle size fractions has proved very instructive. Summaries of this work have been circulated and two papers have been accepted for publication [44, 45]. The first of these deals with the distribution of total, total organic, total inorganic and 0·2N H_2SO_4 soluble inorganic phosphorus in soil samples and particle size fractions representing seven profiles, covering four soil associations and including three pairs of corresponding freely drained and poorly drained members. The results emphasize the importance of drainage conditions in the phosphate relationships of the soils and in general poor drainage is reflected in: (a) much lower total organic, lower total, but rather higher total

inorganic phosphorus; (b) a very abrupt fall in the organic phosphorus with depth; (c) higher phosphorus contents for the sands but much lower contents in the clays; (d) higher amounts and proportions of the soil inorganic phosphorus present as sand and correspondingly lower amounts and proportions as clay; (e) higher acid soluble inorganic phosphorus in the soils, reflecting both the higher amounts and higher solubility of the phosphorus in the sands; and (f) lower contents of hydrosulphite extractable iron in the upper horizons but higher contents in the gleyed subsoils, and lower oxalate soluble aluminium throughout the profiles. Other striking features of the results are:

(1) The clay and silt account for upwards of 85 per cent. of the total soil organic phosphorus. In the topsoils, the proportions of the total phosphorus in organic form are 27-67 per cent. for the soils compared with 50-65 per cent. for the silts and clays.

(2) The phosphorus contents of the fractions vary widely depending on the soil, but the total phosphorus is normally highest in the clay and lowest in the coarse sand, the main exceptions being the gleyed subsoils where the fine sands are richer than the clays.

(3) The phosphorus in the sands is largely inorganic and for about half of the samples, including most of basic igneous soils and the gleyed subsoils, the fine sand is richer in inorganic phosphorus than the clay.

(4) In the topsoils, the coarse sands account for 12-22 per cent. of the total soil inorganic phosphorus and the fine sands for 18-50 per cent., giving totals of 34-62 per cent. in the combined sands. The general tendency is for these proportions to increase with depth and in the gleyed subsoils the values for the combined sands are of the order of 70-80 per cent.

(5) The inorganic phosphorus in the sands, particularly the fine sand, is very highly soluble in 0·2N H_2SO_4 and appears to be largely calcium-bound. For most of the samples, 50-80 per cent. of the inorganic phosphorus extracted by this reagent is derived from the sands, but the composition and significance of the value vary widely depending on the distribution of phosphorus over the fractions. This is true also for total phosphorus by the oxalate and hydrosulphite methods. The latter, particularly, attacks the sands to varying extents and the oxalate values are strongly influenced by organic phosphorus.

(6) The main effect of parent material is that the sands, particularly the fine sands, are richer in phosphorus and account for higher proportions of the total soil phosphorus in the basic igneous soils. These soils are also relatively rich in aluminium and iron.

The presence of large and varying amounts of acid soluble phosphorus in the sands has several implications in relation to the evaluation of phosphorus status. This aspect is dealt with in the second paper[45], with particular reference to the significance of the particle size fractions in readily soluble phosphorus determinations by dilute acid reagents. From determinations on the fractions separately and in combination, the occurrence of secondary reactions during such extractions on soils has been demonstrated and the degree of interaction between fractions measured. The main factor appears

to be sorption by the clay of phosphorus dissolved from the sands. The amount of interaction during soil extractions depends on the first place on the experimental conditions, particularly the pH, period of extraction and solvent:solid ratio, which govern both the solution of phosphorus from the sands and its subsequent sorption by the clay. The extraction of the sands appears to be essentially a dissolution of calcium-bound phosphorus from the relatively coarse particles because the values are higher the lower the pH, increase exponentially with time, but are relatively little affected by changes in solvent:solid ratio. The extraction of the clay is more complicated and subject to internal secondary reactions, but the dominant factor appears to be a desorption of surface phosphate because the amount in solution increases markedly with increasing solvent:solid ratio and attains a maximum in a short time. As a result the extent of interaction between fractions during soil extractions is greatly favoured by a narrow solvent:solid ratio and a long period of extraction which increase not only the amount of phosphorus dissolved from the sands but also its resorption by the clay. Similarly, the amount of interaction is normally highest at a pH in the region where the phosphate sorption capacity of the clay is at or near its maximum, and is greatest in soils which have both a high sorption capacity and a high amount of phosphorus in the sand fractions. On the basis of these principles the relative and absolute extracting powers of the acetic, Truog and lactate methods on the wide range of soils and fractions examined are readily understood. It is also clear that the distribution of phosphorus over the particle size fractions is a factor of major importance in the phosphate relationships of soils.

Air and Rain Water Sampling

An apparatus for this purpose has recently been installed as part of an international scheme in collaboration with the Institute of Meteorology of the University of Stockholm, the Chemistry Department of the Royal Agricultural College of Sweden and the Department of Meteorology, Imperial College, London.

ADVISORY WORK

During the year about 10,000 soil samples have been tested to assess lime, phosphate and potash requirements. These comprised mainly samples from agricultural and horticultural land received through the staff of the North of Scotland College of Agriculture, but they included also a number of soils from forest nurseries which were tested for the Forest Soils Section. As in the past, numerous problems involving magnesium and trace elements, particularly cobalt, have been dealt with in collaboration with the Departments of Spectrochemistry and Plant Physiology.

Grouping of the results for advisory soil samples from agricultural land in Aberdeenshire and Kincardineshire according to soil associations has been continued, and the data for the five-year period 1950-54 are summarized in the accompanying table. Deficiencies of lime and phosphate continue to be both acute and widespread. Potash deficiency is extensive but less pro-

Grouping of Advisory Soil Samples from Rotation Land in Aberdeenshire and Kincardineshire according to their contents of Lime, Phosphate and Potash

1950-54

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

Parent Material Group.	Soil Association.	No. of Samples Exam'd	Lime			Phosphate			Potash		
			S.	S.L.	L.	S.	S.L.	L.	S.	S.L.	L.
All Groups		17665	8	55	37	11	50	39	25	63	12
A. Acid Igneous Boulder Clays	All Associations,	5015	4	44	52	13	56	31	18	70	12
	Countesswells	4305	3	44	53	14	57	29	15	70	15
	Strichen	710	9	47	44	6	49	45	29	68	3
B. Medium and Basic Igneous Boulder Clays	All Associations,	4460	6	55	39	9	53	38	27	66	7
	Insch	1201	5	60	35	12	55	33	23	68	9
	Tarves	3074	6	52	42	8	52	40	30	64	6
	Leslie	115	20	65	15	4	47	49	16	76	8
C. Old Red Sandstone Boulder Clay	All Associations,	2047	13	53	34	27	52	21	42	56	2
	Cruden	740	9	54	37	13	48	39	49	50	1
	Stonehaven	909	11	52	37	33	54	13	36	61	3
	Laurencekirk	398	24	53	23	40	55	5	43	56	1
D. Slate Boulder Clay	All Associations,	2440	4	47	49	5	42	53	32	63	5
	Foudland	2440	4	47	49	5	42	53	32	63	5
E. Water Sorted Sediments	All Associations,	2700	7	50	43	16	58	26	20	66	14
	Corby	1656	6	51	43	14	60	26	16	67	17
	Alluvium	448	7	53	40	12	50	38	21	64	15
	Corby & Boyndie	289	7	46	47	20	54	26	29	63	8
	Auchinblae	227	9	47	44	32	55	13	26	70	4
F. Old Red Sandstone Boulder Clays, Medium and Light Textured	All Associations,	726	3	46	51	8	46	46	22	68	10
	Ordley & Hatton	639	2	44	54	5	43	52	21	67	12
G. Siliceous Deposits	All Associations,	221	0	37	63	4	48	48	27	66	7
	Skelmuir	206	0	29	61	4	47	49	28	64	8

S.—satisfactory: S.L.—slightly low: L.—low.

nounced, the majority of the samples falling into the slightly low category. Comparison of the different associations shows that lime deficiency appears to be somewhat less pronounced on the Laurencekirk and Leslie associations and rather more pronounced on the Skelmuir association. In the case of phosphate, the position is somewhat better on the Stonehaven, Laurencekirk and Auchinblae associations, and slightly poorer on the Strichen, Leslie, Foudland, Ordley and Hatton and Skelmuir soils. The position regarding potash is best on the Cruden, Stonehaven and Laurencekirk associations and tends to be least satisfactory on the Countesswells, Corby, Alluvium and Ordley and Hatton groups.

The main trends in the relationships between the various associations shown by the present results are much the same as those noted for the corresponding data tabulated in the 1949-50 report for samples tested during the period 1941-49. Comparison of the two sets of data, however, shows that the 1950-54 series has higher proportions of samples in the satisfactory and slightly low categories. This trend is fairly consistent for lime, phosphate and potash, and for all the associations. The significance of this apparent improvement is not certain because it is possible, for example, that the 1950-54 series may have contained a higher proportion of samples from the better class of land. However, it seems probable that there has to some extent been a real improvement, resulting from heavier and more widespread use of lime and fertilizers.

FOREST SOILS

Growth of Corsican Pine on Sand Dunes

The study of the major nutrient status of Corsican Pine at Culbin Forest by means of periodic leaf analyses has been continued for a full year, with the object of investigating a possible correlation between the abnormal fluctuations in foliage nutrient content already observed at Culbin and the low levels of soil moisture existing in the dunes during the spring and summer. It appears that heavy thinning delays for several weeks the drying out of the sand which takes place in early spring in the zone of greatest root development, and that during this period the foliage nutrient content of the trees is improved by heavy thinning.

The assessment of the response of young Corsican Pine to phosphate manuring in the plots laid down at Culbin in April 1954 has been continued. No increase in the rate of height growth was detected during the first season, but an increase in the calcium content of the foliage was observed in the manured plots, which became more pronounced during the second growing season. The work is being continued.

Tree Growth on Deep Peat

An investigation has been started into the chemical and physical changes taking place in some of the deep peats of the north and west of Scotland as a result of afforestation, with the object of assessing their possible effects on the future growth of the trees. The sample plots and species trials at the Lon Mor, Inchnacardoch Forest, Inverness-shire, have been chosen as a suitable site for the preliminary work, and chemical analysis of a set of samples from the upper layers of the unplanted peat, and from planted areas treated with ground mineral phosphate at various rates of application, has shown that it is possible to detect by normal chemical means the presence of phosphate applied up to thirty years ago, and suggests that the concentration of readily soluble nutrients in the peat is lowest under trees showing the most vigorous growth.

Soil Investigations in Forestry Commission Thinning Plots

The soils of the Norway Spruce thinning plots at Bowmont Forest, Roxburghshire, are being studied as part of a programme of research initiated by Forestry Commission Research Branch. The weight and major nutrient content of the litter collected at monthly intervals from the different thinning grades are being determined, and possible effects of thinning on the physical and chemical properties of the surface soil are being studied, with particular reference to macro- and micro-aggregate stability and pore space.

Advisory and Collaborative Work

Routine chemical analysis of forest nursery soils on behalf of the Forestry Commission and private owners has been continued, in association with the Department of Soil Fertility. Similar analysis has been carried out on samples of Malayan forest soils submitted by Mr D. S. Lowson, Malayan Forest Service, in connection with his work at the Imperial Forestry Institute, Oxford, on the afforestation of derelict tin mining areas.

On behalf of the section, spectrochemical analysis of the zinc content of seedlings of *Nothofagus obliqua* and *N. procera* has been undertaken by the Department of Spectrochemistry on material submitted by the Forestry Commission, which has confirmed a suspected case of zinc poisoning due to the use of galvanised iron screens over the seedbeds.

STATISTICS

The work of this section can be classified under three main heads:

(1) The planning of experiments and experimental programmes.

(2) Routine statistical analyses of results.

(3) Critical statistical analyses of bodies of experimental and observational data.

Numerous types of short-term field experiments are designed and the routine statistical analyses carried out each year. Increasing numbers of laboratory and pot experiments are also being dealt with, and an account of collaborative work with the Department of Plant Physiology, embodying the statistical design and analysis of a factorial sand-culture experiment, has been published[27]. Further analyses and reports have also been made on the results of the series of co-operative grassland experiments organised by the Grassland Sub-Committee of the Scottish Agricultural Improvement Council.

Some series of field experiments have now reached the stage where critical analyses and assessment of the results are necessary and from one such series, of factorial design, information on the responses to and interactions of nitrogen, phosphate, potash and dung is being obtained. In other cases, where the number of fertilizer levels is suitable, preliminary work has been carried out on the fitting of Mitscherlich type response curves.

During the year a Madas model 20 AG calculating machine was purchased.

Meantime the section is accommodated in the Statistics Department of the University of Aberdeen. Acknowledgement is made for the courtesies shown by The University and in particular to Dr D. J. Finney, F.R.S., for all the assistance given.

PUBLICATIONS

(A) *Published during the year—*

1. The effect of soil forming factors over an area in the south of Scotland. By J. W. Muir. (*J. Soil Sci.*, **6**, 84-93, 1955).

   A general description of the area is given with data on the climate and geology. The area covers approximately 500 square miles consisting of most of Roxburghshire and small parts of Selkirkshire and Dumfriesshire. The major soil groups are described and the influence of each soil-forming factor on their occurrence and distribution is discussed.

2. A review of the mineralogy of Scottish soil clays. By W. A. Mitchell. (*J. Soil Sci.*, **6**, 94-98, 1955).

   A comparison of the results of quantitative mineralogical analyses of Scottish soil clays from 51 profiles shows significant differences between the soils on basic igneous rocks on the one hand, and on granite and various sedimentary and metamorphic rocks on the other. The former group is characterized by the predominence of montmorillonite or vermiculite, whilst in the latter illite predominates. The influence on clay mineralogy of drainage differences in soil profiles is more pronounced in soils on basic than on acidic parent materials. The weathering products of some common rock minerals are discussed with reference to the analytical results. Soil clay minerals are referred to three categories: those inherited from the parent material, those formed by alteration of the parent minerals, and those synthesized in the soil.

3. Mineralogy of the Interbasaltic rocks. By W. A. Mitchell. (Contribution to *The Tertiary lava succession in the northern part of the Antrim plateau.* By E. M. Patterson, University of St. Andrews). (*Proc. Roy. Irish Acad.*, **57**, 115-117, 1955).

   The characterization of the rocks of the Tertiary lava succession in Antrim by E. M. Patterson is based on chemical analysis and optical identification of the minerals. Optical methods, however, cannot be used for the fine-grained minerals of the interbasaltic laterites and these were identified by X-ray diffraction. The samples were taken from a considerable area in North Antrim and the results showed a distinct trend from east to west. This appeared as a decrease in the silica content in the chemical analyses, and in the mineralogy as a decrease in the clay minerals and increase in haematite and gibbsite. Some of the samples contained kaolin minerals which are normally associated with laterites, but others had a high proportion of montmorillonite. Haematite and gibbsite contents exceeded 45 per cent. in samples from the west of the area. The mineralogical results corresponded well with the chemical analyses.

4. A study of the more important soils of the Zanzibar Protectorate. By W. E. Calton (Chemical Laboratory, Dar es Salaam), G. E. Tidbury (Department of Agriculture, Zanzibar), and G. F. Walker. (*E. Afr. agric. J.*, **21**, 53-60, 1955).

   A description is given of the soils of Zanzibar and Pemba islands with special reference to their general pedology, utilization, and clay mineralogy.

5. Comparative performance of nickel and porous alumina sample holders for differential thermal analysis. By R. C. Mackenzie. (*Nature*, **174**, 686, 1954).

   Some data are given for identical metal and ceramic sample holders, confirmatory of and supplementary to those of T. L. Webb (in a preceding note). The decrease in size of exothermic peaks in the metal holder is particularly noteworthy in view of the con-

flicting evidence in the literature. The characteristics of different types of sample holder are discussed and it is pointed out that alumina holders with low porosity may be as efficient in certain applications as metal ones.

6. Trace elements in some constituent species of moorland grazing. By R. L. Mitchell (*J. Brit. Grassl. Soc.*, **9**, 301-311, 1954).

Trace element determinations (Co, Ni, Fe, Mn, Zn, Pb, Sn, Cu, Ti, Ba and Sr) in 6 constituent species of two moorland grazings in Sutherland, sampled at intervals over 3 years, with a few comparative analyses from north-east Scotland.

7. Trace elements and liming. By R. L. Mitchell. (*Scot. Agric.*, **34**, 139-143, 1954/5).

A discussion of the effects of liming on trace element uptake by plants.

8. Trace elements. By R. L. Mitchell. (pp. 253-285 of *Chemistry of the Soil*. Amer. Chem. Soc. Monograph 126. Reinhold, 1955).

An account of the geochemical occurrence of trace elements in soil parent materials, of the influence of pedological processes on their distribution in soil profiles, and of factors affecting their availability. (*No reprints*).

9. Trace elements in Scottish peats. By R. L. Mitchell. (*Papers Int. Peat Symposium, Dublin, 1954, Section B3*).

Analyses of samples from selected horizons of deep peat profiles have shown that in certain lower layers at depths of 100-600 cm. zones of accumulation of certain trace elements occur. In some instances the content may be up to 100 times that of other horizons of the same profile. Elements for which some concentration has been noted include Ba, Co, Ni, Mo, Fe, V, Ti, Cr, Cu, Pb, Mn, Zn, Ge, Be, Ga, Zr and certain rare earths. Further investigation is required before definite conclusions can be drawn regarding the processes involved.

10. Dental depigmentation and lowered iron in the incisor teeth of rats deficient in vitamin A or E. By T. Moore (University of Cambridge) and R. L. Mitchell. (*Brit. J. Nutr.*, **9**, 174-180, 1955).

A study of the relationship of iron content to depigmentation of the incisor teeth of rats fed on diets deficient in vitamins A or E. Iron was determined by an arc emission method. In ash of depigmented enamel from deficient animals the Fe content was lower than that for animals dosed with vitamin A or E.

11. The spectrochemical analysis of plant material. By R. L. Mitchell. (pp. 48-67 of *Analyse des Plantes et Problemes des Engrais mineraux*. Colloque dans le cadre du VIII Congres International de Botanique, Paris, 1954. I.R.H.O., 13, Square Petrarque, Paris 16e).

A review of the various methods of spectrochemical analysis applicable to the determination of major and trace elements in plant materials and of the methods of sampling and pretreatment involved.

12. The pressed-disk technique in infra-red spectroscopy. By V. C. Farmer. (*Chem. and Ind.*, 586-587, 1955).

The infra-red spectra of solid samples can be conveniently obtained from pressed disks of an alkali halide in which the samples have been freely dispersed. Molecules containing hydroxyl groups, however, may become adsorbed on the particles of the alkali halide. The spectrum of the adsorbed molecules often differs markedly from those in the normal crystalline state. Spectra of benzoic acid are given to show the effect, and the conditions under which it occurs are discussed.

13. The formation of anisic acid by oxidation of methylated sphagnum. By V. C. Farmer and R. I. Morrison. (*Chem. and Ind.*, 231, 1955).

The production of anisic acid from diazomethane-methylated *Sphagnum* in 4 per cent, yield (calculated on the unmethylated material) by oxidation with aqueous potassium permanganate is offered as confirmatory evidence of the presence of a

p-hydroxy-phenyl unit with a free phenolic hydroxyl group as an important constituent of the lignin of *Sphagnum*. The fact that no other aromatic acids were obtained indicates that vanillyl and syringyl groups (characteristic of the lignins of higher plants) are absent from *Sphagnum*.

14. Utilization by soil fungi of *p*-hydroxybenzaldehyde, ferulic acid, syringaldehyde and vanillin. By M. E. K. Henderson and V. C. Farmer. (*J. gen. Microbiol.*, **12**, 37-46, 1955).

A number of fungi isolated from soils under a variety of vegetational types was found to attack *p*-hydroxybenzaldehyde, ferulic acid, syringaldehyde and vanillin. These compounds were used as sole source of carbon by the organisms tested. By means of spectrochemical methods and paper chromatography it was shown that vanillin and ferulic acid were converted to vanillic acid before the breaking of the benzene ring, and syringaldehyde was converted to syringic acid. The bearing of these results on the breakdown of lignin in soil is discussed.

15. Classification and nomenclature of peat and peat deposits. By G. K. Fraser. (*Papers Int. Peat Symposium, Dublin, 1954, Section B2*).

A classification system is proposed for discussion divided broadly between (a) Climatic or zonal bogs and (b) Topogenic or intrazonal bogs. Some terms used in peat classification are discussed.

16. Soil organic matter. By G. K. Fraser. (pp. 149-176 of *Chemistry of the Soil*. Amer. Chem. Soc. Monograph 126. Reinhold, 1955).

An account is given of the present state of knowledge concerning soil organic matter. The nature of its component substances, their origin and transformation, together with methods of fractionation and analysis, are the principal topics considered. (*No reprints*).

17. Two Scottish pollen diagrams: Carnwath Moss, Lanarkshire, and Strichen Moss, Aberdeenshire. Data for the study of post-glacial history. XVII. By G. K. Fraser and H. Godwin (University of Cambridge). (*New Phytol.*, **54**, 216-221, 1955).

Pollen diagrams prepared by Dr Fraser are interpreted and commented on by Dr Godwin. These diagrams from Scottish sites, represent a northern facies of the pattern of post-glacial forest history already confirmed for England and Wales. In addition to the variations of proportion establishing the main zones which are here relatively small, there are certain long-term drifts which deserve consideration, in particular the steady increase of birch corresponding to steady decreases in alder and hazel. The explanation of this may lie in the progressive leaching of fresh soils and the building up over wide areas of acid moor soils (and subsequently of oligotrophic bog).

18. The partial identification of O-methyl sugars occurring in soil and peat compost By R. B. Duff. (*Chem. and Ind.*, 1513, 1954).

Two of the three O-methyl sugars found in small amounts in soil, peat and compost have been partially identified. Application of a micro-periodate oxidation technique has shown that these are 2-O-methyl aldoses, and there is a suggestion that they are 2:6 or 2:7 di-O-methyl aldoheptoses which is of interest in view of the recent prominence given to heptose sugars in carbohydrate dissimilation in plants, yeasts and animals.

19. The morphology of *Nocardia opaca* Waksman and Henrici (*Proactinomyces opacus Jensen*) when grown on hydrocarbons, vegetable oils, fatty acids and related substances. By D. M. Webley. (*J. gen. Microbiol.*, **11**, 220-225, 1954).

Nocardia opaca Waksman and Henrici can use certain long chain saturated aliphatic hydrocarbons and many vegetable oils as sole carbon and energy source in the presence of simple mineral salts. Long chain saturated aliphatic acids (*e.g.*, myristic, palmitic and stearic) can similarly serve. The same morphological development is obtained on

all these compounds but the initial mycelial phase is more pronounced on oily substrates (particularly hydrocarbons) than on water soluble or insoluble solid substances. Granules are demonstrable inside the cells. These granules are more intensely stained with fat and polysaccharide reagents than the rest of the cell. Well-defined electron dense bodies are also observed which behave similarly to the "mitochondria" described by Mudd, Winterscheid, Delamater and Henderson (*J. Bact.*, **62**, 459, 1951) in *Mycobacterium thamnopheos* under intense electron bombardment.

20. Release of aromatic compounds from birch and spruce sawdust during decomposition by white-rot fungi. By M. E. K. Henderson. (*Nature*, **175**, 634, 1955).

Two white-rot fungi, *Polystictus versicolor* and *Trametes pini* were allowed to grow on birch and spruce sawdust for 6 months when it was found that both vanillic and syringic acid had formed from beech wood yet only vanillic acid from spruce wood. Their presence was identified by paper chromatography.

21. A convenient shaking machine for growing micro-organisms. By D. M. Webley and R. B. Duff. (*J. appl. Bact.*, **18**, 122-123, 1955).

Details are given for the construction of a simple reciprocal shaking machine for use in small constant temperature rooms. It is particularly useful for the uniform growth of pellicle forming organisms.

22. Factors contributing to the growth promoting properties of Veleje lignite. By E. L. Strmecki and P. C. de Kock. (*Soil and Plant*, Beograd, **3**, 1-20, 1954). (*Slovenian, with English summary*).

The mineral elements, including trace elements, present in Velenje lignite were determined. The growth promoting properties of the lignite were investigated using mustard in water culture. It was concluded that the micro-nutrients present in the lignite did not account for the growth stimulation obtained but rather that the humic substances were responsible presumably acting as complexing agents for iron which thus rendered the iron more available to the plant. As chlorotic leaves were found to contain as much iron as healthy leaves, the humic acid probably influenced the form of iron within the plant. (*No reprints*).

23. The phosphorus-iron relationship in genetical chlorosis. By P. C. de Kock and A. Hall. (*Plant Physiol.*, **30**, 293-295, 1955).

The ratios of phosphorus to iron and of calcium to potassium of chlorotic leaves of variegated plants show the same trends from those of normal leaves as are shown in other forms of chlorosis, the phosphorus-iron ratio being higher and the calcium-potassium ratio lower than for normal green leaves. This also applies to chlorosis due to virological or pathological causes.

24. Chlorosis and the iron nutrition of plants. By P. C. de Kock. (*A.R.C. Memo*, 667/54, 1954).

The ratio of phosphorus to iron, potassium to calcium, and citric acid to malic acid are metabolically controlled. If a leaf which is chlorotic due to iron deficiency is greened by application of iron all the above ratios, which are high in a chlorotic leaf, alter to values characteristic of green leaves.

25. Influence of humic acids on plant growth. By P. C. de Kock. (*Science*, **121**, 473-474, 1955).

Brief note of experiments confirming that ethylenediamine tetraacetic acid, absorbed by the roots in one compartment, caused translocation to the leaves of iron supplied in the presence of high phosphate from the roots of the other compartment. Water extract of peat and a humus-like substance synthesized from sucrose were equally effective in preventing iron chlorosis. It would appear that it is the level of soluble iron in the cells of the root that determines how much iron will be translocated to the leaf.

26. Iron nutrition of plants at high pH. By P. C. de Kock. (*Soil Sci.*, **79**, 167-175, 1955).

Mustard plants were grown in nutrient solution at pH 7·8 with iron (1 ppm) supplied as the chloride, Versenate, Versen-ol, and Versene-diol. Sodium chloride or sodium bicarbonate was added to each treatment, and each set of eight was aerated with 1 per cent. or 20 per cent. oxygen (air). Iron nutrition of the plants showed a progressive improvement in the four forms of iron in the nutrient in the order mentioned. Bicarbonate tended to increase the severity of chlorosis, whereas reduction of oxygen supplied to the roots reduced chlorosis. Analyses of these plants are given and the various effects are discussed with special reference to the phosphorus-iron ratio as an index of the iron status of plants.

27. The relationship between nickel toxicity and major nutrient supply. By W. M. Crooke and R. H. E. Inkson. (*Plant and Soil*, **6**, 1-15, 1955).

A factorial sand-culture experiment was utilized to investigate the effect of variation in the level of supply of major nutrients on nickel toxicity in oat plants. Two levels of each of the nutrients, nitrogen, phosphorus, potassium, calcium and magnesium solution (0 and 2·5 ppm). The yield of dry matter is markedly reduced by nickel, the effect being greatest when calcium or potassium supply is low or phosphorus supply is high. Yield can be improved by increasing the first two factors or reducing the third. Symptoms of nickel toxicity in oat plants are briefly described; an increase in the rate of supply of nitrogen, potassium, calcium, or magnesium decreases the toxic symptoms while an increase in phosphorus supply has the reverse effect. Uptake of nickel by plants is not correlated with level of symptoms found. Similarly, the use of the Ni/Fe ratio in the plant, which has previously been shown to give a measure of toxicity, is found to be of limited applicability in this case. The correlation between symptoms and the Ni/Fe ratio is not statistically significant when treatment differences are removed. An increase in rate of supply of phosphorus causes a significant increase in the uptake of nickel. Variation in the supply of the other major nutrients does not significantly affect the uptake of nickel. The pattern of behaviour between nickel and major nutrients found here for sand-cultured oats agrees well with results observed in the field.

28. Further aspects of the relationship between nickel toxicity and iron supply. By W. M. Crooke. (*Ann. appl. Biol.*, **43**, 465-476, 1955).

Absorption of nickel by oat plants increased with increasing pH for a fixed iron supply. Nickel uptake and toxicity symptoms (necrosis and chlorosis) were both reduced when the concentration of iron in the nutrient solution was high. Absorption of nickel and the intensity of necrosis increased with increase in the Ni/Fe ratio in the nutrient solution. For solutions with the same Ni/Fe ratio, toxicity symptoms increased with increase in the absolute amount of nickel. There was a linear relationship between the degree of necrotic symptoms and the Ni/Fe ratio in the plant. Nickel consistently reduced the iron content of roots and tops. In the absence of nickel the iron content of the roots, but not of the tops, increased with iron supply. In nickel-toxic plants the magnesium, calcium and phosphorus contents of the tops and the potassium, calcium and phosphorus contents of the roots were higher than in healthy plants, but the potassium content of the tops and the magnesium content of the roots were lower.

29. The relationship between nickel-toxicity symptoms and the absorption of iron and nickel. By W. M. Crooke and A. H. Knight. (*Ann. appl. Biol.*, **43**, 454-464, 1955).

During a 70-day experimental period from germination to maturity, the iron content of oat plants that showed symptoms of nickel toxicity changed little, but the nickel content increased rapidly for about 30 days and then decreased slowly. Necrosis varied little with time, while chlorosis increased in severity for 40 days then decreased until unfolding young leaves were no longer chlorotic. This change in chlorotic symptoms was correlated with the Ni/Fe ratio in the plant. Autoradiographs of leaves from plants supplied with radioactive iron showed that necrotic areas in the leaf matched areas in the autoradiograph having a very low content. Chlorotic areas

were found to correspond with areas whose iron content was lower than that of healthy tissue. More iron was found in the veins than in the interveinal tissue, and its distribution was the same whether supplied as ferric citrate or in a chelated form. The concentration of iron in mature leaves from oat plants growing in a nickel-toxic soil was lowest in the necrotic areas of the leaf, suggesting a migration of nutrients out of this dying tissue.

30. Soil moisture determination by neutron scattering. By A. H. Knight and T. W. Wright. (*Proc. II. Radioisotope Conf.*, **2**, 111-120, 1954).

When a fast neutron source is buried in soil the production of slow neutrons, chiefly by collision with hydrogen nuclei, has been found to be proportional to the moisture content of the soil. A probe-type unit suitable for field use, employing a 50 mc. Ra-Be source and either indium or silver foil as the slow neutron detector has been constructed and calibrated. The volume of soil sampled by the unit has been determined, and the effect of exposure time on counting rate has been investigated. Hydrogen in organic matter appears to have little effect on counting rate, and the instrument may therefore be applicable to all types of soil and to other organic materials.

31. Paper chromatography of inositol phosphates. By G. Anderson. (*Nature*, **175**, 863, 1955).

Paper partition chromatography of mixtures of inositol phosphates, obtained by partial hydrolysis of inositol hexaphosphate, yields four spots when a methanol-ammonium hydroxide solvent is used for development The identity of the compounds is being confirmed. The method of separation is a useful approach to a qualitative and quantitative study of soil inositol phosphates.

32. Observations on the determination of total organic phosphorus in soils. By W. M. H. Saunders and E. G. Williams. (*J. Soil Sci.*, **6**, 254-267, 1955).

The validity of total organic P values measured as the increase in inorganic P extracted by 0·2 N H_2SO_4 following ignition of soils at 550°C has been tested by examining the effects of varying the experimental conditions and comparing with values obtained by extractions with 0·5N NH_4OH and 0·1N NaOH after different acid pretreatments. The sources of error and range of application of the different methods are discussed. It is concluded that for acid soils of the types examined the simple and rapid ignition method gives valid results, and is very suitable for characterizing soils in pedological studies and fertility investigations.

33. Cereal responses to fertilizers. By J. W. S. Reith. (*Scot. Agric.*, **34**, 90-94, 1954).

The need for nitrogen, phosphorus and potassium under Scottish conditions and the increases in yield of grain that can be expected from single nutrient and mixed fertilizers are discussed in the light of field experiment results. Attention is drawn to the fact that lack of lime often limits crop production while the injurious effects of overliming are mentioned. The time and method of applying fertilizers are also discussed. For instance, experiments on oats do not show any benefit from delaying the application of part of the nitrogen dressing until a few weeks before ear emergence.

34. Effects of calcic and magnesian liming materials on the calcium and magnesium contents of crops and pasture. By J. W. S. Reith. (*Emp. J. exp. Agric.*, **22**, 305-313, 1954).

A range of crops was grown in 5 field experiments involving treatments with calcic and magnesian liming materials, and the effect of these treatments on the amounts of calcium and magnesium in the crops was determined. Results showed that applying limes rich in magnesium produced quite large increases in the percentage of this nutrient in the tops of mangolds, fodder beet, sugar-beet, and turnips, in the leaves of kale, in cereal straw and in hay. The magnesium contents of the roots, stems, and grains were practically unaffected by the types of liming material used. With mixed herbage cut at regular intervals of 2 to 4 weeks, there was a 60 to 100 per cent. variation in the percentages of calcium and magnesium during the growing season. These values were

relatively low during April, May and early June, and gradually increased until August, after which they remained reasonably constant. Over a 3-year period magnesian limestone increased the magnesium content of mixed herbage throughout the growing season by 55 per cent. as compared with no lime or ordinary ground limestone.

35. Profile development in the sand dunes of Culbin Forest, Morayshire. I. Physical properties By T. W. Wright. (*J. Soil Sci.*, **6**, 270-283, 1955).

Changes in some physical properties of the sand dunes of Culbin Forest, Morayshire, brought about by fixation and afforestation of the sand, have been studied on sites ranging from bare sand to mature plantations. Trees appear to be having no measurable effect on the mechanical composition of the sand apart from the deposition of litter, but studies of soil moisture and temperature, using gypsum moisture blocks and thermistors have shown that, while the moisture content of the unplanted dunes remains comparatively high throughout the growing season, due to their coarse texture, the growth of trees dries out the sand considerably, although the total moisture-holding capacity of the upper soil layers in the older stands is greatly increased by the incorporation of organic matter. The artificial fixation of the dunes by means of brushwood ("thatching") has been found to be an efficient method of conserving soil moisture.

(B) *Submitted for publication—*

36. The soils of the country round Jedburgh and Morebattle (Sheets 17 and 18). By J. W. Muir. (To appear as *Memoir of the Soil Survey of Great Britain: Scotland*).

37. Potassium in clay minerals. By R. C. Mackenzie. (To appear in *Symposium Int. Potassium Inst., Rome*, 1955).

38. The mineralogy of some soils from central Italy. By C. Lippi-Boncambi (University of Perugia), R. C. Mackenzie and W. A. Mitchell. (To appear in *Clay Min. Bull.*).

39. The trace element content of soils. By D. J. Swaine. (To appear as *Technical Communication No.* 48, *Commonwealth Bureau of Soil Science*).

40. A petrochemical study of tertiary tholeiitic basalts: the middle lavas of the Antrim plateau. By E. M. Patterson (University of St. Andrews) and D. J. Swaine. (To appear in *Geochim. et Cosmochim. Acta*).

41. Beta-oxidation of fatty acids by *Nocardia opaca* (Waksman and Henrici). By D. M. Webley, R. B. Duff and V. C. Farmer. (To appear in *J. gen. Microbiol*).

42. A simple apparatus for handling radioactive barium carbonate obtained by wet combustion. By R. B. Duff and A. H. Knight. (To appear in *Chem.* and *Ind.*).

43. Heavy metal toxicity and iron chlorosis. By P. C. de Kock. (To appear in *Ann. Bot.*).

44. Distribution of phosphorus in profiles and particle size fractions of some Scottish soils. By E. G. Williams and W. M. H. Saunders. (To appear in *J. Soil Sci.*).

45. Significance of particle size fractions in phosphorus extractions by acetic, Truog, and lactate methods. By E. G. Williams and W. M. H. Saunders. (To appear in *J. Soil Sci.*).

46. The effects of magnesian liming on the magnesium content of pasture and on the magnesium level of the blood of cows grazing the pasture. By J. Stewart (Animal Diseases Research Association) and J. W. S. Reith. (To appear in *J. comp. Path.*).

APPENDIX

The following are more detailed descriptions of the soils found in the areas surveyed.

NORTH-EAST SCOTLAND

Aberdeenshire (*Soil Survey Sheets* 76 *and* 87)

Sheet 76

ASSOCIATIONS

Countesswells Association

Distribution . . The areas of Bennachie, Cairn William and Tillyfourie Hill; the general area stretching southwards to Skene and south-west to the Corrennie Forest.

Parent Material . . Till derived from granite and granitic gneiss.

Dominant Series . Freely drained.

Profile

As described in Annual Report 1950-51

Topography . . Hilly and gently rolling.

Tarves Association

Distribution . . An area stretching south-west from Monymusk and separating Cairn William and Tillyfourie Hill. A limited area lying to the west of Inverurie and bordering the Bennachie Mass.

Parent Material . . Till derived from acid and basic-igneous and metamorphic rocks.

Dominant Series . Imperfectly to poorly drained.

Profile

As described in Annual Report 1949-50

Topography . . Hilly and gently rolling.

Foudland Association

Distribution . . The area of the Correen Hills; the upper slopes of Corrennie Forest.

Parent Material . . Till derived mainly from andalusite-schist.

Dominant Series . Freely drained.

Profile

As described in Annual Report 1950-51

Topography . . Hilly.

Insch Association

Distribution . . The general area stretching from Inverurie, northwards towards Oldmeldrum and north-west towards Oyne.
Parent Material . . Till derived from basic-igneous rocks.
Dominant Series . Freely to imperfectly drained.

Profile

As described in Annual Report 1949-50.

Topography . . Undulating and gently sloping.

Boyndie Association

Distribution . . . Areas bordering the alluvium of the River Don in the Kemnay area and immediately south-west; areas around Kintore.
Parent Material . . Sand.
Dominant Series . Freely drained.

Profile

Horizon	*Depth*	
S	0-8 in.	Brown sandy loam; loose crumb structure. Sharp change into A_1
A_1	8-12 in.	Light brown loamy sand; loose crumb structure breaking down into single grains. Merges into B_2.
B_2	12-29 in.	Light orange-brown loamy sand; weak crumb structure breaking down to single grains; faint rusty mottling below 24 in. Merges into C.
C	29 in. +	Light brown sand; single-grain structure.

Topography . . Flat to gently sloping.

Corby Association

Distribution . . In the Kemnay and Kintore areas and northwards following the River Don to Inverurie.
Parent Material . . Water-sorted and morainic gravel.
Dominant Series . Freely drained.

Profile

As described in Annual Report 1949-50.

Topography . . Moundy.

Cuminestown Association

Distribution . . Isolated patches over the Old Red Sandstone area from Rhynie to Kildrummy.
Parent Material . . Sandy till, of Old Red Sandstone Age.
Dominant Series . Freely drained.

Profile

As described in Annual Reports 1942-43, 1945-46.

Topography . . Gently to moderately rolling.

ORDLEY ASSOCIATION

Distribution . . In vicinity of Lumsden, Kildrummy and Towie.
Parent Material . . Sandy clay loam till derived from a mixture of arenaceous Old Red Sandstone and schists.
Dominant Series . Imperfectly drained.

Profile

As described in Annual Reports 1941-42 and 1953-54.

Topography . . Gently to moderately rolling.

ALLUVIUM

Alluvium occurs along the line of the River Don in the Monymusk-Kemnay area, around Inverurie, and between Inverurie and Kintore. The texture is sandy loam, and extensive areas are liable to seasonal flooding.

BASIN PEAT

Basin peat is found at Bandshed Moss, Lauchintilly Moss and Firley Moss south-west of Kintore and at Red Moss north-west of Kemnay. Several other minor patches occur in poorly-drained hollows.

HILL PEAT

Several areas of eroded peat occur over the Bennachie Mass with evidence that it was, at one time, more extensive. A few minor patches occur on the hills of Corrennie Forest.

Sheet 87

ASSOCIATIONS

CRUDEN ASSOCIATION

Distribution . . A belt of some two to six miles wide extending along the coast from Ellon to Crimond.
Parent Materials . Till and water sorted deposits derived from Old Red Sandstone material. This association will be sub-divided into three associations on the following parent materials:

1. a clay till,
2. a brick-earth of water-sorted material varying between a clay loam to heavy clay,
3. a mixed till in which the red till or brick earth is comingled with adjacent till on the western side of the red soil belt.

Dominant Series .

Profile

The dominant profile common to the three parent materials is a poorly drained surface water gley.

Horizon	*Depth*	
S	0-9 in.	Grey-brown clay loam; granular; low organic content; generally few stones. Sharp change into

A_2-G	9-12 in.	Grey clay loam with moderate iron mottling; blocky; grey coating on surface of blocks, light red interior. Merging into
B_2-G	12-24 in.	Red clay; large prismatic structure; iron mottling.
C	24 in. +	Massive red clay till, or brick earth, with slight iron mottling.

Topography . . Gently undulating.

SKELMUIR ASSOCIATION

Distribution . . An area encircling the Corse of Balloch and a smaller area on Skelmuir Hill.

Parent Material . . Pale yellow sandy loam to clay loam till with a high content of rounded flints and quartzites.

Dominant Series . Poorly drained, peaty gleyed podzol with iron pan.

Profile

Horizon	*Depth*	
A_0L	0-2 in.	Undecomposed litter.
A_0F	2-4 in.	Dark brown partially decomposed mor, felty and fibrous.
A_0H	4-10 in.	Black, well decomposed greasy mor.
A_2	10-14 in.	Grey stony sandy loam, with many flints and quartzite cobbles.
A_2G	14-18 in.	Pale olive sandy loam; more compact than above; wet.
B_1	18-18⅛ in.	Thin continuous iron pan.
B_2	18-24 in.	Reddish yellow stony loam; compact.
C	24 in.	Pale yellow clay loam, with flints and quartzite cobbles; massive.

Topography . . Gently to moderately rolling.

COUNTESSWELLS ASSOCIATION

Distribution . . 1. Area south of Rora Moss and north of the River Ugie.
2. Area south of Peterhead west of Longhaven.

Parent Material . . Stony coarse sandy loam, granitic till.

Dominant Series . Freely drained.

Profile

As described in Annual Report 1950-51.

Topography . . Undulating to moderately rolling.

TARVES ASSOCIATION

Distribution . . An area south of the River Ugie, extending through Mintlaw and Longside to the Corse of Balloch.

Parent Material . . Sandy clay loam till derived from acid and basic-igneous and metamorphic rocks.

Dominant Series . Poorly drained.

Profile

As described in Annual Report 1949-50.

Topography . . Gently undulating.

BOYNDIE ASSOCIATION

Distribution . . North of Peterhead to Loch of Strathbeg.
Parent Material . . Water sorted sand.
Dominant Series . Freely drained.

Profile

As described for Sheet 76.

Topography . . Flat to gently sloping.

CORBY ASSOCIATION

Distribution . . Isolated areas between Ellon and Peterhead.
Parent Material . . Water sorted gravel.
Dominant Series . Freely drained.

Profile

As described in Annual Report 1949-50.

Topography . . Moundy.

BLACKWATER ASSOCIATION

(provisionally named, probably equivalent to the Carse Association)

Distribution . . An area east of St. Fergus on the 50 foot raised beach.
Parent Material . . Marine clay.
Dominant Series . Poorly drained.

Profile

Horizon	*Depth*	
S	0-9 in.	Grey clay; blocky structure.
B_2G	10-30 in.	Dark grey heavy clay; prismatic structure; ochreous mottling.
C	30 in. +	Massive dark grey heavy clay.
Topography	. . .	Depressed to flat.

ALLUVIUM

A first terrace of deep fine sandy loam is extensive along the North and South Ugie Waters; it is mainly overgrown with *Juncus* and is used for pasture, being liable to seasonal flooding.

BASIN PEAT

Basin peat is extensive about Lochlundie Moss, Rora and St. Fergus mosses. Cut over peat has been mapped immediately east of St. Fergus on the 50 foot raised beach and also south of Rattray.

HILL PEAT

Hill peat is extensive about the Moss of Cruden where it is being actively worked for fuel. The thickness is from 6 to 8 feet.

EAST SCOTLAND

Angus (*Soil Survey Sheet* 57)

ASSOCIATIONS

Auchinblae Association

Distribution . . A small area near Tannadice; a few small mounds on the north side of Montreathmont moor.
Parent Material . . Red fluvioglacial sand and gravel.
Dominant Series . Freely drained.

Profile

As described in Annual Report 1950-51

Topography . . Moundy.

Corby Association

Distribution . . An area along the north bank of the river South Esk between Tannadice and the Noran Water; a small area on the south bank at Tannadice. Occasional scattered gravel mounds.
Parent Material . . Fluvio-glacial gravels.
Dominant Series . Freely drained.

Profile

As described in Annual Report 1950-51.

Topography . . Flat terraced gravels; occasional mounds.

Balrownie Association

Distribution . . Generally in the lower ground round about Finavon and Turin hills, excepting the alluvium and gravel terraces of the river South Esk and localised patches occupied by the Drumgley association.
Parent Material . . Red fluvio-glacially modified till material or till of sandy loam to loam texture.
Dominant Series . Imperfectly drained.

Profile

As described in Annual Report 1950-51.

Topography . . Gently undulating, occasionally hilly, generally with low angle slopes.

Turin Association

Distribution . . The Finavon ridge, Angus Hill, Turin Hill.
Parent Material . . Till derived mainly from flaggy and shaly beds of Lower Old Red Sandstone age.
Dominant Series . Freely and imperfectly drained.

Profile

As described in Annual Report 1952-53.

Topography . . Hilly.

DRUMGLEY ASSOCIATION

Distribution	Three patches between a half and one square mile in extent, and a number of much smaller ones between Tannadice and Finavon ridge. Several small patches between Angus hill and the east end of Turin hill.
Parent Material	Light textured fluvio-glacially modified red till material; rather variable.
Dominant Series	Imperfectly drained.

Profile

As described in Annual Report 1952-53.

Topography	Gently sloping.

ALLUVIUM

Alluvium is found on the lower terraces of the River South Esk from Finavon to Inverquharity, and the lower reaches of the Lemno burn. There are a number of small scattered patches of lacustrine alluvium.

PEAT

A few very minor patches of basin peat have been noted.

CENTRAL SCOTLAND

Stirling (*Soil Survey Sheet* 39)

ASSOCIATIONS

SOURHOPE ASSOCIATION

Distribution	The Ochil Hills.
Parent Material	Andesitic lavas of Lower Old Red Sandstone age.
Dominant Series	Freely drained.

Profile

Horizon	*Depth*	
S	0-8 in.	Dark grey-brown loam; crumb structure; many small andesite stones. Merging into
A_1	8-14 in.	Dark reddish brown gritty loam; medium sub-angular blocky structure; few stones.
B_1	14 in.	Weak iron pan.
B_2	14-28 in.	Dark reddish brown stony gritty loam; strongly indurated; stones plentiful (andesites). Sharp change into
C	28 in. +	Reddish brown stony gritty loam; medium blocky structure; many boulders.

Topography	Hilly.

CARSE ASSOCIATION

Distribution	The Lower Raised Beach.
Parent Material	Marine alluvium.
Dominant Series	Poorly drained.

Profile

Horizon	*Depth*	
S	0-10 in.	Light grey silty loam, blocky structure.
	10-28 in.	Dark brown-grey silty loam; prismatic structure; pronounced ochreous mottling.
	28 in. +	Massive dark grey-brown silty clay.

Topography . . Level.

SOUTH-EAST SCOTLAND

Berwickshire, Midlothian, Peeblesshire, Roxburghshire and Selkirkshire (Soil Survey Sheets 25 and 26)

ASSOCIATIONS

Ettrick Association

Distribution . . West of the Leader Water.

Parent Material . . Glacial drifts derived from Silurian greywackes and shales.

Dominant Series . Brown podzolic, freely drained.

Profile

Horizon	*Depth*	
A_0L	0-2 in.	Turfy litter.
A_0F	2-3 in.	Brownish black decaying vegetation.
A	3-10 in.	Brown silt loam; small sub-angular blocky; slight organic staining. Merging into
B_2	10-27 in.	Strong brown stony silt loam; granular and loose. Distinct change to
C	27 in. +	Brown very stony gritty silt loam resting on rock at a variable depth.

Topography . . Hilly to mountainous.

Vegetation . . *Festuca-agrostis.*

Rainfall . . . 30-35 in. per annum (Except on slopes exceeding 20° where this series exists under much higher rainfall).

Hobkirk Association

Distribution . . Between Earlston, Duns and Greenlaw.

Parent Material . . Till derived from sandstones shales and marls of Upper Old Red Sandstone age.

Dominant Series . Brown podzolic, freely drained.

Profile

Horizon	*Depth*	
S	0-8 in.	Dark reddish brown loam; small sub-angular blocky; slight organic staining; clear boundary.
B_2	8-12 in.	Red fine sandy loam; weak sub-angular blocky. Merging into
B_3	12-24 in.	Red loam; sub-angular blocky; compacted. Merging into

C	24 in. +	Dark reddish brown sandy loam; weak sub-angular blocky.
Topography	. .	Gently rolling.
Annual Rainfall	.	Under 35 in.

MINTO ASSOCIATION

Distribution . .	Between the River Tweed near Mertoun Bridge and Butchercoat. Between Dalcove Mains and Old Nenthorn House and in a small area north-west of Earlston Mains.
Parent Material . .	Mixed till derived from Upper Old Red Sandstone and Silurian sediments as described above.
Dominant Series .	Grey brown podzolic, imperfectly drained.

Profile

Horizon	*Depth*	
S	0-10 in.	Dark grey-brown silty loam; small angular blocky; moderate organic content; distinct boundary.
B_2-G	10-24 in.	Reddish brown loam; sub-angular blocky; some ochreous mottling. Merging into
C-G	24 in. +	Reddish brown clay loam; massive; grey and black mottling.
Topography . .		Rolling.
Annual Rainfall .		25-30 in.

ECKFORD ASSOCIATION

Distribution . .	In the lower ground between Greenlaw and Earlston
Parent Material . .	Fluvio-glacial sands and gravels in sheets and fans derived from the till of Hobkirk Association or direct from sandstones of the Upper Old Red Sandstone formation.
Dominant Series .	Brown podzolic, freely drained, stony phase.

Profile

Horizon	*Depth*	
S	0-9 in.	Reddish brown sandy loam; fine granular structure; abundant rounded greywacke stones; sharp boundary.
B_2	9-17 in.	Red loamy sand; fine granular structure; very abundant rounded greywacke stones. Merging into
C	17 in. +	Dark red coarse sand; single grain structure; very abundant rounded greywacke stones.
Topography . .		Moundy.
Annual Rainfall .		About 30 in.

DARLEITH ASSOCIATION

Distribution . .	On olivine basalt, plugs at Dryburgh, Redpath, Brotherstone, Butchercoat and Smailholm.

Parent Material . . Olivine basalt.
Dominant Series . Brown earth of low base status, freely drained.

Profile

Horizon	*Depth*	
A_0L	0-½ in.	Grass litter.
A_1	½-9 in.	Very dark brown loam; granular; organic matter present. Sharp change into
B_2	9-20 in.	Dark brown loam; granular; stones very abundant. Merging into
B_3	20-28 in.	Dark reddish brown loam; granular and slightly indurated; stones very abundant.
C	28 in. +	Rotten rock.

Topography . . Hilly.
Vegetation . . *Festuca-agrostis.*
Annual Rainfall . About 30 in.

WHITSOME ASSOCIATION

Distribution . . From between Kelso and Duns to between Blackadder House and Birgham.
Parent Material . . Till derived from sandstones shales and cementstones of Upper Old Red Sandstone and Lower Carboniferous ages, Lower Carboniferous olivine basalts and Silurian greywacke.
Dominant Series . Grey-brown podzolic, imperfectly drained.

Profile

As described in Annual Report 1953-54.

Topography . . Rolling.
Annual Rainfall . 25-30 in.

COLDSTREAM COMPLEX

Distribution . . In isolated elongated patches within the area covered by the Whitsome Association.
Parent Material . . A range of material from the till of the Whitsome Association to pure sand of unknown origin.

4 *Representative Profiles*

(a) Whitsome Series as described in Annual Report 1953-54. (In the following 3 profiles horizons are not named as their genesis is mainly geological and not pedological).

(b)

Horizon	*Depth*	
S	0-8 in.	Brown sandy loam; granular; moderate organic content; all stones rounded; distinct boundary.
	8-12 in.	Brown sandy loam; single grain structure; compacted; frequent small rounded and sub-rounded stones. Merging into

	12-35 in.	Reddish brown loam with streaks of sandy loam at top of horizon; sub-angular blocky stones as above. Merging into
	35 in. +	Reddish brown clay loam; sub-angular blocky; abundant sub-angular and sub-rounded stones.

(c)

Horizon	*Depth*	
S	0-9 in.	Brown loamy sand; single grain structure; moderate organic content; sharp boundary.
	9 in. +	Reddish brown stratified fine sand becoming gradually redder with depth.

(d)

S	0-4 in.	Dark brown loam; granular; moderate organic content; abundant rounded stones; sharp boundary.
	4-24 in.	Brown gritty sandy loam; abundant rounded stones; boundary merging and undulating.
	24-52 in.	Dark reddish brown gravel with lenses of clay.

BEMERSYDE ASSOCIATION

Distribution . .	Eildon Hills, White Hill, Black Hill, Bemersyde Hill, Dirrington Little Law, Hallywell Rig, Blacksmill Hill.
Parent Material . .	Trachyte of Lower Carboniferous intrusions.
Dominant Series .	Peaty podzol, freely drained.

Profile

Horizon	*Depth*	
A_0H	0-2 in.	Very dusky red fibrous humus.
A_1	2-5 in.	Very dark grey organic fine sandy loam; granular with a very high organic content; frequent small stones; distinct boundary.
A_2	5-7 in.	Light grey fine sandy loam; weakly platy; moderate organic content; small stones abundant; sharp boundary.
B_2	7-15 in.	Dark red loam; angular blocky; large angular stones very abundant.
C-D	15 in. +	Solid trachyte, slightly weathered.

Topography . .	Hilly.
Vegetation . .	*Calluna-festuca.*
Annual Rainfall .	40 in.

SMAILHOLM ASSOCIATION

Distribution . .	A strip one to two miles wide from Smailholm to Greenlaw.
Parent Material . .	Till derived from Upper Old Red Sandstone sandstones and Lower Carboniferous olivine basalt lavas.
Dominant Series .	Brown forest soil of low base status, freely drained.

Profile

Horizon	*Depth*	
S	0-9 in.	Dark reddish brown loam; granular; moderate organic structure; abundant stones. Merging into
A	9-19 in.	As above, but structural units more coherent.
B	19-28 in.	Reddish brown loam; small sub-angular blocky; stones abundant. Merging into
C	28 in. +	Dark red loam; sub-angular blocky; abundant stones; slight ochreous mottling.

Topography . . Rolling.
Annual Rainfall . 30 in.

YARROW ASSOCIATION

Distribution . . Flanking the River Tweed between Holylee and Leaderfoot.
Parent Material . . Fluvio-glacial terraces of gravel composed of Silurian greywacke.
Dominant Series . Brown podzolic, freely drained.

Profile

Horizon	*Depth*	
S	0-14 in.	Dark brown loam; granular; moderate organic content; frequent stones; sharp boundary.
B_2	14-30 in.	Strong brown sandy loam; granular; frequent to abundant stones. Merging into
C	30 in. +	Brown gritty sandy loam; indurated; stones so abundant that no structure discernible.

Topography . . Moundy.
Annual Rainfall . 30-40 in.

ALLUVIUM

Alluvium has been found as terraces to the Tweed and its subsequent rivers and also as glacio-lacustrine deposits at various levels in the Merse. While the former is subject to transient mineral accumulation the latter, being above the present river system, is not being added to. The river terraces develop little or no soil profile but the lacustrine deposits usually develop gley soils.

PEAT-ALLUVIUM COMPLEX

This term is self-explanatory and the complex is always found in sites similar to those described for Basin Peat. The alluvium varies in texture from clay to sand.

BASIN PEAT

Basin peat is found deposited on some of the low lying sites which were occupied by transient lakes during late Pleistocene times.

HILL PEAT

Small patches of stable hill peat, usually with a grassy vegetation, are found above 1,500 ft. in the hills between the Yarrow Water and the River Tweed.

SOUTH-WEST SCOTLAND

Central Ayrshire (*Soil Survey Sheet* 14)

ASSOCIATIONS

Darleith Association

Distribution . . Small areas south of Straiton; at Fardenwilliam; Dowan's Hill, Roodland and East Sanquhar.

Parent Material . . Thin till derived from basic lavas.

Dominant Series . Freely drained.

Profile

As described in Annual Report 1953-54.

Topography . . Hilly, with frequent outcrops.

Dreghorn Association

Distribution . . A belt up to three miles wide extending along the coast from Alloway to north of Monkton.

Parent Material . . Raised beach deposits.

Dominant Series . Freely drained.

Profile

As described in Annual Report 1950-51.

Topography . . Flat to gently undulating.

Rowanhill Association

Distribution . . A small area in the north-west of the sheet near Monktonhill and Hobsland.

Parent Material . . Till derived from mixed Coal Measures sediments including much shale and coal.

Dominant Series . Poorly drained.

Profile

As described in Annual Report 1950-51.

Topography . . Undulating.

Bargour Association

Distribution . . In the north-west corner of the area between Monkton and Adamton.

Parent Material . . Till derived from Barren Red Measures.

Dominant Series . Imperfectly drained.

Profile

As described in Annual Report 1950-51.

Topography . . Rolling.

Darvel Association

Distribution . . Irregular deposits along the Girvan valley from Kirkmichael to Straiton and similar spreads on the banks of the Doon near Skeldon.

Parent Material . . Fluvio-glacial sands and gravels.

Dominant Series . Freely drained.

Profile

As described in Annual Report 1951-52.

Topography . . Moundy, with low ridges and terraces.

Lanfine Association

Distribution . . In the north of the sheet near Ladykirk and Wardneuk.

Parent Material . . Mixed till derived from Barren Red Measures and Permian basic lava.

Dominant Series . Imperfectly drained.

Profile

As described in Annual Report 1951-52.

Topography . . Rolling.

Glenalmond Association

Distribution . . Fairly widespread in the area east of Maybole; around Kirkmichael and south from Cloncaird.

Parent Material . . Till derived mainly from Lower Old Red Sandstone.

Dominant Series . Imperfectly drained.

Profile

Horizon	*Depth*	
S	0-8 in.	Dark grey-brown sandy loam; weak cloddy structure; frequent stones. Sharp change to
A	8-12 in.	Reddish brown loam; cloddy; stony. Merging into
B_2-G	12-19 in.	Reddish brown sandy clay loam; compact cloddy; stony; some rusty mottling and slight gleying. Merging into
C	19-42 in.	Reddish brown sandy clay loam; very compact.

Topography . . Moderately rolling.

Ettrick Association

Distribution . . A small area south of Blairquhan near Straiton.

Parent Material . . Till derived from Silurian greywackes.

Dominant Series . Poorly drained.

Profile

As described in Annual Report 1953-54.

Topography . . Undulating.

Braston Association

Distribution . . South-east of Ayr around Kincaidston and Glengall.
Parent Material . . Till derived mainly from Coal Measures.
Dominant Series . Poorly drained.

Profile

Horizon	*Depth*	
S	0-8 in.	Dark grey-brown silty clay loam; cloddy; clear boundary.
B-G	8-12 in.	Yellowish brown clay; cloddy; much fine yellow orange mottling. Sharp change to
B_2-G	12-20 in.	Dark yellowish brown clay; well marked prismatic structure; much diffuse grey and brown mottling; some bright orange mottling and greying of structure faces. Merging into
C-G	20-42 in.	Dark grey clay; prismatic structure fading to massive at base; slightly calcareous.

Topography . . Rolling.

Glenpark Association

Distribution . . Widespread in the area north and east of Dalrymple.
Parent Material . . Till derived mainly from mixed sedimentary rocks of Calciferous Sandstone age.
Dominant Series . Imperfectly drained.

Profile

Horizon	*Depth*	
S	0-9 in.	Dark grey-brown silt loam; soft cloddy structure. Clear change to
B_2-G	9-16 in.	Brown silty clay loam; medium angular blocky structure tending to prismatic; much fine diffuse rusty mottling and slight greying of structure faces. Clear change to
B_2-G	16-25 in.	Brown clay loam; weak prismatic structure; much grey and rusty mottling. Merging into
C	25-45 in.	Light clay till; massive; many decomposing small stones and rock fragments.

Topography . . Undulating.

Tranew Association

Distribution . . Along the sides of the Girvan valley from Straiton to Kirkmichael
Parent Material . . Moraine deposits with greywacke and sandstone dominant.
Dominant Series . Freely drained.

Profile

Horizon	*Depth*	
S	0-9 in.	Brown loam; crumb structure; frequent stones; sharp boundary.
B_2	9-12 in.	Medium brown sandy loam; slightly compact, crumbling easily; uniformly ochre-stained. Merging into
B_3	12-22 in.	Brown gravelly loamy sand; strongly indurated. Merging with decreasing induration to
C	22-36 in.	Brown loamy sand with abundant stones.
Topography	. .	Mounds and ridges following valley sides.

LINKS

Distribution	. .	A small area at Belleisle; a more extensive coastal strip from Prestwick to Troon.

Profile

As described in Annual Report 1950-51.

Topography	. .	Gently undulating with occasional hummocks.

ALLUVIUM

Small spreads of alluvium, with a complete range of textures, occur throughout the area. The more important alluvial soils are found where the Rivers Ayr, Doon and Girvan have wide floodplains as at Straiton, Crosshill, Dalrymple and south-west of Auchincruive.

HILL AND BASIN PEAT

Basin peat is comparatively scarce in the area mapped, occurring only in small pockets in a few of the alluvial flats. Hill peat has been mapped in the south of the area on Cloncaird and Sclenteuch Moors.

SOIL HORIZON SYMBOLS USED BY THE SOIL SURVEY OF SCOTLAND

ELUVIAL HORIZONS

A undifferentiated

Subdivisions of Eluvial Horizons

A_0L undecomposed plant remains.

A_0F partially decomposed organic matter.

A_0H well decomposed organic matter.

A_1 intimate mixture organic and mineral matter.

A_2 grey silicious.

ILLUVIAL HORIZONS

B undifferentiated

Subdivisions of Illuvial Horizons

B_1 iron pan, or humus concentration or both.

B_2 diffuse deposition of sesquioxides or humus or both.

B_3 indurated or compacted.

PARENT MATERIAL

C undifferentiated

GLEY HORIZONS

G undifferentiated

CULTIVATED HORIZONS

S undifferentiated

GLEYED ELUVIAL HORIZONS

A-G gleyed A.

Subdivisions of Gleyed Eluvial Horizons

A_2-G gleyed A_2.

GLEYED ILLUVIAL HORIZONS

B-G gleyed B.

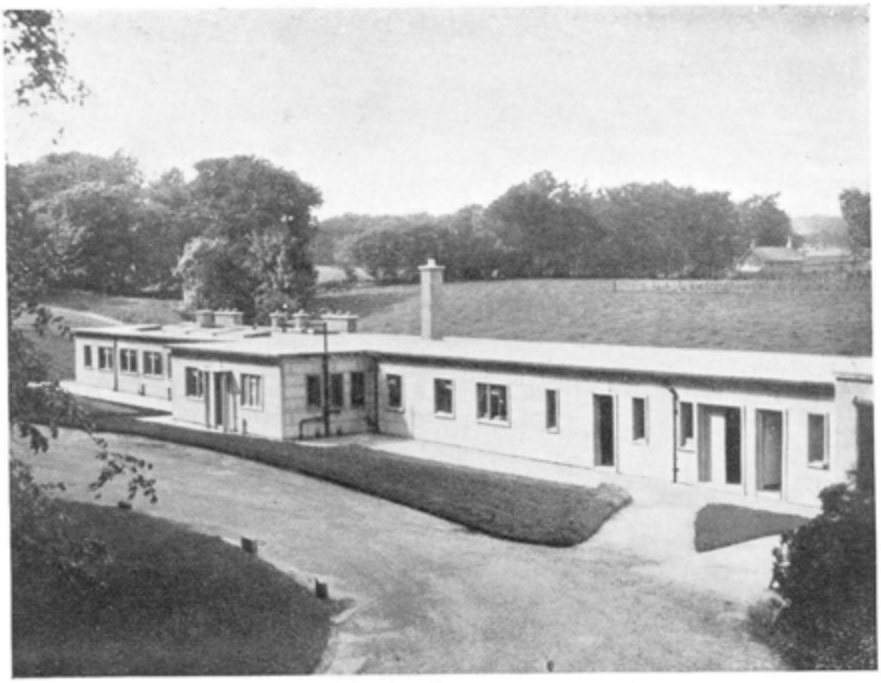
Subdivisions of Gleyed Illuvial Horizons

B_2-G gleyed B_2.

B_3-G gleyed B_3.

GLEYED PARENT MATERIAL

C-G gleyed C.



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