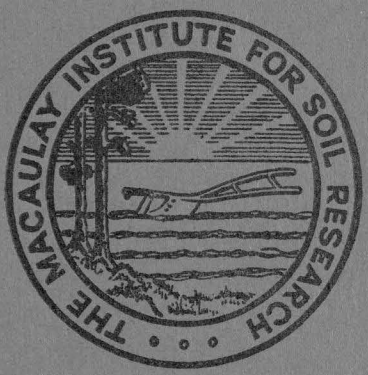
THE MACAULAY INSTITUTE FOR SOIL RESEARCH



FOUNDED 1930

ANNUAL REPORT 1955-1956

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

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CRAIGIEBUCKLER, ABERDEEN

(Founded 1930)

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W. BICK.
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A. H. GORDON.

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W. M. CROOKE, B.Sc., Ph.D., A.R.I.C. (leave of absence)
*I. R. MACDONALD, B.Sc., Ph.D.
Mrs E. M. BIRSE, B.Sc. (temporary appointment)
A. HALL.

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POST-GRADUATE RESEARCH WORKERS

E. Z. ARLIDGE (Massey Agricultural College, Palmerston North, New Zealand).

M. L. BERROW (Agricultural Research Council Training Grant).

K. COMMISSIONG (University College of the West Indies, Mona, St. Andrew, Jamaica, B.W.I.).

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

D. P. DROVER (University of Western Australia, Nedlands, Western Australia).

A. S. de ENDREDY (Department of Soil and Land Use Survey, Kumasi, Gold Coast).

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

M. HOSSAIN (Agricultural Research Laboratory, Dacca Farm, Dacca, East Pakistan).

A. B. M. F. HOQUE (Soil Research Laboratory, Ganges-Kobadak Scheme, Tejgaon, Dacca, East Pakistan).

W. A. HOPE (Colonial Office, London).

D. M. LANG (Colonial Office, London).

H. A. LOUW (Stellenbosch-Elsenburg Agricultural College, Stellenbosch, South Africa).

J. H. MCCRAITH (National Coal Board, Coal Survey Laboratory, Corstorphine, Edinburgh).

P. D. MALHOTRA (Geological Survey of India, Calcutta, India).

A. C. MASON (East Malling Research Station, nr. Maidstone, Kent).

J. F. OSBORNE (Sisal Research Station, Mlingano, D.O. Ngomeni, Tanganyika Territory).

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

I. TEZCAN (Orman Umum Müdürlugii, Ankara, Turkey).

J. A. TOOGOOD (Department of Soil Science, University of Alberta, Edmonton, Canada).

G. M. WILL (New Zealand Forest Research Institute, Whakarewarewa, Rotorua, New Zealand).

*Appointed 1955-6. †Resigned 1955. ‡Seconded from Colonial Pool of Soil Surveyors.

CONTENTS

INTRODUCTION

This report presents a brief record of the progress made during the year in investigations covering diverse branches of soil science, all of which contribute to the ultimate aim of the research programme, the maintenance and improvement of soil fertility. As in previous years, close collaboration has been maintained with other research organizations, the Colleges of Agriculture in Scotland, the Forestry Commission, and the Department of Agriculture for Scotland.

Generous financial grants were again received from the Department of Agriculture for Scotland, the Agricultural Research Council and the Forestry Commission, and grateful thanks are returned to these bodies and to other benefactors for their interest and assistance in advancing the work of the Institute.

STAFF

Dr R. L. Mitchell, Head of the Department of Spectrochemistry, was appointed to succeed Dr A. B. Stewart as Deputy Director of the Institute.

Dr E. G. Williams was appointed Head of the Department of Soil Fertility, and Dr J. S. D. Bacon, Senior Lecturer, The Department of Biochemistry, University of Sheffield, was appointed to take charge of the newly established Department of Biochemistry.

Other appointments were:

Department of Pedology—

R. Boggie, B.Sc., Ph.D. (Soil Survey of Scotland).
K. S. Caldwell (Soil Survey of Scotland).
J. B. Craig (Section of Physical Chemistry).

Department of Plant Physiology—

I. R. MacDonald, B.Sc., Ph.D.

Miss K. R. Farquharson (Section of Physical Chemistry) resigned on marriage.

In November 1955 Dr R. L. Mitchell visited the United States where he attended the Trace Analysis Symposium in New York and meetings of the Soil Science Society of Florida in Orlando and of the Society for Applied Spectroscopy in New York. Papers were presented at most of these meetings. By invitation, Dr Mitchell read a paper on soil analysis and trace elements to a Seminar on Organization and Rationalization of Soil Analysis sponsored by the European Productivity Agency of the O.E.E.C. in Wageningen. Dr Mitchell also attended a meeting of the Society of Chemical Industry in Bangor, and Dr R. O. Scott represented the Institute at the Sixth International Colloquium on Spectroscopy in Amsterdam.

Under a Fellowship awarded by the Canadian Department of Agriculture, Dr W. M. Crooke spent a year with the Chemistry Division of the Science Service in Ottawa. During his period of study there he took the opportunity to visit several research stations in Canada and the United States.

At the invitation of the Swedish Society for Clay Research and the University of Uppsala, Dr R. C. Mackenzie delivered lectures to the Society in Stockholm and to the University, and by arrangement with the Danish Heath Society and the Scottish Peat and Land Development Association, Mr R. A. Robertson visited Denmark to inspect reclamation work and peat utilization projects.

Dr E. G. Williams and Dr R. Glentworth attended the Easter meeting of the British Society of Soil Science in London, and Dr Glentworth presented a paper. Mr S. E. Durno joined the Easter Vacation course on Quaternary Research held by the University of Cambridge. The Institute was well represented at the Sixth International Congress of Soil Science, held in Paris during the summer, and several papers were read. In July, Dr T. W. Wright attended the Twelfth Congress of the International Union of Forest Research Organisations held in Oxford, and on the invitation of the Society, Dr J. W. S. Reith and Mr E. L. Birse were present at the Annual Meeting of the British Grassland Society in Hereford.

PUBLICATIONS

The twenty-seven publications issued during the year are summarized in this report. Reprints of papers, where available, can be obtained from the Librarian.

VISITORS

Each year many visiting workers from home and abroad are welcomed to the Institute and shown something of the work in progress. Among the overseas visitors received this year were research workers from Australia, Canada, Cyprus, Fiji, Finland, Germany, Hungary, India, Iran, Jamaica, Mexico, Morocco, Netherlands, New Zealand, Nigeria, Norway, Pakistan, Portugal, South Africa, U.S.A., and U.S.S.R. Organized parties included members of the staff of the Department of Agriculture for Scotland (North-eastern area), the International Union of Forest Research Organisations, the Field Trials Committee of the Scottish Agricultural Improvement Council, the NPK Club, the Road Research Laboratory, and the Scottish Peat and Land Development Association.

POST-GRADUATE RESEARCH WORKERS

The training facilities provided by the Institute continue to attract post-graduate research workers from all parts of the world. During the year the following research workers were associated in the work of the Institute:

Department of Pedology:

F. Gulcur (Orman Facültesi, Istanbul Üniversitesi, Büyükdere, Istanbul, Turkey).

Soil Survey—

M. Hossain (Agricultural Research Laboratory, Dacca Farm, Dacca, East Pakistan).

A. B. M. F. Hoque (Soil Research Laboratory, Ganges-Kobadak Scheme, Tejgaon, Dacca, East Pakistan).

W. A. Hope (Colonial Office, London).

D. M. Lang (Colonial Office, London).

I. Tezcan (Orman Umum Mudürlügü, Ankara, Turkey).

Soil Geology and Mineralogy—

E. Z. Arlidge (Massey Agricultural College, Palmerston North, New Zealand).

Physical Chemistry—

A. S. de Endredy (Department of Soil and Land Use Survey, Kumasi, Gold Coast).

Department of Plant Physiology:

K. Commissiong (University College of the West Indies, Mona, St. Andrew, Jamaica, B.W.I.).

Department of Soil Fertility:

D. P. Drover (University of Western Australia, Nedlands, Western Australia.

J. A. Toogood (Department of Soil Science, University of Alberta, Edmonton, Canada).

Department of Spectrochemistry:

M. L. Berrow (Agricultural Research Council Training Grant).

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

J. H. McCraith (National Coal Board, Coal Survey Laboratory, Corstorphine, Edinburgh).

P. D. Malhotra (Geological Survey of India, Calcutta, India).

A. C. Mason (East Malling Research Station, Nr. Maidstone, Kent).

J. F. Osborne (Sisal Research Station, Mlingano, P.O. Ngomeni, Tanganyika Territory).

Section of Microbiology:

H. A. Louw (Stellenbosch-Elsenburg Agricultural College, Stellenbosch, South Africa).

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

Section of Forest Soils:

G. M. Will (New Zealand Forest Research Institute, Whakarewarewa, Rotorua, New Zealand).

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

H. M. Hassanein (Chemical Department, Ministry of Industry and Commerce, Cairo, Egypt).
A. Irmak (Orman Facültesi, Istanbul Üniversitesi, Büyükdere, Istanbul, Turkey).
C. W. Montgomery (Department of Soil and Land Use Survey, Kumasi, Gold Coast).
Y. Sakai (Ministry of Agriculture, Tokyo, Japan).
J. Spector (Imperial College of Tropical Agriculture, Trinida, B.W.I.).
Miss D. Williams (Forestry Research Station, Wrecclesham, Farnham, Surrey).

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*) Technical Committee on Fertilizers.
- (*b*) Technical Committee on Mineral Deficiencies in Agricultural and Horticultural Crops.
- (*c*) Technical Committee on Mineral Deficiencies and Excesses in Animals.
- (*d*) Technical Committee on Research on Field Water Control.
- (*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.

30*th September*, 1956.

PEDOLOGY

SOIL SURVEY (SCOTLAND)

The Soil Survey memoir[1] for Sheets 17 (Jedburgh) and 18 (Morebattle) was published in May and the memoir for Sheet 22 (Kilmarnock)[28] is nearing publication. The soil surveys of Sheets 57 (Forfar), 76 (Inverurie), and 87 (Peterhead) have been completed and the fair copies of Sheets 57 and 76 have been submitted to the Ordnance Survey. Field work has been continued on Sheets 25 (Kelso) and 26 (Berwick-upon-Tweed), which are almost completed, and on Sheets 14 (Ayr) and 39 (Stirling). Surveys of Sheet 6 (Annan), Sheet 11 (Langholm), and Sheet 48 (Perth) have been commenced. Revision has been carried out on Sheets 66 (Banchory) and 67 (Stonehaven).

The ecological survey of Sheet 66 (Banchory) was completed in October 1955. In 1956 the vegetation of Sheet 76 (Inverurie), Sheet 25 (Kelso), and Sheet 26 (Berwick-upon-Tweed) was recorded.

In all, some 370 square miles of new mapping and some 230 square miles of revision have been completed.

The Joint Field Meeting of the Soil Survey of Scotland and the Soil Survey of England and Wales was held at Kelso in June, and the soils of Sheets 17 (Jedburgh), 18 (Morebattle), Sheet 25 (Kelso) and 26 (Berwick-upon-Tweed) were examined. Eighteen monoliths representative of these areas were obtained and prepared for exhibition.

NORTH-EAST SCOTLAND

Soil Survey Sheet 87 (*Peterhead*)

The revision of Sheet 87 has been concluded. Approximately 30 square miles of remapping and major adjustment of association boundaries has been carried out in an area mainly to the north and west of Peterhead. This area is bounded on the north by a line from St. Fergus to Strichen, on the west by a line from Strichen to Old Deer, on the south by a line from Old Deer through Longside to Peterhead, and on the east by the sea. In addition three smaller areas have been remapped—a strip two miles broad between Strichen and New Pitsligo, an area between Old Deer and Stuartfield, and an area surrounding the Den of Boddam.

One new association, the Peterhead Association, has been defined, and as a result of the remapping the areas covered by some of the established associations have been altered. Thus the area covered by the Strichen Association in the vicinity of Stuartfield, Old Deer, and Mintlaw has been reduced; the soils of this area are now included in the Tarves Association. A small area of soils in the Den of Boddam has now been included in the Skelmuir Association. The boundary separating the Countesswells and Foudland Associations

between New Pitsligo and Strichen has been defined in greater detail. Minor changes in drainage boundaries have been made throughout the area.

The Peterhead Association extends north and south from the town of Peterhead in a strip about two miles broad. The southern boundary of this strip is south of the village of Stirling and the northern boundary is just north of Crimond. The parent material is a clay till derived from mixed acid rocks and Old Red Sandstone sediments.

Forty-one profiles have been sampled this season in the area covered by Soil Survey Sheets 87 and 97, to enable analytical records to be compiled and brought up to date. Twenty-four of these profiles were for Sheet 87 (Peterhead) and seventeen were for Sheet 97 (Fraserburgh).

The following soils are found in the area surveyed and are described in more detail in the appendix. Where an association has been previously mentioned, reference to the appropriate annual reports is made below.

Associations

Peterhead (New Association)
Strichen (1942-43; 1948-49 to 1950-51)
Tarves (1943-44 to 1945-46; 1948-49; 1949-50; 1953-54; 1954-55)
Countesswells (1943-44 to 1946-47; 1948-49; 1950-51; 1953-54; 1954-55)
Foudland (1941-42; 1944-45 to 1946-47; 1948-49; 1950-51; 1953-54; 1954-55)
Corby (1944-45 to 1947-48; 1949-50 to 1954-55)
Boyndie (1948-49 to 1954-55)
Skelmuir (1942-43; 1954-55)
Fraserburgh (1942-43; 1943-44; 1948-49; 1949-50)

Blackwater Complex
Links
Alluvium
Skeletal Soils
Basin Peat

EAST SCOTLAND

Soil Survey Sheets 66 (*Banchory*), 67 (*Stonehaven*) *and* 48 (*Perth*)

Revision of Sheets 66 and 67 has been continued. Activity has been mainly concentrated in the southern sections of both sheets over an area of about 200 square miles. In the hills drainage boundaries within the Strichen Association have been more closely defined, particularly on Sheet 66. The boundary between the Strichen Association and the Countesswells Association (which together cover a large part of the northern sections of both sheets) has been adjusted. Association and drainage boundaries have been more extensively remapped in the lowlands of north-east Strathmore between Edzell, Gourdon, and Stonehaven; associations more particularly affected by these adjustments are Laurencekirk, Stonehaven, Auchinblae, Balrownie, Mountboy, and Drumgley. No new associations have been defined in this area though the possibility of separating and naming certain soils developed on raised beach

deposits is under consideration. It is hoped that revision will be sufficiently complete by the end of the field season to enable drafts of the one-inch-to-one-mile maps of Sheets 66 and 67 to be compiled.

The following soils occur within the area at present under revision and are described in more detail in the appendix. All the associations have been mentioned previously in the annual reports indicated.

Associations

Strichen (1942-43; 1948-49 to 1950-51)
Strathfinella (1947-48; 1949-50; 1950-51)
Stonehaven (1946-47; 1947-48; 1949-50; 1950-51)
Laurencekirk (1946-47; 1947-48; 1949-50)
Balrownie (1950-51; 1951-52; 1953-54; 1954-55)
Mountboy (1951-52)
Drumgley (1952-53 to 1954-55)
Dean (1952-53; 1953-54)
Corby (1944-45 to 1947-48; 1949-50 to 1954-55)
Auchinblae (1947-48; 1949-50; 1950-51; 1953-54; 1954-55)

Alluvium
Hill Peat

The soil survey of Sheet 48 (Perth) was commenced this season. The area is bounded in the north by a line from Dunkeld to Gallow Hill; in the east, from Gallow Hill through Dundee to Cupar; in the south, from Cupar to Dunning; and in the west, from Dunning to Dunkeld. The main portion of the sheet lies in the county of Perth with the north-east corner extending into Angus, while, on the south side of the Tay estuary, the area from Newburgh to Cupar lies in Fife.

At the north-west corner of the sheet, the Dalradian series of Highland schists is represented in the rocks which constitute the foothills about Dunkeld. These hills form the western boundary of the Old Red Sandstone Valley which runs diagonally across the sheet from north-east to south-west. The eastern edge of the valley is bounded by the Sidlaw Hills composed mainly of lavas of Old Red Sandstone age and stretching from Kinpurney Hill in the north to Kinnoull Hill beside Perth. Beyond the Sidlaw range an Old Red Sandstone plain with occasional intrusions of diabase extends to the eastern boundary and rises to the high ground about Gallow Hill in the north-east. On the south side of the Tay estuary, the greater part of the area is occupied by porphyritic lavas.

Surveying on a scale of 2½ inches to 1 mile has been carried out over approximately 50 square miles in two main areas, one stretching north-east from Perth to Burrelton, bounded on the west by the Perth-Cargill road and on the east by the Sidlaw Hills, and the other stretching south-west from Dundee along the Tay estuary towards Errol and north-west to Fowlis.

In addition, a detailed survey on the scale of 25 inches to 1 mile has been made on the farms of Mylnefield and Bullion, belonging to the Scottish Horticultural Research Institute, Invergowrie.

The greater part of the former area lies in the Old Red Sandstone Valley and is covered by till derived from red sandstone. The dominant association is Balrownie with limited areas of the more sandy Drumgley Association. A few small patches of soil developed on red sand and gravel have been mapped as Auchinblae Association.

On the slopes of Campsie Hill, south-west of Burrelton, till from red sandstone marl forms the parent material of the Laurencekirk Association.

The topography over this part of the valley is generally undulating, rising to between 400 and 500 feet. Arable farming with some dairying is carried on over the greater part of the area. The main crops grown are wheat, barley, oats, turnips, and potatoes. Towards the north, the growing of soft fruits, *i.e.*, raspberries and strawberries, is a notable variant.

The southern portion of the Sidlaw range rising in parts to between 800 and 1,000 feet has been surveyed. The thin lava till covering the upper slopes forms the parent material of the soils which have been mapped as Darleith Association. Arable cultivation is not general above about 700 feet, most of the upper ground being given over to sheep-grazing or forestry.

In the second area, immediately to the west of Dundee, the red drift is generally sandy and gives rise to soils of the Auchinblae Association. Northwards, towards Fowlis, the texture becomes heavier and transition to Balrownie Association takes place. Between Longforgan village and North Mains farm about one mile to the south-west, an intrusion of diabase occurs giving a purple-brown till with textures from loam to clay loam. The soils developed on this till have not been identified with any existing association and further examination will be necessary before naming them.

The south-west portion of this area, extending from Kingoodie to Errol, lies in the Carse of Gowrie, and the soils developed on estuarine alluvium have been mapped as Carse Association.

Arable cultivation is general throughout the area, wheat and, to a lesser extent, barley being common crops in the Carse.

The following soils are found in this area and are described in more detail in the Appendix. All the associations have been mentioned previously in the annual reports indicated.

Associations

Balrownie (1950-51; 1951-52; 1953-54; 1954-55)
Drumgley (1952-53 to 1954-55)
Laurencekirk (1946-47; 1947-48; 1949-50)
Auchinblae (1947-48; 1949-50; 1950-51; 1953-54; 1954-55)
Darleith (1949-50 to 1954-55)
Boyndie (1948-49 to 1954-55)
Carse (1954-55)

CENTRAL SCOTLAND

Soil Survey Sheet 39 (*Stirling*)

A further 48 square miles have been mapped from three centres in the area of Sheet 39.

From Dunblane a broad strip extending from the River Forth near Gargunnock to the Argaty moorlands has been mapped. This is contiguous with the Kippenross unit recorded in the Annual Report for 1954-55. The southern part is level estuarine alluvial land with carse soil showing very little variation. Before the eighteenth century much of this land lay under peat, namely the mosses of Lecropt, Drip, Ochtertyre, and Blairdrummond. A narrow strip two miles long has remained since 1865 when fishery interests succeeded in prohibiting the deposition of peat into the River Forth. Freshwater warp soils occur near the Rivers Teith and Forth.

In the centre of the area is a zone of rolling land occupied by Keir estate, with a freely drained deep fine sandy loam soil developed from Lower Old Red Sandstone material. With an increase in elevation to the north peaty-topped soils become dominant, with much basin peat in the depressions.

From Auchterarder the area of the Ochil Hills south of Frandy Reservoir and south-west of Glendevon was surveyed. It consists of deep valleys and long ridges leading up to broad summit areas over 2,000 feet above sea level. Andesitic lavas and tuffs give rise to a very uniform soil parent material, a freely drained gritty loam. The only significant variation is the occurrence of a poorly drained moderately fine-textured glacial till in valley bottoms. Above these, slope and climate play a dominant role in soil formation, a common upward sequence being (a) brown forest soils on the lower slopes with *Agrostis-Festuca* grassland with *Pteridium aquilinum*, (*b*) podzols, often with iron pan supporting Nardetum, (c) on shoulders of hills, a structureless peat with a tussocky Nardetum—this has apparently been washed from the ridge tops and summits where is found (d) deep hill peat under Eriophoretum. The soils belong to the Sourhope Association.

To the north of Auchterarder, adjacent to Tullibardine Muir, further mapping of soils on material derived from Lower Old Red Sandstone has been carried out. The soils belong to the Largs Association; a freely drained fine sandy loam is the dominant series on gently undulating ground, while imperfectly drained soils occur on drumlins composed of a sandy clay loam till.

From Callander the north-western corner of Sheet 39 has been surveyed. This includes an area north of the Highland Boundary Fault consisting of high ridges projecting southwards from Ben Vorlich and Stuc a Chroin, with deep U-shaped valleys containing hummocky moraines and scattered fluvio-glacial formations. The dominant rocks are Aberfoyle slates and Ben Ledi grits. The ridge tops, which reach 2,300 feet above sea level, are covered with deep hill peat, extensively hagged, while on the steep hillsides shallow stony soils occur, with freely drained creep soils below. Less steep hillsides are covered with deep peat. The morainic areas in the valleys have a characteristic soil relationship consisting of a well-developed peaty podzol on the steep hummocks with waterlogged humus soils in the surrounding hollows. The pattern is too detailed to be recorded on the 1:25,000 scale, and, as hummocky moraine is a common landscape feature in the Highlands, a soil complex within the Strichen Association has been established—the Moraine Complex. Fluvio-glacial gravel mounds yield similar soils to the moraine hummocks.

The sandstone and conglomerate country to the south of the Highland Boundary Fault is largely covered by hill and basin peat, except near the Keltie Burn where the dominant parent material is an olive-grey till derived from Highland rocks in the conglomerate or beyond the Fault. Non-calcareous surface-water gleys and peaty gleys predominate. Except for isolated residual soils, profiles developed on Old Red Sandstone material do not appear north of Callander Crags and Tom Dubh.

Twenty-four profiles have been described and samples taken for analysis.

The following soils are found in the areas surveyed and are described in more detail in the appendix. The associations have been mentioned previously in the annual reports indicated.

Associations

Largs (formerly Kirkland) (1949-50; 1952-53)
Sourhope (1948-49; 1949-50; 1954-55)
Carse (1954-55)
Strichen (1942-43: 1948-49 to 1950-51)

Hill Peat

Basin Peat

SOUTH-EAST SCOTLAND

Soil Survey Sheets 25 (*Kelso*) *and* 26 (*Berwick-upon-Tweed*)

In the north-west of Sheet 25, 160 of the remaining 185 square miles have now been mapped. The larger part of the area lies to the north and west of Lauder and Greenlaw.

Soils derived from rocks of three geological systems—Ordovician, Silurian, and Old Red Sandstone—have been identified in the area. Those derived from the Ordovician rocks were found to be similar or identical to the soils of the Ettrick Association derived from Silurian greywackes and shales; they differ only in having a larger greywacke content much of which is reddish in colour. Two soil associations are now recognized on material derived from the Upper Old Red Sandstone sediments. The first of these is the previously encountered Hobkirk Association and the second a new association which has been named Lauder. This new association is developed on Upper Old Red Sandstone conglomerates and drifts derived from them. As the conglomerates are rich in greywacke cobbles, the Lauder Association often shows close affinities to the Ettrick and Yarrow Associations.

Excluding Lauderdale and the south-eastern corner between Gordon and Greenlaw, most of the area lies above the 750 feet contour and has an annual rainfall of 35-45 inches. It is almost all in semi-permanent pasture or under natural vegetation and is devoted to hill sheep farming. In proximity to the farms arable crops, mainly oats, turnips, and hay for winter feed, are cultivated up to about 1,000 feet. Above this altitude, due to the severity of the climate, most of the soils are podzolized and have a thick organic surface horizon under a Callunetum, Nardetum or Eriophoretum or intermediate plant community. Where heavy liming is practised or the slope is steep (>20°),

however, a more grassy vegetation such as *Agrostis* or *Agrostis-Festuca* occurs over brown forest soils of low base status.

Large areas of hill and basin peat have been encountered, the former covering about 5 square miles and the latter about 2½ square miles. Most of the hill peat occurs in the Lammermuir Hills above 1,200 feet and is variable in depth. The true hill peat is mostly 1½-3 feet deep, but some in saddles or depressions exceeds 6 feet. The basin peat occurs mainly in three raised mosses —Threepwood, Dogden, and Jordanlaw—all of which are over 20 feet deep.

Thirty-five profiles have been sampled this season. Four of these were from experimental *Molinia* burning plots at Sourhope, a hill farm belonging to the Hill Farming Research Organization, and three were from building sites in Edinburgh, sampled on behalf of the D.S.I.R. Road Research Laboratory. In addition to these, 32 soil profiles were prepared for the Soil Surveyors' Field Meeting held at Kelso in June. Soil series from Carter, Darleith, Eckford, Ettrick, Hobkirk, Sourhope, Whitsome, and Yarrow Associations were shown at the meeting, being representative of some 1,000 square miles surveyed to date in the Borders.

The following soils are found in the area surveyed and are described in more detail in the appendix. Where an association has been mentioned previously, reference to the appropriate annual reports is made below.

Associations

Ettrick (formerly Hindhope) (1949-50 to 1954-55)
Hobkirk (formerly Bowmont) (1948-49 to 1951-52; 1953-54; 1954-55)
Eckford (1948-49; 1949-50; 1954-55)
Lauder (New Association)

Hill Peat
Basin Peat
Alluvium

SOUTH-WEST SCOTLAND

Soil Survey Sheets 14 (*Ayr*), 6 (*Annan*) *and* 11 (*Langholm*)

During the current season approximately 65 square miles have been surveyed on Sheet 14.

Mapping has been confined to the north-eastern part of the sheet in an area bounded roughly by a line from Hollybush to Tarbolton in the west, the northern and eastern margins of the sheet, and a line from Lugar to Hollybush in the south. This area is structurally a wide basin where most of the outcropping rocks are Coal Measures. The centre of the basin is in the north where the Coal Measures are overlain first by Permian volcanic rocks and then by the desert sandstones of Mauchline. Much-faulted older Carboniferous rocks (Millstone Grit, Carboniferous Limestone Series and Calciferous Sandstone Series) form a border encircling the Coal Measures. A small outcrop of Upper Old Red Sandstone occurs in the south-west at Milreoch. The sedimentary rocks have been intruded in places by numerous sills, mainly of Permian age teschenite and theralite. The Permian volcanic rocks are mainly olivine basalts, but these are underlain by a variable thickness of tuff and

marly ash. The Coal Measures are conveniently divided into two series, Barren Red Measures, which are characterized by a predominantly red colour, with prevalent rock types micaceous sandstones and marly shales, and Productive Measures largely made up of alternations of sandstone, sandy shale, and shale, with dominant colours pale grey, yellow, and white. Coal seams are numerous in these lower beds.

The landscape has been considerably modified by glaciation and practically the whole area is covered by a mantle of till. The broader physiographical features are controlled by the solid geology. The outcrop of Permian rocks around Mauchline is well defined by surface relief, the basic lavas forming a ring of elevated ground rising above the surrounding coalfield to a height of 400 to 500 feet. To the south the ground rises to over 1,000 feet where the thick sills have resisted erosion to form such prominent features as the Craigs of Kyle and Ewe Hill, south of Coylton. Minor topographical features due to glacial deposits include a series of drumlins in the rolling country between Stair and Mauchline, frequent alluvial flats caused by late-glacial ponding, and occasional spreads of sand and gravel.

The main rivers traversing the area are the River Ayr, which flows in a deep gorge through the Permian outcrop, and its tributaries, the Lugar Water and the Water of Coyle, which drain the high ground to the west and south.

Most of the till is of clay loam or clay texture and the soils are dominantly imperfectly or poorly drained with slope a major factor. Dairy farming is the main agricultural practice, and this area is favoured by a number of breeders of pedigree Ayrshire cattle. Where the sandstones of the Permian and Barren Red Measures have influenced the till to a greater extent, cropping becomes more important, and on the comparatively light soils around Mauchline a fair acreage is devoted to potato-growing. In the south, where there is a greater proportion of permanent grazing, sheep are carried in addition to the dairy herd. The average size of holding is about 120 acres.

The following soils are found in the area mapped and are described in more detail in the appendix. Where an association has been mentioned previously, reference to the appropriate annual reports is given below.

Associations

Darleith (1949-50 to 1954-55)
Rowanhill (1950-51; 1954-55)
Bargour (1950-51 to 1952-53; 1954-55)
Kilmarnock (1949-50 to 1952-53)
Darvel (1951-52; 1953-54; 1954-55)
Lanfine (1951-52; 1952-53)
Mauchline (1952-53)
Glenpark (1954-55)
Lindston (New Association)
Drongan (New Association)
Auchinleck (New Association)

Alluvium

Basin Peat

Forty square miles have been surveyed in the areas of Sheets 6 and 11. Mapping was carried out in three contrasting regions in which all the geological formations found in the area of the two sheets are represented.

The first region to be described is the area of 25 square miles of Sheet 6 west of Lochar Moss. On the coast of Kirkcudbrightshire the relief and soils are dominated by Criffel (1,866 feet). Brown forest soils have developed on a granitic morainic drift of sandy loam texture and are named the Dalbeattie Association. East of the River Nith, between Glencaple and Caerlaverock, is a low ridge of Permian sandstones and conglomerates. Freely drained soils derived from the rock are most widespread; the texture is a sandy loam and an indurated horizon is common. A red clay loam till occupies the hollows and the imperfectly drained soils that have developed may be grouped in the Mauchline Association found in Ayrshire.

Deposits of the 100-feet and 30-feet raised beaches along the coast provide a great variety of soil parent materials. The deposits of the higher beach are relatively unsorted, gravelly loam and sandy loam textures being common. In contrast, the deposits of the 30-feet raised beach are well sorted, though all grades from gravel to silt are found. Three associations are recorded based on textural classes: Dreghorn (gravel), Lochar (fine sand), and Carse (silt and silty clay). The relief is flat except where old spits, bars, or dunes are found. Contemporary marine alluvium covers some 40 square miles in the Solway Firth north of the border. The intermittently flooded saltings, mapped as the Merse Series, support a halophytic vegetation and efflorescences of salt are sometimes found. The very poorly drained fine sand has an immature profile. Both the saltings and the intertidal sands, which have no soil profile, would yield upon reclamation soils of the Lochar Association.

On Sheet 11 an area of 5 square miles has been mapped between Canonbie and the border at Scot's Dyke. The area is part of a till plain overlying the New Red Sandstone which may be seen in the banks of the River Esk. The soils are dominantly imperfectly drained clays and clay loams of the Mauchline Association. Small areas of blanket peat are present, although the altitude is below 300 feet, and there is evidence that greater areas were formerly covered by peat.

The River Esk has a small flood-plain but a striking assemblage of terraces; as many as six are present one mile south of Canonbie. The higher terraces are composed of gravels, possibly glacial outwash, and on them are podzolized soils of the Yarrow Association. The lower three or four terraces are of a brown fine sandy loam resembling the alluvium currently being deposited on the flood-plain. They are grouped in the Esk Association and have a brown forest soil profile.

The remaining 10 square miles surveyed are in the hill country between Langholm and Riccarton Junction. The series mapped have already been recognized in the area of Sheet 17, and are included in the Ettrick, Carter, Hobkirk, and Darleith Associations.

The following soils are found in the area surveyed and are described in more detail in the appendix. Where an association has been mentioned previously, reference to the appropriate annual reports is given below.

Associations

Dalbeattie (New Association)
Mauchline (1952-53)
Dreghorn (1949-50; 1950-51; 1952-53 to 1954-55)
Lochar (New Association)
Carse (1954-55)
Esk (New Association)
Yarrow (1954-55)
Ettrick (formerly Hindhope) (1949-50 to 1954-55)
Hobkirk (formerly Bowmont) (1948-49 to 1951-52; 1953-54; 1954-55)
Carter (formerly Martinlee) (1949-50; 1952-53)
Darleith (1949-50 to 1954-55)

Hill Peat
Basin Peat
Alluvium

VEGETATION SURVEYS

Records were made of the vegetation in the areas being surveyed and accounts prepared for inclusion in the memoirs.

The relationship between vegetation and major soil group was studied in North Ayrshire where a correlation was always evident, although sometimes obscured by man's interference.

Succisa pratensis was collected during the season from serpentine and non-serpentine soils in connection with physiological studies.

In connection with the work being done on forest soils at Bowmont Forest, Roxburghshire, it was found that where thinning is light there is practically no ground vegetation while under heavy thinning there is an open but continuous community of shade-tolerant species such as *Dryopteris austriaca*, *Urtica dioica*, *Stellaria media*, and *Eurhynchium praelongum*.

A review[2] of the possibilities of the reclamation of Scottish peat land has been published.

MAPS AND REPORTS

The Soil Survey memoir[1] and maps for Sheets 17 (Jedburgh) and 18 (Morebattle) have been published. The final page proof of the memoir for Sheet 22 (Kilmarnock) has been returned to H.M. Stationery Office and the colour proof of the map has been checked and returned to the Ordnance Survey.

A soil survey on a scale of 25 inches to 1 mile was made of the Lawers School of Agriculture, belonging to the Perth and Kinross Joint County Council. At the request of the Scottish Peat Committee an investigation of the subsoils of the following peat mosses was made:—East and West Flanders, Gardrum, Darnrig (Stirlingshire), and Airds (Ayrshire). A soil survey on a scale of 6 inches to 1 mile was made of Balnastraid Farm, Dinnet, for the North of Scotland College of Agriculture. The soils of Skedbush Farm, belonging to the Animal Breeding Research Organization, were examined jointly with the Department of Soil Fertility.

COLLABORATIVE WORK

Soil profiles from eight sites near Glasgow, Greenock, Edinburgh, and Dundee were sampled in collaboration with the D.S.I.R. Road Research Laboratory as part of their programme on soil cement. Sites for long-term heather and *Molinia* burning experiments and for other soil-ecological investigations were selected in collaboration with the Hill Farming Research Organization.

Assistance has been given in the selection and characterization of sites for field trials conducted by the Institute and the Scottish Colleges of Agriculture.

PEAT ECOLOGY

Ecology

The ecological studies on heather have continued on a limited scale. The experiments on recolonization are still in progress at Glensaugh Research Farm, and further samples of the regenerating vegetation have been taken for yield and chemical analysis. Ecological work has also continued on the *Callunetum* of Brimmond Hill where a grazing trial is in progress in collaboration with the Rowett Research Institute.

The survey of conditions and practices on heather moors has not been extended during the year, but it is felt that sufficient data has now been collected to enable certain broad recommendations to be made regarding heather management with particular reference to heather burning.

Further soil and herbage samples have been taken from four types of hill vegetation where the effects of manurial treatments are being investigated. A final botanical analysis of the 144 plots has been carried out and the experiment concluded. Preliminary results indicate that without adequate stocking no marked change in the botanical composition of the swards or in the nutrient content of the herbage can be expected.

The general characterization of peat deposits and the study of their vegetation is being carried out in collaboration with the Soil Survey of Scotland. A broad survey of hill and basin peats on Sheet 25 (Kelso) has been completed and work has begun on Sheet 57 (Forfar) and Sheet 76 (Inverurie).

Close co-operation has been established with the Hill Farming Research Organization and a joint investigation has begun on the effect of long and short term burning rotations on three distinct types of vegetation and their associated soils.

Pollen Analysis

Pollen analysis of peat has been continued and selected deposits from various parts of the country have been sampled for this purpose. Two further pollen diagrams have been completed from the raised moss basin peats of Blairderry, Wigtownshire, and Darnrig, Stirlingshire. The pollen sequence as represented in the hill peat of the eastern Grampians is under investigation. Collaboration with the Department of Geography of the University of Aberdeen has continued with the examination of certain glacial deposits in the north-east of Scotland which may result in pollen data of an earlier period than we have yet found becoming available.

Basal Soils

The mineral soils adjoining and underlying three large deposits of raised moss basin peat have been surveyed in association with the Soil Survey staff. At Airds Moss, Ayrshire, and Gardrum and Darnrig Mosses, Stirlingshire, the subsoils are derived mainly from Carboniferous sandstones and shales but some of the profiles from Airds Moss showed low to moderate amounts of igneous material in the till. The third area which comprises West Flanders Moss, Stirlingshire, and East Flanders Moss, Perthshire, is characterized by a very uniform grey silty estuarine clay (carse clay) which underlies almost the whole of the peat.

In order to assess the suitability of these basal soils for reclamation, a number of profiles were described and samples taken for analyses. Recommendations have been submitted regarding drainage, cultivation, and fertilizer requirements.

Bog Cultivation

The section is co-operating with the Crofters Commission and the North of Scotland College of Agriculture on the reclamation of peat deposits in north-west Scotland. Two areas of shallow eroded peat near Kinlochbervie have been selected for surface seeding and a survey of the mineral soils, peat, and vegetation at these sites has been completed. Nearby at Traigh Bad na Baighe the reclamation of a small area of deep peat is being contemplated and similar records have been taken and a report submitted. The progress of these schemes will be recorded at intervals.

This work forms part of a broad survey designed to obtain standard information on methods of bog cultivation and reclamation.

Laboratory Investigations

Analytical work has continued on samples sent by the Department of Agriculture for Scotland (Peat Section). During the year over 1,000 peat samples were received from the following areas:

Achairn Moss, Caithness	330
Shielton Moss, Caithness	695
Lon Mor, Inverness-shire	45
Traigh Bad na Baighe, Sutherland	23

The moisture content, ash content, density, and botanical origin of these samples have been determined and a limited number of fibre estimations have been carried out. The results of these analyses are used to assess the suitability of the peat for fuel, moss litter production, reclamation for agriculture, and afforestation.

The chemical characterization of peat is being investigated in collaboration with the Department of Biochemistry.

SOIL GEOLOGY AND MINERALOGY

Scottish Soils

During the year clay and fine sand fractions of selected soil profiles from Ayrshire, Angus, Kincardine, and Aberdeenshire have been analysed mineralogically, using X-ray diffraction and optical methods. Some of the

Ayrshire soils have higher kaolin contents than any other Scottish soils so far examined and this was found to be due to a high kaolin content in the sandstones of the Calciferous Sandstone Series. The interbedded shales of this series contain illite and give rise to heavy-textured illitic soils. A joint paper on the Ayrshire soils and their parent materials, prepared in collaboration with the Section of Physical Chemistry, was read at a meeting of the Clay Minerals Group in Cambridge, in April, and a paper on the quantitative estimation of non-clay minerals in clays was also read. At a meeting of the same group in London, in November, a paper[30] was presented describing a focussing X-ray camera for the rapid identification of clay minerals.

The clay fractions of a number of soils which have been extensively studied by the Department of Soil Fertility have been examined.

Foreign Soils

The clay mineralogy of Turkish forest soils has been correlated with parent material, chemical data, climatic conditions, and soil type. A significant relationship is found between clay mineralogy, cation exchange capacity, and parent rock type. Although variations in clay mineralogy are greater than for Scottish soils, the range is surprisingly small considering the extreme climatic differences existing in Turkey. A joint paper[31] has been accepted for publication.

Phosphate Fixation

An investigation has been started on the interaction of phosphate solutions with clay minerals and iron and aluminium compounds. Insoluble phosphates which are precipitated in these reactions include the minerals tarnakite and the variscite-strengite series. These minerals have been synthesized under controlled conditions of temperature and pH and examined.

Rock Weathering

The study of the weathering of the minerals in basic igneous rocks in south-east Scotland has been continued. The fresh rock, weathered rock, and soil profiles are being studied by optical and X-ray diffraction methods. The minerals olivine, augite, and plagioclase weather in the order given and the soil clays contain montmorillonite, vermiculite, and kaolin with only small amounts of illite.

PHYSICAL CHEMISTRY

Differential Thermal Analysis

During the period under review the apparatus in use has undergone considerable development. Modifications to design now allow the temperature-difference trace to be obtained directly against temperature (thus obviating replotting of curves in routine determinations) and more accurate measurement of temperatures in the 990-1050°C region. In addition, a completely separate apparatus for controlled atmosphere work has been constructed and is currently being tested; the photoelectric programme control system is not yet complete, but the apparatus is operating reasonably satisfactorily on manual control.

In view of the extensive apparatus modifications and the consequent testing and recalibration, the number of samples examined during the year was rather fewer than in the previous year. Soil clays from Aberdeenshire, Ayrshire, and Angus have been examined and the usual series of minerals was observed. The Angus soil clays appear to be much lower in kaolin than the Ayrshire ones. Those developed from Old Red Sandstone parent material again show the peculiar type of illite previously noted in this formation. It has also been observed that soil clays containing vermiculite appear to give smaller hygroscopic moisture peaks the higher the vermiculite content; whether this peculiar behaviour is connected with pretreatment of the clays is not yet known. Some soil clays from Turkey have also been examined. A systematic investigation into the behaviour of organic matter in soil clays in inert and oxidizing atmospheres has just commenced.

Minerals examined during the year have included interstratified minerals, gibbsite samples of different particle sizes, gypsum, saponite, sepiolites, and vermiculites. The effect of ions other than potassium upon montmorillonite after cycles of wetting and heating has also been investigated, and the effect of wet and dry mixing upon quantitative estimations has been checked.

Chemical Studies

Semi-micro chemical analyses have been carried out on relatively pure Old Red Sandstone illite, on a saponite from Skye, and on some other minerals of interest. Many semi-micro cation-exchange determinations have also been performed, and attention has been paid to more accurate methods for determination of calcium and magnesium.

During the year three lectures were given at Stockholm and Uppsala at the invitation of the Swedish Society for Clay Research and the University of Uppsala. One of these dealing with the application of differential thermal analysis to Scottish soil clays is in press[32]; the other two dealt with hydration and hydroxylation and with unsolved problems in clay mineralogy. Three chapters[33], [34], [35] dealing with thermal methods of investigation, with apparatus and techniques for differential thermal analysis, and with the oxides of iron, aluminium, and manganese, have been written for a book on *The Differential Thermal Investigation of Clays* which will shortly appear. Reports of the methods used for clay separation[36] and a method for concentrating weak clay suspensions[37] are also in press. Papers dealing with the mineralogy of some Italian soils[3], with potassium in clay minerals[6] and with the effect of wet and dry grinding upon the structure and morphology of the micas[7] have appeared during the year.

Dr A. S. de Endredy, Gold Coast Department of Soil and Land Use Survey, spent some time in the Section studying the methods at present in use and applying them to some Gold Coast soil clays.

SOIL ANALYSIS

Routine analyses have been carried out on samples taken by the Soil Survey officers during 1954 (417 samples representing 93 profiles). During 1955, 614 samples (129 profiles) were taken and on these the following determinations

have been completed:—moisture; loss on ignition; mechanical analysis; hydrogen ion concentration; total and readily soluble phosphorus. Exchangeable base determinations have been completed on two-thirds of the samples and exchangeable hydrogen, total carbon, and nitrogen determinations on one-third.

Total silica, iron, and aluminium determinations have been carried out on 141 clay samples (29 profiles) separated from selected profiles from Ayrshire, Roxburghshire, and Kincardineshire. Ultimate analyses have been carried out on six soils from Roxburghshire.

In addition, 175 samples of soil, rock, etc., were analysed for the Departments of Plant Physiology and Spectrochemistry and the Section of Physical Chemistry, the Midge Control Unit of the University of Edinburgh (investigation on breeding grounds of midge), the Scottish Home Department (Marine Laboratory), Lawers School of Agriculture, Perthshire, and the Department of Agriculture for Scotland (Peat Survey).

SPECTROCHEMISTRY

There have been three main lines of work during the past year. The major effort has been the application of existing spectrochemical methods to the determination of the biologically important trace elements in soils and plants. In addition to seven scientific assistants, this aspect of the work occupies the time of three of the graduate workers and two research students. This has resulted in considerable progress being made in the search for methods of assessing the soil availability of trace elements and in the understanding of the factors affecting plant uptake. Secondly, development of methods has continued, and a new technique for magnesium has been introduced. Lack of accommodation has restricted the use of other new items of equipment at present being tested. The third important line of work, infrared and ultraviolet absorption spectrophotometry, is proving increasingly valuable for the identification or characterization of materials separated in the course of the biochemical and microbiological work of the Institute.

Samples for trace element examination have been received from various external sources, including other British research stations, the National Agricultural Advisory Service of England and Wales, and numerous Commonwealth agricultural research organizations. In addition to soils and plants, the materials received have included samples of fish, rocks and minerals, animal and human organs and fertilizers. Requirements have varied from full trace element analysis to the determination of specific elements in samples available only in very small amount. Such determinations are occasionally quite difficult, as the methods developed in the department have been evolved to provide a comprehensive trace element survey of agricultural materials, which are generally obtainable in unrestricted amount.

As in previous years, the facilities for training in spectrochemical methods have been fully utilized, and demands are increasing. Practically no long-term vacancies are available for the next two years. Among the visiting research workers who spent appreciable periods in the department were Mr B. G. Davey, New South Wales Department of Agriculture, Mr M. L. Berrow, A.R.C. Research Scholar, Mr J. F. Osborne, Tanganyika Sisal Growers Association, Mr P. D. Malhotra, Geological Survey of India, Mr J. H. McCraith, National Coal Board, Mr J. Spector, Imperial College of Tropical Agriculture, and Mr A. E. Mason, East Malling Research Station.

Members of the staff of the department attended the 6th International Congress of Soil Science in Paris, the Trace Analysis Symposium in New York, the Sixth International Colloquium on Spectroscopy in Amsterdam, and meetings of the Soil Science Society of Florida in Orlando, the Society for Applied Spectroscopy in New York and the Society of Chemical Industry in Bangor, and papers were presented at most of these. By invitation, a paper

on Soil Analysis and Trace Elements was presented to a Seminar on Organization and Rationalization of Soil Analysis sponsored by the European Productivity Agency of O.E.E.C. in Wageningen.

TRACE ELEMENTS IN SOILS, PLANTS AND BIOLOGICAL MATERIALS

Soil Status and Plant Uptake

The investigation of copper deficiency in oats in parts of north-east Scotland has been continued. It has been found that the incidence of this disorder can be correlated with the copper content of clover grown on the same soil, but not with the copper content of the grasses of the pasture herbage. The copper content of clover, sampled at the time of flowering in June, is related to the copper status of the soil as indicated by E.D.T.A. extraction, but not as indicated by extraction with water or dilute acetic acid, or by total soil copper. A paper[38] reporting these findings was presented to a Colloquium on Plant Analysis and Fertilizer Problems which met in Paris concurrently with the International Congress of Soil Science.

Other elements, including the biologically significant cobalt, molybdenum, zinc and manganese, are being studied in a similar manner in order to develop more precise methods of assessing soil status. The behaviour of the different elements varies in different plant species; cobalt for instance does not show the marked distinction which occurs with copper between clovers and grasses.

The study of the effects of various trace element and fertilizer soil dressings on plant uptake has continued, with findings which in general confirm the results indicated last year. In work of this nature, it is necessary to carry out analyses over a period of years. The observation that the addition of vanadium (as vanadate) to the soil does not result in an increase in the content of vanadium in the above-ground part of the plant has been confirmed. The effect of different phosphatic dressings on the trace element uptake of mixed pasture herbage is being examined in samples from plots laid down by the North of Scotland College of Agriculture. These investigations are all made in collaboration with the Department of Soil Fertility.

The differential uptake of different plant species and the distribution of trace elements within the plants themselves are being studied in detail in an investigation which involves the determination of some 20 elements in over 500 samples taken at intervals throughout the growing season from four plots, covering different conditions of drainage and pasture management.

Soils and Soil Parent Materials

An extensive bibliography of references to papers which include quantitative information on the occurrence of trace elements in soils has now been published[8]. Our files are being kept up-to-date with a view to making a supplement available in due course.

The trace element status of a soil depends ultimately on the geological nature of the parent material from which the soil is formed. In this connection, some results dealing with basaltic rocks from Northern Ireland have been published[9], and examination of other rocks from various sources are in progress.

Collaboration with the Soil Survey of Scotland has continued. Soil profiles from the areas surveyed have been examined for both total and extractable trace elements. The findings are presented in summary form in the appropriate memoirs[1], [28].

The work on soil profiles has been extended to the more detailed study of different size fractions from typical freely and poorly drained members of associations developed on basic igneous and granitic soils. Results so far available indicate that there is a marked size differentiation effect in the distribution of trace elements in soils. Methods of investigating the availability of the trace elements in the different size fractions are being examined: the separation of the different fractions without disturbing the readily extractable trace elements is one problem of considerable complexity which is being studied.

In considering the distribution and availability of trace elements, the role of soil organic matter must not be ignored, and in this connection, further analyses have been made of peat profiles and of the mineral horizons underlying peats. In the latter, the extractable contents are often greater than those found in mineral soils, presumably because the drainage is generally restricted in such horizons.

SPECTROCHEMICAL METHODS OF ANALYSIS

A number of general descriptions of the methods developed in this department have been prepared. The concentration technique was described at a Trace Analysis Symposium in New York[39], and the application of the method to soil and plant analysis at a meeting of the Soil Science Society of Florida[40]. A more complete review of the spectrochemical methods, including the porous cup solution spark technique, was given to the Society for Applied Spectroscopy in New York[41]. A discussion of the application of such methods to soil analysis will appear in a special number of Soil Science[42]. A description of a power pack for the Hilger microphotometer has been published[10].

The preparation of a comprehensive card index bibliography of references covering all aspects of spectrochemical determinations continues, and the work involved is proving exceedingly worth while in making abstracts of previous work readily available.

Flame Emission

One notable change has been the almost complete abandonment of the flame technique for the determination of magnesium, now carried out by the spark technique described below. Flame photometric methods are now used almost exclusively for the determination of calcium, potassium and sodium, spectrographic techniques being introduced only for the determination of such elements as strontium, manganese and, when present in adequate amount, lead, nickel and copper.

An improved 3-channel flame photometer has been designed and built and is at present being tested.

Arc Emission and Chemical Pretreatment

No major changes in the methods employed fall to be recorded. A double background correction method for zinc has been introduced to improve accuracy at low zinc contents. Water purified by mixed bed resins is being employed for many purposes for which glass distilled water was previously used, and polythene or plasticized P.V.C. is being employed wherever possible in place of rubber, which is liable to introduce such elements as zinc. Care must however be taken that the plastic materials themselves do not introduce contamination. The most reliable material is undoubtedly polythene, although this may not always be so, as new methods of production are being introduced. As an example of possible effects may be mentioned the finding that a sample of P.V.C. tubing used for a fume duct contained relatively large amounts of cadmium.

Spark Emission

Since the introduction of the porous cup solution spark, thousands of determinations of magnesium have been made spectrographically, but a rate of determination equivalent to that obtainable for potassium, sodium and calcium by flame photometry was not possible. A direct reading attachment for the Hilger Small Quartz spectrograph has been designed and built, and many more magnesium determinations are now feasible. Strontium is used as internal standard. The magnesium sensitivity is such that concentrations as low as 0·3 p.p.m. (0·3 mg. per litre) can be determined to an accuracy of better than ± 3 per cent. using only 0·1 ml. of sample. At present, a thousand samples of soil or plant extracts are being analysed per month, and the potential output is much greater.

ABSORPTION SPECTROMETRY OF SOIL CONSTITUENTS

The application of infrared spectroscopy to the examination of both organic and inorganic constituents of soils and peats has now been broadly surveyed and fields have been selected in which more detailed study appears profitable. A considerable number of peats and some fractions isolated from peats and soils in the Department of Biochemistry have been examined. Few differences have been noted in the spectra of peats of differing age and origin, but after fractionation considerably more information can be obtained from the spectra. Some of the fractions have been found to contain lignin-like components, and it seems likely that some interpretation of the chemical changes which lignin undergoes during peat formation can be made by joint chemical and spectrochemical work. In the inorganic field a study has been made of some insoluble phosphate minerals, prepared in the Department of Pedology in connection with an investigation of phosphate fixation in soils. Their spectra have been found to be distinctive, and the presence of acidic hydroxyl groups in some of them has been established. Infrared spectroscopy has also been found suitable for distinguishing the various hydrous aluminas and iron oxides.

Co-operative studies with the Section of Microbiology and Department of Biochemistry on the metabolism of soil nocardias have continued, and the

close liaison between chromatography, ultraviolet and infrared spectrometry, and microbiological techniques has proved fruitful. The work establishing β-oxidation in the breakdown of ω-phenyl substituted fatty acids by *N. opaca*, already reported, has now been published[11], and observations have been extended to fatty acids with other substituents, including the agriculturally important phenoxy substituted fatty acids. Similar techniques have also shown that substituted long chain paraffins are converted to substituted fatty acids by some nocardia species, and an account of this work is being prepared for publication.

Both infrared and ultraviolet spectrometry have made useful contributions to the estimation or identification of organic compounds. These include plant acids, metabolic products of fungi and bacteria, and oxidation products of soil and peat organic matter. The value of infrared spectroscopy is particularly apparent where an unexpected product is obtained. Thus a product obtained from glucose by the action of *B. megaterium* was identified as an acetylglucose from a detailed study of its spectrum, although this compound was not previously known. In collaboration with workers in the Department of Chemistry of the University of Aberdeen, investigations have been made on the structure of phloroglucinol trioxime[12] and on the characterization of *peri*-hydroxycarbonyl compounds[13].

The pressed disk technique has proved of great value in obtaining the spectra of insoluble natural products. Although, as already reported, the spectra of compounds containing hydroxyl groups may be modified by prolonged grinding with the alkali halides, further work has now established conditions under which these changes are minimized. It has been found that the new bands which appear in the spectra of phenols and acids arise from molecules adsorbed on the surface of the finely ground alkali halides by hydrogen bonding between the hydroxyl groups and halide ions. Some other effects have been noted and an account of the findings will be published shortly[43].

BIOCHEMISTRY

NITROGENOUS AND CYCLIC COMPOUNDS

Organic Acids and Amino-acids of Plants

In collaboration with the Departments of Plant Physiology and Soil Fertility special attention has been devoted to the determination of the free amino- and organic acids in plant extracts.

The technique developed for the separation and determination of plant organic acids by gradient elution from columns of silica gel has proved very successful in practice, and has now been applied to a large number of plant extracts. The method has been found suitable for the separation and determination of most of the commonly occurring plant organic acids, including fumaric, succinic, aconitic, oxalic, malic, and citric acids. The method unfortunately has been found inapplicable to the determination of quinic acid which is sometimes a major acid in plant material, *e.g.*, pine needles, although shikimic acid can be determined.

The visual comparison method for the semi-quantitative determination of individual amino-acids has been replaced by a more accurate but still rapid method using a double-beam reflectance densitometer. Most of the amino-acids in an extract can now be determined from a single two-dimensional paper chromatogram; but for small relative amounts of individual acids it may be necessary to use additional chromatograms.

In a joint experiment upon the effect of the application of fertilizers upon the growth of rye grass (*Lolium*), it was found that the free amino-acid content made a significant contribution to the total nitrogen content and that the treatment markedly affected the proportions and amounts of free amino-acids.

Lignin in Soil Organic Matter

The investigation of the yields of phenolic aldehydes obtainable by the alkali-nitrobenzene oxidation of various types of soil organic matter has been continued. Samples taken from a peat profile at 0·5 metre intervals down to 5 metres have been examined and the yields of syringaldehyde, vanillin, and p-hydroxybenzaldehyde obtained have shown a distinct correlation with the differing botanical origins of successive levels of the peat as determined by microscopic examination. Results have also been obtained for a number of samples of different types of peat and for certain fractions of phragmites peat.

Organic Nitrogen in Soils

Knowledge of the conditions that promote the accumulation of organic nitrogen in the soil is of practical importance. In order to find out the effect, if any, of dressings of inorganic nitrogenous fertilizers, a series of samples from plots of a field soil which have received different levels of nitrogenous fertilizer over a number of years has been obtained from the Department of

Soil Fertility, and an examination of the amino-acid composition of acid hydrolysates of these samples has begun.

CARBOHYDRATES

In the course of an investigation of the carbohydrates produced by various soil micro-organisms growing on synthetic media, it was observed that a cobalamin-producing strain of *B. megaterium* gave a comparatively large quantity of an unknown carbohydrate. It was thought that further work on this was justified in view of the universal distribution of the organism, the indications that the unknown carbohydrate was a major product of its metabolism, and the possible connection with cobalamin.

The strain was grown in synthetic liquid media containing glucose and the unknown metabolite was separated from excess substrate by column chromatography after removal of inorganic salts with ion exchange resins. The substance crystallized readily. Examination by infra-red spectrometry (Department of Spectrochemistry) showed that it was likely to be an acetylated glucose.

Hydrolysis of the material with acid gave glucose and acetic acid, the former identified by paper chromatography, preparation of derivatives, and optical rotation, and the latter by chromatography and X-ray examination o the sodium salt (Section of Soil Geology and Mineralogy). Despite difficulties presented by the labile nature of the ester, chemical studies have indicated clearly that it is 6-*O*-acetyl-D-glucopyranose. It belongs to a class of substances (mono-acetylhexoses) unknown to synthetic chemistry and not hitherto suspected to occur in nature. Little can therefore be predicted about its place in the economy of the bacteria concerned, or of any other micro-organisms. The mechanism of its biological synthesis, and of its utilization by *B. megaterium*, is being studied in conjunction with the Section of Microbiology. It is formed by resting cell suspensions (added pyruvate, known to be a biological source of acetyl residues, enhancing the synthesis), but not by the cell-free extracts so far prepared. It persists in the medium after the disappearance of glucose, and thus might serve as a temporary reserve of carbohydrate in the soil and decomposing litter (the normal habitat of *B. megaterium*), if it were not utilizable by other micro-organisms.

In view of the possible relation between cobalamin and acetylglucose, various strains of *B. megaterium* were examined. Of fourteen strains, eleven have been reported to yield cobalamin but only three (including the strain used in this work) produced acetylglucose.

An account[11] of work on the β-oxidation of fatty acids by *Nocardia opaca* has been published. The methods used are now being applied to a study of the breakdown of hydrocarbons and herbicidal ω-phenoxy substituted fatty acids by the same organisms and by others.

Work has continued on the determination of some of the constituents of peat. The chemical characterization of the organic matter of peat (*i.e.*, determination of alcohol-benzene solubles, humic acid, hemicelluloses, cellulose, uronic acid, pentose, and cation exchange capacity of some fractions) is laborious and at present only a small number of samples can be examined.

PLANT PHYSIOLOGY

The relationship which exists between the elements in plant leaves has been further investigated as well as their correlation with the organic and amino-acids. If this were a true metabolic picture, some relationship between mineral content and respiration would be expected and this was found to be so. The most rewarding feature of this study has been the finding that the sensitivity to respiratory inhibitors of leaf tissue is also correlated with the phosphorus-iron and potassium-calcium ratios. This finding introduces certain fundamental concepts of the control of respiration rate by metal ions.

ANALYTICAL

Analyses of a great variety of plants—ferns, conifers, monocotyledons, and dicotyledons—suffering from various deficiencies or toxicities[15] have underlined the universal applicability of the metabolic scheme. Considerable attention has been paid to the ageing of leaves, as both the phosphorus-iron and potassium-calcium ratios were found to decrease rapidly during the life of the leaf. This was true whether a succession of leaves on a growing twig was studied as an ageing sequence or whether portions were cut from the same leaf over a period of time. A number of studies on the relation between organic acid and amino-acid content of ageing leaves has also shown a marked interdependence between these and the mineral content of the leaves. A joint communication was presented at the Glasgow meeting of the Biochemical Society in April 1956. Investigation of the mineral content of certain albino maize hydrids which turn green at elevated temperatures, has shown a change to lower phosphorus-iron and potassium-calcium ratios as the leaves become green. Variation of these ratios when plants were supplied with inadequate or excessive amounts of boron or with nitrogen either as the ammonium or the nitrate ion was also studied.

RESPIRATION

Leaves with high phosphorus-iron and potassium-calcium ratios, such as found in iron deficiency or genetical chlorosis, show high respiration rates and are sensitive to respiratory inhibitors. On the other hand, leaves with low ratios were found to have low respiration rates and to show only slight inhibition or even stimulation of respiration in the presence of respiratory inhibitors. Most interesting were found to be the old and young leaves of mustard. Whereas the young leaves showed a 75 per cent. inhibition of respiration in the presence of cyanide, the old leaves showed a corresponding stimulation. When comparing the effects of inhibitors on comparable young and old leaves of a batch of tomato plants grown under similar conditions, it

was found that the responses obtained were always proportional and independent of the specific action of the poison. It thus appears that for plants the processes of oxidation, decarboxylation, phosphorylation are obligately linked. Similar findings were obtained for the respiration of old and young animal tissues in the presence of respiratory inhibitors in joint investigations with the Department of Zoology, University of Aberdeen.

CYTOLOGY

Studies on plant tissues at cellular level have been conducted during the past year to investigate the morphological changes, especially of mitochrondria which occur in the iron-deficient and iron-toxic states. In spite of the difficulties encountered in the uniform staining of the tissues with mitochondrial reagents, the characteristic clumping of mitochondria into chondriosomes in the iron-toxic (advancing age or manganese deficiency) state has been observed. Nuclear fast red has been successfully used to show the progressive accumulation of calcium with time in the chloroplasts of mustard leaves.

ENZYMIC

As manganese determines the state of oxidation of iron in a leaf, it appears likely that peroxidase and manganese may act as the terminal oxidase of leaves. This system oxidizing indole-acetic acid was studied, using crude and highly purified preparations of peroxidase. It was found that the reaction was inhibited by carbon monoxide and that this inhibition was reversed by light.

RADIOACTIVITY

In collaboration with the Department of Soil Fertility. a study has been made of radioactive methods of assessing the value of a series of rock phosphates as fertilizers. Good correlations were found between increases in yields and a radiochemical method in pot experiments and also with measurements of surface phosphate in laboratory experiments. A report[16] of this work was presented in Paris to the Sixth Congress of the International Society of Soil Science. The pot culture method has been extended to measurements of the residual values of the rock phosphates after twelve months contact with the soil. Radioactive phosphorus has also been used to determine the alteration of the phosphate status of soils after oven-drying and after moist incubation at a lower temperature.

Radioactive iron has been used in laboratory experiments to determine the surface iron of soils, with the view to obtaining an improved evaluation of reactive iron. This work is being done by a visiting research worker, Dr D. P. Drover of the University of Western Australia, and it is hoped that it will prove useful in connection with studies on the phosphate relations of soils. The variation of the values for surface iron in a range of soils is being investigated for different extracting reagents, extracting times and other factors.

The aspect of nickel toxicity in plants which has been investigated is the interaction between nickel and calcium in plants. In a preliminary report[17] it has been shown that nickel apparently affects the uptake of calcium differ-

ently in different crops. However, when a split root technique was employed by which the action of nickel in the top can be separated from the action in the roots, it was found that the "top-effect" in each crop was consistently a tendency to increase the uptake of calcium and the "root-effect" to decrease the absorption of calcium. The separation of the toxic effects and a study of the upset in calcium balance may lead to a better understanding of the mode of action of nickel in plants. A paper[18] on the effect of soil reaction on uptake of nickel from a serpentine soil has been published.

An account of a radioactive method for studying the root systems of plants in ecological work has been prepared for publication. A collaborative experiment has been done with the Hill Farming Research Organization extending the work to vegetation growing on peat instead of sandy soils as in the previous study and using radioactive rubidium as a tracer as well as radioactive phosphorus.

SOIL FERTILITY

The fertility investigations are directed towards the improvement of manurial practice and crop production through better understanding of: (1) the nutrient requirements of different crops, (2) the nutrient status of different soils, (3) the influence of soil properties and pedological and environmental factors, and (4) the effectiveness of different types of fertilizers and liming materials and the influence of factors such as frequency, time and method of application. The experimental approach is therefore based on concurrent development and integration of field, pot, and laboratory studies covering the main soil types and agricultural crops. Close contact is maintained with the Section of Statistics in the design of experiments and evaluation of results, and with the Department of Spectrochemistry in trace element investigations and analytical work. As indicated in the review of experimental work below, collaboration is also being developed with other departments and sections.

Importance is attached to the practical implications of results, particularly from the field experiment programme, and consultative work, with supplementary lectures and contributions to the agricultural press, has been continued in conjunction with the North of Scotland College of Agriculture. In collaboration with the Section of Statistics, a further report has been prepared on results from the regional manurial trials organized by the Grassland Sub-Committee of the Scottish Agricultural Improvement Council.

Summary statements on soil conditions and lime and fertilizer practices in Scotland, with comments on the wider aspects of these subjects, have been supplied to the Food and Agriculture Organization in connection with the preparation of a revised edition of the bulletin *The Efficient Use of Fertilizers*. The department also co-operated with the Department of Agriculture for Scotland, the Agricultural Research Council's Unit of Statistics, and the Statistics Section of the Institute in preparing plans for the surveys of fertilizer practice being carried out by the Colleges of Agriculture.

Five publications mentioned in last year's report have now appeared. These comprise two papers on soil phosphorus relationships[19], [20], an account[21] of joint work with the Animal Diseases Research Association on magnesium, and revised editions 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). An account[22] of further work on organic phosphorus has also appeared and papers dealing with fertilizer placement[23] and the influence of drainage conditions on soil phosphorus[24] were presented at the Sixth International Congress of Soil Science in Paris, together with accounts of collaborative work with the Section of Radioactivity[16] and the Department of Spectrochemistry[38]. An article on liming[44] has been accepted for publication.

FIELD EXPERIMENTS

To provide the basis for studying the significance of soil characteristics in relation to manurial practice and crop production the field experiments continue to be distributed over recognized soil types at sites chosen in consultation with the Soil Survey of Scotland. To cover seasonal effects, various types of experiments are repeated over a period of years. The importance of this factor was well illustrated by the generally lower level of the yield responses to phosphate obtained in 1955 when the season was abnormally fine and dry.

The soil substitution experiment at Craigiebuckler and a number of long-term liming experiments have been continued. For the broad characterization of the field behaviour of different soils and the responses of different crops further use has been made of one-year factorial NPK experiments with four levels of each nutrient. Work has also been continued on nitrogen, phosphate and trace elements, with particular reference to residual effects and the influence of time, frequency and method of application.

Phosphate Investigations

Four series of long-term experiments have been continued and extended. They cover: (a) straight residual effects of heavy dressings of phosphate (up to 1000 lb. P_2O_5 per acre as superphosphate and ground mineral phosphate), (b) comparisons of single heavy dressings with light annual applications, (c) lime-phosphate interactions, (d) effectiveness of heavy dressings of ground mineral phosphate supplemented with light broadcast and placed annual applications of superphosphate, and (e) continued evaluation of superphosphate residues in terms of fresh dressings. Particular importance is attached to the last point and this type of experiment is being gradually extended to cover the main soil types in north-east Scotland.

The 1956 programme also included six new one-year experiments on the effectiveness of various phosphate fertilizers on swedes, turnips, potatoes, and grassland. Further experiments involving comparisons of autumn and spring applications of phosphate and the effects of ploughing and cultivations on positional availability have also been carried out. These covered oats, swedes, and potatoes and were designed to clarify a number of points arising from the results of a similar series of experiments recently completed.

Methods and Times of Fertilizer Application

As mentioned in last year's report, the main effects of placing fertilizers for cereals, swedes, turnips, and potatoes have been established. An account[23] of further results for swedes and turnips has been published. This summarizes comparisons of placed and broadcast applications of sulphate of ammonia, muriate of potash, and superphosphate, with particular reference to the uptake of nutrients. For nitrogen and potash the nutrient contents of the crops, like the yields, show no clear effect of the method of application. With phosphate also there is little effect on the nutrient content, but the total phosphate uptake follows the yield and is considerably higher for the placed treatments.

Work on times of application of nitrogen for cereals, including comparisons of solid and spray applications of urea, has been continued. In this

connection, the possibility of spraying nitrogen together with hormone weed-killer was tested in an experiment on oats and another on barley. With the MCPA product used, urea applied in this way was fully effective.

Further comparisons of broadcasting, combine-drilling and spraying have been carried out for manganese sulphate and copper sulphate on oats and barley. Similar experiments carried out in 1955 showed that on slightly acid soils combine-drilled or broadcast applications of manganese sulphate, in admixture with fertilizer, were highly effective and in some instances superior to spraying. Soil applications of copper sulphate also proved highly effective and there appears to be no major difference between placing and broadcasting.

Trace Elements

The scope of the field work is being broadened to facilitate development of diagnostic methods and clarify the trace element status of different soils and crops in relation to the increasingly numerous enquiries being received concerning suspected deficiencies and excesses, affecting both animal health and crop production. In addition to the work on methods of application mentioned above, the 1956 programme included experiments to examine the effects of copper sulphate on the yield of grass in areas where oats have given clear responses. Data are also being obtained on the effects of basic slag on the trace element content of herbage.

Soil and crop samples from the field experiments are being supplemented with samples from ordinary agricultural soils and crops representing the main associations. Produce samples are taken at various stages of growth, and in the case of grass individual species as well as mixed herbage are being examined.

Collaboration in trace element investigations with the Animal Diseases Research Association is also being continued.

POT EXPERIMENTS

The major part of the 1956 programme was devoted to measurements of the phosphate fixation capacities of a series of thirteen soils representing field experiment areas on four soil associations and chosen to provide a range of properties. Fixation was induced by an oven-drying technique established from previous preliminary experiments. Depending on the soil, the effectiveness of a dressing added before drying may be reduced by up to 60 per cent. or more compared with the same dressing added after the drying has been completed. This comparison eliminates any other effects of drying and the preliminary results suggest that the extreme fixation capacities measured in this way should provide a clearer indication of the factors governing phosphate fixation and availability in the different soils. In collaboration with the Section of Radioactivity, the phosphate dressings in these experiments were added as KH_2PO_4 solution labelled with P^{32} to study further the influence of fixation on the significance of evaluations of phosphate status obtained by this method. In subsidiary series on some of the soils the extent of fixation under the influence of six months moist contact, alternate wetting and drying at greenhouse temperature, and moist incubation for one week has also been measured.

Other experiments covered measurements of the residual effects of various phosphate fertilizers, including subsidiary evaluation with the aid of P^{32}, and supplementary examination of the manganese and copper status of soils from field experiment areas.

LABORATORY WORK

A major part of the laboratory work is of necessity devoted to analyses of produce samples and characterization of soils from field and pot experiments, together with examination of soil samples received in the course of consultative work. The total number of soil and crop samples involved each year is of the order of 18,000. In collaboration with the Departments of Biochemistry and Plant Physiology, the examination of produce samples is being extended to cover organic constituents.

Attention continues to be given to the improvement of analytical techniques and equipment. Collaboration in the international scheme for air and rainwater sampling has also been continued. In addition, further progress has been made in studies on the phosphorus relationships of soils.

Inorganic Phosphorus

The investigations on this subject include collaborative work with the Section of Radioactivity. Attention has been concentrated mainly on the solubility relationships and sorption properties of soils from field and pot experiments, including samples treated with varying amounts of phosphate and subjected to drying and other treatments to induce fixation. The experimental approach is based on the use of a range of extraction methods of varying properties with respect to pH, ionic strength, nature and concentration of anions, period of extraction and extractant:soil ratio, supplemented with determinations of various other soil characteristics and constituents, particularly categories of aluminium and iron. In the latter connection, Dr D. P. Drover from the University of Western Australia has been collaborating in a joint project with the Section of Radioactivity to investigate the use of radioactive iron for evaluating the reactive iron content of soils. In relation to aluminium, it has been found that neutral ammonium fluoride is a fairly specific extractant for aluminium-bound phosphorus[24]. It has very little effect on the acid-soluble (calcium-bound) phosphorus in the coarser fractions and the fluoride values for soils appear to represent mainly aluminium-bound phosphorus from the clay. Neutral ammonium fluoride also extracts large amounts of aluminium and is particularly useful in characterizing soils developed under different drainage conditions. Comparisons of freely drained and poorly drained soils from various parent material groups have shown that poor drainage is consistently associated with much lower contents of fluoride soluble phosphorus and aluminium.

Organic Phosphorus

Further progress has been made in studies on the organic phosphorus fraction in soils, with particular reference to the nature, stability, and breakdown of the esters present. The ultimate objective of these investigations is

to enable the significance of the organic phosphorus components to be assessed in relation to the phosphate nutrition of crops.

A method for the extraction and isolation of inositol phosphates and their identification by paper chromatography has been published[22]. This method is being applied to surface soils and profiles from field experiment areas to study the distribution of inositol phosphates in different soil types. In the soils so far examined inositol phosphate is present in considerable quantity, amounting to about one-third of the total organic phosphorus. The main constituent is the hexaphosphate. There are also small amounts of the tri- and/or tetraphosphate, but no trace of the mono- or diphosphate has yet been found.

Further work has been done on other forms of organic phosphorus, particularly the nucleic acids and related substances, and further investigations have been planned to link up the organic phosphorus work with studies on carbon and nitrogen.

CONSULTATIVE WORK

Examination of the lime and nutrient status of soil samples taken from agricultural and horticultural land by the staff of the North of Scotland College of Agriculture has been continued, and during the year over 10,500 samples were dealt with. In addition numerous samples from forest nurseries were examined for the Section of Forest Soils. As in previous years, special problems concerning crop production and animal health have been dealt with in collaboration with the Departments of Spectrochemistry and Plant Physiology.

Grouping of results for the lime and nutrient status of samples from agricultural land according to soil association has been continued for Aberdeenshire and Kincardineshire and extended to cover Banffshire. A similar grouping has also been carried out on a county basis. The data for samples received during 1952-55 show that on the mainland the proportion of samples with satisfactory lime contents is lowest in Aberdeenshire, Banffshire, and Ross-shire, intermediate in Inverness-shire and Caithness, and highest in Morayshire, Sutherland, and Kincardineshire. The proportion of samples with reasonably satisfactory phosphate status is highest for Kincardineshire and Morayshire and lowest for Caithness and Banffshire. For potash, the proportion with satisfactory contents is lowest for Ross-shire and Morayshire. The general trend with regard to potash, however, is much better than for lime and phosphate. Depending on locality, 13-34 per cent. of the samples have a satisfactory potash status, compared with only 7-15 per cent. for lime and 5-24 per cent. for phosphate.

MICROBIOLOGY

The work of the section is principally concerned with (i) nutrition and physiology of certain groups of soil micro-organisms—mainly actinomycetes and fungi and (ii) relationships between soil micro-organisms and the roots of higher plants (rhizosphere).

Part of the work in the first field of study is carried out in collaboration with the Departments of Biochemistry and Spectrochemistry. In this connection too, a study of the breakdown of the fatty acid side chain of substituted phenoxy acids (hormonal herbicides) is being undertaken in co-operation with Professor R. L. Wain (A.R.C. Unit of Plant Growth Substances and Systemic Fungicides).

A. D. Rovira (C.S.I.R.O. overseas research student) left the section in January. H. A. Louw (Stellenbosch-Elsenberg Agricultural College, South Africa) joined the section in September to study for the degree of Doctor of Philosophy of the University of Aberdeen.

ACTINOMYCETES

Paraffin and Fat-decomposing Soil Nocardias

The mechanism by which *Nocardia opaca* attacks fatty acids has been described[11]. This work has been extended to other species and strains of the genus *Nocardia* with substantially the same results. Some of the strains, however, differed in their ability to attack benzoic and phenylacetic acid. Thus *N. salmonicolor* grew well on both benzoic and phenylacetic acids while *Nocardia* sp. (Strain P_2) would not attack either compound. This latter strain when incubated with ω-phenyl substituted fatty acids with an odd number of methylene groups in the side chain gave therefore phenylacetic acid as the final product and not *o*-hydroxyphenylacetic acid as found for *N. opaca* and *N. salmonicolor*.

A paper is in preparation for publication embodying the results of a study on the mechanism by which long chain saturated aliphatic hydrocarbons are metabolized by these organisms. In this work ring substituted hydrocarbons are being used in an analogous manner to ω-phenyl substituted fatty acids.

The techniques and methods used in the above studies are also being applied to the breakdown of the fatty acid side chain of substituted phenoxy acids. It is known that the application of 2-4 D.B. (2-4 dichlorophenoxy butyric acid) brings about the destruction of many weed plants leaving crop plants unaffected. With the soil nocardias it has been found that whereas there is little or no conversion of the dichlorophenoxybutyric acids to the corresponding acetate derivatives, conversion of the monochlorophenoxy butyric acids takes place. Further it has been shown that the rate of β-oxidation of the side chain is dependent on the position of the chlorine substituent

on the ring. Evidence has also been obtained of the production of an intermediate between 3- and 4- chlorophenoxybutyric acids and their corresponding acetate derivatives. This work is continuing.

Enzymatic studies with extracts of *N. opaca* prepared by alumina grinding have been continued. The cell free supernatants obtained on centrifuging for 30 minutes at 5,000 r.p.m. give increased oxygen uptakes in the Warburg apparatus in the presence of some of the organic acids of the Krebs cycle. At the end of the experiments keto acids were shown to have been formed from citric, isocitric, malic, and fumaric acids. Evidence has also been obtained of citric acid formation from malic and fumaric acids by these crude extracts.

Thermophilic Actinomycetes from Composts

Work has been continued on the growth of the aerobic thermophilic actinomycete *Micromonospora vulgaris*. Last year it was reported that biotin was an essential growth factor for this organism and that some growth could be obtained on an amino-acid mixture, based on the amino-acid composition of hydrolysed casein, in the presence of biotin. However this growth was very variable and always inferior to that obtained on the complex medium usually employed. Experiments designed to find out if biotin could be supplemented with other known growth factors have been carried out. Of the 30 tested singly and in combination with biotin only Tween 80 (sorbitan monoleate) could replace the former. It is suggested that the effect of Tween 80 is due to its ability to supply oleic acid in a non-toxic form to the organism.

FUNGI

The study of the metabolism of aromatic compounds by fungi, which is being made in connection with the investigation of lignin decomposition in soil, has been continued. A paper[25] on the metabolism of phenolic compounds has been published. This paper deals mainly with experiments carried out in the Warburg apparatus utilizing spore suspensions of the fungi. In addition to ordinary respiration studies with *p*-hydroxybenzaldehyde, ferulic acid, syringaldehyde, and vanillin and the intermediate products in their metabolism, *p*-hydroxybenzoic, syringic, and vanillic acids, the technique has been successfully applied to the study of adaptation to these substances by the spores. These investigations revealed that the acids were oxidized only after a lag period, whereas oxidation of the aldehydes commenced immediately. This indicated that adaptive enzymes were being formed, a fact which was confirmed when it was found that the lag period could be eliminated by previous incubation of the spores in the presence of the aldehydes. Furthermore, it was found that this adaptation could be considerably reduced by the antibiotic citrinin.

In further metabolic studies the technique of Kluyver and van Zijp was used. This consists of growing a mat of mycelium on a rich medium, pouring off the medium and then adding a solution of the substance under investigation to the mat. It has proved useful in the identification of intermediate products of metabolism, which can be obtained in greater amounts by this method than by growth experiments. The formation of *p*-hydroxybenzoic acid, the expected

intermediate from *p*-hydroxybenzaldehyde, which could not be demonstrated by growth experiments, has been confirmed by this technique.

An investigation of the removal of the methoxyl group from several aromatic compounds is being made, since this is considered to be an important feature of lignin decomposition. Kluyver and van Zijp's technique has been extensively used in this study, in conjunction with paper chromatography, for the identification of intermediate products. The work indicates that the fungi can remove methoxyl groups from aromatic compounds with the formation of the corresponding phenolic compounds.

A brief investigation of a method which it was hoped might prove successful in the isolation of basidiomycetes from soil was carried out. Although the isolates differed from those obtained by the normal dilution plate technique, they did not include any basidiomycetes.

RHIZOSPHERE

The development of the root surface microflora during the initial stages of plant growth has been the subject of a publication[26]. Evidence has been obtained that the further development of this flora after germination of the seed, is dependent on normal plant growth.

Experiments designed to follow the establishment of pure cultures of organisms inoculated on to the seed coats of tomato and oats were carried out. It was shown that rhizosphere isolates developed more rapidly than did non-rhizosphere organisms on the emerging root. Further, when tomato seeds are germinated on agar seeded with various cultures, inhibition of the growth of spore formers in the immediate vicinity of the root took place. This did not occur when non-spore forming organisms were tested.

CULTURE COLLECTION

At present 223 cultures of micro-organisms are maintained in the section. They comprise 150 fungi, 39 actinomycetes, and 34 bacteria.

OTHER WORK

Growth experiments have been carried out in connection with the production of a new metabolite by a cobalamin synthesizing strain of *Bacillus megaterium*. Mass growth of this organism has been undertaken for resting cell and cell free extract experiments. Fourteen other strains of *B. megaterium* have also been investigated in this work.

FOREST SOILS

GROWTH OF CORSICAN PINE ON SAND DUNES

The chemical aspects of profile development at Culbin Forest, Morayshire, are discussed in a recent paper[27]. The study of the abnormal seasonal fluctuations in nutrient content of the foliage of Corsican Pine growing on the dunes under different thinning grades, and their relationship to soil moisture, has been completed, and the results have been accepted for publication[45].

Response during the year of young Corsican Pine to phosphate fertilizers applied in 1954 has been very small. There has again been no increase in the rate of height grown due to the fertilizer, and the increase in the calcium content of the needles, observed during the first and second growing seasons after application, has not been maintained. It may be concluded that phosphate is not a primary limiting factor to tree growth on the dunes, as it is on many upland heath and peat soils.

Since earlier work has shown that it is the potassium and magnesium contents of the needles which are most affected by seasonal soil moisture fluctuations, and since the foliage nitrogen content of the trees at Culbin is considerably lower than that of Corsican Pine growing on more normal soils in the same area, the fertilizer trials have been extended to test the effect of these three elements on tree growth. Colour differences are clearly discernible in the foliage at the end of the first growing season after application.

TREE GROWTH ON DEEP PEAT

During the year work at the Lon Mor, Inverness-shire, on the physical and chemical changes taking place in deep peat as a result of afforestation, has been concentrated on an experimental plot of *Pinus contorta* planted in 1928, part of which was manured with ground mineral phosphate in 1939. Analysis of samples from depths down to ten inches have been completed, and confirms that nutrient concentrations in the peat are lowest under the manured trees, which are clearly showing more vigorous growth. The greatest reduction, compared with unplanted peat, is in total potassium and inorganic phosphate, but total calcium and nitrogen show similar trends. Intermediate values are given by the upper layers of the peat under the unmanured trees; at greater depths the amounts are not appreciably different from those in the unplanted ground.

The moisture content of the peat under the manured trees is lower than that in adjacent unplanted ground, and where the peat is less than eighteen inches deep the drying effect of the trees appears to be irreversible, resulting in considerable shrinkage of the peat, with the formation of deep vertical cracks. On these shallower peats, the roots of the most vigorous trees have reached the underlying moraine.

THE EFFECT OF THINNING ON THE SOIL

Collection of litter from sample plots of Norway Spruce at Bowmont Forest Roxburghshire, has been continued for a full year, and chemical and physical analyses of the surface soil have been completed. These show that thinning, by reducing the total amount of nutrients returned to the soil as litter and by altering other environmental factors, causes important changes in soil conditions. The results are being prepared for publication.

THE EFFECT OF CROPPING SYSTEMS ON FOREST NURSERY SOILS

Samples have been taken from long-term fertility demonstrations laid down by the Forestry Commission at Fleet, Newton, Inchnacardoch, and Teindland nurseries, with the object of studying the long-term effects of the different cropping systems currently employed by the Forestry Commission on the structure and nutrient content of widely differing types of nursery soil, in particular the use of greencrops and organic manure (raw hop waste), with and without the addition of artificial fertilizers. The work is complementary to the normal Forestry Commission assessments of seedling growth in the plots and preliminary results indicate that appreciable changes are apparent in the soil after a comparatively short period.

IMMOBILIZATION OF NUTRIENTS BY A TREE CROP

Mr G. M. Will of the New Zealand Forest Research Institute, Whakarewarewa, is determining the total nutrient content of individual Corsican and Scots Pine of different ages growing at Culbin, in order to assess the amount of nutrients temporarily immobilized in the crop, and also the amounts removed from the site in thinning.

CONSULTATIVE WORK

Fertilizer recommendations for both Forestry Commission and private nurseries, based on analyses carried out by the Department of Soil Fertility, have been continued.

The section has collaborated with the Section of Peat Ecology in a trial of *Lotus major* as a suitable species for grazing strips used for fire protection, laid down at Cullendoch Forest, Kirkcudbrightshire.

The work at Culbin and the Lon Mor was demonstrated to delegates to the Twelfth Congress of the International Union of Forest Research Organizations, when they visited these areas in July 1956.

STATISTICS

As in previous years the main work of the section continues to arise from the field experiment programme of the Department of Soil Fertility. About 100 sets of yield data from 1955 crops and from a few 1956 crops were received for analysis. Tables were drawn up to show the results and reports submitted. Complications dealt with in the analyses included covariance adjustments for effects of drainage, drought, number of plants per plot and fertility trends within blocks. In several experiments the number of levels of fertilizer used were not spaced at equal intervals and standard tables of orthogonal polynomicals were calculated for the particular sets of unequally spaced levels to permit a more critical examination of the components of the fertilizer response curves.

In all, 27 designs were produced for field experiments to be commenced in 1956. A number of short term experiments of Latin Square and Lattice Square design are concerned with copper and manganese applications to oats, barley, and grass. Randomized blocks, Latin Squares and Lattice Squares are also used in short-term experiments on responses to different types of phosphates and to different times of application of superphosphate. NPK factorial arrangements of 4^3 design were used for swede and potato crops and of a mixed design for grass crops.

Experiments continued from previous years include a series of Lattice Square and Split-plot Latin Square designs concerned with the effectiveness of single heavy dressings of phosphate and a comparison with light annual dressings. This series is being carried through a second crop rotation. One further complex factorial experiment has been added to the series investigating the long-term effects of heavy dressings of phosphate and their comparison with light annual dressings.

Comparisons have been made of the mean values and accuracies of different methods of estimating the percentage of MgO in plant materials. The results show the value of investigating the precision of the various stages involved in sampling and testing methods.

Further analyses and reports have been made on data from a phosphate manuring experiment for the Section of Forest Soils.

The series of co-operative grassland experiments organized by the Grassland Sub-Committee of the Scottish Agricultural Improvement Council has provided data on yield of grass, yield of crude protein, percentage of dry matter, percentage of crude protein, and content of various minerals in herbage and soil samples. A report on the results of the statistical examination of the data has been submitted to the Grassland Sub-Committee.

CONSULTATIVE WORK

Meetings have been attended at the North of Scotland College of Agriculture and the West of Scotland Agricultural College in connection with the Survey of Fertilizer Practice in Scotland. Plans for the survey have been prepared by the Department of Agriculture in consultation with the Agricultural Research Council Unit of Statistics, the Department of Soil Fertility and the Section of Statistics. Close co-operation with the Agricultural Research Council Unit of Statistics which has existed during the planning of the *Instructions for Surveyors* and the designing of record cards is being maintained during the statistical analysis of the data.

Collaborative work with the North of Scotland College of Agriculture includes the analysis of data from oat variety trials and the planning of an experiment on the control of carrot fly.

Co-operation has been given in the design of a lamb feeding experiment for the Department of Agriculture of the University of Aberdeen. A change-over design arranged in Latin Squares was used and an account[46] of this work has been submitted for publication.

Meantime the section is accommodated in the Department of Statistics of the University of Aberdeen. To further the policy of co-operation a course of ten introductory lectures on *Statistical Science in Agriculture and Forestry* was given to second year students during the winter term.

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

PUBLICATIONS

(A) *Published during the year—*

1. The soils of the country round Jedburgh and Morebattle (Sheets 17 and 18). By J. W. Muir. (*Memoirs of the Soil Survey of Great Britain: Scotland.* 1955. 178 pp. With soil maps of Sheets 17 and 18. H.M.S.O., 30/-).

   The first few chapters of the memoir include discussions of the climate, geology, and soil-forming processes of the area. The major part is devoted to a detailed description of each soil type in standard terms followed by a less technical account suitable for the general reader. There are chapters on agriculture, vegetation, and forestry, and the final chapter and appendices deal with the physical and chemical properties of the soils. Two soil maps, in a pocket attached to the memoir, show the distribution of the soil types. Each has a key by means of which the local soil types are readily related to each other and to recognized world types.

2. Reclamation of Scottish peat land. By E. L. Birse. (*Town and Country Planning*, 172-176, *March* 1956).

   A short popular account of past and current work on peat reclamation.

3. The mineralogy of some soils from Central Italy. By C. Lippi-Boncambi (University of Perugia), R. C. Mackenzie, and W. A. Mitchell. (*Clay Min. Bull.*, **2**, 281-288, 1955).

   Seven soils representative of types of considerable pedological importance in the Umbrian region of Italy have been examined by petrological and clay mineralogical methods in order to supplement previous data on field and chemical characteristics. Some basic data on colour, locality of the sample examined, parent material, rainfall, temperature, rain factor, and pH are given. The soils form an interesting colour group, ranging from red through intermediate colours to yellow and then through brown to black; all except one are derived from calcareous rocks; all except one are neutral to alkaline in reaction.

4. The adsorption of sugars by montmorillonite. I. X-ray studies. By D. J. Greenland. (*J. Soil Sci.*, **7**, 319-328, 1956).

   The adsorption of sugars by montmorillonite has been studied by X-ray diffraction methods. Complexes were found to be formed with a wide variety of sugars, each sugar forming complexes with one or two layers of molecules in each interlamellar region. For the one-layer complexes there was a close agreement between the interlamellar separation and the minimum molecular thickness of the sugar molecules determined from scale drawings. By comparison of the readiness of formation of the complexes under similar conditions, information about relative adsorption energies was obtained. Methylated sugars were found to be more strongly adsorbed than the other sugars examined, and sodium montmorillonite was found to yield two-layer complexes more readily than the clay with other exchangeable cations present.

5. The adsorption of sugars by montmorillonite. II. Chemical studies. By D. J. Greenland. (*J. Soil Sci.*, **7**, 329-334, 1956).

   The effect of methoxyl, amino and carboxyl groups on the adsorption of sugars by montmorillonite has been examined by simple chemical methods. The strong adsorption of methylated sugars has been confirmed. Mechanisms by which the adsorptions of these substituted sugars may take place are suggested. It is considered that these mechanisms contributed to the observed large adsorption of a soil polysaccharide.

6. Potassium in clay minerals. By R. C. Mackenzie. (pp. 123-143 of *Potassium Symposium 1955*. International Potash Institute, Berne).

Occurrence of potassium is confined to certain positions in clay mineral lattices and appreciable amounts are found only in the mica group. The relationships of the minerals in this group are discussed and it is concluded that differences between members is greater than the *potassium decrease—water increase* sequence might lead one to expect. Supporting evidence is adduced from the fixation of potassium by montmorillonite and the release of potassium from muscovite.

7. Einfluss der Feinstmahlung auf die Kristallstruktur von Glimmern. By R. C. Mackenzie and R. Meldau (Harsewinkel, W. Germany), with infra-red data by V. C. Farmer. (*Ber. dtsch. keram. Ges.*, **33**, 222-229, 1956).

Experiments upon the dry- and wet-grinding of muscovite and the dry-grinding of vermiculite are described. Chemical, dehydration, differential thermal, infra-red, X-ray, electron diffraction, and electron-optical data are given and discussed in relation to the process of grinding. Wet-grinding causes muscovite to split principally along the cleavage planes, while dry-grinding causes breakage in all directions; vermiculite, with its interlamellar water, appears to be rather more resistant to dry-grinding than is muscovite. Continuous dry-grinding for 24 hours appears to cause some recrystallization in muscovite. Interesting interference diagrams observed on electron-micrographs of muscovite appear to be complex Bragg-reflection patterns; similar patterns were noted by one of the authors (R.M.) for many other micas some twelve years ago.

8. The trace element content of soils. By D. J. Swaine. (*Technical Communication No. 48, Commonwealth Bureau of Soil Science*. pp. viii, 157. 1955. Price 25/-).

Information on the occurrence of trace elements in soils is arranged for each element under the following headings: location, number of samples, content (in parts per million), method of analysis, and remarks. The references are collected together to form a bibliography of relevant papers up to the end of 1953).

9. 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. (*Geochim. et Cosmochim. Acta*, **8**, 173-181, 1955).

Nine basalts which occur as flows in the Middle Lava series of the Antrim Plateau have been analysed chemically and spectrographically. Seven of the specimens come from the complete flow succession in the neighbourhood of the Giant's Causeway. The petrochemistry of the major and trace elements is discussed.

10. A stabilized microphotometer-lamp power supply. By A. M. Ure. (*Spectrochim. Acta*, **8**, 180-183, 1956).

A mains-operated power unit, to provide a stabilized supply for the photometer lamp of the Hilger H451 microphotometer is described. The circuit makes use of a saturated diode to control a multivibrator oscillator, transformer coupled to the load. A 10 per cent. change in mains voltage within the range 220V to 250V produces a galvanometer deflection change of 0·2 per cent. Readily available valves and components are used throughout. Reliable daily operation with the microphotometer for over 18 months has been obtained with greater convenience and less maintenance than with an accumulator supply.

11. Beta-oxidation of fatty acids by *Nocardia opaca*. By D. M. Webley, R. B. Duff and V. C. Farmer. (*J. gen. Microbiol.*, **13**, 361-369, 1955).

A study of the mechanism of breakdown of ω-phenyl-substituted fatty acids by *Nocardia opaca* has been made. Acids with an odd number of carbon atoms in the side chain (phenylpropionic, phenylvaleric and phenylheptylic acids) were converted to benzoic acid, and cinnamic acid was an intermediate. *o*-Hydroxyphenylacetic acid was identified as a common product when acids with an even number of carbon atoms (phenylacetic, phenylbutyric, phenylcaproic and phenylcaprylic) were used. This evidence supports β-oxidation as a mechanism of breakdown of short chain fatty acids by *N. opaca*.

12. Phloroglucinol trioxime. By V. C. Farmer and R. H. Thomson (University of Aberdeen). (*Chem. and Ind.*, **86**, 1956).

Phloroglucinal trioxime may be alternatively formulated as 1:3:5-tri (hydroxylamino) benzene. Examination of its ultraviolet and infrared spectra confirmed the trioxime structure, by comparison with acetoxime and phenylhydroxylamine. Phloroglucinol itself exists entirely as trihydroxybenzene.

13. *peri*-Hydroxylcarbonyl compounds. Part II. The effect of ring size on hydrogen bonding. By V. C. Farmer and N. F. Hayes and R. H. Thomson (University of Aberdeen). (*J. Chem. Soc.*, 3600-3607, 1956).

Hydrogen bonding in *peri*-hydroxy-indanones, -tetralones, and -benzo*cyclo*heptenones and related compounds has been studied spectroscopically and by reactions with diazomethane and phenyl *iso*cyanate. It is shown that chelation in the five-membered is much weaker than in the six- and seven-membered ring ketones, but there is no sharp distinction between the two larger ring systems. Two major anomalies are reported: (a) some quinol ketones are not methylated by diazomethane; (b) all the peri-hydroxylated five-membered ring ketones examined failed to react with phenyl *iso*cyanate.

14. A simple apparatus for handling radioactive barium carbonate obtained by wet combustion. By R. B. Duff and A. H. Knight. (*Chem. and Ind.*, 1469, 1955).

Organic substances containing ^{14}C are oxidised by the quantitative procedure of Van Slyke and Folche. A simple apparatus is described in which the radioactive barium carbonate obtained can be washed, filtered, and dried with no danger of contamination by material derived from aerial (inactive) carbon dioxide.

15. Heavy metal toxicity and iron chlorosis. By P. C. DeKock. (*Ann. Bot., n.s.*, **20**, 133-141, 1956).

The toxicity of copper, nickel, cobalt, zinc, chromium, and manganese to mustard was studied in water culture, utilizing either the ionic form or the EDTA chelate of the metal in the presence of either ferric chloride or ferric EDTA. In the presence of ferric chloride the activity of the metals in producing chlorosis was as given above, *i.e.*, in the order of stability of their chelates. In the presence of ferric versenate, toxicity of the ionic metal was much reduced. The metal chelates gave very little indication of toxicity with either form of iron. It was found that the ratio of total phosphorus to total iron was higher in the chlorotic plants than in green plants, irrespective of which metal was causing the toxicity. Copper could be demonstrated in the phloem cells of the root using *bis*-cyclohexanone-oxalydihydrazone as histochemical reagent. It is postulated that transport of iron probably takes place in the phloem as an active process. It would appear that as a major part of the iron in plant cells is attached to nucleo- or phospho-proteins, the heavy metals must be similarly attached to phosphoproteins.

16. An evaluation of phosphate fertilizers with the aid of P^{32}. By A. H. Knight and E. G. Williams. (*Trans. VI Int. Congr. Soil Sci., D*, 311-317, 1956).

P^{32} evaluations based on laboratory estimations of surface phosphorus and pot determinations of "A" values are reported for a series of ten mineral (rock) phosphates, together with determinations by the conventional 2 per cent. citric acid extraction method. The best correlations with yield are given by the citric solubilities and the "A" values, but the surface phosphorus measurements also give highly significant relationships.

17. Interaction between nickel and calcium in plants. By A. H. Knight and W. M. Crooke. (*Nature*, **178**, 220, 1956).

An effect of nickel toxicity in oats is an increased uptake of calcium by the leaves when compared with normal plants. In contrast a decreased uptake of calcium is shown by nickel toxic tomato plants until nickel is supplied to only one half of the root system of plants growing in water culture, when a marked increase in uptake of calcium

is found. It appears that the toxic action of nickel and its influence on calcium uptake in the roots and tops can be studied separately.

18. Effect of soil reaction on uptake of nickel from a serpentine soil. By W. M. Crooke. (*Soil Sci.*, **81**, 269-276, 1956).

In pot experiments with a serpentine soil, increase in soil pH, whether produced by $CaCO_3$ or Na_2CO_3, was found to reduce nickel extractable by ammonium acetate and also that absorbed by oat plants. Laboratory studies were made of the recovery of nickel added to a granitic soil limed by either $CaCO_3$ or Na_2CO_3. Increase in soil pH was found to reduce recovery. The results of the experiments suggest that the reduction in toxicity symptoms and nickel absorption produced by liming of these serpentine soils in the field depends on a reduction in available nickel due to change in soil pH, rather than on the improved calcium status of the soil. In a peaty serpentine soil, there are indications that part of the nickel exists as a complex with the soil organic matter.

19. Distribution of phosphorus in profiles and particle-size fractions of some Scottish soils. By E. G. Williams and W. M. H. Saunders. (*J. Soil Sci.*, 7, 90-108, 1956).

Date are given for soils and particle-size fractions from seven profiles representing contrasting parent materials and drainage conditions. The results show several effects of parent material but the major contrasts hinge on drainage conditions. The numerous effects of this factor are discussed with particular reference to variations in the organic and inorganic phosphorus contents of the fractions.

20. Significance of particle-size fractions in readily-soluble phosphorus extractions by the acetic, Truog, and lactate methods. By E. G. Williams and W. M. H. Saunders. (*J. Soil Sci.*, 7, 189-202, 1956).

Particle-size fractions were extracted individually and in combination to assess their significance in soil extractions. The results demonstrate the importance of extractant: solid ratio, period of extraction, and pH as experimental factors, and of phosphate sorption capacity and distribution of phosphorus over the particle-size fractions as soil properties. The relative and absolute behaviour of the three methods on the soils and fractions can be interpreted on the basis of varying balance of these factors.

21. The effects of magnesium liming on the magnesium content of pasture and the blood level of magnesium in cows. By J. Stewart (Animal Diseases Research Association) and J. W. S. Reith. (*J. comp. Path.*, **66**, 1-9, 1956).

Recent work has shown that there is a large seasonal variation in the magnesium content of herbage, the lowest content being in April and May when magnesium tetany is most prevalent. It has also been shown that dressings of magnesium limestone spread on the herbage can increase the magnesium content by over 75 per cent. Experiments described in this paper suggest that the higher magnesium content of the herbage in April and May produced by magnesium limestone dressings considerably reduced the degree of hypomagnesaemia in a herd of cows on a farm where magnesium tetany was prevalent.

22. The identification and estimation of soil inositol phosphates. By G. Anderson. (*J. Sci. Fd. Agric.*, 7, 437-444, 1956).

A technique is described for the identification and estimation of inositol phosphates by paper partition chromatography, in either one or two dimensions. Development with methanol/aqueous ammonia resolved inositol mono-, di-, tri-, tetra-, and hexaphosphates into four spots, the tri- and tetra-phosphate moving together. Acid solvents, such as acetone/acetic acid, moved all these compounds in a compact group. The method has been used to estimate the inositol phosphates in soils. The inositol phosphates were extracted with sodium hydroxide and, after the removal of many organic and inorganic concomitants, were precipitated as the barium salts, converted to the free acids or sodium salts, and examined chromatographically. In the soils so far examined, inositol hexaphosphate accounted for about one-third of the soil organic

phosphate; the tetra-tri-phosphate was present in very small quantity but neither the di- nor the mono-phosphate was detected.

23. Comparisons of broadcasting and placing fertilizers for swedes and turnips. By J. W. S. Reith. (*Trans. VI Int. Congr. Soil Sci., D*, 239-245, 1956).

Field experiments were carried out on swedes and turnips grown in ridges to study the effects of broadcasting fertilizers, compared with band placement in various positions near the seed, on the germination, growth, and composition of crops. The paper deals mainly with the composition of the bulbs and the apparent recoveries of the nutrients. With sulphate of ammonia placement directly below the seed may be injurious to growth and is not to be recommended. Placing this fertilizer 2 inches to the side of the row gave practically the same results as broadcasting. Placing superphosphate was superior both in yield and P_2O_5 uptake to broadcasting and the most effective position was at a depth of 3-3·5 inches directly below the seed. The results for muriate of potash show no important differences between broadcasting and placing.

24. Influence of drainage conditions on fluoride soluble phosphorus in some Scottish soils. By E. G. Williams and W. M. H. Saunders. (*Trans. VI Int. Congr. Soil Sci., B*, 797-803, 1956).

The distribution of neutral ammonium fluoride soluble phosphorus and aluminium has been determined for soils and particle-size fractions from three pairs of freely-drained and poorly drained profiles representing three parent material groups in north-east Scotland. The acid soluble phosphorus in the sand fraction is extracted to only very small extents (0-5 per cent. of the total inorganic phosphorus) and the soil values are derived mainly from the clay. Neutral ammonium fluoride extracts substantial amounts of almuninium from the soils, the values in several cases being higher than by Tamm's acid-oxalate method. The results support the view that neutral ammonium fluoride extracts mainly aluminium-bound phosphorus and show that poor drainage is associated with low fluoride soluble phosphorus and low fluoride and oxalate soluble aluminium. This contrast is most pronounced for the basic igneous profiles.

25. A study of the metabolism of phenolic compounds by soil fungi, using spore suspensions. By M. E. K. Henderson. (*J. gen. Microbiol.*, **14**, 684-691, 1956).

Spore suspensions were used to investigate the metabolism of *p*-hydroxybenzaldehyde, ferulic acid, syringaldehyde, and vanillin by *Haplographium* sp., *Hormodendrum* sp., *Penicillium* sp., and *Spicaria* sp. The intermediate products of their metabolism, *p*-hydroxybenzoic, syringic and vanillic acids, were found to be attacked by adaptive enzymes. The formation of these enzymes was greatly decreased by the antibiotic citrinin.

26. A study of the development of the root surface microflora during the initial stages of plant growth. By A. D. Rovira. (*J. appl. Bact.*, **19**, 72-79, 1956).

A study of the development of the microflora on the seeds and roots of tomatoes and oats during germination and subsequent root development showed a rapid selective multiplication on the seed during the intial stages of germination and also on the root almost immediately after emergence. Evidence is presented that further development of the root surface population after the initial high rate of multiplication was dependent on the normal development of the plant. Direct microscopic observations of the micro-organisms of the root surfaces showed interesting differences between the roots of tomatoes and oats. In the former, the root hairs of young plants were free from bacteria but in the oats even young root hairs supported large numbers of organisms. In both plants the root tips were invariably free from organisms.

27. Profile development in the sand dunes of Culbin Forest, Morayshire. II. Chemical properties. By T. W. Wright. (*J. Soil Sci.*, **7**, 33-42, 1956).

Chemical analysis of the soil from a range of sites at Culbin Forest, Morayshire, has revealed considerable redistribution of the major nutrients taking place after dune fixation, and has distinguished between the downward movement due to leaching and

the circulation initiated by the tree crop. Analysis of the litter has shown abnormal seasonal variation in its chemical content.

(B) *Submitted for Publication—*

28. The soils of the country round Kilmarnock (Sheet 22 and part of Sheet 21). By B. D. Mitchell and R. A. Jarvis. (To appear as *Memoir of the Soil Survey of Great Britain*: Scotland).

29. Pollen analysis of Scottish peat deposits. By S. E. Durno. (To appear in *Scot. geog. Mag.*).

30. A double-focussing X-ray powder camera. By W. A. Mitchell. (To appear in *Clay Min. Bull.*, **3**, No. 15, 36-39, 1956).

31. Turkish forest soils. By W. A. Mitchell and A. Irmak (University of Istanbul). (To appear in *J. Soil Sci.*).

32. Differential thermal analysis and its use in soil-clay mineralogy. By R. C. Mackenzie. (To appear in *Geol. Foren. Stockh. Forh.*, **78**, 508-525, 1956).

33. Thermal methods. By R. C. Mackenzie. (To appear as Chapter I of *The Differential Thermal Investigation of Clays*, to be published by the Mineralogical Society).

34. Apparatus and techniques for differential thermal analysis. By R. C. Mackenzie and B. D. Mitchell. (To appear as Chapter II of *The Differential Thermal Investigation of Clays*, to be published by the Mineralogical Society).

35. Oxides of iron, aluminium and manganese. By R. C. Mackenzie. (To appear as Chapter XII of *The Differential Thermal Investigation of Clays*, to be published by the Mineralogical Society).

36. Methods for separation of soil clays in use at the Macaulay Institute for Soil Research. By R. C. Mackenzie. (To appear in *Clay Min. Bull.*).

37. A method for concentration of dilute clay suspensions without coagulation. By R. C. Mackenzie and K. R. Farquharson. (To appear in *Clay Min. Bull.*).

38. Soil copper status and plant uptake. By R. L. Mitchell, J. W. S. Reith and Isabel M. Johnston. (To appear in 2nd Symposium on *Analyse des Plantes et Problemes des Engrais mineraux*. VIth International Congress of Soil Science, Paris, 1956).

39. The spectrochemical determination of trace elements in plants and other biological materials. By R. L. Mitchell. (To appear in *Proc. Symposium on Trace Analysis. New York*, 1955).

40. Spectrochemical analysis of plants and soils. By R. L. Mitchell. (To appear in *Proc. Soil Sci. Soc. Fla.*).

41. Application of spectrochemical methods to agricultural problems. By R. L. Mitchell and R. O. Scott. (To appear in *Appl. Spectrosc.*).

42. Spectrochemical methods in soil investigations. By R. L. Mitchell. (To appear in *Soil Sci.*).

43. Effects of grinding during the preparation of alkali halide disks on the infrared spectra of hydroxylic compounds. By V. C. Farmer. (To appear in *Spectrochim. Acta*).

44. Does your land need lime? By J. W. S. Reith and A. M. Smith (Edinburgh and East of Scotland College of Agriculture). (To appear in *The Farming Leader*).

45. Abnormalities in nutrient uptake by Corsican Pine growing on sand dunes. By T. W. Wright. (To appear in *J. Soil Sci.*).

46. The effect of different suckling frequencies on the quantity of milk consumed by young lambs. By Joan Munro (University of Aberdeen) and R. H. E. Inkson. (To appear in *J. agric. Sci.*).

APPENDIX

The following are detailed descriptions of the principal soils found in the areas surveyed during the season.

NORTH-EAST SCOTLAND

Soil Survey Sheet 87 (*Peterhead*)

ASSOCIATIONS

Peterhead Association

Distribution . . A belt 2 miles broad from Stirling village northwards along the coast to just north of Crimond.

Parent Material . . Till derived from Old Red Sandstone sediments and mixed acid rocks.

Dominant Series . Poorly drained.

Profile

Horizon	*Depth*	
S	0-8 in.	Very dark grey brown clay loam; moderate fine sub-angular blocky; medium organic content; frequent stones. Sharp change into
G_1	8-15 in.	Reddish brown clay loam; blocky; grey coating on surface of peds, reddish brown interior with yellow ochreous mottling; frequent decomposing stones. Merging into
G_2	15-25 in.	Reddish brown clay with pockets of lighter sandier material from many decomposing stones; prismatic structure; increasing number of larger decomposing stones. Merging into
C-G	25 in. +	Massive reddish brown clay till; ochreous mottling and grey mottling around decomposing stones increasing with depth; blue clay accumulation round larger rotting stones becoming more conspicuous with depth.

Topography . . Gently undulating.

Strichen Association

Distribution . . A general area stretching from Strichen eastwards to the peat mosses of St. Fergus and Rora and southwards almost to Mintlaw and the River Ugie.

Parent Material . . Till derived from quartz-schist and quartz-mica-schist.

Dominant Series . Freely drained.

Profile

As described in Annual Report 1949-50

Topography . . Undulating to moderately rolling.

TARVES ASSOCIATION

Distribution . . An area south of the River Ugie between Mintlaw and Longside and extending south-westwards from Mintlaw through Old Deer and Stuartfield to Crichie Hill.

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

Dominant Series . Poorly drained.

Profile

As described in Annual Report 1949-50

Topography . . Undulating to moderately rolling.

COUNTESSWELLS ASSOCIATION

Distribution . . A strip approximately a mile broad between Strichen and New Pitsligo.

Parent Material . Till derived from granitic rocks.

Dominant Series . Freely drained.

Profile

As described in Annual Report 1950-51

Topography . . Undulating.

FOUDLAND ASSOCIATION

Distribution . . A strip approximately a mile broad between Strichen and New Pitsligo.

Parent Material . . Till derived from andalusite-schist.

Dominant Series . Freely drained.

Profile

As described in Annual Report 1950-51

Topography . . Undulating to moderately rolling.

CORBY ASSOCIATION

Distribution . . Areas flanking the alluvium along the banks of the River Ugie from Bridge of Gavel to Inverugie.

Parent Material . . Fluvio-glacial gravel.

Dominant Series . Freely drained.

Profile

As described in Annual Report 1949-50

Topography . . Gently undulating to moundy.

Boyndie Association

Distribution . . Areas flanking the alluvium along the banks of the River Ugie from Bridge of Gavel to its estuary just north of Peterhead. A larger spread occurs between the North Ugie and Longside village.

Parent Material . . Fluvio-glacial sand with some intercalations of gravel.

Dominant Series . Freely drained.

Profile

As described in Annual Report 1949-50

Topography . . Flat to gently undulating; occasionally moundy.

Skelmuir Association

Distribution . . A small area flanking each side of the Den of Boddam.

Parent Material . . Yellow till with a high content of rounded flints and quartzite pebbles.

Dominant Series . Peaty podzol with iron pan, poorly drained above pan.

Profile

As described in Annual Report 1954-55

Topography . . Moderately rolling to hilly.

Fraserburgh Association

Distribution . . A relatively narrow strip on the raised beach north-east of St. Fergus from Blackwater to Rattray House.

Parent Material . . Windblown shelly sand—underlain at depth by clay.

Dominant Series . Freely drained in top horizons.

Profile

Horizon	*Depth*	
A	0-8 in.	Dark grey brown loamy shelly sand; soft cloddy structure in root mat otherwise single grain; medium organic content; no stones. Sharp change into
B_2	8-18 in.	Light brown shelly sand; weakly cloddy breaking easily to single grain; slightly humose stained. Merging into
	18 in. +	Light brown more compact shelly sand with frequent bright rusty orange mottles; well developed iron pipes round old root channels.

Topography . . Generally flat.

BLACKWATER COMPLEX

Marine alluvium underlies much of the raised beach from St. Fergus to Blackwater and Pittenheath and is exposed at several points along the edge of the raised beach immediately behind the coastal sand dunes.

The topsoil is very variable; it may be wind blown sand, peaty sand, sandy peat or raised beach clay. The underlying marine alluvium is a dark grey generally massive clay very similar to the carse clays of Stirlingshire. When dried out it shows a weak prismatic structure but it is usually massive and sticky with characteristic ochreous mottling. (See description of carse marine clays in Annual Report 1954-55).

The topography is generally flat.

In the Annual Report for 1954-55, soils developed on marine clay in this area were placed provisionally in the Blackwater Association. These soils have been found to be very variable and it has been decided to change the nomenclature to Blackwater Complex.

LINKS

Distribution . . The coastal strip from the mouth of the River Ugie northwards to St. Fergus.

The soil is mainly freely drained and has 4-8 inches of dark brown loamy sand with soft cloddy structure over light yellowish brown sand with single grain structure.

Topography . . Generally flat.

ALLUVIUM

Extensive spreads of alluvium occur along the North and South Ugie Waters, with smaller areas along tributary burns.

There is little profile development and a deep fine sandy loam is the commonest textural class, although all classes from sand to silty clay may be found. The drainage is dominantly poor and the alluvial areas are often overgrown with *Juncus* spp.

SKELETAL SOILS

Dune Sands

Distribution . . A relatively narrow belt extending northwards along the coast from the Ugie estuary to Rattray Head.

Parent Material . . Blown sand.

The area is mainly bare of vegetation and no profile has developed.

BASIN PEAT

A few small patches of peat occur throughout the areas of alluvium. Several patches are also found on the raised beach east of St. Fergus.

EAST SCOTLAND

Soil Survey Sheets 66 (*Banchory*) *and* 67 (*Stonehaven*)

ASSOCIATIONS

Strichen Association

Distribution . . An extensive belt of hill country between the head of Glen Lethnot and Stonehaven.
Parent Material . . Till derived from acid schists.
Dominant Series . Freely drained.

Profile

As described in Annual Report 1950-51

Topography . . Mountainous.

Strathfinella Association

Distribution . . Grampian foothills between Edzell and Stonehaven.
Parent Material . . Till derived from sandstones and conglomerates of Lower Old Red Sandstone age.
Dominant Series . Freely drained.

Profile

As described in Annual Report 1949-50

Topography . . Generally hilly.

Stonehaven Association

Distribution . . Discontinuous patches over an area between Laurencekirk, Gourdon, and Stonehaven.
Parent Material . . Till derived from sandstones, conglomerates, and lava of Lower Old Red Sandstone age.
Dominant Series . Imperfectly drained.

Profile

As described in Annual Report 1949-50

Topography . . Rolling to gently sloping.

Laurencekirk Association

Distribution . . Discontinuous patches throughout the How of the Mearns, about Laurencekirk.
Parent Material . . Till derived from red sandstones and marls of Lower Red Sandstone age.
Dominant Series . Imperfectly drained.

Profile

As described in Annual Report 1949-50

Topography . . Gently sloping.

BALROWNIE ASSOCIATION

Distribution . . Occurs intermittently throughout the lowland area between Edzell, Gourdon, and Stonehaven; within Sheet 67 a particularly stony phase is common.

Parent Material . . Red 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 to hilly.

MOUNTBOY ASSOCIATION

Distribution . . Occurs locally on hilly ground in the coastal area, and on some of the Grampian foothills between Auchinblae and Stonehaven.

Parent Material . . Red brown modified till material and till derived from Lower Old Red Sandstone strata and lava.

Dominant Series . Imperfectly drained.

Profile

As described in Annual Report 1951-52

Topography . . Hilly and undulating.

DRUMGLEY ASSOCIATION

Distribution . . A few minor patches within the area between the east end of the Garvock ridge, Inverbervie, and Crawton.

Parent Material . . Light textured modified red till material; rather variable.

Dominant Series . Imperfectly drained.

Profile

As described in Annual Report 1952-53

Topography . . Gently sloping.

DEAN ASSOCIATION

Distribution . . A limited area about Tarfside, and a small patch just east of Edzell.

Parent Material . . Light textured morainic material of mixed origin.

Dominant Series . Imperfectly drained.

Profile

As described in Annual Report 1952-53

Topography . . Flat to gently sloping.

CORBY ASSOCIATION

Distribution . . Moraines and terraces within Glen Esk and near Edzell.
Parent Material . . Morainic and fluvio-glacial gravels.
Dominant Series . Freely drained.

Profile

As described in Annual Report 1949-50

Topography . . Terraces or mounds.

AUCHINBLAE ASSOCIATION

Distribution . . Groups of mounds concentrated near the glen mouths between Edzell and Stonehaven; occasionally elsewhere throughout the lowland area.
Parent Material . . Red fluvio-glacial sands and gravels.
Dominant Series . . Freely drained.

Profile

As described in Annual Report 1950-51

Topography . . Moundy.

ALLUVIUM

Scattered alluvial channels are frequent in the How of the Mearns area. Otherwise, apart from localized patches of lacustrine alluvium, it is mainly restricted to the channels of the Cowie, Carron, and Bervie Waters.

HILL PEAT

Hill peat occurs throughout the hill areas.

Soil Survey Sheet 48 (*Perth*)

ASSOCIATIONS

BALROWNIE ASSOCIATION

Distribution . . The general area of the Old Red Sandstone valley stretching north-east from Perth to Burrelton.
Parent Material . . Red modified till on till of loam texture.
Dominant Series . Imperfectly drained.

Profile

As described in Annual Report 1950-51

Topography . . Undulating.

DRUMGLEY ASSOCIATION

Distribution . . Limited areas throughout the Balrownie Association in the Old Red Sandstone valley.
Parent Material . . Red or red brown modified till of sandy loam to loamy sand texture.
Dominant Series . Imperfectly drained.

Profile

As described in Annual Report 1952-53

Topography . . Gently sloping.

LAURENCEKIRK ASSOCIATION

Distribution . . The western slopes of Campsie Hill from Campsie Wood to Burnside Farm.

Parent Material . . Till derived from red sandstone marl.

Dominant Series . Freely drained.

Profile

Horizon	*Depth*	
A	0-1 in.	Dark reddish brown loam; good crumb structure. Sharp change into
A	1-9 in.	Reddish brown loam; sub-angular blocky structure breaking to medium crumb; many fragments of red sandstone marl. Merging into
B-C	9-20 in.	Weak red stony heavy clay loam with structure as above; very many angular pieces of red sandstone marl. Merging into
D	20 in. +	Reddish brown soft marl rock.

Topography . . Undulating.

AUCHINBLAE ASSOCIATION

Distribution . . Small patches throughout the Balrownie Association in the Old Red Sandstone valley; an area immediately west of Dundee bordering the Tay estuary.

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

Dominant Series . Freely drained.

Profile

As described in Annual Report 1950-51

Topography . . Moundy.

DARLEITH ASSOCIATION

Distribution . . Upper slopes of the Sidlaw Hills.

Parent Material . . Thin till derived from basic lavas.

Dominant Series . Freely drained.

Profile

As described in Annual Report 1953-54

Topography . . Hilly

BOYNDIE ASSOCIATION

Distribution . . Limited areas in the Old Red Sandstone Valley; areas bordering the alluvium of the River Tay in the vicinity of Old Scone.

Parent Material . . Sand.
Dominant Series . Freely drained.

Profile

As described in Annual Report 1949-50

Topography . . Flat to gently sloping.

CARSE ASSOCIATION

Distribution . . In the Carse of Gowrie bordering the estuary of the River Tay.
Parent Material . . Estuarine alluvium.
Dominant Series . Poorly drained.

Profile

As described in Annual Report 1954-55

Topography . . Level.

CENTRAL SCOTLAND

Soil Survey Sheet 39 (*Stirling*)

ASSOCIATIONS

LARGS ASSOCIATION

Distribution . . The Dunblane and Auchterarder districts.
Parent Material . . Till derived from Old Red Sandstone, containing stones of Highland origin.
Dominant Series . Imperfectly drained.

Profile

Horizon	*Depth*	
S	0-7 in.	Dark brown sandy loam; crumb; friable; Sharp change into
B_2	7-14 in.	Reddish brown sandy clay loam; subangular blocky; firm; slight gleying on faces of peds. Merging into
C	14-40 in.	Dark reddish brown gritty clay loam till, subangular blocky, firm.

Topography . . Rolling.

SOURHOPE ASSOCIATION

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

Profile

As described in Annual Report 1954-55

Topography . . Hilly.

CARSE ASSOCIATION

Distribution . . Carse-land between Stirling and Flanders Moss.
Parent Material . . Estuarine alluvium of 25-foot beach.
Dominant Series . Improved very poorly drained.

Profile

Horizon	*Depth*	
S	0-6 in.	Dark grey silty clay loam; weak fine blocky; firm; distinct ochreous mottling. Sharp change into
G_1	6-32 in.	Grey silty clay; strong coarse prismatic; very firm; many fine distinct ochreous mottles along root channels; gleying on unit faces and in root channels (increasing with depth). Merging into
G_2	32-38 in.	Grey silty clay; weak coarse prismatic; very plastic; intense gleying on unit faces.

Topography . . Level.

STRICHEN ASSOCIATION

Distribution . . Highland valleys.
Parent Material . . Moraine complex derived from Aberfoyle slates and other metamorphic rocks.
Dominant Series . Freely drained.

Profile

As described in Annual Report 1949-50

HILL PEAT

Hill Peat has been found on the broad tops of the Ochil Hills and in the vicinity of the Highland Boundary Fault.

BASIN PEAT

Basin peat has been mapped in the flat or concave areas just south of the Highland Boundary Fault where the underlying strata are principally sediments of Old Red Sandstone age.

SOUTH-EAST SCOTLAND

Soil Survey Sheets 25 (*Kelso*) *and* 26 (*Berwick-upon-Tweed*)

ASSOCIATIONS

ETTRICK ASSOCIATION

Distribution . . West and north-east of Lauderdale.
Parent Material . . Glacial drifts derived from Silurian and Ordovician greywackes and shales.
Dominant Series . Freely drained.

Profile

As described in Annual Report 1954-55

Topography . . Hilly.
Annual Rainfall . 35 in.

HOBKIRK ASSOCIATION

Distribution . . On the higher ground between Greenlaw and Lauderdale.

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

Dominant Series . Freely drained.

Profile

As described in Annual Report 1954-55

Topography . . Rolling.

Annual Rainfall . 30-35 in.

ECKFORD ASSOCIATION

Distribution . . On the lower ground between Greenlaw and Lauderdale.

Parent Material . . Fluvio-glacial sands and gravels in sheets and fans derived from till of the Hobkirk Association or direct from sandstones of the Upper Old Red Sandstone formation.

Dominant Series . Freely drained.

Profile

As described in Annual Report 1954-55.

Topography . . Moundy and rolling.

Annual Rainfall . 30 in.

LAUDER ASSOCIATION

Distribution . . Lauderdale.

Parent Material . . Drifts derived from conglomerates of the Upper Old Red Sandstone formation.

Dominant Series . Freely drained.

Profile

Horizon	*Depth*	
S	0-8 in.	Dark reddish brown loose granular loam; abundant small rounded greywacke stones. Sharp change into
B_2	8-13 in.	Dark red subangular blocky gritty sandy loam; abundant rounded greywacke stones. Merging into
C-D	13 in. +	Dark red conglomerates with boulders up to 18 in. in diameter. (Tree roots found at a depth of 13 feet).

Topography . . Rolling and hilly.

Annual Rainfall . 30 in.

ALLUVIUM

Alluvium occurs in the valleys of the Leader and Gala Waters and also in areas which were occupied by transient lakes in post glacial times.

HILL PEAT

Large areas of hill peat have been mapped in the Lammermuirs north of Blythe and also to the west of the Gala Water.

BASIN PEAT

Basin peat is found at Threepwood, Dogden and Jordanlaw all of which are Raised Mosses. Basin peat is also found in sites formerly occupied by post glacial lakes.

SOUTH-WEST SCOTLAND

Soil Survey Sheet 14 (*Ayr*)

ASSOCIATIONS

Darleith Association

Distribution . . Small areas at the Craigs of Kyle, Tarbolton, Killoch, Raithhill and Mauchline.

Parent Material . . Thin till derived from basic igneous rocks.

Dominant Series . Freely drained.

Profile

As described in Annual Report 1953-54.

Topography . . Hilly, with frequent outcrops.

Rowanhill Association

Distribution . . Patchily distributed throughout an area of several square miles south-east of Coylton.

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

Dominant Series . Poorly drained.

Profile

As described in Annual Report 1950-51

Topography . . Undulating.

Bargour Association

Distribution . . Extensive in the western part of the area, notably in the vicinity of Annbank and Trabboch.

Parent Material . . Till derived mainly from sandstones of the Barren Red Measures with a slight addition of lava.

Dominant Series . Imperfectly drained.

Profile

As described in Annual Report 1950-51

Topography . . Rolling.

Kilmarnock Association

Distribution . . In the area south of the Coylton-Ochiltree road towards Littlemill.

Parent Material . . Mixed till derived from basic igneous rocks and Coal Measures sediments.
Dominant Series . Imperfectly drained.

Profile

As described in Annual Report 1950-51

Topography . . Undulating.

DARVEL ASSOCIATION

Distribution . . Small scattered deposits throughout the area, especially at Drongan, Ochiltree and Plotcock.
Parent Material . . Fluvio-glacial sands and gravels.
Dominant Series . Freely drained.

Profile

As described in Annual Report 1951-52

Topography . . Moundy.

LANFINE ASSOCIATION

Distribution . . Widespread throughout the Mauchline basin south of Tarbolton and in Stair Parish.
Parent Material . . Mixed till derived from basaltic lavas and red sandstones of Barren Red Measures.
Dominant Series . Imperfectly drained.

Profile

As described in Annual Report 1951-52

Topography . . Rolling.

MAUCHLINE ASSOCIATION

Distribution . . In the north-east of the area in the vicinity of Mauchline.
Parent Material . . Till derived from Permian sandstones.
Dominant Series . Imperfectly drained.

Profile

As described in Annual Report 1952-53

Topography . . Rolling.

GLENPARK ASSOCIATION

Distribution . . Small areas in the south-west at Martnaham Moor, and in the vicinity of Joppa.
Parent Material . . Till derived from mixed sediments of Calciferous Sandstone age.
Dominant Series . Imperfectly drained.

Profile

As described in Annual Report 1954-55

Topography . . Undulating.

LINDSTON ASSOCIATION

Distribution . . A narrow belt in the south-west between Milreoch and Whitehill.

Parent Material . . Mixed till derived from various Upper Old Red Sandstone sediments.

Dominant Series . Poorly drained.

Horizon	*Depth*	*Profile*
A_0	0-4 in.	Peaty humus. Sharp boundary.
G_1	4-10 in.	Grey clay; strongly gleyed; massive. Sharp change into
G_2	10-19 in.	Reddish brown clay; strong prismatic structure; much grey and orange mottling. Merging into
C-G	19-34 in.	Red clay till; massive; many decomposing rock fragments.

Topography . . Gently rolling.

DRONGAN ASSOCIATION

Distribution . . A two mile wide belt running east-west from Coylton to Ochiltree.

Parent Material . . Fine-textured till derived mainly from the marls of the Barren Red Measures.

Dominant Series . Imperfectly drained.

Horizon	*Depth*	*Profile*
S	0-10 in.	Brown silt loam; sub-angular blocky structure. Sharp boundary.
B_2-G	10-17 in.	Pale reddish grey silty clay loam; marked prismatic structure; slight yellow mottling. Merging into
C	17-36 in.	Red clay loam till; massive.

Topography . . Undulating.

AUCHINLECK ASSOCIATION

Distribution . . Fairly extensive in the eastern part of the area, south of the River Ayr between Ochiltree and Catrine.

Parent Material . . Mixed till derived from Barren Red Measures marls and sandstones, Permian sandstones and lavas.

Dominant Series . Imperfectly drained.

Horizon	*Depth*	*Profile*
S	0-10 in.	Brown loam; weak sub-angular blocky structure. Sharp boundary.

B_2-G	10-16 in.	Pale brown clay loam; weak prismatic structure with some grey gleying, and rusty mottling associated with weathering basic igneous fragments. Merging into
C	16-40 in.	Pale red brown clay loam till; massive; frequent fragments of sandstone, marl, basalt and teschenite.
Topography	. .	Rolling.

ALLUVIUM

Alluvial soils are found on small areas of flat ground, notably at Failford, Pant, Trabbochburn and Plaid Loch, and where the rivers have a wide flood plain as on the Lugar between Cumnock and Ochiltree, and on the Ayr between Stair and Gadgirth. Textures are extremely variable and include brick clays at Pant and Ochiltree.

BASIN PEAT

Basin peat is found in several former lake-beds such as at Plaid Loch, Holehouse and Mosshead, but the only extensive stretch of peat is the well-known Airds Moss, south of Sorn in the eastern part of the sheet.

Soil Survey Sheets 6 (*Annan*) *and* 11 (*Langholm*)

ASSOCIATIONS

DALBEATTIE ASSOCIATION

Distribution . .	The eastern foot slopes of Criffel between Kirkconnell and Kirkbean.
Parent Material . .	Morainic drift derived from granite.
Dominant Series .	Freely drained.

Profile

Horizon	*Depth*	
S	0-9 in.	Dark brown gritty loam; crumb structure; moist. Merging into
B_2	9-24 in.	Brown gritty sandy loam; crumb structure; many fragments of granite; moist. Sharp change into
B_3	24 in. +	Light brownish grey gritty loamy sand; strongly indurated; many fragments of granite; dry; occasional ochreous mottles; exposed to 38 in.
Topography	. .	Rolling.

MAUCHLINE ASSOCIATION

Distribution . .	Southwest of Canonbie and irregularly between Glencaple and Bankend.
Parent Material . .	Till derived from the New Red Sandstone formation.
Dominant Series .	Imperfectly drained.

Profile

As described in Annual Report 1952-53

Topography . . Rolling.

DREGHORN ASSOCIATION

Distribution . . Along the Kirkcudbrightshire coast from Southerness to Airds.

Parent Material . . Raised beach sand and gravel.

Dominant Series . Freely drained.

Profile

As described in Annual Report 1950-51

Topography . . Flat to gently sloping.

LOCHAR ASSOCIATION

Distribution . . A half mile wide strip on either side of the Lochar water.

Parent Material . . Fine sand of the 30 ft. raised beach. Probably estuarine.

Dominant Series . Poorly drained.

Profile

Horizon	*Depth*	
S	0-8 in.	Dark grey brown fine sandy loam; weak cloddy structure; moist; occasional rusty mottling. Sharp change into
G_1	8-15 in.	Light grey brown fine sand; prismatic structure; moist; much ochreous mottling. Merging into
C-G	15 in. +	Light grey fine sand, frequently stratified; prismatic structure; some ochreous mottling.

Topography . . Flat.

CARSE ASSOCIATION

Distribution . . Between Carsethorn and Kirkbean and west of Caerlaverock Castle.

Parent Material . . Silt or silty clay of the 30 ft. raised beach; probably marine.

Dominant Series . Poorly drained.

Profile

As described in Annual Report 1954-55

Topography . . Flat.

Esk Association

Distribution . . A quarter-mile wide strip bordering the River Esk south of Canonbie.
Parent Material . . Fine sandy fluviatile alluvium of river terraces.
Dominant Series . Freely drained.

Profile

Horizon	*Depth*	
S	0-10 in.	Brown fine sandy loam; crumb structure. Merging into
B_2	10-17 in.	Orange brown loamy sand; weak cloddy structure. Merging into
C	17 in. +	Light brown gravelly loamy sand; single grains; occasional rusty mottles.

Topography . . Flat terrace features separated by small scarps.

Yarrow Association

Distribution . . Small areas along the course of the River Esk south of Canonbie.
Parent Material . . Terrace gravels, probably of fluvio-glacial origin.
Dominant Series . Freely drained.

Profile

As described in Annual Report 1954-55

Topography . . Slightly undulating.

Ettrick Association

Distribution . . Arnton Fell, south of Riccarton Junction, and smaller areas to the south-west.
Parent Material . . Shallow hilltop debris deepening down the slopes to a thick deposit of clay loam texture.
Dominant Series . Peaty podzol with thin iron pan.

Profile

As described in *The Soils round Jedburgh and Morebattle*[1] and (as Hindhope Association) in Annual Report 1952-53

Topography . . Hilly.

Hobkirk Association

Distribution . . Outcrop of Old Red Sandstone north and east of Cooms, 5 miles north-east of Langholm.
Parent Material . . Coomb deposits derived from Old Red Sandstone.
Dominant Series . Poorly drained peaty gley.

Profile

Horizon	*Depth*	
A_0L	1 in.	Molinia litter.
A_0F	8 in.	Very dark brown peat.
A_0H	3 in.	Black greasy humus.
A_2-G	0-6 in.	Light grey loam; weak blocky structure; slight rusty mottling. Merging into....
B_2-G	6-15 in.	Light brown clay loam; prismatic structure; abundant ochreous mottling. Merging into
C-G	15 in. +	Reddish brown sandy clay loam; massive; some ochreous mottling.
Topography	. .	Hilly.

CARTER ASSOCIATION

Distribution	. .	Between Steele Road and Hermitage, and smaller areas to the south-west.
Parent Material	. .	Till or coomb deposits derived from Lower Carboniferous sediments of mixed lithology.
Dominant Series	.	Peaty gley.

Profile

As described in *The Soils round Jedburgh and Morebattle*[1] and (as Martinlee Association) in Annual Report 1949-50

Topography	. .	Hilly.

DARLEITH ASSOCIATION

Distribution	. .	Outcrops of Lower Carboniferous lavas north and east of Cooms, 5 miles north-east of Langholm.
Parent Material	. .	Basic lavas of Lower Carboniferous age.
Dominant Series	.	Freely drained.

Profile

As described in *The Soils round Jedburgh and Morebattle*[1] and Annual Report 1954-55

Topography	. .	Hilly.

ALLUVIUM

Small strips of alluvium are found on the flood plains of the principal rivers. These are the Nith, Lochar Water, Esk, Hermitage Water and Liddel Water.

HILL PEAT

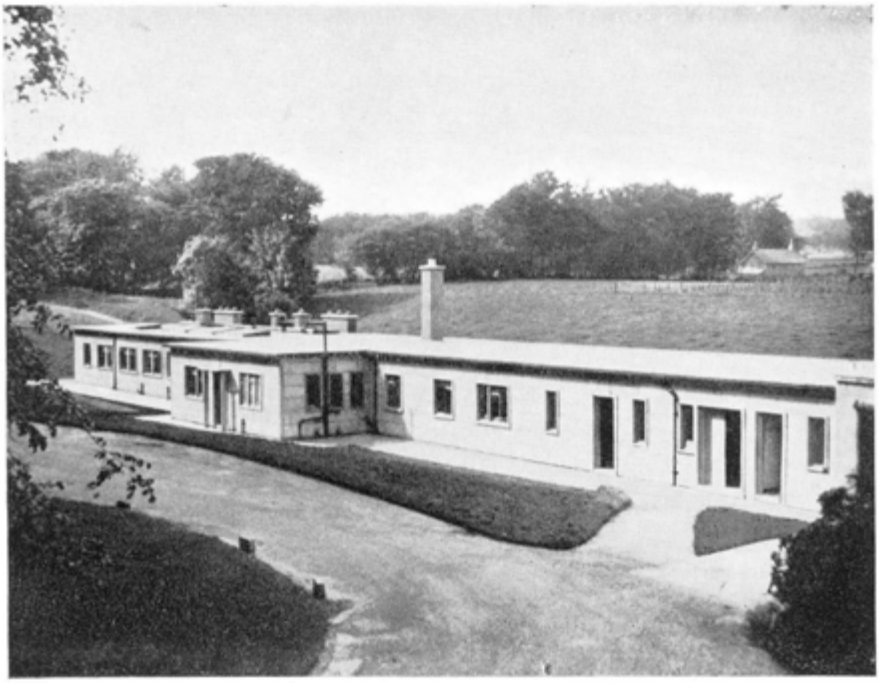
Several square miles of hill peat have been mapped on Watch Hill and Rowan Fell on the border of Dumfriesshire and Roxburghshire. It is particularly extensive over the less deeply dissected hills of Carboniferous sediments.

BASIN PEAT

Lochar Moss is one of the largest peat bogs in Scotland. Its south-western corner was mapped and found to support a vigorous community of *Calluna vulgaris*, *Erica tetralix* and *Sphagnum* spp. Locally there are small coppices of Birch and Pine. In the centre the peat reaches a thickness of twenty feet. Three other small peat bogs were mapped just west of Canonbie.

SOIL HORIZON SYMBOLS USED BY THE SOIL SURVEY OF SCOTLAND

ELUVIAL HORIZONS		GLEYED ELUVIAL HORIZONS	
A	undifferentiated	A-G	gleyed A.
Subdivisions of Eluvial Horizons		*Subdivisions of Gleyed Eluvial Horizons*	
A_0L	undecomposed plant remains.		
A_0F	partially decompo_ed organic matter.		
A_0H	well decomposed organic matter.		
A_1	intimate mixture organic and mineral matter.		
A_2	grey silicious.	A_2-G	gleyed A_2.
ILLUVIAL HORIZONS		GLEYED ILLUVIAL HORIZONS	
B	undifferentiated	B-G	gleyed B.
Subdivisions of Illuvial Horizons		*Subdivisions of Gleyed Illuvial Horizons*	
B_1	iron pan, or humus concentration or both.		
B_2	diffuse deposition of sesquioxides or humus or both.	B_2-G	gleyed B_2.
B_3	indurated or compacted.	B_3-G	gleyed B_3.
PARENT MATERIAL		GLEYED PARENT MATERIAL	
C	undifferentiated	C-G	gleyed C.
GLEY HORIZONS			
G	undifferentiated		
CULTIVATED HORIZONS			
S	undifferentiated		
PARENT ROCK or NON-CONFORMING DRIFT			
D	undifferentiated		



DEPARTMENT OF SOIL FERTILITY

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