THE MACAULAY INSTITUTE FOR SOIL RESEARCH

FOUNDED 1930

ANNUAL REPORT 1956-1957

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

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

(Founded 1930)

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Librarian	Miss A. M. B. Geddes, M.A., F.L.A.

*Appointed during the year. †Resigned during the year.
‡Seconded from Colonial Pool of Soil Surveyors .

POST-GRADUATE RESEARCH WORKERS

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

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

B. M. Bishui (Central Glass and Ceramic Research Institute, Calcutta, India).

J. C. Burridge (West African Cocoa Research Institute, Tafo, Ghana, West Africa).

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

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

L. A. B. Ferreira (Laboratório Químico Agrícola 'L. A. Rebelo da Silva', Lisbon, Portugal).

Senhora M. A. C. F. Ferreira (Laboratório Químico Agrícola 'L. A. Rebelo da Silva', Lisbon, Portugal).

G. N. Harve (Biochemical Institute, Norwegian Veterinary School, Oslo, Norway).

M. Lachica Garrido (Estación Experimental del Zaidin, Granada, Spain).

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

J. A. Perez Geijo (Instituto de Edafologia y Fisiologia Vegetal, Madrid, Spain).

D. Purves (Chemistry Department, Edinburgh and East of Scotland College of Agriculture, Edinburgh).

W. Robertson (Grassland Research Station, Kitale, Kenya).

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

CONTENTS

INTRODUCTION

The Institute is concerned with the study of the soil in all its aspects and the year under review has seen considerable development and expansion in the various lines of research on which the staff is engaged. The investigations in progress are briefly summarized in this report. There has been an increased integration of the work of the various departments within the Institute, and collaboration with Government Departments and other research institutes continues.

The research programme has again benefited from financial grants given by the Department of Agriculture for Scotland, the Agricultural Research Council, the Forestry Commission, and other bodies, and grateful acknowledgement is made of this generous support. The Institute is also indebted to the Rockefeller Foundation for a grant of 9,500 dollars for the development of spectrochemical methods of analysis. This grant will be applied to the purchase and installation of a direct-reading equipment.

COUNCIL

Mr Maitland Mackie, O.B.E., who had given ten years of valued service to the Institute as a representative of The North of Scotland College of Agriculture, resigned from the Council of Management in October 1956. He has been succeeded by Mr A. J. Blackhall.

STAFF

Appointments—

Department of Spectrochemistry—
Miss M. M. McRae, B.Sc.

Department of Soil Fertility—
A. A. Rutherford, B.Agr.
H. C. Duncan, B.Sc. (Agr.).

Resignations—

Department of Pedology—
R. A. Jarvis, B.Sc., F.R.G.S. (Soil Survey of Scotland).
Miss E. S. Murdoch (Section of Soil Geology and Mineralogy).

Department of Spectrochemistry—
Miss D. M. Keith.

Department of Soil Fertility—
J. R. Devine, B.Sc. (Agr.).

As in previous years the Institute has been represented at many conferences both at home and abroad; papers have been contributed and contacts maintained with other research workers in the field of soil science. In the autumn of 1956, Dr R. Glentworth, Head of the Soil Survey Section, visited Malaya and Hong Kong. With Mr C. J. Grant, a Colonial Pool Surveyor based at the Institute, he started a soil survey in Hong Kong which is now being carried on by Mr Grant. Another Colonial Pool Surveyor based at the Institute, Mr D. Lang, visited and surveyed the Maltese Islands. Mr J. Smith of the Survey Staff has been granted leave of absence to study glaciology in South Georgia as a member of The Royal Society's expedition in connection with the Geophysical Year studies.

PUBLICATIONS

Thirty-four publications were issued during the year and are summarized in this report. With the few exceptions indicated, reprints can be obtained on application to the Librarian.

THESES

The following theses were accepted:

(*a*) by the University of Edinburgh for the degree of Doctor of Science—
Some contributions to clay mineralogy. By R. C. Mackenzie.

(*b*) by the University of Aberdeen for the degree of Doctor of Philosophy—
The seasonal distribution of trace elements in pasture species. By Brian G. Davey.

VISITORS

The activities of the Institute continue to attract many interested visitors, and amongst those who inspected the laboratories this year were overseas workers from Australia, Canada, Ceylon, Cyprus, Germany, India, Israel, Jamaica, Japan, Malaya, New Zealand, Nigeria, Norway, Poland, South Africa, Sweden, Uganda, U.S.A., and Venezuela. Members of the Agricultural Education Association Summer Conference and the directors of Scottish Agricultural Industries Ltd. were amongst the organized parties visiting the Institute.

POST-GRADUATE RESEARCH WORKERS

During the year the following research workers carried out post-graduate studies at the Institute:—

Department of Pedology—

Soil Geology and Mineralogy—

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

Physical Chemistry—

B. M. Bishui (Central Glass and Ceramic Research Institute, Calcutta, India).

Soil Analysis—

W. Robertson (Grassland Research Station, Kitale, Kenya).

Department of Spectrochemistry—

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

J. C. Burridge (West African Cocoa Research Institute, Tafo, Ghana, West Africa).

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

L. A. B. Ferreira (Laboratório Químico Agrícola "L. A. Rebelo da Silva," Lisbon, Portugal).

Senhora M. A. C. F. Ferreira (Laboratório Químico Agrícola "L. A. Rebelo da Silva," Lisbon, Portugal).

G. N. Havre (Biochemical Institute, Norwegian Veterinary School, Oslo, Norway).

M. Lachica Garrido (Estación Experimental del Zaidin, Granada, Spain).

D. Purves (Chemistry Department, Edinburgh and East of Scotland College of Agriculture, Edinburgh).

Department of Plant Physiology—

J. A. Perez Geijo (Instituto de Edafologia y Fisiologia Vegetal, Madrid, Spain).

Department of Soil Fertility—

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

Section of Microbiology—

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

Section of Forest Soils—

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

Several other workers spent short periods studying the work in progress—

J. A. R. Bates, Department of Agriculture, Nigeria.

B. E. Heath, The British Petroleum Co. Ltd., Research Station, Kirklington Hall, Nr. Newark, Notts.

A. Kruger, Department of Agriculture, Division of Chemical Services, Pretoria, South Africa.

A. F. Machin, Ministry of Agriculture, Fisheries and Food, Weybridge, Surrey.

Dr M. S. Niklewski, University of Szczecin, Poland.

H. Payne, Land Use Officer, Department of Agriculture, Hope, Jamaica.

Miss J. M. Rooke, Department of Geology, The University, Leeds.

P. S. Subido, Bureau of Plant Industry, Manila, Philippines.

E. Webster, Pilkington Bros., St. Helens, Lancashire.

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*, 1957.

PEDOLOGY

SOIL SURVEY (SCOTLAND)

Soil surveys are in progress in the north-east, east, south-east and south-west Scotland and three soil survey memoirs with accompanying maps have now been published, for the Huntly-Banff-Turriff district, for the Jedburgh-Morebattle district, and for the Kilmarnock district. As soil survey is essentially a long term investigation and as previous Annual Reports have discussed surveys of specific localities purely from the field aspect, the time would appear opportune to summarize some of the more general findings as described in these publications. A map showing the present stage of the survey is given on page 25.

The soils so far encountered can be classified in the following Major Soil Groups: (1) peaty podzols, (2) podzols, (3) brown forest soils of low base status, (4) brown forest soils with gleyed B and C horizons, (5) non-calcareous ground water gleys, (6) non-calcareous surface water gleys, and (7) peaty gleys.

In the uncultivated state each of these soils exhibits the particular sequence of horizons described below. For purposes of comparison a symbol is given to each well-defined horizon; thickness of horizons is given when significant.

Peaty Podzol with iron pan—

L	2 ins.	Undecomposed plant litter.
F	3 ins.	Partially decomposed litter.
H	3-9 ins.	Decomposed organic matter—dark brown or black.
A_1		The uppermost mineral layer, dark coloured organic matter mixed with mineral matter relatively rich in silica.
A_2		A layer immediately below the A_1 which is low in organic matter, pale grey in colour, and rich in silica. May show signs of gleying when it is designated either $A_2(g)$ when the gleying is slight or A_2g when the gleying is strong. A concentration of roots may be present at the bottom of this layer and may be partially decomposed.
B_1		A thin iron pan about 1/16 inch thick. Maximum enrichment of sesquioxides. May be continuous and impermeable to water and roots; there is a strong tendency for gleying and for roots to concentrate immediately above in the A_2.
B_2		Brighter than the A or C horizons. Relative enrichment of sesquioxides.
B_3		Not so bright as B_2. Shows some relative enrichment of sesquioxides and a degree of induration.
C		The relatively unweathered parent material.

Podzol—

L	2 ins.	Undecomposed plant litter.
F	3 ins.	Partially decomposed plant litter.
H	½-2 ins.	Decomposed organic matter.
A_2	½-2 ins.	Dark grey, drying pale grey. Rich in bleached mineral material.
B_2		Brighter brown than any other horizon. Relative enrichment with free sesquioxides.
B_3		Paler than B_2 horizon. A degree of induration.
C		Relatively unweathered parent material.

Brown Forest Soil (low base status)—

These soils are roughly equivalent to the brown podzolic soils of the U.S.A.

L	Undecomposed plant litter.
F	Partially decomposed plant litter.
H	Trace of decomposed organic matter. May be absent.
A	Brown colour with medium organic matter, moder type; crumb structure. No differentiation into A_1 or A_2.
B_2	Brighter brown colour than the A horizon. A relative enrichment of sesquioxides.
B_3	Less bright than the B_2 horizon and nearer to the colour of the parent material. Some degree of induration.
C	Relatively unweathered parent material.

Brown Forest Soil with gleyed B and C Horizon—

L-F ½ ins.	Undecomposed and partially decomposed litter.
A	Grey brown. Granular to blocky structure.
A_2(g)	Mottled with grey and ochre. Blocky structure.
B_2(g)	Brighter colour with mottling of ochre and a little grey. Prismatic structure.
C(g)	Parent material. Relatively uniform colour with occasional mottle.

(g) indicates a small amount of gleying.

Ground-water Non-calcareous Gley—

L	Undecomposed plant litter.
F	Partially decomposed litter.
H	Trace of decomposed organic matter—normally absent.
Ag	Uppermost mineral layer. Organic matter content low to moderate. Structure weak. Ochreous mottling associated with roots.
Bg	Weak prismatic structure. Faces of peds grey coloured and more or less strongly mottled with grey and ochreous colours internally.

Cg	Massive structure. More or less strongly gleyed with grey colours much in evidence. Well-defined iron tubes around dead roots.

Surface-water Non-calcareous Gley—

L	Undecomposed plant litter.
F	Partially decomposed litter.
H	Trace of decomposed organic matter—often absent.
A_1g	Mixed mineral and organic layer. Some ochreous mottling associated with roots. Weak structure.
A_2g	Pale-coloured mineral layer, low in organic matter. Structure weak. May be some ochreous mottling.
B_2g	Well-defined blocky or prismatic structure. Peds coated with grey and mottled inside with ochre and grey.
B_3g	Less well-defined blocky or prismatic structure. Peds coated with grey and mottled inside with ochre and grey.
Cg	Original colour of parent material more apparent. Structure more massive although peds may still have grey coatings and ochreous and grey mottling inside.

Peaty Gley—

L	Undecomposed plant remains.
F	Partially decomposed litter.
H	Decomposed organic matter usually more than 2 inches thick and dark brown or black in colour.
A_1g	Mixed organic and mineral layer. A little ochreous mottling associated with roots. Weak structure.
A_2g	Pale-coloured layer. There may be some ochreous mottling. Weak structure. Low content of organic matter.
B_2g	Blocky or prismatic structure very apparent. Peds coated with grey but inside show ochreous and grey mottling.
B_3g	Blocky or prismatic structure less apparent. Still grey coating to peds and inside ochreous and grey mottling.
Cg	Original colour of parent material more apparent. Structure more massive but peds still coated with grey and inside there is still ochreous mottling.

The modification of the soils brought about by cultivation does not affect the lower horizons, and cultivated soils can therefore be classified as members of one or other of these groups.

Two of the factors responsible for significant variations in the morphological features of soil profiles are the lithological composition of the parent material and the degree of freedom of the natural drainage, or the hydrologic condition of the soil.

In mapping soils the units distinguished are called Soil Series. A series is defined as a group of soils having soil horizons similar in differentiating characteristics and arrangement in the soil profile and developed from a particular kind of parent material. The soil series is therefore both a primary classification unit and a primary cartographic unit.

Five drainage classes are recognized, namely excessive, free, imperfect, poor, and very poor.

Considering the Major Soil Groups in relation to the drainage classes one anomaly occurs, that of the peaty podzol. This soil, which has an iron pan below the A_2 horizon, may be considered to be very poorly drained above the iron pan and freely drained beneath. The podzol and brown forest soils have free drainage; the brown forest soils with gleyed B and C horizons have imperfect drainage; the non-calcareous ground-water and surface-water gleys have poor drainage, and the peaty gleys very poor drainage.

In the Soil Survey of Scotland, Soil Series developed on material from similar parent rock are grouped together into a Soil Association which is a cartographic unit. Soil associations tend to cover the natural landscape units and the soil series within them reflect the micro-topography and the drainage pattern. Since the soil association combines soil series as they are found in the landscape, the relationship between soil and landscape is readily established. The Major Soil Group, on the other hand, is the means of comparing the soils in one part of the world with those in another. The number of genetic soils contained within a soil association is dependent very largely on the texture of the parent material, relief and altitude.

The first area surveyed, of 560 square miles, has been described in the memoir entitled *The Soils of the Country round Banff, Huntly, and Turriff* which includes soil maps on the scale of 1 inch to 1 mile for Sheets 86 (Huntly) and 96 (Banff).

The physical features of this district conform to the folding of the Highland Schist rocks. There is a range in altitude up to 1850 feet, the highest point being Tap o' Noth in the south-west of Sheet 86, and rolling relief typifies the whole landscape. Arable land extends up to about 1000 feet, above which uncultivated moorland occurs which is mostly heather covered. More and more of the hill land is being planted with conifers by the Forestry Commission.

Mixed farming with emphasis on the fattening of beef cattle is the main agricultural pursuit. Land occupied for this purpose is mainly of the podzol or brown forest soil group. The soils which occur on rolling relief have naturally free drainage. Only relatively small areas of the non-calcareous surface-water gley soils occur, mainly in the valley bottoms or on foot slopes. A representative farm is of 75 to 100 acres and a six course rotation of crops is usual, namely three years of grass followed by oats, turnips, oats plus grass seed. Half the farm is therefore in grass and half under the plough. Stock rearing tends to be confined to the higher lying districts where the soils are usually light-textured and were derived from podzols before cultivation. Here the practice is to leave the grass ley down for a longer period than in the mixed farms. Hill sheep farming is of no real consequence within the confines of the area described, except in isolated hilly localities in the vicinity of Gartly and Huntly (south-west corner of Sheet 86).

The average annual rainfall over an extensive area of north-east Scotland varies between 32 and 35 inches, but is undoubtedly higher than this on the hills above 1000 feet.

Glacial tills derived from rocks of the Highland Schist formation or from acid and basic igneous rocks, together with two areas of Old Red Sandstone, form the main parent materials of the soils. Fluvio-glacial sands and gravels are extensive along the Moray Firth and are a feature of a high level terrace along the main water courses—the Ythan, North and South Ugie Waters, etc. A unique deposit of almost pure white quartzite gravel occurs at Woodhead of Fyvie. This is considered to be of an earlier age than the glacial deposits and is probably Pliocene.

The Highland Schists were originally laid down as marine sediments of sands, silts, clays, and siliceous marls. These have been subjected to a varying degree of metamorphism and are highly folded so that they now appear as slates, phyllites, schists, gneisses and quartzites. In the western or Keith Division the rocks are highly metamorphosed and appear as quartzites, flags and mica-schists. The quartzites form the parent rocks of the Durnhill Soil Association and the flags and mica-schists contribute to the parent material of the Strichen Association. The eastern or Banff Division has been only slightly metamorphosed and the rocks are slates, phyllites, and greywackes; these form the constituent rocks of the extensive Foudland Association.

At a later date than the Highland Schists, acid and basic igneous rocks were extruded as sills through the schists. These Older and Younger Igneous rocks give rise to the granite from which the parent material of the Countesswells Association of soils has been formed, and the gabbros (olivine norite) form the parent material of the Insch Association. Ultra basic rocks, of picrite, troctolite, and serpentine, are the main constituents in the iron and magnesium rich parent material of the Leslie Association. The only sedimentary rocks in the area are found in the two outliers of the Middle Division of the Old Red Sandstone—the Gamrie-Turriff outlier, and the Rhynie outlier. In the succession of beds in this formation, an upper group of conglomerate rocks gives rise to the Hatton Association. The middle group, consisting largely of red sandstone, is the main constitutent in the parent material of the Cuminestown Association, while the basal conglomerate rocks derived from the slates and grits from the Banff Division of the Highland Schists on which it rests, is the material of which the till of the Ordley Association is largely composed. In the Rhynie outlier, a contemporaneous flow of andesitic lava forms the parent material of the small Gartly Association.

Ice movements from north-west to south-east, south-west to north-east, and from west to east are considered to have traversed the region. A black Jurassic clay containing ammonites and forming the parent material of the Whitehills Association is thought to be material brought in from the bed of the Moray Firth by the first ice moving from north-west to south-east. It can be seen at Whitehills on the Moray Firth coast. Silty clays of the Coastal

Deposits, representative of an interglacial period between the First and Second Ice Ages, form the parent material of the Bogtown Association near Sandend Bay also adjacent to the Moray Firth. By and large, however, the last movement from the west to east is mainly responsible for a displacement of glacial till for a distance of a mile or two to the east of the solid.

A very striking feature of the soils with free drainage, both of podzols and brown forest soils with low base status, is the presence of an indurated horizon which occurs at a depth of from 8 to 18 inches on arable soils. This horizon which is widespread throughout the soils of Scotland, and particularly over north-east Scotland, is so dense that roots fail to penetrate it and it effectively limits their feeding range. Air space values in this horizon are reduced to about 25 per cent., whereas the B_2 horizon above has a pore space of over 50 per cent. The induration is greatest at the top of this horizon and gradually fades out with depth. The indurated horizon is markedly lighter in texture than the layer above it and often than the parent material below. It breaks into a platy structure and the undersides of the plates are coated with a brown organic staining. It is now thought to be a peri-glacial phenomenon which marks the surface of the permafrost or permanently frozen subsoil, and is a relic from the long tundra-like period which persisted following the close of the Ice Age. Insufficient recognition of the check on root development and consequently on yield has as yet been given to this phenomenon. The possible beneficial effects of some form of subsoil tining remains to be ascertained.

Of the sixteen soil associations occurring in the area, three contrasting examples will be cited as typifying some of the salient soil features, both morphological and chemical, of the soils of the region; these are the Durnhill on quartzite till, the Foudland on argillaceous schist till—the most extensive and covering some 42 per cent. of the total area—and the Insch Association on basic igneous till.

The Durnhill Association on quartzite till generally occupies isolated and conspicuous hill features such as the Balloch, Knock, Sillyearn, and Durn Hills. The flatter sites are invariably occupied by the peaty podzol soils which have a well-developed iron pan, the steep slopes have podzols lacking the pan. Steep slopes on some parts, light textures (stony sandy loams), strong acidity (pH 3·5 to 4·0) and consequent poverty of nutrient reserve, preclude the use of these soils to agriculture; they also provide poor grazing. One area—the Bauds of Cullen—with flatter relief is cultivated and is extensively used for the production of early potatoes, but in this locality considerable quantities of town refuse and fish manure have been applied. The Balloch is now planted, but was formerly a heather moor underlain by a peaty podzol soil having an organic layer of 4 to 12 inches thick, an A_2 horizon of 6 to 18 inches underlain by a continuous iron pan which overlay an indurated layer on stony sandy loam quartzite till. Previous to planting, the vegetation was that of a wet moorland, but before planting it was ploughed at a spacing of 5 feet to a depth of 12 inches. This was instrumental in rupturing the iron pan in places and has enabled a downward movement of water to take place and has thereby transformed a wet peaty hill into a dry hill. Scots Pine, Corsican Pine, and Japanese Larch are now growing successfully; all have received applications of phosphate and experimental plots of Japanese Larch which have received a complete fertilizer are showing unusually good growth.

While the soils of the Durnhill Association are inherently very poor in nutrients, by contrast the soils of the Insch Association, derived from basic-igneous rock till, have a high level of natural fertility. Hill grazing land of the Cabrach district within this association, and at a height approaching 1000 feet, is known for the high quality of stock raised there; this may be related to the naturally high content of phosphate—values of up to 1·0 per cent. total P_2O_5 have been found as compared with an average figure for arable land of 0·25 per cent.

The Insch freely drained soils are representative of brown forest soils with low base status. In the American terminology they would be considered to be brown podzolic soils. The surface layer of the arable soils is a medium brown colour and the uncultivated semi-natural soils tend to have only a slight development of surface litter beneath which they have the appearance of the arable surface soil. The texture is generally a loam and a well-developed crumb structure is a marked feature. The structure is in part due to a high biological activity and to the high iron content. The underlying B_2 is a yellow brown colour and under this is the previously mentioned indurated layer, pale yellow in colour, lighter textured (gritty coarse sandy loam) overlying the parent material which varies from a sandy loam to a sandy clay loam.

About 60 per cent. of the Insch Association occurs on land with naturally free drainage. The poorly drained soils have a much greyer surface and a cloddy rather than a crumb structure. The underlying horizons are profusely mottled with ochreous colours, and pronounced grey coatings appear on the faces of the large prismatic aggregates which compose the structure of the subsurface horizons. The poorly drained soils tend to have a higher clay content than the freely drained, a modal texture being sandy clay loam. A feature of the Insch Association is the widespread development of soils with a deep surface horizon, up to and exceeding two feet in thickness. This is commonly found surrounding the villages, glebes and older farm steadings and is undoubtedly a remnant from the former in-fields of the pre-fertilizer era.

Ancient man had long occupied the Insch valley, as betokened from the records of the very numerous findings of his remains in this area. The reason for this is the relatively high level of natural fertility of these soils.

The natural soils of the Foudland Association are, in the main, podzol soils—soils with a surface accumulation of 4 to 6 inches of organic matter, underlain by a grey siliceous A_2 horizon followed by a yellow orange, iron-rich B_2 horizon which passes into a compact pale yellow B_3 layer and so into the glacial till which has a high concentration of small slaty stones. The arable soils derived from the podzol have a pale brown colour and occupy the long moderate slopes of the hills. Well-water shortage is common over many of the hills. The poorly drained soils occupy only 12 per cent. of this association and are found in the valley bottoms. The argillaceous schist rock from which the till is derived is shattered, enabling the passage of water through it.

The poorly drained soils which are representative of the non-calcareous ground water gley have a surface horizon which is grey in colour rather than the pale brown of the freely drained, and the structure is blocky to weakly cloddy. There is a sharp change into the subsurface B_2g horizon which is markedly grey with comparatively little iron mottling. Yellow-brown iron staining tends to appear below a depth of 24 inches, but the soil is low in iron. The colours of the subsurface horizons are in marked contrast to those of the poorly drained Insch soils which have an overall bright orange colouration.

The texture of the Foudland soils is a silt loam, characterized by a smooth feel due to the high silt content which exceeds that of clay. This is unusual for the soils of the region where the silt content is generally lower than the clay.

Agriculturally the Foudland Association soils are responsive to good management but are inherently lower in nutrients than the Insch soils. They are easily worked and can be cultivated soon after rain. They are free from boulders. In the Insch Association the fields tend to be subdivided by dry stone dykes—stone walls constructed of boulders taken from the fields. The flat pieces of slate chips in the Foudland soils are too small for use in the construction of dykes, and in consequence the fields are divided by wire fences. The Foudland Association is virtually bare and treeless, and much improvement could be effected by the planting of shelter belts, whereas the Insch Association has a high proportion of policy parks and small wood belts.

Since the publication of the memoir the individual soil series have been named. Appendix 1 details the names for the soil series formerly identified only by drainage symbols. A subdivision of the freely drained series on the basis of depth (shallow, intermediate, and deep) is given in the memoir. These phases would receive the appropriate series name but will continue to be labelled on a depth basis.

Among the chemical properties which emerged as a result of the systematic investigation of soil survey profiles was the different trend in the distribution of many constituents in arable soils with naturally free drainage as compared with soils of poor drainage. In Appendices 2 and 3 analytical data are given for two pairs of profiles from the Insch and Foudland Associations, freely drained and poorly drained associates being obtained from the same field in order to minimize cultural and treatment differences.

These tables show that the amounts of, and distribution down the profile of carbon, nitrogen, exchangeable calcium and magnesium, percentage saturation, pH, total and readily soluble phosphorus, follow a certain pattern in the freely drained soil and a different pattern in the poorly drained. This also applies to amorphous sesquioxides which are not quoted.

Considering the mechanical analysis figures, the silt quoted is based on the International size and scale. On the United States system the silt values are increased by approximately 50 per cent. Higher silt than clay is found in the Foudland profiles. The decrease in clay in the B_3 horizons of the freely drained profile is shown; this marks the indurated layer below which the horizons are ineffective in plant nutrition.

Exchangeable calcium is more uniformly high in the poorly drained profiles and tends to be at its minimal value in the B_3 indurated layer of the freely drained profile; the high value in the basal horizon of the freely drained soil is a consistent feature of this series of the Insch Association.

The increase in exchangeable magnesium with depth in the poorly drained soils and the overall higher amounts as compared with the freely drained is characteristic.

The pH value (including the surface layer which may be affected by recent treatment) tends to be higher throughout the poorly drained soil as compared with the freely drained, and conversely exchangeable hydrogen is higher in the freely drained profile. The percentage base saturation is consequently higher in the poorly drained soil.

The total exchange capacity when judged by the summation of the exchangeable cations determined will be seen to be considerably greater in the Insch than in the Foudland soils. Studies have shown that a considerable proportion of the exchange capacity is attributable to the silt and fine sand fraction in the soils of the Insch Association. One practical implication of the high exchange capacity of the Insch soils is that larger amounts of lime are required to alter the pH value by a given amount.

The lower values of carbon and nitrogen in the surface horizons of the poorly drained profiles as compared with the freely drained is to be constantly found in the poorly drained soils having the grey-coloured surface soils. These soils, being wetter, are slower to warm up and nitrification is thereby delayed. A yellowing of the crop attributable to low nitrogen is often to be seen. Consequent ripening of the crop is often fully two weeks later in the poorly drained soils.

The higher amounts of total phosphate, almost 50 per cent. of which is in the organic form, which occur in the freely drained profiles have been consistently found and the tendency for the readily soluble phosphate to be higher in the poorly drained soils, despite the lower total, points to more ready solubility in the poorly drained. Extensive studies of this phenomenon have been made (*Ann. Rep.* 1954-55 and 1955-56) and it appears that phosphate tends to be held as iron and aluminium bound phosphate in the upper horizons of the freely drained soils and more particularly calcium bound in the poorly drained. In practical terms the freely drained soils are more particularly phosphate fixing soils and require phosphate applied little but often rather than in heavy applications. It has been found (*Ann. Rep.* 1955-56) that different extractants, for example, citric acid, acetic acid, ammonium fluoride, etc., remove different proportions of phosphate from lithologically different soils and that as a measure of the availability to the plant no one extractant is best suited for all soils.

Equally striking differences in the contents of heavy metals were found in a comparison of freely drained and very poorly drained (peaty gley) profiles of the Insch Association (*Ann. Rep.* 1954-55). Neutral normal ammonium acetate removed greater amounts of cobalt, nickel, iron, vanadium, chromium, and manganese from the gley horizons of the very poorly drained soils as compared with the freely drained. Aluminium solubility in the poorly and very poorly drained soils is, on the other hand, much less than in the freely drained.

Clay studies (*Ann. Rep.* 1954-55) on the freely and poorly drained soils of the Insch Association revealed kaolin with vermiculite to be dominant in the freely drained and kaolin and montmorillonite in the poorly drained; in the latter kaolin decreases with depth and is replaced by illite. The influence of hydrologic conditions in the clay mineralogy of soil profiles is more pronounced on basic than on acidic parent materials; while vermiculite predominates in the freely drained and montmorillonite in the poorly drained soils on basic parent materials, illite is the dominant clay mineral in soils derived from granite, argillaceous and other schists and from Old Red Sandstone parent materials, irrespective of drainage conditions.

From the chemical studies undertaken on soil survey profiles it appears that the generalization may be made that the lithological composition of the parent material determines the general level of the chemical constituents in a soil, while the drainage class determines the amount of constituents extractable.

In the second area of 500 square miles covering most of Roxburghshire and small parts of Selkirkshire and Dumfriesshire the highest peak is Auchope Cairn (2382 feet) in the Cheviots in the southern and western part of the area, but there are many hills with over 1000 feet elevation. Hilly and rolling country occupies the northern and eastern parts and upland moors the western part of the region. The country is drained by the Teviot, the Liddel, and the Bowmont and their numerous tributaries. It is a fine grazing country supporting thousands of sheep and cattle on the grassy slopes.

There is a steady increase in annual rainfall from 30 inches in the Teviot Valley to 50 inches some 20 miles away in the Cheviot Hills. The arable cultivation is therefore found around the Teviot Valley. The arable farms are large by Aberdeenshire standards, being around 400 acres, while the average size of hill farm is around 1600 acres. Sheep breeding is the chief farming activity whether on low ground, upland farms, or hill farms.

The soils are derived from glacial tills, mostly of sedimentary rocks: Silurian greywackes and shales occupy about half the mapped area, giving rise to soils of the Ettrick Association. Sandstone marls of Upper Old Red Sandstone age are accommodated in the Hobkirk Association. A mixture of Silurian greywackes and shales with Upper Old Red Sandstone sandstone and marls is the parent material of the Minto Association. Sediments of the Calciferous Sandstone Series of Lower Carboniferous age are grouped into the Carter Association. Lavas of Lower Old Red Sandstone age—Sourhope Association—are extensive in the eastern side of the surveyed area. The character of the till is generally similar to that of the underlying rock and there has been little mixing of materials from two or more formations except in the Minto Association. A feature noted is that two tills are formed from each parent rock. A light-textured stony till is found on the high-level plateaux and shoulders of the hills, a heavier-textured till occupies the valleys and smooth slopes. This together with climate largely influences the distribution of the genetic soils.

Soils of four Major Soil Groups are found: (1) brown forest soils of low base status, (2) peaty podzol with iron pan, (3) non-calcareous gleys, and (4) peaty gleys. The distribution of these soils is related to altitude and climate in which rainfall is the most important element. Hill peat, peaty podzols, and peaty gleys occur under the high rainfall of the watersheds. Brown forest soils and non-calcareous gleys generally occur in the lower rainfall districts of the low ground. Where brown forest soils are found in high rainfall areas they are invariably associated with steeply sloping sites.

The Ettrick Association is the most extensive association. The Dod Series (peaty podzol, freely drained beneath the peaty surface) together with the Alemoor Series (a peaty gley) illustrates the peat-forming tendency on high altitude-high rainfall sites. Hill peat is associated with these soils of the watersheds. Molinetum, Nardetum, and Callunetum is the characteristic vegetation. On the grassy convex slopes freely drained brown forest soils of the Linhope Series occur, while much of the foot slopes and flatter valley land is occupied by the poorly drained non-calcareous gleys of the Ettrick Series. The Dod, Alemoor, and Linhope Series are on light-textured till, while the poorly drained Ettrick Series is on heavy-textured till. Due to the highly folded nature of the Silurian rocks, large areas consist of a micro-corrugated ridge and valley formation orientated in a north-east to south-westerly direction. Rock outcrops at the apex of the ridges. This kind of feature has been mapped as a corrugated complex.

The other associations, Sourhope, Hobkirk, Carter and Minto, contain representatives of the genetic soil groups listed in the Ettrick Association, and all have a light-textured and a heavy-textured till. The proportion of light or heavy till differs in the several associations. By comparison with the soils from the Huntly-Banff area, the Jedburgh-Morebattle soils contain in the main more clay. Clay contents of the Border soils are frequently of from 30 to 40 per cent. while the north-east soils are commonly from 10 to 20 per cent. In the Border region the soils studied are from uncultivated land, while the majority of the profiles from the Huntly-Banff area are from arable land. A comparison of the freely drained soils—mainly brown forest soils of low base status—shows that despite the comparatively high clay content, the amount of exchangeable calcium tends to be very low. B horizons with 30 to 40 per cent. clay may have less than 1 m.e./100g of exchangeable calcium. Exchangeable magnesium in the soils with low calcium closely approximates the value for calcium. The pH value of these soils varies between 4 and 5, and they are about 10 to 20 per cent. base saturated.

The poorly drained soils of the Border region may have clay contents of 30 to 50 per cent. They are well leached and are classified as non-calcareous gleys. They have pH values of 5·5 to 7 or over and often have free lime in the basal Cg horizon or parent material. Their percentage saturation ranges from 30 per cent. to 100 per cent. in the parent material. Soils with a peaty surface, both poorly drained and very poorly drained (peaty gley) are lower in calcium and magnesium than the poorly drained soils without the peaty surface. The percentage base saturation and calcium and magnesium values for both freely drained and poorly drained soils tend to be at their lowest in the upper middle horizons, that is in the A_2g, B_2 or B_2g horizons. The pH values tend to increase with depth in all the Major Soil Groups.

Carbon and nitrogen values commonly decrease with depth in all the Major Soil Groups, but in the peaty podzols with iron pan there may be an increase in these constituents above the iron pan where a root concentration is often present.

The distribution of total and readily soluble phosphorus differs in the various Major Soil Groups. In the free-draining soils the tendency is for total phosphorus to decrease in value from the surface down. In the poorly drained soils there is a definite tendency for both the total and readily soluble phosphorus to be at a minimal value in the upper part of the gley horizon. Peaty podzols show no consistent trends.

The clay fractions of the soils are in the main dominated by illite, particularly those derived from Old Red Sandstone materials. Considerable amounts of chlorite are found in the Ettrick soils derived from Silurian material. The soils of the Sourhope Association contain kaolin, vermiculite, and montmorillonite, together with illite. The brown forest soils of this association tend to have vermiculite in the surface horizons and montmorillonite in the basal horizons, while the non-calcareous gley soils of this association have montmorillonite throughout which increases in amount with depth.

The soils of the area have been described in the memoir entitled *The Soils of the Country round Jedburgh and Morebattle* which includes soil maps of Sheets 17 (Jedburgh) and 18 (Morebattle).

An area of 408 square miles covering North Ayrshire and parts of Renfrewshire and Lanarkshire has been surveyed. Climatically this is a wetter region than those already discussed having a mean annual rainfall of 41·2 inches and a variation of from 32 inches along the coast to over 70 inches on the high Renfrew Plateau in the north-west. A range of 27 to over 70 inches also occurs in the Jedburgh-Morebattle region. It is significant in north Ayrshire that the greater part of the arable region has 10 to 12 inches more rainfall than the previously reported areas. Strong winds from the west and south-west are highly influential elements of the climate, and few farms can be said to have a sheltered situation.

The peat forming tendency by which layers of organic accumulation are formed in profiles as in those of peaty podzols and peaty gleys, becomes a noticeable feature in the south-west of Scotland at an altitude of 600 feet. In south-east Scotland this occurs nearer the 1000 feet contour.

The greater part of north Ayrshire is a plain occupied by surface-water gley soils and soils which are at best imperfectly drained. Rushes, *Juncus* sp., appear in the fields very readily and betoken something of the wet conditions. A high level plateau with a fairly sharp boundary between plain and plateau occurs on the north-western side from Ardrossan to Kilbirnie. On the north and east there is an imperceptible merging of plain into plateau. Soil changes involved in the transition from plain to plateau tend to follow a pattern—surface-water gley (on the plain) passing through brown forest soil with gleyed B and C horizon (imperfectly drained), brown forest soil, peaty podzol, and peaty gleys to hill peat. The highest parts occur in the north-west and in the south-east where hill peat covered moorland reaches a maximum height of 1400 feet.

With the exception of areas in the north-east and north-west where drainage is northward to the Clyde, the main drainage flows south to south-east in a radial pattern of streams from the upland rim crossing the plain and converging to the coast at Irvine. The main streams, the River Garnock, the Dusk, Lugton, Annick, Fenwick, and Craufurdland Waters, the River Irvine, and the Cessnock Water, have reverted to their pre-glacial beds. The tributary or subsequent streams meander in circuitous courses through a network of shallow depressions in the glacial till.

The physical features of the district are comparable with much of the Central Valley of Scotland. The principal outlines are controlled in the main by the differential erosion of the softer sedimentary rocks and the harder, interbedded or intruded igneous rocks among these. Every division of the Scottish Carboniferous system is represented in the area, about half of which is underlain by sediments of this age forming the plain. North-west of this the upland areas are mainly underlain by volcanic rocks of Calciferous Sandstone age. To the north and east of the plain similar rocks build up the broad moorlands of the Clyde-Irvine watershed, much of which is over 800 feet. The high ground on the southern section is formed from Old Red Sandstone age volcanic rocks. Granodiorite intrusions with an aureole of baked Downtonian sediments constitute the Distinkhorn mass of 1200-1300 feet in the extreme south-east. Many minor volcanic formations occur, in addition to necks, plugs, and vents, of which some but not all influence the topography.

All parts of the region have been affected in some way by ice movements, mainly from the north-west to south-east, and in few places can the soil parent material be said to arise directly from the rock beneath. Most of the area has a thick mantle of till which either reflects the form of the buried landscape or is independent of it where the till is moulded into gentle undulations and drumlins. The till, however, is not far travelled and its composition is related to the geology of the district. Most of the north Ayrshire till is clayey, and excluding the shallow, stony, moderately coarse-textured till of the glacially abraded uplands, the deep till may be divided according to texture into medium, moderately fine and fine-textured categories. Under conditions of poor drainage all these categories of till exhibit a high degree of weathering which is not apparent under imperfect or very poor drainage. Fluvioglacial gravel and morainic drift occupy only a small proportion of the sheet area. Raised beach deposits of considerable agricultural significance fringe the whole length of the coast. They vary from a strip of one quarter of a mile in width to four miles where they follow the Irvine upstream to Kilmarnock.

Unlike the soils of south-east Scotland where there has been little mixing of rock materials in the till, the Ayrshire tills and the soil associations distinguished are derived from a mixture of rocks. Brown forest soils occupy about one half of the map area, while non-calcareous gleys cover 20 per cent. It should be noted, however, that 64 per cent. of the brown forest soils have gleyed B and C horizons and are imperfectly drained and require some form of artificial drainage. Hill and basin peat cover some 13 per cent., while aeolian sand, alluvium plus mixed bottom land and peaty gleys occupy the remainder. Soils with poor or imperfect drainage on heavy or moderately heavy tills (35-45 per cent. clay) predominate.

Fourteen soil associations containing 54 soil series have been distinguished. One of the most extensive associations, Kilmarnock, covers 88 square miles, and is developed on a mixed till derived from Carboniferous sandstones shales and contemporaneous lavas. It is found under widely differing conditions of rainfall from the 30-35 inches zone to 60 inches. The topography varies from undulating to gently rolling. On the gentle to moderate slopes the Kilmarnock Series of imperfectly drained brown forest soils is most extensive. Wherever the rainfall is above 45 inches the poorly drained Kilmaurs Series is commonly found. The Kilmarnock Series has a brown clay loam surface with a medium, friable crumb structure. At 10 inches the colour changes to a more yellow brown (less organic matter) clay loam with a blocky structure; some faint yellow orange mottling and grey mottles on the faces of the peds occur. This continues to the basal horizon (30 inches) where the till is slightly indurated and laminated. The poorly drained Kilmaurs Series differs from the above in having a surface soil with a blocky rather than a granular structure, a subsurface horizon of light, yellowish brown with distinct yellow mottles and many distinct grey mottles on the faces of the large prisms which are plastic and wet. With depth the mottling, both yellow and grey, decreases, and there is a noticeable increase in fineness of texture from clay loam to clay; the prismatic structure fades out and gives place to a parent material which is massive to coarse platy, only slightly plastic, brown in colour, and only weakly mottled. In this soil gleying is most strongly developed immediately below the surface horizon and fades out in the basal horizons. The soil is a surface-water gley and differs from the poorly drained ground-water gleys of the Aberdeenshire-Banffshire region in this perched water-table effect.

In the Ashgrove Association, which covers 40 square miles, and which is developed on a till composed of Carboniferous Limestone Series sandstone and shales with a clay content greater than 45 per cent. (highest recorded being 68 per cent. clay), the major portion of the association, occupying the Cunningham Plain to the north of the River Irvine, is of the Ashgrove Series poorly drained surface-water gley soils.

The grassland of the Ayrshire dairy-farming industry is predominantly located on the two types of soils, imperfectly drained brown forest soil and non-calcareous surface-water gley soils as described. A consequence of these wet soils is the common occurrence of rushes *Juncus* sp. in the fields. The practice of leaving the grass ley down for a much longer period than three years, which was customary prior to the 1939-1945 war, was modified by the ploughing up campaign and the drive for cereal crops; the long ley is again common now that there is freedom of choice as to cropping. Soil structure takes time to develop in grassland, but once formed, is conducive to better drainage. Too frequent ploughing of heavy soils is known to affect soil structure adversely. The duration of the ley is therefore longer on the heavier soils and in the wetter districts. On breaking the ley, an oat crop follows, which is succeeded by a root crop, then another cereal crop, hay, and, followed by a varying number of years, pasture. At least one Ayrshire cow and one follower per two acres is the usual stocking of the north-Ayrshire dairy farm, and large amounts of feeding stuffs are purchased during the winter.

The largest and most widespread association in north Ayrshire, covering 103 square miles, is the Darleith Association, derived mainly from Calciferous Sandstone age lavas of intermediate and basic composition. This association is also found in the Jedburgh-Morebattle area, but is only a minor component there. It is mainly confined to the higher ground, the most extensive series being the freely drained Darleith Series which is usually located on the hill tops and steeper slopes. It is a brown forest soil developed on a shallow loam to clay loam till, which is sometimes stony. The soils are rarely more than three feet deep, of a rich brown colour throughout. A striking feature is the well developed crumb structure of the surface horizon, also found in the Insch Association of Aberdeenshire and probably related to the high content of ferruginous material in the till. There is little horizon differentiation, the colour and texture being fairly constant. Sometimes there is a weak induration at about 18 inches. A range of genetic soils varying from the free to the very poor drainage class, including peaty podzols, peaty gleys, and humic gleys, has been mapped and included in this association. The poorly drained Amlaird Series, found on foot slopes and flatter positions is a surface-water-gley soil with morphological characters comparable with similar soils previously described. It is developed on a more clayey parent material than the freely drained series and is illustrative of the two till features of a heavy and a light texture such as is commonly found in the Jedburgh-Morebattle region.

The famous Ayrshire early potato ground on raised beach deposits is delineated by the Dreghorn Association. Deep soils, long cultivated, of the brown forest soil group dominate this association. The early potatoes are planted towards the end of February and receive a liberal dressing of artificial fertilizer, up to one ton per acre, as well as dung and seaweed. The potatoes are lifted to meet the early demand when a return yield of about 4 tons per acre has been reached.

The predominant arable soils of north Ayrshire are brown forest soils with imperfect drainage and non-calcareous surface-water gley soils. A feature of both these soil groups is a rise in clay content in the lower middle horizons, sometimes of the order of 10 per cent. In the latter group, weathering of the mineral fractions is particularly pronounced; stones tend to be soft and in a decomposed condition. Clay contents of over 35 per cent. are common in these soil groups.

Owing to the high clay content of the middle and lower horizons, it is not advisable to place field drains deeper than 27 inches to the top of the pipe. In the ground-water gleys of the Huntly-Banff region, drains function at a greater depth. A practice of deep-draining the peaty gleys, in which drains are placed at the base of the till overlying the rocks, sometimes at 6 to 12 feet down, which is very successful in removing surplus water in the north-east, has no application in north Ayrshire where surplus water runs off the surface or just below plough depth.

Peaty podzol soils, highly unsaturated and of low base status, which are extensive in the Jedburgh-Morebattle and the Huntly, Banff and Turriff regions, are of comparatively insignificant extent in north Ayrshire. The two dominant genetic groups in the uncultivated state have a lower percentage base saturation and pH than the corresponding cultivated soils. Cultivation therefore appears to have raised the level of base saturation considerably and also raised the over-all pH value about one unit. A feature which is general for these groups in all areas is for exchangeable calcium and magnesium to increase with depth. In the arable soils organic matter tends to be low with consequently low carbon and nitrogen values. A relatively high base status, and moist conditions, appears to aid decomposition of organic matter. This feature of low organic matter in cultivated poorly drained gley soils, both surface-water and ground-water, has previously been noted. The indications are that the organic matter in poorly drained soils differs from that in the freely drained, but this requires investigation.

The clay minerals of the Ayrshire soils are mainly mixtures of kaolin, illite, and vermiculite. All the gley soils, non-calcareous surface-water, humic, and peaty gleys, together with the brown forest soil with imperfectly drained B and C horizons, show illite to increase with depth, often to a value approaching or above 50 per cent. of the total clay; vermiculite decreases from the surface downwards, kaolin remains fairly constant or tends to decrease in amount down the profile. Certain of the soil associations with a high proportion of Old Red Sandstone material have a clay content dominated by illite—a tendency common to all the Old Red Sandstone soils so far examined. Soils of the Ashgrove Association (till derived from shale and sandstones of the Carboniferous Limestone Series) have a high kaolin content—higher than in any other association so far examined.

The Largs Association, developed on arenaceous till of Upper and Lower Old Red Sandstone sediments, is the only group of soils in the area which has a low extractable cobalt content, less than 0·2 p.p.m., and in which there would appear to be a possibility of cobalt deficiency in cattle and sheep. The copper status of this association also appears to be rather low.

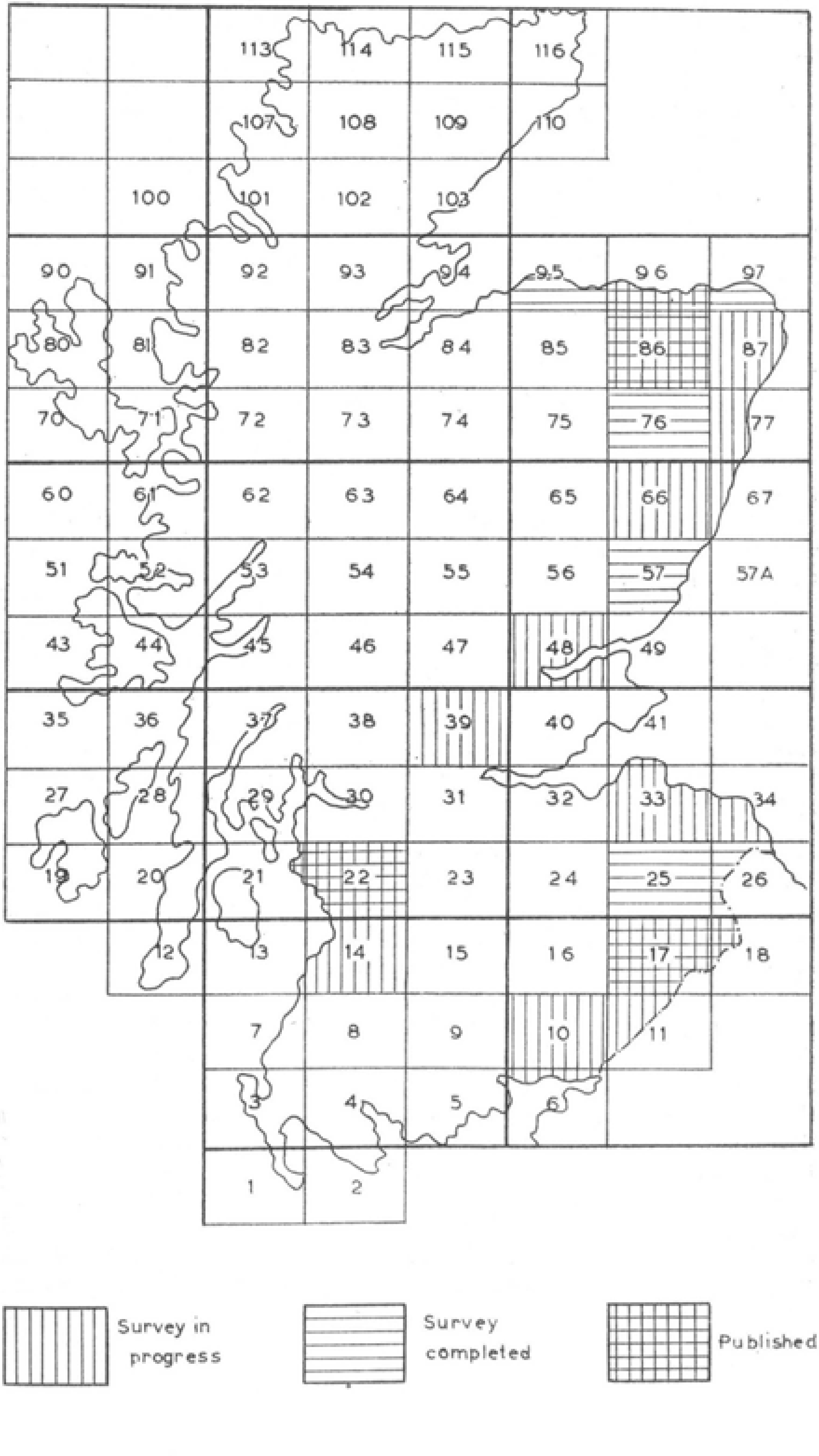
The soils of the area have been described in the memoir *The Soils of the Country round Kilmarnock*[1] which includes soil maps of Sheet 22 and part of Sheet 21.

In the three areas for which the surveys have been published, three distinct types of farming are practised, mixed farming and stock fattening in the north-east, sheep raising in the south-east, and dairying in the south-west. Representatives of the main genetic soil groups, podzols, brown forest soils, brown forest soils with gleyed B and C horizons, non-calcareous ground-water gleys, non-calcareous surface-water gleys, and peaty gleys, do not necessarily occur in all areas. In the north-east, podzols, brown forest soils, and non-calcareous ground-water gleys are widespread, in the south-west brown forest soils with gleyed B and C horizons together with non-calcareous surface-water gleys predominate, and in the south-east peaty podzols and brown forest soils occur on the hills while non-calcareous gleys and brown forest soils occupy the lower ground.

SOIL SURVEY OF SCOTLAND

INDEX OF SHEETS

1 inch to 1 mile



From the inventory of the soils of Scotland now being made, research work of the future can be directed to significant soil differences in different parts of the country. The results of the research work so far carried out justify the validity of the classification system employed. The soil series distinguished by the survey are valid units which can be related to definite chemical properties which can in turn be equated with manurial and cultural practice.

As will be apparent from the adjoining map, survey has proceeded during the past year in eastern, central, and southern Scotland, and the field work in several areas has now been completed. Details of this work will be given in subsequent reports after laboratory examination of selected profiles has been completed.

PEAT ECOLOGY

Ecology

Investigations in this field are being carried out in close collaboration with the Hill Farming Research Organization. Experiments designed to study the effect of rotational burning on soils and vegetation of upland grazings are in progress at three centres. At each site provision has been made for a grazed and ungrazed series of plots each involving three separate rotations and a control. Analyses will be carried out at suitable intervals to record changes in soil morphology and the botanical composition of the herbage.

Ecological work on the recolonization of *Calluna* is still in progress at two centres and observations on the heather grazing plots at Brimmond Hill have continued. Papers dealing with heather management[37] and the ecology of an upland grazing in north-east Scotland[38] will appear shortly.

At Coalburn Moss, Lanarkshire, a joint investigation has begun on the effect of high, low, and fluctuating water levels on natural and improved vegetation on deep peat and the concomitant effects on the chemical, physical, and biological properties of the peat profile.

Pollen Analysis and Quaternary Research

A joint investigation with the Nature Conservancy into the forest history of the Beinn Eighe Nature Reserve is nearly complete. Pollen analysis is being carried out on peat samples from St. Kilda sent by the Department of Geography of the University of Edinburgh.

In collaboration with the Soil Survey of Scotland various peat deposits in Sheet 14 (Ayr) were visited and samples taken for pollen analysis including a deep profile from a raised moss basin peat near Mauchline. Investigation of a buried peat at Tarholm near Ayr has continued and there are indications that this deposit is of glacial age. Another buried peat, at Bridgend, Aberdeenshire, was examined and in this case pollen analysis showed the peat to be of post-glacial age.

In order to carry out further investigation on the history of the Ancient Caledonian Forest (*Pinus sylvestris*), which still survives in a few Highland counties, peat deposits in Glentanar, Aberdeenshire, were visited along with the Survey ecologist and samples taken. For the same purpose samples from a high level peat in the Loch Muick area were collected.

A paper[39] on the post-glacial history of the vegetation of north-east Scotland has been accepted for publication.

Bog Cultivation and Reclamation

In collaboration with the Department of Soil Fertility an experiment has been laid down at Gadrum Moss, Stirlingshire, to study the effect of different rates, forms, and combinations of nitrogen, phosphorus, potassium, and lime on the establishment and subsequent development of grassland on deep peat, with particular reference to yield and botanical composition.

Further progress has been made on the systematic accumulation of data from which comprehensive schemes for bog cultivation and reclamation are being prepared in association with the Scottish Peat Committee (Moss Survey Group). A survey of the basal soils of Dava Moss, Nairn, has been completed.

Consultations have continued with the Forestry Commission on the establishment of grazing strips for fire protection on hill peat at Cullendoch Forest, Kirkcudbrightshire. Preliminary trials carried out in association with the Section of Forest Soils have proved successful and the area under grass is now being extended.

Laboratory Investigations

Routine analyses of samples supplied by the Department of Agriculture for Scotland (Peat Section) have continued. During the year over 2,000 peat samples were received from the following areas: Ryeflat Moss, Coalburn Moss, and Cranley Moss in Lanarkshire, Racks Moss, Ironhurst Moss, and Longbridge Moss in Dumfriesshire, and Auchencorth Moss, Midlothian. Fibre contents have been estimated on forty additional samples from these deposits. Chemical analyses have continued on peat and herbage samples from field experiments, and other analytical work has been undertaken for the Hill Farming Research Organization.

Collaboration with other departments of the Institute has been continued. A number of peats of different botanical origin and humification have been submitted to the Section of Physical Chemistry for an investigation of their thermal characters, and in association with the Department of Plant Physiology a preliminary series of pot experiments has been set up to determine the horticultural value of different peats.

SOIL GEOLOGY AND MINERALOGY

Scottish Soils

The routine identification of the clay minerals by X-ray diffraction methods in the profiles sampled by the Soil Survey of Scotland has continued with the examination of characteristic soils from the counties of Angus, Kincardine, Berwick and Roxburgh. Various complex mixed-layer minerals have been found in many of these clays, particularly when basic igneous rocks contribute to the parent materials. The mineralogy of the fine sand fraction of these soils has been investigated by optical methods. The focusing camera designed for the rapid identification of clay minerals has proved very useful and a paper[3] on it has been published. A joint paper[4] on the clay mineralogy of Ayrshire soils and their parent materials has also appeared.

Phosphate Fixation

In collaboration with the Department of Soil Fertility the availability to plants of a series of synthetic iron and aluminium phosphate of known composition and structure has been tested in pot experiments as a preliminary to further work on the significance of such compounds as end-products of phosphate fixation in soils.

Rock Weathering

Considerable progress has been made in the study of the weathering of basic igneous rocks from south-east Scotland by the application of single crystal X-ray methods to individual minerals. Pseudomorphs after olivine were found to consist of an intergrowth of an expanding chlorite mineral and haematite in parallel crystallographic orientation. X-ray powder methods have been used for quantitative mineralogical analysis of the fine sand fractions from the overlying soils. For the major components the results differed considerably from those obtained by optical methods, in which errors arise from the large range of particle size and shape that occurs in the fine sand minerals. Opaline silica particles found in the fine sand and silt fractions had characteristic shapes similar to those described by other workers who have established their origin in living plants.

Other Investigations

Among the various miscellaneous samples examined at the request of other departments were a number of phosphate compounds, including suspensions of fine-grained phosphates in agar culture media from the Section of Microbiology. Two joint papers, one on the clay[43] and one on the silt[44] fractions of basaltic soils from Northern Ireland have been accepted for publication, and a paper on the particle size distribution of the minerals in one profile on the same basalts[5] has been published. The joint paper on Turkish forest soils[6] has now appeared.

PHYSICAL CHEMISTRY

The work of the Section may be conveniently grouped under three headings: (*a*) separation of clays; (*b*) differential thermal analysis; (*c*) chemical studies.

SEPARATION OF CLAYS

The techniques used for separating the clay fraction from soils for examination by differential thermal analysis and by X-ray diffraction have been described in a paper published during the year.[7] Clay separations are currently being carried out on something like 350 samples per year.

DIFFERENTIAL THERMAL ANALYSIS

The major work of the Section is the study of the mineralogy of clays by means of differential thermal analysis. This technique involves heating up at a known rate (about 10° C/min.) a sample of the material under test side-by-side with a sample of thermally inert material and continuously recording the difference in temperature between the two over the chosen temperature range (on our equipment, room temperature to 1000°C). If no reaction occurs in the material over the range studied, then no temperature difference is developed and one obtains a straight line (the base-line) on the graph for temperature difference against temperature of the material. If, on the other hand, a reaction occurs, then heat is absorbed or evolved by the material under test, resulting in the superposition of a peak on the base-line.

The usefulness of the method lies in the fact that the temperature of this peak is characteristic of the material under test and the area of the peak is proportional to the amount of material present. A full discussion of the method, its limitations and advantages, and its application to clay minerals, has been given in a book on *The Differential Thermal Investigation of Clays* which has recently been published by the Mineralogical Society, and for which three chapters[8, 9, 10] have been provided. In the past this method has largely been used here for the investigation of soil clays, but recently-developed techniques have enabled its application to, *inter alia*, organic materials.

Thermal methods for soil clay investigation have been considered in two papers[11, 12] published during the year, and an assessment of such methods as compared to other methods for investigating clays was contained in a paper[45] read, by invitation, at a symposium on *Clays and Clay Soils* held during the centenary celebrations of the Faculty of Agriculture of the University of Pisa.

Normal Differential Thermal Technique

The apparatus modification allowing the curve for temperature difference against temperature to be recorded directly (described in last year's report) has enabled a considerable speeding up of routine work, and the apparatus is currently working at its full capacity of four samples per day. In the soil clays from Aberdeenshire, Angus, Berwickshire, and Morayshire examined, the usual suite of minerals (for differential thermal analysis, kandites, illite, smectites, and sesquioxides) have been observed, with the addition of considerable amounts of antigorite in soils derived from serpentine. Variation in antigorite content with the drainage class of the soil is being further studied. A paper[4] on the clay minerals in Ayrshire soils, in collaboration with the Section of Soil Geology and Mineralogy, has now been published. The differential thermal behaviour of clays separated from Old Red Sandstone rocks representing the Lower, Middle, and Upper divisions has been examined and it would appear that the atypical illite previously observed in soils developed on Old Red Sandstone till and known to be present in some strata of the parent rock,[46] may not be present in all strata.

The differential thermal method is frequently not sufficiently diagnostic to enable definite distinction of individual mineral species, particularly in mixture. Consequently, a systematic investigation has commenced of possible methods of sample pretreatment which might render the technique more useful in this respect. So far, published methods for distinguishing smectites have not proved particularly successful for *abnormal* species; published methods for other minerals are being exhaustively checked. This study involves a considerable amount of work with pure minerals. Apart from this, however, samples of iron and aluminium oxides, apophyllite, rhodesite, afwillite, thorite, pure interstratified minerals, etc., have been investigated, and a systematic study of various adsorbed ions on the montmorillonite differential thermal curve is in progress. Papers describing the general variability of the montmorillonite differential thermal curve[47] and a pure saponite from Skye[48] are in press.

Controlled-atmosphere Technique for Investigation of Materials containing Organic Matter

The controlled-atmosphere apparatus (see last year's report) has been thoroughly tested and has been in use at full capacity for the greater part of the year. The photo-electric temperature control system appears to be reasonably satisfactory over the greater part of the range, but there are some limitations due to the optical components employed. The photographic recording system, on the other hand, has proved a great asset because of its high sensitivity and has enabled regular use of samples diluted with inert material to 5 per cent. (that is, 10mg in 200 mg) for complete combustion and 25 per cent. (that is, 50mg in 200 mg) for inert atmosphere techniques, a desirable feature from the theoretical aspect of quantitative estimation. It has indeed proved possible to detect less than one milligram of certain substances.

When the organic matter content of a soil is higher than about 20 per cent. (about 40 per cent. in the clay fraction), it has been noted that the clay mineral peaks are not observable even using undiluted samples under inert atmosphere conditions. Whether this indicates a chemical binding between the organic matter and the clay minerals is being further investigated. That co-precipitates of kaolinite with humic material from peat do not react in this manner certainly suggests a very close binding. Use of the inert-atmosphere (nitrogen) technique for soil clays from most surface and immediately subsurface horizons has effected a considerable saving in time and materials, since it is no longer necessary to subject the clay to the time-consuming, and even theoretically objectionable, hydrogen peroxide treatment to remove organic matter.

Complete-combustion differential thermal curves (in oxygen) have been obtained for a large range of organic materials, many of which were supplied by the Department of Biochemistry and the Section of Peat Ecology. Thus, it has been observed that the curves for peat vary with the botanical composition of the peat,[49] and possibly with the degree of humification, and that curves for different fractions of peat (for example, humic acid, holocellulose, lignin, etc.) have family resemblances, although there may be minor variations depending on botanical composition.

Curves for simple sugars and polymers were determined both in oxygen and in nitrogen; the latter show, in addition to the melting point, various stages of pyrolysis. Graphite samples of different particle size have been studied in oxygen, while standard curves for various clay minerals in nitrogen have been obtained. The output of results on these aspects is limited by the present form of the apparatus, but it is hoped soon to improve this position.

CHEMICAL STUDIES

Semi-micro chemical analyses of various smectites, apophyllites, and illites have been performed. Dehydration curves, cation-exchange capacities, and free silica determinations have also been made on selected samples. The methods currently in use for chemical analysis seem reasonably satisfactory, but development of more rapid techniques might be advantageous. A method for the concentration of dilute clay suspensions has been described.[13]

SOIL ANALYSIS

Routine analysis have been completed on samples taken by the Soil Survey officers during 1955 (614 samples, representing 129 profiles). During 1956, 911 samples (193 profiles) were taken and on these the following determinations have been completed: hydrogen ion concentration, exchangeable bases, total carbon and nitrogen. Exchangeable hydrogen determinations have been completed on three quarters of the samples, and moisture, loss on ignition, mechanical analysis, total and readily soluble phosphorus determinations on approximately one half. Mechanical analysis of 170 samples from Kincardineshire has been completed.

Total silica, iron, and aluminium determinations have been carried out on 150 clay samples (34 profiles) separated from selected profiles from Ayrshire and Roxburghshire. Ultimate analysis of 24 clay, sand, and silt samples from Roxburgh have been completed.

In addition 230 samples of soil, plant extracts, etc., were analysed for the Section of Soil Geology and Mineralogy and the Departments of Spectrochemistry and Plant Physiology, and for the Department of Agriculture for Scotland (Peat Survey), the Hill Farming Research Organization, and the Scottish Horticultural Research Institute, Mylnefield, Perthshire.

Analyses have been completed on 107 soils sampled in connection with a soil survey of Hong Kong carried out by Dr R. Glentworth.

SPECTROCHEMISTRY

The demands for spectrochemical determinations to assist in the investigation of soil problems continue to increase. This is true both of emission methods for the determination of inorganic, chiefly metallic, elements and of absorption methods, ultraviolet and infrared, for the study of organic and inorganic constituents. The uses to which the methods can be put are much more diverse than might at first sight appear possible. There are the obvious applications such as the quantitative determination of major and trace elements required by plants or animals, or of elements which are deleterious in excess. Much of the work of the department concerns problems relating to specific instances of plant or animal disorders. If the necessary background information is available, it may be possible to give a diagnostic assessment of the factor or factors involved. But it must be emphasized that all relevant availability problems cannot be solved by a single determination of a trace constituent in a soil or a plant material. Many years of work have gone to produce our present knowledge of the major nutrients, and the trace element factors are at least equally complex. Nor is the spectrograph the answer to all the analyst's problems. Many determinations are better performed by chemical or other physicochemical techniques. It is seldom possible to carry out spectrochemical analyses of agricultural materials without elaborate standardization and chemical pretreatment, and for a few isolated determinations of a single element the alternative methods may be preferable. These aspects have been discussed more fully in a recent publication.[14] Despite these reservations, spectrochemical methods generally provide the best approach to the routine determination of a number of different metallic constituents in a series of similar samples.

In addition to diagnostic problems, emission spectrochemical determinations of trace elements are finding a wide application in the study of soil forming processes. In such investigations, apart from the direct determination of the amounts of the various trace elements present at different degrees of solubility, specific elements can be used to elucidate particular problems. As an example, the clay fraction of a soil generally contains a considerably greater total cobalt content than does the sand. This effect can be used to determine whether a high clay content in any horizon has resulted from weathering *in situ* or from translocation of clay. If the latter, the cobalt content of the whole horizon should be higher than it is in neighbouring horizons. It should be possible to devise means of investigating other types of soil problem as our knowledge of trace element behaviour increases.

Collaboration with other research establishments and advisory services has continued throughout the year: in particular we have been glad to assist various regions of the National Agricultural Advisory Service for England and Wales, and various Commonwealth research organizations.

Demands on the facilities available for training research workers from other institutions in spectrochemical methods have exceeded the accommodation, and again several applications have had to be delayed or refused. Visiting workers who have spent over a month in the Department were Dr B. G. Davey, New South Wales Department of Agriculture, Mr M. L. Berrow, A.R.C. Research Scholar, Dr D. Purves, Edinburgh and East of Scotland College of Agriculture, Mr G. N. Havre, Norges Veterinaerhogskole, Oslo, Prof. Manuel Lachica Garrido, Instituto de Edafologia y Fisiologia Vegetal, Granada, Spain, Senhor and Senhora L. A. Branco Ferreira, Laboratório Químico Agricola L.A. Rebelo da Silva, Lisbon, Portugal, and Mr J. C. Burridge, West African Cocoa Research Institute, Tafo, Ghana.

Members of the staff of the Department attended the Society of Chemical Industry Symposium on Trace Elements in Soils, Plants and Animals at Bristol, the Society for Analytical Chemistry Congress on Modern Analytical Chemistry in Industry at St. Andrews, and meetings of the British Society of Soil Science, the Institute of Physics Industrial Spectroscopy Group, and the Infra-Red Discussion Group.

The paper on soil analysis and trace elements[15] presented to a Seminar on Organization and Rationalization of Soil Analysis sponsored by the European Productivity Agency of O.E.E.C. in Wageningen has been published.

TRACE ELEMENTS IN SOILS, PLANTS AND BIOLOGICAL MATERIALS

Soil Status and Plant Uptake

Investigations into the correlation of the trace element content of plants with the amount present in the soil in different forms have been continued. This work, which is being carried out in collaboration with the Department of Soil Fertility, involves analyses of various plant species grown on selected soil types. These plant contents are compared with the amounts extracted from the corresponding soils by different reagents. As already reported,[16] reasonable correlation between clover uptake and the amount of copper extracted from the soil by EDTA has been found, and at the Symposium on Trace Elements in Soils, Plants and Animals, some further results covering the first three years of this investigation have been presented.[17] No one extractant seems likely to fulfil all requirements, particularly as different plants growing together on the same soil may have quite different contents of trace elements. This effect can be demonstrated in two ways. On the one hand, comparison of grass and clover in a pasture herbage may show quite different copper contents, the clover being much more sensitive to changes in soil copper status, although evidence of copper deficiency is seldom displayed by either plant. On the other hand, obviously copper deficient oat plants and healthy plants grown on the same soil after copper treatment may have similar copper contents. The content of the copper deficient plant therefore does not necessarily indicate by straightforward chemical analysis the presence of copper deficiency, although it can be diagnosed by soil analysis, or less directly by analysis of clover grown on the same soil. A general discussion of a number of factors controlling plant uptake, particularly in relation to possible effects on animal nutrition, has been published.[18]

A detailed study of the uptake of the constituent species of pasture herbage, and of the content of the different plant parts therefrom, has been completed and the results presented in the form of a thesis for the degree of Doctor of Philosophy accepted by the University of Aberdeen. This investigation, involving the analysis of some 500 samples for 20 elements, dealt with samples taken at intervals of three weeks throughout the growing season from plots on freely and poorly drained soils which were either allowed to grow to maturity or regularly cut. The full interpretation and preparation of this material for publication will require some time, and detailed results are therefore not yet available.

Studies of the effect of fertilizer dressings or other soil treatment on trace element uptake have been continued, again in collaboration with the Department of Soil Fertility, and numerous investigations of specific problems have been carried out. Of particular interest is one small area in Aberdeenshire where a disorder of cattle would appear to be related to a high soil content of available molybdenum, although the soil is quite acid in reaction. The effect is associated with an area of restricted drainage, and further investigations are in progress to study the form in which the molybdenum occurs in the soil.

Determinations of the uptake of trace elements by plants grown in culture solution have indicated the importance of the form in which the trace element is present in the culture medium. An account of work demonstrating the effect of chelating agents in controlling trace element uptake, carried out in collaboration with the Department of Plant Physiology, has been published.[19]

Soils and Soil Parent Materials

The examination of the distribution of trace elements in soil profiles has been continued, the extractable and total contents in some twenty profiles from eastern Scotland having been determined during the year. A brief account of the trace element distribution in the soils of the Kilmarnock neighbourhood has been given in the recently published Soil Survey Memoir.[1]

A detailed investigation of the distribution of trace elements in the different particle size fractions of the different layers of four soil profiles is nearing completion. This study has involved the separation of each soil sample into five fractions and the determination in each of total and extractable trace elements. The profiles being studied are freely drained and poorly drained soils on granitic and basic igneous parent materials from the Countesswells and Insch associations.

Some further results on the trace element contents of rocks from north-east Ireland have been published,[20] as has a detailed report of the trace elements in some 280 Scottish limestones.[21] This Memoir records work carried out on behalf of the Geological Survey during 1939-1944.

SPECTROCHEMICAL METHODS OF ANALYSIS

Two general descriptions of the methods in use in the Department have been published during the year[22, 23].

Flame Emission

The improved 3-channel flame photometer mentioned in the previous report is being used for the study of interference effects which arise in the determination of alkali and alkaline earth metals, particularly the effect of phosphate on calcium. Attention is being given to the effects arising from changes in the flame conditions, in order to establish the most favourable conditions for routine analysis.

Arc Emission and Chemical Pretreatment

A number of additional elements, including zirconium and indium, have been determined by the variable internal standard cathode layer arc method in the course of the investigations of the uptake of chelated ions by plants.

Spark and Pulsed Arc Emission

The direct reading attachment, reported last year, for the Hilger Small Quartz Spectrograph is now in continual use for the determination of magnesium by the porous cup solution spark method. The instrument is proving very satisfactory and practically no maintenance has been required in its twenty months of use. No change in the calibration curves has arisen from 10°C variation in the room temperature. Magnesium is determined directly, without further concentration, in acetic acid and ammonium acetate extracts of soils, and in extracts derived from plant ashes, minerals, limestones, and biological materials. Interference from other elements present has proved insignificant at the levels so far encountered.

The porous cup method with a Medium Quartz Spectrograph is being applied to the determination of copper, zinc, and manganese in EDTA extracts of soils. The use of this method for the determination of manganese and magnesium directly in acetic acid and ammonium acetate extracts of soils has been investigated.

A rotating disk method with a pulsed arc source is being developed for the direct determination of various elements, including phosphorus and boron, in ground oven dry plant material. Pellets are prepared by compressing a mixture of graphite powder, cellulose powder, and the plant material. A commercially available rotating disk electrode stand has been modified to carry the pressed disks on a spring loaded shaft.

ABSORPTION SPECTROMETRY OF SOIL CONSTITUENTS

Although the infrared spectra of the clay minerals have been broadly surveyed by several workers, they are not yet well understood in detail, so full use cannot be made of the information they provide. Accordingly, attention has been directed to making a more detailed interpretation of the spectra of well characterized specimens, which have been made available by the Physical Chemistry and Mineralogy Sections of the Department of Pedology. It has proved possible to identify the origin of the principal absorption bands of the trioctahedral minerals, talc, saponite, and hectorite, whose spectra are closely inter-related, but markedly different in several respects from those of the corresponding dioctahedral minerals. Because of these differences, it has been found that the infrared absorption of interlayer water is more clearly revealed in saponite than in montmorillonite, allowing some new information on the hydrogen bonding of these water molecules to be obtained.

Co-operative work with Microbiology and Biochemistry has continued. Work previously reported and now published includes the identification of 6-0-acetylglucose, a new metabolite formed by a strain of *Bacillus megaterium*,[24] and studies on the breakdown of substituted long-chain paraffins by Nocardia species,[25] where it has been shown that the terminal methyl group is probably first attacked. The β-oxidation of variously substituted phenoxybutyric acids by Nocardia species has been closely examined. Generally the end products are the corresponding acetic acids, but the rate of conversion is markedly affected by the type and number of substituents on the benzene ring. Considerable amounts of the intermediate β-hydroxyphenoxybutyric acids have been shown to accumulate in some instances.[26] Using characteristic infrared absorption bands, an analytical method has been developed which permits the estimation of phenoxyacetic acids and β-hydroxyphenoxybutyric acids in the presence of each other, and of the phenoxybutyric acids from which they are formed.

Attention has been drawn[27] to errors which may result from the presence of basic impurities in alcohols used as solvents in ultraviolet spectrometry. Any base present interacts with acidic solutes to give their anions, and as absorption measurements are commonly made at 10^{-4} to 10^{-5} molar, very little base is sufficient to modify their spectra markedly. A sample of ethanol, commercially purified for ultraviolet spectrometry, was found to contain bases amounting to 3×10^{-3}N.

Studies on effects of grinding, during the preparation of alkali halide disks, on the infrared spectra of hydroxylic compounds have now been published.[28] As previously reported, the changes in the spectra of acids and phenols arise from adsorption of the molecules through their hydroxyl groups on to the surface of the finely alkali halides. Changes in the spectra of sugars in potassium bromide disks could not be so interpreted, and have now been found to be associated with traces of sodium in the potassium bromide. With glucose, this leads to a new crystalline spectrum, corresponding to the complex $(C_6H_{12}O_6)_2$. NaBr. To avoid these effects, the concentration of sodium in the potassium bromide must not exceed 0·01 per cent.

BIOCHEMISTRY

In the past year there has been a further development of work on the biochemistry of plants and soil microorganisms, in collaboration with the Department of Plant Physiology and the Section of Microbiology. Work has also continued on the chemical nature of soil organic matter, attention being concentrated on the lignin-like fraction and on the unusual sugars previously found in the polysaccharide fraction (*Ann. Rep.* 1953-1954). Methods for the separation and estimation of the substances concerned have been developed and improved. Help has been given to other departments and to research workers outside the Institute; in particular a series of samples of organic materials has been supplied to the Section of Physical Chemistry for examination by the technique of differential thermal analysis.

LIGNIN DERIVATIVES FROM SOIL ORGANIC MATTER

The study of the yields of phenolic aldehydes obtained by the alkaline nitrobenzene oxidation of soils and peats has now been brought to a conclusion and a detailed account has been accepted for publication.[51] The results have demonstrated the presence of syringyl, guaiacyl, and *p*-hydroxyphenyl residues in the organic fraction of a number of soils and peats, and have indicated a correlation between the relative proportions of these residues in the soil organic matter and in the lignin of the parent plant material, where this is known. This constitutes the strongest evidence so far obtained for the presence in humus of a significant fraction derived directly from plant residues, as opposed to material synthesized by microorganisms from simple breakdown products.

Other lines of investigation are now being examined. The oxidation of diazomethane-methylated peat humic acid with permanganate yielded anisic acid (4 per cent.) but no veratric acid or trimethylgallic acid. This was unexpected since the original humic acid contained residues that might have been expected to yield all three acids after methylation. It has been found possible to prepare stabilized reduced humic acids by treatment with sodium amalgam (in nitrogen) followed by exhaustive methylation with dimethyl sulphate. These products are colourless powders consisting of two well-defined fractions, one soluble in aqueous alkali and containing carboxyl groups, the other (the larger fraction) insoluble in alkali and containing no carboxyl groups detectable by infra-red spectroscopy. The total yield represents about 50 per cent. of the original humic acid. These investigations are continuing in collaboration with the Department of Spectrochemistry.

OTHER ORGANIC CONSTITUENTS OF SOILS AND PEATS

The analytical methods for carbohydrates are best suited to peats, or to soils with a very high content of organic matter: the presence of mineral matter would be expected to interfere seriously with some of the determinations. However, in view of the interest attached to the vegetation substitution plots (Bracken and Calluna) at Glensaugh, Kincardineshire, uronic acid, pentose, and humic acid determinations have been carried out on the upper layers of profiles and the results will be compared with those obtained when substitution is further advanced.

Amino-acid analyses of the samples of soils treated with different levels of nitrogenous fertilizer (*Ann. Rep.*, 1955-1956) have not yet been completed.

The improvement of certain analytical techniques, in particular infra-red analysis and chromatography on Celite columns, has prompted a re-examination of the partly methylated sugars previously obtained from soil and peat polysaccharides.

THE METABOLISM OF SOIL MICROORGANISMS

Work has continued on the unique carbohydrate ester (6-0-acetyl-D-glucopyranose) produced as a major metabolite by *B. megaterium*. A note[24] has been published dealing with the chemical characterization of the substance, and a paper[52] now in the press describes its preparation in the laboratory. Preferential acetylation of the primary alcoholic group was effected by heating glucose with 50 per cent. aqueous acetic acid. The crystalline ester was isolated by column chromatography and shown to be identical with the naturally-occurring material. In characterizing the substance it was necessary to modify the usual methods of periodate oxidation of carbohydrates because of the labile nature of the ester group.

The reaction of carbohydrates with aqueous acetic acid appears to be a general one: a crystalline 6-0-acetyl-D-galactopyranose and an unstable syrupy xylopyranose acetate were prepared in the same way. The degree of acetylation obtained under various conditions and with various other carbohydrates has been measured colorimetrically. The results indicate that caution should be exercised in dealing with substances containing the hydroxyl group, where the method of isolation has involved treatment with relatively concentrated acetic acid.

A study of the biological synthesis and utilization of acetylglucose by *B. megaterium* has made some progress and will shortly be submitted for publication. Failure to achieve biosynthesis with cell-free extracts of the bacterium is now seen to be due to the presence of a very active hydrolytic enzyme. Suspensions of resting cells have a much weaker hydrolytic action, and the accumulation of the ester in the culture medium may be due to the fact that the bacterial cell wall is relatively impermeable to sugar acetates, as it is to sugar phosphates. Extracts of a variety of other soil bacteria have no hydrolytic action on acetylglucose, which may therefore serve as a reserve of energy-producing material for *B. megaterium* as suggested in last year's report.

Collaboration with the Section of Microbiology and the Department of Spectrochemistry has also continued in work on the metabolism of soil nocardias. Notes[25, 26] have been published showing that aliphatic hydrocarbons and the herbicidal ω-phenoxy-substituted fatty acids are broken down by a β-oxidation mechanism. In two cases evidence has been found for the formation of a β-hydroxy-acid intermediate. Some improvements in technique have made it possible to recrystallize small amounts of material and so to obtain by direct comparison of pure substances confirmation of the structures inferred from infra-red analysis and chromatography.

The investigations of the nocardias have now been extended to include their carbohydrate metabolism. The evidence so far indicates that both the pentose cycle and the citric acid cycle are operative in carbohydrate oxidation.

THE ORGANIC ACIDS AND AMINO-ACIDS OF PLANTS

The techniques developed for the separation and determination of the non-volatile organic acids and free amino-acids in plant material have now been applied to nearly 50 samples supplied by the Department of Plant Physiology. The reproducibility of results has been tested and found to be satisfactory. Well-marked displacement from the normal organic acid and free amino-acid pattern has been found in various chlorotic conditions. The effect of ageing has also been studied.

THE WATER-SOLUBLE CARBOHYDRATES OF SOME MONOCOTYLEDONS

The carbohydrates of certain plants have been examined in order to get some idea of the nature of the water-soluble carbohydrates which may be leached from the leaves, stems, and roots of grasses. These plants are known to contain little or no starch, but to store instead large amounts of fructose polysaccharides (fructosans), some of relatively low molecular weight. Attention has been confined to the trisaccharide fraction, and methods already developed have been used to isolate and characterize the two main trisaccharides of the onion bulb. These substances, 1^{F}-β-fructosylsucrose and 6^{G}-β-fructosylsucrose, are present also in the leek, and similar substances are in process of isolation from Italian rye grass. 1^{F}-β-fructosylsucrose is known to occur in bacterial enzyme systems synthesizing fructosans from sucrose. It is a point of interest that neither trisaccharide possesses the fructose-to-fructose linkage characteristic of the polysaccharides.

In the onions examined the trisaccharide fraction may account for as much as 20 per cent. of the total carbohydrate, but in the leek and in grasses for much less. Unexpectedly large variations in the content of this and other oligosaccharides were found from point to point in the bulbs.

After difficulties of sampling had been overcome it proved possible to demonstrate the synthesis of sucrose from glucose or fructose introduced into small pieces of onion bulb by the technique of vacuum infiltration. If portions were selected in which the initial concentrations were low, the tri- and tetra-saccharide fractions could also be shown to increase. This system might thus be a suitable one in which to study the biosynthesis of plant fructosans, about which very little is yet known. Part of this work was communicated to the meeting of Biochemical Society held in July 1957.

METHODS

By substituting 50 per cent. aqueous glycerol for water in the stationary phase for partition chromatography of *organic acids* on silica gel, an improved separation of *cis*-aconitic from oxalic, and of *trans*-aconitic from malonic acid has been achieved.

A method for the separation and determination of *quinic acid* has been developed, based on ion-exchange chromatography.

In the determination of amino-acids using the reflectance densitometer, ninhydrin has proved the best colour reagent for most amino-acids, but *tryptophane* is best determined by the use of *p*-dimethylaminobenzaldehyde, and *histidine* by diazotized sulphanilic acid.

The method for the separation of sugars by partition chromatography described by Lemieux, Bishop and Pelletier has been tested and found superior in some respects to the use of cellulose powder.

A specific enzymic method used by Huggett and Nixon for colorimetric estimation of blood glucose has been investigated and seems suitable for the estimation of glucose in many biological materials.

A method has been developed for the estimation of humic acid in 5g. samples of material, much less than is usual.

PLANT PHYSIOLOGY

The work of the department has been much on the same lines as in the previous year. Dr W. M. Crooke returned from a year's study leave in Canada, and Dr J. A. Perez-Geigo, of the University of Madrid, spent the academic year in the department as British Council Scholar.

PEAT UTILIZATION

Greenhouse studies to determine the suitability of certain varieties of peat for use in horticulture have been conducted in collaboration with the Section of Peat Ecology. Studies on the nutrient balance of mustard plants growing on a sedge peat have shown that iron toxicity is not the major cause of the failure of mustard plants growing on peat, but that a balance of potassium, calcium, magnesium, and phosphorus is essential for normal growth.

CHELATES

Studies on the absorption of metal chelates has shown that trivalent metals chelated with ethylenediamine tetra-acetic acid are readily absorbed into the leaves, whereas the EDTA chelates of divalent metals are not. A paper[19] on this work has been published. Residual charge on the chelate molecule appears to be one of the factors which influence the absorption of chelates. The effect of various iron chelates on the mineral composition of plant leaves has been studied as also the influence of excess chelate on growth and metabolism. A paper on these studies was presented to the Edinburgh Botanical Society in May, 1957.

MINERAL BALANCE

Major Element Interaction

The interaction between phosphorus, iron, potassium and calcium has been studied in leaves of mustard plants grown in water culture in a replicated experiment involving 96 treatments. The results obtained have been submitted to the Section of Statistics. A paper on the nutrient balance in plant leaves[53] was read to the Aberdeen meeting of the Agricultural Education Association and is to be published.

The Nitrate-Ammonium Effect

Considerable attention has been paid to the different growth effects obtained when nitrogen is supplied as the nitrate or ammonium ion. High phosphorus-iron and potassium-calcium ratios are obtained in ammonium-grown leaves, whereas these ratios are lower in nitrate-grown leaves. Correlation of these ratios with the organic and amino-acid content of the leaves has been studied.

Ageing of Leaves

A contribution on the mineral changes occurring in ageing leaves was made to the Institute of Biology symposium on the *Biology of Ageing* held in London in September of last year. Further studies have been made and the work is being written up.

Amino and Organic Acids

Work in this sphere is continuing in conjunction with the Department of Biochemistry. Two papers on the comparison of free amino and organic acids of chlorotic and healthy leaves are in preparation. Techniques are in use for the estimation of total non-volatile organic acidity and also for the micro-determination of oxalic acid.

RESPIRATION

The sensitivity of the respiration of dwarf shoots of larch and cedar to potassium cyanide has been followed throughout a growing season, during which time the inhibition declines steadily from 85 per cent. to a very low level. A paper[54] on this work has been submitted for publication.

Investigations on the metabolism of disks of storage tissue have continued. In order to maintain the disks under rigorously controlled conditions, an apparatus has been designed and constructed which provides uniform conditions of temperature and aeration in conjunction with a continuously changing water supply. Disks of sugar beet, red beet, carrot, swede, and potato have been preconditioned at different temperatures before use in respiration experiments. It was found that the cyanide-stable respiration pattern varies with time and with the nature of the storage tissue. There appears to be a distinct difference between tissue containing cambial cells and tissue composed entirely of parenchymatous cells. In both types of tissue the cyanide-stable pattern can be altered by varying the temperature.

CATION EXCHANGE CAPACITY OF PLANT ROOTS

Studies of the root exchange capacity of oats under conditions of nickel toxicity have continued and have been extended to other crops and other heavy metal toxicities. This phase of the work follows on the earlier reported effect of nickel in increasing calcium absorption by oats. The present findings indicate that excess nickel increases the root exchange capacity of oats, tomato, sunflower, and bean as do other heavy metals with the exception of manganese where a reduction in exchange capacity is generally found.

The method which has been evolved for the production of hydrogen-saturated roots uses a rapid acid-washing technique in preference to the much slower and more severe electrodialysis procedure used by other workers in this field. These hydrogen-saturated roots are then placed in molar KCl and titrated with standard alkali to pH 7 to obtain a measure of their exchange capacity, which range from 70-80 per cent. of those obtained by electrodialysis.

RADIOACTIVITY

Soil Phosphate

Collaboration with the Department of Soil Fertility on soil phosphate problems has been continued.

Laboratory experiments have included the estimation of the surface phosphate of the soils which were used in the 1956 pot experiments. A detailed study has been made on the determination of the surface phosphate by suspension of the soil in water and salt solutions instead of dilute acidic extractants. The experimental difficulties resulting from the very much lower concentration of soluble phosphate in water extractions compared with dilute acids have been overcome.

The radiochemical method of determining the phosphate status of soil, the "A" value, has been tested in a series of pot experiments in which the nitrogen supply was varied.

Nickel Toxicity

Autoradiography has been used to determine the distribution of a number of the mineral nutrients in the leaves of normal and nickel-toxic plants. This study was part of an extensive investigation involving mineral analysis, organic acid determinations, and root exchange measurements.

Root Penetration

Further work has been done with the Hill Farming Research Organization on a number of areas of deep peat. The possible influence on the method of extraneous radioactivity in the samples of vegetation due to fall-out of fission products has been investigated.

SOIL FERTILITY

The fertility investigations continue to be based on concurrent development and integration of field, pot, and laboratory studies covering major soil types and the main agricultural crops.

The first objective of the field experiment programme is to establish the behaviour of the different soil types and crops with respect to the immediate and residual effects of lime, fertilizers, and farmyard manure on the yield and composition of crops, including the occurrence of interactions. In addition, the field programme is arranged to provide more immediate direct answers to the practical manurial questions of rate, form, time, frequency, and method of application of lime and fertilizers. To these ends the experiments are distributed over the major soil types at centres chosen in consultation with the Soil Survey of Scotland and the various types of experiments are repeated over a period of years to cover seasonal variations. The 1957 programme comprised some seventy experiments, nearly all on private farms, and the willing and efficient co-operation of the farmers concerned is greatly appreciated.

The pot experiment programme is an essential supplement to the field work and a connecting link with laboratory investigations. The pot and laboratory studies are all based on soils from field experiment areas, so that all results can be related to appropriate aspects of the field behaviour of the soils.

Attention continues to be given to translation of results into practice through lectures, contributions to the agricultural press[29, 30] and consultative work in conjunction with the North of Scotland College of Agriculture. Collaboration has also been maintained with other research organizations and with technical committees, including the Agricultural Research Council Technical Committee on Fertilizers and the Field Trials and Grassland Committees of the Scottish Agricultural Improvement Council. In collaboration with the Section of Statistics a report on co-operative experiments on the time of application of nitrogen for oats has been prepared for the former committee and is being submitted to the Improvement Council. A modified version of this report is being prepared for publication. A paper on regional grassland manuring experiments co-ordinated by the Grassland Committee is also in preparation. The Department also collaborated with the Agricultural Research Council Unit of Statistics in the preparation of reports on the Surveys of Fertilizer Practice carried out by the Scottish colleges of agriculture in 1956, and in the planning of further surveys for 1957.

Close contact continues to be maintained with the Section of Statistics in planning experiments and evaluating results, and with the Department of Spectrochemistry in trace element investigations and analytical work. As indicated below in the review of subjects under investigation, collaboration is also being developed with other departments and sections.

CROP RESPONSES TO MAJOR NUTRIENTS

Further field experiments have been carried out to characterize the responses of different crops to nitrogen, phosphate, and potash on the major soil types, using factorial designs with four levels of each nutrient, adjusted according to crop. Results from an earlier series of experiments of this type, including farmyard manure as well, are being evaluated. It appears that potatoes normally give fairly large responses to all three nutrients. In the presence of dung the responses to potash were considerably reduced but the responses to nitrogen and phosphate were not materially affected. This finding for phosphate is contrary to results from other parts of Britain and provides another illustration of the outstanding importance of phosphate under north-east Scottish conditions.

METHODS OF FERTILIZER APPLICATION

A final assessment of results on placement of fertilizers for turnips and swedes grown in ridges is being carried out and comparisons of placed and broadcast light annual applications of superphosphate over the normal rotation of crops have been continued.

TRACE ELEMENTS

Field studies on crop responses to copper, manganese, molybdenum, and boron have been continued and extended. These cover the influence of cropping on the availability of soil copper, the effects of nitrogen applications on the uptake of various elements by plants, and the effectiveness of different forms and rates of application of boron in controlling raan in swedes. For copper and molybdenum supplementary pot experiments have also been carried out, with oats as indicator crop for the former and cauliflower for the latter.

To widen the basis for studying relationships between soil type and trace element uptake by crops, soil and produce samples from the field experiments continue to be supplemented with samples from normal agricultural soils and crops representing main soil associations.

A major objective of these investigations is the development of analytical reference standards and diagnostic techniques. The analytical work and laboratory studies involved are carried out by the Department of Spectrochemistry, and papers covering joint work on copper[16] and on trace element uptake by plants in relation to soil content[17] have appeared. The EDTA extraction method for soil copper described in the first of these papers is proving of considerable value in practical advisory work.

Collaboration in trace element problems with the Animal Diseases Research Association has been maintained.

MAGNESIUM

To cover the possibility that yield restrictions attributable to sub-optimal levels of soil magnesium may be of practical importance in some areas, field work is being extended to investigate the status of different soil types, the responses of different crops, the effectiveness of different forms and the influence of potassium on the need for magnesium. A long-term experiment on the last point has been laid down in collaboration with the North of Scotland College of Agriculture on one of their demonstration farms.

The various soils concerned have also been examined under pot conditions.

RESIDUAL EFFECTS OF LIME

Three long-term experiments covering a range of liming materials and rates of application which were started in 1944 have now been discontinued and the results are being evaluated.

NITROGEN

To complement the general field coverage of crop responses to nitrogen, a more specific and integrated experimental scheme including supplementary pot experiments and laboratory studies on soil nitrogen has been initiated. Crop responses have been determined in the field and in pot experiments, using soil-sand and soil media, for a series of sixteen soils representing four associations and the nitrogen status of the soils is being examined by laboratory methods. A preliminary field trial has also been carried out to establish a suitable technique for studying the role of clover in the nitrogen relationships in mixed swards.

PHOSPHATE INVESTIGATIONS

Inorganic Phosphorus

Field investigations on residual effects, lime-phosphate interactions, the effects of time and frequency of application, the significance of positional availability, and the effectiveness of different forms of phosphate have been continued and extended. In the latter connection, and arising out of results obtained under pot conditions in 1956, particular attention is being paid to the significance of particle-size in relation to the effectiveness and time of application of water-soluble forms, and to comparisons between solid forms and phosphate applied in solution. In addition to field work, a major part of the 1957 pot experiment programme was devoted to these questions.

Other features of the pot experiments were further collaborative work with the Section of Radioactivity of the Department of Plant Physiology on the application of P^{32} to evaluate the phosphate status of soils, collaboration with the Section of Microbiology in studies on the significance of microorganisms in relation to the effectiveness of insoluble phosphates, and investigations with the Section of Soil Geology and Mineralogy on the availability of a series of synthetic iron and aluminium phosphates in sand and soil-sand media. In the latter connections, preliminary experiments have been carried out to check conditions for growing buckwheat and lupins and test their ability to utilize some of the insoluble phosphates concerned.

Laboratory investigations on the inorganic phosphorus relationships and other relevant properties of soils from the field and pot experiments have also been continued. In collaboration with the Section of Statistics an examination of relationships between phosphate sorption and soil properties has been carried out for a range of forty soils representing four associations. An account of these results is to be presented at a symposium on *Phosphorus in Soils and Plants* organized by the Agriculture Group of the Society of Chemical Industry (London, October 1957). There are several differences in behaviour between the four soil groups, but it appears highly probable that the dominant factor governing phosphate sorption in nearly all cases is the reactive aluminium. In general, the correlation with sorption is very high for aluminium and substantially higher than for iron. In all cases the most appropriate estimate of both aluminium and iron is given by the Tamm acid-oxalate method. In all four groups phosphate sorption is also highly correlated with loss on ignition and carbon content, indicating that both the reactive aluminium and iron are closely associated with the organic matter. The high correlation with loss on ignition is of particular interest because it is easily determined and for these soils it provides a potentially useful and simple index of phosphate sorption capacity.

The first of a series of papers[55] covering studies on Australian soils, carried out by Dr J. D. Colwell during his stay in the Department, has been accepted for publication.

Organic Phosphorus

Further progress has been made in investigating the distribution, composition and stability of soil nucleic acids. The presence of the purine and pyrimidine bases guanine, adenine, cytosine, thymine, and uracil has been confirmed in the humic acid fractions of three ordinary agricultural soils, indicating the presence of both deoxyribonucleic acid (DNA) and ribonucleic acid. A preliminary note outlining the separation[31] has appeared, and fuller details together with an assessment of the probable origin of the DNA have been prepared for publication.

Work has also been continued on soil inositol phosphates, including a collaborative study with the Section of Soil Geology and Mineralogy on the mechanism of their fixation by clays. Progress has also been made in developing techniques for micro-fractionation of the soil organic phosphorus fraction and in investigating the occurrence of other specific compounds such as lipids.

ANALYTICAL WORK

In addition to the laboratory investigations mentioned above, normal analytical work has been carried out on soils and crops from field and pot experiments and on soil and produce samples received in the course of consultative activities, representing a total approaching 20,000 samples. The most detailed analyses are carried out on soil samples taken from field experiment areas before any treatments are applied. The objective with these samples is to build up as extensive a characterization as possible because they provide the main starting point for studying relationships between soil properties and field behaviour.

Collaboration in the international scheme for air and rain-water sampling has continued.

CONSULTATIVE WORK

During the year about 12,000 soil samples have been examined, representing mainly samples from agricultural land taken by the staff of the North of Scotland College of Agriculture but including also considerable numbers from horticultural areas and forest nurseries. Compared with last year this represents an increase of about 1,500 samples, attributable partly to the exceptionally open winter which enabled sampling to proceed with little interruption. In collaboration with the Departments of Spectrochemistry and Plant Physiology, numerous soil and produce samples relating to special problems concerning crop production and animal health have again been dealt with. It is of interest to note that no definite instance of molybdenum deficiency has so far been encountered, but a number of herbage samples with excessively high contents of this element were received.

Classification of the soil results according to lime and nutrient status has been continued. As illustrated by the following figures for the North of Scotland region as a whole, the increased use of lime and fertilizers seems to have produced appreciable improvements in potash and lime status but very little for phosphate.

Percentage Distribution of Advisory Soil Samples according to Lime, Phosphate and Potash Contents

Years	No. of Samples	Lime			Phosphate			Potash		
		S.	S.L.	L.	S.	S.L.	L.	S.	S.L.	L.
1940-44	11992	4	59	37	14	48	38	14	71	15
1952-56	40823	12	55	33	14	50	36	29	64	7

S. = satisfactory; S.L. = slightly low; L. = low.

Apart from establishing a direct link with the agricultural community, revealing problems requiring investigation, and providing a channel for translating research findings into practice, the consultative work is a most valuable and desirable complement to the research programme in several other ways. There is, of course, no clear line of demarcation between the two, and advisory problems very frequently develop into research investigations. The grouping of the soil results on the basis of the soil survey maps, which is also carried out, provides a valuable picture of the general lime and nutrient status of different soil types, and the results are also extremely useful in facilitating the selection of sites for field experiments.

MICROBIOLOGY

The main lines of investigation are the same as last year, namely (i) studies on the nutrition and physiology of certain groups of soil microorganisms and (ii) studies on relationships between soil microorganisms and the roots of higher plants.

Part of the work under the first heading continues to be carried out in collaboration with the Departments of Biochemistry and Spectrochemistry. Under the second heading the work on the role of microorganisms in the phosphate nutrition of higher plants is being undertaken in collaboration with the Department of Soil Fertility.

ACTINOMYCETES

Paraffin- and Fat-decomposing Soil Nocardias

Considerable attention has been given to the study of the β-oxidation of the fatty acid side chain of substituted phenoxy acids (hormonal herbicides) by these organisms. The techniques and methods described previously (*Ann. Rep.* 1955-1956) have been used for this purpose. The intermediate (*Ann. Rep.* 1955-1956) produced during the conversion of 3- and 4-chlorophenoxybutyric acids to their corresponding acetate derivatives has been identified. The product obtained from 4-chlorophenoxybutyric acid was shown by infra red analysis to be β-hydroxy-(4-chlorophenoxy)butyric acid. A similar compound was formed during the conversion of 3-chlorophenoxybutyric acid by the organism. It was also shown that the intermediate was further converted to the acetate derivatives as was a synthetic specimen of β-hydroxy-(4-chlorophenoxy)butyric acid. This work has been published.[26]

It was reported last year that the rate of β-oxidation of the fatty acid side chain of monochlorophenoxybutyric acids by *Nocardia opaca* is dependent on the position of the substituents in the ring. Studies on the breakdown of the side chain of monomethylphenoxybutyric acids have shown the same thing to occur. It has now been found possible by modification of the techniques used in the above work to bring about some conversion of 2-4 D.B. (2-4 dichlorophenoxybutyric acid) and M.C.P.B. (2-methyl-4-chlorophenoxybutyric acid) by the organism. Evidence has been obtained of the formation of a β-hydroxy acid in both cases.

Attention has also been given to the β-oxidation of the fatty acid side chain of ω-(1-naphthyloxy)- and ω-(2-naphthyloxy)-propionic and -butyric acids. It has been found that during the conversion of ω-(2-naphthyloxy)butyric acid to the corresponding acetate derivative a β-hydroxy acid is formed. Further work is in progress. The herbicides and related substances used in the above work were obtained through the courtesy of Professor Wain (A.R.C. Unit of Plant Growth Substances and Systematic Fungicides), Dr Heywood, (Chemical Division, May and Baker) and Drs Byrde and Woodcock (Long Ashton Research Station).

A note[25] has been published on the mechanism by which certain long chain saturated hydrocarbons are metabolized by soil nocardias. *N. opaca* (strain T16) and *Nocardia* sp (strain P_2) were used in conjunction with substituted long chain hydrocarbons. The shorter chain ethyl, *n*-propyl and *n*-butyl benzenes were not attacked by the organisms. The results obtained suggest that β-oxidation of fatty acids formed from the substituted long chain hydrocarbons is the mechanism by which these compounds are broken down.

A study of the carbohydrate metabolism of soil nocardias is being carried out in collaboration with the Department of Biochemistry. A number of growth experiments with varying nutritional conditions have been undertaken in this connection.

Thermophilic Actinomycetes from Composts

Work has continued on the growth of the thermophilic actinomycete *Micromonospora vulgaris*. Last year it was reported that some growth could be obtained on an amino-acid mixture, based on the amino-acid composition of hydrolysed casein with the addition of biotin. This growth was generally very variable and always inferior to that obtained on the complex medium usually employed. Much more consistent results have now been obtained by the addition of soluble starch to the above medium. In addition it has been found that the production of aerial mycelium is more pronounced if the air space above the growing culture is cut off from the atmosphere. The development of the aerial mycelium under these conditions usually takes place after 2-4 days. Further, the amino-acids required for growth under these conditions have been reduced to the following: arginine, serine, threonine, leucine, isoleucine, valine, glutamic acid, aspartic acid, glycine, alanine, and methionine. It has been found that methionine is essential for the production of aerial mycelium. Further work is in progress.

FUNGI

Investigations into the process of lignin decomposition in soil have been continued with a study of demethoxylation of simple aromatic compounds by soil fungi. A reduction in methoxyl content is one of the features of lignin decomposition under natural conditions. Using selected soil micro-fungi it was found that *o*, *m*, and *p* methoxybenzoic acids were converted to the corresponding hydroxybenzoic acids while 3 : 4-dimethoxybenzoic acid was converted to vanillic acid, that is the methoxyl group in the para position was converted to an hydroxyl group. The orientation of the substituent groups on the benzene ring was a governing factor in the metabolism of these aromatic compounds. The mono-methoxybenzoic acids and the monohydroxybenzoic acids derived from them were metabolized in the order para, meta, and ortho—para being attacked most rapidly. Attempts were made to follow further stages in the metabolism of the monohydroxybenzoic acids. These were successful only in the case of the para compound from which protocatechuic acid was formed. This step is well known in bacterial metabolism but has not been demonstrated previously for fungi. These results have been published.[32] This work has been continued with wood rotting basidomycetes. A different type of attack on the compounds, apparently involving a strong reducing system, has been shown to occur and detailed studies on this are being carried out in collaboration with the Department of Spectrochemistry.

The influence of trace elements on the metabolism of fungi is at present being investigated. Considerable preliminary work has been necessary to establish techniques but experiments are now being carried out in which the metabolism of phenolic compounds by *Aspergillus niger*, grown in media deficient in various elements, is being studied.

MICROBIOLOGY OF THE ROOT REGION

A study has been started on the role of the microorganisms of the root region in the phosphate nutrition of plants. For this purpose suitable pot experiments have been set up by the Department of Soil Fertility. Particular attention has been paid to the presence of organisms capable of stabilizing insoluble forms of phosphate. A technique has been developed for the detection and estimation of organisms of this type.

Changes in the general bacterial flora of the rhizosphere soil and rhizoplane during plant growth are also being investigated. For this purpose modifications of a previously used medium have been introduced. Also the direct method for counting soil bacteria of Jones and Mollison has been adapted for this work.

Work on the inhibition of growth of spore formers around germinating tomato seed has been continued. It has been shown that this inhibition occurs with other seeds tested, namely oats, buckwheat, clover, and timothy, when they are surface sterilized in the same manner (hypochlorite solution). Similar results are obtained if the surface sterilization is performed with mercuric chloride. Eight subsequent washings with sterile distilled water for five minutes (each washing) does not remove the inhibiting effect. Germinated seeds and seeds which have been left overnight in sterile distilled water after surface sterilization failed to produce the zone of inhibition when placed on agar plates seeded with spore formers. This suggests that the seed coats can adsorb chloride and/or mercuric ions which are not easily removed by normal washing procedures. This is further supported by the fact that no zone of inhibition is observed if the seed coats are sterilized with formaldehyde.

OTHER INVESTIGATIONS

A note[24] on the new metabolite—6-0-acetylglucose—produced by a cobalamin synthesizing strain of *Bacillus megaterium* has been published. The breakdown of the metabolite by cell free extracts of the organism has been investigated. Further strains of *B. megaterium* and other bacteria have been tested in this connection.

FOREST SOILS

FOREST FERTILIZER TRIALS

Assessment of the response of young Corsican Pine to inorganic fertilizers in the plots at Culbin Forest, Morayshire, has continued. At the end of the 1956 growing season, a small but significant height response to phosphate was obtained for the first time since the plots were laid out in 1954. Analyses of needles from trees which had received nitrogen, potash, and magnesium applications in the spring of 1956 showed very marked responses to nitrogen and potassium, but no response to magnesium. Increased height growth was not observed, and was not to be expected at this early stage.

In view of the present widespread interest in the possibility of increasing timber yield by the use of artificial fertilizers, the work at Culbin is being extended to cover other economically important species on a range of sites. Analysis of foliage collected in September, 1956 from *Pinus contorta* and Sitka Spruce growing on deep peat at the Lon Mor, Inverness-shire, indicated a positive correlation between height growth and levels of nitrogen, potassium, and magnesium in the foliage of both species in plots which had received phosphate at the time of planting, suggesting that these elements were likely to limit growth in larger trees whose initial phosphate requirements had been satisfied. A factorial trial similar to that at Culbin was accordingly laid out in April 1957 to test the effect of sulphate of ammonia, muriate of potash, and magnesium sulphate on these two species.

The Forestry Commission has recently established a large number of fertilizer trials throughout Great Britain to test, *inter alia*, the effects of ground mineral phosphate, triple superphosphate, and lime on the early growth of a number of coniferous species. Besides the normal assessment of response by measurement of height growth carried out by the Commission, these plots constitute a valuable source of material for foliar analysis, and arrangements have been made with the Commission Research Branch for the collection of material from plots on a number of sites in Scotland and north England in order to investigate the effect of the fertilizers and of soil type on nutrient uptake.

Foliar analysis has shown that Sitka Spruce growing on deep peat continues to benefit from ground mineral phosphate applied eighteen years ago. If nitrogen and potassium fertilizers are found to be necessary, equally sparingly soluble forms of these elements will be required. The use of granite dust as a slow-acting potash fertilizer is being studied, with particular reference to the effect of grain size on potassium solubility.

TREE GROWTH ON DEEP PEAT

The intensive studies on the effects of *Pinus contorta* on deep peat at the Lon Mor have continued, and sampling down to a depth of two feet (or to the underlying rock where this is shallower) have been completed. Removal of nutrients from the upper layers of peat, particularly by the most vigorous trees manured with ground mineral phosphate, has been largely confirmed, although the trend previously reported for total nitrogen has not been repeated. No appreciable removal has been detected below depths of ten to twelve inches.

Considerable drying of the peat has been found under the un-manured trees to a depth of ten inches, and under the manured trees to a depth of sixteen inches. Although the moisture content of the dry peat is still relatively high it is possible that much of this moisture is unavailable to the trees. pF studies on samples of unplanted peat from various depths are therefore being carried out, using a pressure membrane apparatus.

A similar scheme of sampling and analysis has been started in a comparable plot of Scots Pine.

THE EFFECT OF THINNING ON THE SOIL

The study of changes in the surface soil of the Forestry Commission sample plots of Norway Spruce at Bowmont Forest, Roxburghshire, resulting from the thinning of the tree crop, has been completed and accepted for publication.[56] Thinning a dense stand, by reduction of the litter fall and particularly by improvement of the microclimate at the soil surface, has been shown to increase the rate of breakdown of the forest floor and the amount of nutrients available to the trees, and to reduce losses of the more mobile nutrients through leaching. Of the physical properties studied, only the aggregation of the silt and clay was affected, the heavier thinning grades causing a reduction in micro-aggregate stability.

IMMOBILIZATION OF NUTRIENTS BY A TREE CROP

A paper on the total nutrient content of individual Scots and Corsican Pine of different ages, growing on sand dunes at Culbin, has been accepted for publication.[57] Of the variations observed in the major nutrient content of the different parts of the trees, the most interesting are those in the heartwood and sapwood of the main stems. The phosphorus and potassium contents of the heartwood of both species are very low, but calcium, magnesium and sodium tend to accumulate. In the sapwood zone immediately surrounding the heartwood, high levels of all major nutrients occur. These differences are of particular importance in Scots Pine whose heartwood development is greater than Corsican.

The bark and stem have been shown to contain between one third and one half of the total nutrients in a tree, depending on age. Barking of stems before removal would reduce losses from the site, but appreciable quantities are still removed in the wood.

FOREST NURSERY SOILS

Analyses of the first season's samples from the long-term fertility demonstrations at Newton and Teindland nurseries have shown significant differences in the physical and chemical properties of the soil due to the various cropping treatments. In both nurseries, the application of raw hop waste has resulted in higher available nutrient contents and improved micro-aggregate stability. Arrangements have been made with the Forestry Commission for annual sampling of the soils in these experiments, so that changes can be followed over a sufficiently long period.

ADVISORY AND COLLABORATIVE WORK

Fertilizer recommendations for both Forestry Commission and private nurseries, based on analyses carried out by the Department of Soil Fertility, have continued. The establishment of a grazing strip for fire protection at Cullendoch Forest, Kirkcudbrightshire, by reseeding and heavy fertilizer dressings, has been successful, and is being extended.

STATISTICS

The main work of the section is the co-operation in the preparation of the field experiment programme of the Department of Soil Fertility and the analysis of data and reporting of results arising from it. In addition to yield data, analyses and reports have been made on a considerable number of crop analysis results from 4^3, NPK factorial experiments on potatoes and swedes. Quite a large body of data from the analysis of field experiment soil samples is being examined. The results from these include information on the relationship between two methods of determining readily-soluble CaO in soils. Several experiments involve the comparison between different forms or methods of application of a fertilizer. In these, the comparisons are based on the hypothesis of proportional response, that is the differences between forms or methods are proportional to the quantity of fertilizer applied instead of constant for all quantities.

The 1957 field experiment programme contains designs for 40 experiments in addition to those continued from previous years. A considerable number of randomized block and Lattice square designs are concerned with the responses to different types of phosphates and to different times and positions of application of phosphate. These cover a variety of crops including grass sown on an area of reclaimed rough ground. Latin square and randomized block designs are used in a group of four experiments to investigate the effects of boron and the time of application of lime on the incidence of raan in swedes. Short-term experiments on trace element investigations are of randomized block, Latin square, and factorial design. The series of one-year 4^3, NPK factorial experiments is being continued with swede and potato 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. Further data is to be obtained in the series of complex factorial experiments investigating the long-term effects of heavy dressings of phosphate and their comparison with light annual dressings. Two experiments of Latin square design, continued from 1956, are concerned with the response to copper of grass.

During the years 1951-1956 a series of experiments on late applications of nitrogen to oats were carried out by the Department of Soil Fertility and the three colleges of agriculture in Scotland. The same nitrogen levels were not used in all groups of experiments and in combining the results of the series the analysis was based on the proportional response hypothesis. The differences between the times of application were expressed as the differences in yield for a standard dressing of 28 lb. nitrogen per acre. A report has been submitted to the Field Trials Sub-committee of the Scottish Agricultural Improvement Council and an account of the work will be prepared for publication.

Two other joint papers are being prepared for publication. One is the first part, dealing with the potato crop, of a report on a series of NPKD factorial experiments which provide information on the responses to and the interactions between nitrogen, phosphate, potash, and dung. The other is concerned with the yield results from the regional manurial trials organized by the Grassland Sub-committee of the Scottish Agricultural Improvement Council.

On data from the Department of Spectrochemistry a test was made of the relationship between the cobalt content of pasture and of soil, taking into account the pH level of the soil.

The results of a factorial experiment investigating P/Fe ratio were analysed and a report submitted to the Department of Plant Physiology. Two further experiments have been planned to test the factors Fe, K/Ca ratio and P/N ratio. The analysis of these results is now in progress.

Analysis of data and reports have been made on a number of experiments for the Section of Forest Soils. These include long-term fertility maintenance demonstrations, and continuing phosphate and NKMg experiments at Culbin Forest. Another NKMg factorial experiment has been designed. The relationship between tree height and nutrient content of needles was investigated for Sitka Spruce and *Pinus contorta*.

CONSULTATIVE WORK

In collaboration with the Department of Soil Fertility, three NPK factorial experiments on potatoes were designed for the Crop Husbandry Department of the West of Scotland Agricultural College. A report on the results from one of these trials, on an early potato crop, has been submitted to the experimenter.

The section co-operated with the Agricultural Research Council Unit of Statistics during the analysis of results from and the preparation of reports on the surveys of fertilizer practices in Scotland being carried out by the colleges of agriculture.

Collaborative work with the North of Scotland College of Agriculture includes the analysis of Majestic clone trials and seed rate and nitrogen trials. Further work has been planned on the control of carrot fly and wheat bulb fly.

Co-operation has been given in planning experimental work, on the response of grass to nitrogen and on the feeding habits of sheep, for the Department of Agriculture of the University of Aberdeen. A paper[34] mentioned in last year's report has now been published. It gives an account of a lamb feeding experiment employing a change-over design arranged in Latin squares. A course of introductory lectures on Statistical Science in Agriculture and Forestry was given to second year students at the University of Aberdeen during the winter term.

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

PUBLICATIONS

(A) *Published—*

1. The soils of the country round Kilmarnock. (Sheet 22 and part of Sheet 21). By B. D. Mitchell and R. A. Jarvis. (*Memoirs of the Soil Survey of Great Britain: Scotland*, 1956. 234pp. With soil maps of Sheet 22 and part of Sheet 21. H.M.S.O., 30/-).

   The physical features, climate, and geology of the district are dealt with in the early chapters of the memoir. The principles of soil mapping, the standard terms of field pedology, soil classification, and soil formation are also considered. The greater part of the publication is, however, devoted to detailed descriptions of the physical morphology of the soil types encountered. A full account of the vegetation of the area is given, while agriculture and forestry are covered in chapters of a general nature. The physical and chemical properties of the soils are dealt with in the final chapter and appendices. A map delineating the characteristic soils accompanies the memoir. The map is provided with a comprehensive key enabling the ready determination of the parent material, drainage class, and universal soil group of the local soil type.

2. Pollen analysis of peat deposits in Scotland. By S. E. Durno. (*Scot. geog. Mag.*, **72,** 177-187, 1956).

   A brief account of past pollen analytical work in Scotland is followed by the presentation of pollen diagrams from five raised moss basin peats. These are provisionally zoned as nearly as possible in accordance with other British diagrams and certain comparisions and vegetational developments indicated.

3. A double focusing X-ray powder camera. By W. A. Mitchell. (*Clay Min. Bull.*, **3,** 36-39, 1956).

   A focusing X-ray powder camera is described in which the degree of focusing varies with 2θ and can be made a maximum for any one reflection. It is of simple design and has two main uses: (*a*) for routine identification of the main clay mineral groups by their basal reflections, and (*b*) for the detection of very small amounts of any one crystalline component in a mixture.

4. The clay mineralogy of Ayrshire soils and their parent rocks. By B. D. Mitchell and W. A. Mitchell. (*Clay Min. Bull.*, **3,** 91-97, 1956).

   The clay mineralogy of the soils developed on glacial till derived from Carboniferous igneous and sedimentary rocks, and from sediments of Downtonian, Old Red Sandstone, and Permian ages, is compared with that of the parent rock. The results show that a definite relationship exists between the different soil types developed on the till from each parent rock, particularly in the case of the sediments. The influence of pedogenic processes on the clay mineral distribution in the soil profiles is discussed.

5. A mineralogical study of weathering and soil formation from olivine basalt in Northern Ireland. By J. Smith. (*J. Soil Sci.*, **8,** 225-239, 1957).

   The composition of a soil profile derived from olivine basalt in Northern Ireland is described with the assistance of a series of diagrams of the cumulative curve type incorporating mineralogical and particle size data. The weathering sequence of primary minerals in the basalt is olivine, labradorite, augite. Olivine alters to vermiculite and labradorite to kaolin. The soils resisted all attempts to achieve complete dispersion and its high state of aggregation is considered to affect its physical properties. The presence of quartz is attributed to glacial contamination.

6. Turkish forest soils. By W. A. Mitchell and A. Irmak (University of Istanbul). (*J. Soil Sci.*, **8**, 184-192, 1957).

   Parent material, climatic and chemical data for a number of Turkish forest soils are discussed with particular reference to their clay mineralogy. In spite of extreme climatic variations, there is a distinct relationship between clay mineralogy, parent material, and cation exchange capacity.

7. Methods for separation of soil clays in use at the Macaulay Institute for Soil Research. By R. C. Mackenzie. (*Clay Min. Bull.*, **3**, 4-6, 1956).

   The methods for clay separation described involve dispersion, sedimentation, coagulation, and peroxidation. Modifications to deal with organic soils are also described.

8. Thermal methods. By R. C. Mackenzie. (pp. 1-22 of *The Differential Thermal Investigation of Clays*. 1957. Mineralogical Society, 60/-). (No reprints).

   A review of the thermal methods available for clay investigations outlining their applicability and limitations.

9. Apparatus and techniques for differential thermal analysis. By R. C. Mackenzie and B. D. Mitchell. (pp. 23-64 of *The Differential Thermal Investigation of Clays*. 1957. Mineralogical Society, 60/-). (No reprints).

   The considerations underlying design of differential thermal apparatus are considered and the various components assessed individually. A selected range of apparatuses and factors of technique influencing results are critically discussed.

10. The oxides of iron, aluminium, and manganese. By R. C. Mackenzie. (pp. 299-328 of *The Differential Thermal Investigation of Clays*. 1957. Mineralogical Society. 60/-). (No reprints).

    The differential thermal characteristics of the various crystalline and amorphous forms of those oxides are critically discussed. The mechanism of decomposition and the use of differential thermal curves for identification are also considered.

11. Differential thermal analysis and its use in soil-clay mineralogy. By R. C. Mackenzie. (*Geol. Fören. Stockh. Förh.*, **78**, 508-525, 1956).

    After a brief discussion of the applicability of differential thermal analysis and the apparatus used, the clay mineralogy of various soils from different parts of Scotland is examined with special reference to their differential thermal characteristics.

12. The thermal investigation of soil clays. By R. C. Mackenzie. (*Agrochimica*, **1**, 1-22, 1956).

    Thermal methods are being increasingly applied to the study of the clay fraction of soils. These methods depend upon the changes in dimension, weight, or energy of the clay as it is heated. Their applicability and limitations are discussed with particular reference to differential thermal analysis, and some examples illustrating their use are given.

13. A method for concentration of dilute clay suspensions without coagulation. By R. C. Mackenzie and K. R. Farquharson. (*Clay Min. Bull.*, **3**, 7, 1956).

    A brief description is given of a vacuum distillation method which, because of the low temperatures involved, does not tend to coagulate the clay when used for concentration of dilute suspensions.

14. Spectrochemical methods in soil investigations. By R. L. Mitchell. (*Soil Sci.*, **83**, 1-13, 1957).

    A discussion of the applications of spectrochemical methods to soil investigations. The relative merits of the different modes of excitation are assessed, and the feasibility of the different methods for specific determinations is considered. Some indication is given of equipment and staff required for an efficient spectrochemical laboratory dealing with trace and major element determination.

15. Soil analysis and trace elements. By R. L. Mitchell. (pp. 137-148 of *The Organisation and Rationalisation of Soil Analysis*. 1956. O.E.E.C. Project No. 156, 12/6).

A discussion of the soil availability of biologically important elements and the most satisfactory methods at present available for their determination. (No reprints).

16. Soil copper status and plant uptake. By R. L. Mitchell, J. W. S. Reith, and Isabel M. Johnston. (pp. 249-261 of 2nd Symposium on *Analyse des Plantes et Problèmes des Engrais Minéraux*. VIth Int. Congr. Soil Sci., Paris, 1956).

A report of investigations into soils on which copper deficiency in oats (blind ear) occurs. It has been found that 0·05M EDTA is the most satisfactory soil extractant for diagnostic purposes, and that red clover is the plant whose copper content best reflects the available copper content of the soil. Grasses and cereals do not vary much in copper content in different soils, it is rather the yield which varies.

17. Trace element uptake in relation to soil content. By R. L. Mitchell, J. W. S. Reith, and Isabel M. Johnston. (*J. Sci. Fd. Agric.*, **8**, S51-S59, 1957).

Numerous factors affect the uptake of trace elements by plants and lead to variations in the distribution within the plants themselves. All serve to complicate the diagnostic assessment of the trace-element status of a soil by plant analysis. In Scottish soils the most important pedological factor influencing trace-element availability is the drainage status. Under poor drainage conditions the extractable contents of many trace elements in soils are increased, and in certain instances, notably cobalt and nickel, there is a corresponding increase in plant uptake. The relative contents of trace elements in the constituent species of a mixed herbage are not constant; in one mixed herbage cocksfoot contained the highest cobalt content. Several examples of the effect of soil treatment on plant content of trace elements are quoted, illustrating in particular the difference between different species in their response to soil additions. The use of acetic acid and ethylenediaminetetra-acetic acid (EDTA) as extractants for the diagnostic assessment of the copper and cobalt status of soils is illustrated by results for some 50 soils of various types. There is some indication that EDTA may be better than acetic acid for these elements.

18. The trace element content of plants. By R. L. Mitchell. (*Research*, **10**, 357-362, 1957).

A brief discussion of the occurrence of trace elements in plants in so far as they are affected by soil conditions, with particular reference to the elements required by animals consuming the plants.

19. Uptake of chelated metals by plants. By P. C. DeKock and R. L. Mitchell. (*Soil Sci.*, **84**, 55-62, 1957).

Experiments with mustard and tomatoes indicate that divalent cations (Co, Ni, Zn, Cu) which are readily taken up by plants when present in solution in ionic form are not so readily absorbed when chelated, particularly with EDTA. There is also a reduction in uptake of these metals when Fe-EDTA replaces ferric chloride as the source of iron. Trivalent cations (Cr, Al, Ga, In), which are taken up only in trace amounts when present in ionic solution, are on the other hand readily taken up and translocated to the leaves when present in chelated form. Less is absorbed when DTPA is the chelating agent than with ATA or EDTA, at least for Cr, Al, and Ga. A possible explanation is that the charge on the chelated molecule is one factor controlling absorption by the root, those with no charge or a single negative charge being taken up while complexes with two charges are not.

20. The Tertiary dolerite plugs of north-east Ireland—a survey of their geology and geochemistry. By E. M. Patterson (West Kilbride, Ayrshire) and D. J. Swaine. (*Trans. roy. Soc. Edinb.*, LXIII, Pt II, No. 14, 1957).

A summary is given of the field relations, geographical distribution and petrography of 29 dolerite plugs associated with the Tertiary lava plateau of north-east

Ireland. All but two of the plugs are composed of olivine-dolerite. The exceptions are a pyroxene-rich dolerite and a tholeitic type containing abundant chlorophaeite. Trace-element determinations have been made on specimens from 13 of the plugs. Slight but definite chemical differences are shown to exist between the olivine-dolerites and the average Tertiary olivine-basalt lava of the area. The petrogenetic relationships of the two are briefly considered.

21. The limestones of Scotland: Chemical analyses and petrography. Chemical analyses by A. Muir and H. G. M. Hardie. Spectrographic determinations of trace elements by R. L. Mitchell. Petrography by J. Phemister (H.M. Geological Survey). (*Spec. Rep. Min. Resour. G.B.*, **37**, 1956. H.M.S.O., 21/-).

22. Spectrochemical analysis of plants and soils. By R. L. Mitchell. (*Proc. Soil Sci. Soc. Fla.*, **15**, 12-21, 1955).

A short description of the spectrochemical methods and chemical concentration techniques in use for the determination of trace elements in plants and soil extracts.

23. Application of spectrochemical methods to agricultural problems. By R. L. Mitchell and R. O. Scott. (*Appl. Spectrosc.*, **11**, 6-12, 1957).

A brief description of the spectrochemical methods in use at the Macaulay Institute, including some details of the porous cup solution spark technique.

24. 6-0-Acetylglucose: a new metabolite formed by a cobalamin-producing strain of *Bacillus megaterium*. By R. B. Duff, D. M. Webley and V. C. Farmer. (*Nature*, **179**, 103-104, 1957).

In the course of a survey of the metabolism of important soil organisms it was found that a vitamin B_{12} producing strain of *B. megaterium* produced a new metabolite. This was identified by chemical and physical (infra-red) examination. It belonged to a class of carbohydrates hitherto unknown in nature and proved to be 6-0-acetyl-D-glucopyranose. Some derivatives are described and chemical and biochemical reactions indicated. The ester is a major product of metabolism of the above strain but was produced by only two other strains of the fourteen examined.

25. Evidence for β-oxidation in the metabolism of saturated aliphatic hydrocarbons by soil species of *Nocardia*. By D. M. Webley, R. B. Duff and V. C. Farmer. (*Nature*, **178**, 1467-1468, 1956).

Describes the mechanism by which certain long-chain saturated aliphatic hydrocarbons are broken down by members of the genus *Nocardia*. Incubation with phenyldecane, phenyldodecane and phenyloctodecane gave phenylacetic acid. Phenylethylacetic acid was obtained from β-phenyleicosane, and 2-α(-naphthyl) propionic acid from 1-(α-naphthyl)hendecane. Conclusions are drawn about the breakdown of these important model substances in soil.

26. Formation of a β-hydroxy acid as an intermediate in the microbiological conversion of monochlorophenoxybutyric acids to the corresponding substituted acetic acids. By D. M. Webley, R. B. Duff, and V. C. Farmer. (*Nature*, **179**, 1130-1131, 1957).

It has been shown that the soil microorganism *N. opaca* will convert 3- and 4-monochlorophenoxybutyric acids to their corresponding acetic acids (hormonal herbicides). During these conversions a β-hydroxy acid intermediate is formed which from γ (4-chlorophenoxy)butyric acid proved to be β-hydroxy-γ-(4-chlorophenoxy) butyric acid. This provides direct evidence for the formation of such compounds during β-oxidation.

27. Absorption spectrometry of acids and bases in alcoholic solutions. By V. C. Farmer. (*Chem. and Ind.*, 112-113, 1957).

The presence of traces of basic impurities in alcohols used as spectroscopic solvents is shown to be not unusual, and the effect of this on the spectra of solutes with acid functional groups is illustrated.

28. Effects of grinding during the preparation of alkali-halide disks on the infra-red spectra of hydroxylic compounds. By V. C. Farmer. (*Spectrochim. Acta*, **8**, 374-389, 1957).

Changes in the spectra of phenols and organic acids induced by grinding with alkali halides are ascribed to the adsorption of molecules on the surface of the alkali halides through their hydroxyl groups. Carboxylic acids are shown to be adsorbed principally as monomers, linked to halide ions by hydrogen bonding, so that the spectral changes which occur serve to identify vibrations to which the carboxyl group contributes. In addition, a rearrangement of the crystalline structures of cinnamic acid and hydroquinone on grinding with alkali halides is reported. Glucose gives a new crystalline spectrum when ground with potassium iodide, but other sugars are either unchanged or converted to an amorphous state; similar effects occur with some samples of potassium bromide. The pressed-disk technique is discussed in the light of these results.

29. Liming is still important. By E. G. Williams. (pp. 51-53 of *Annual Farming Digest and Agricultural Directory of Scotland.* 1957. Mearns Agricultural Publications, Aberdeen, 10/6).

The practical considerations are briefly reviewed with emphasis on the benefits from and continued need for liming.

30. Does your land need lime? By J. W. S. Reith and A. M. Smith (Edinburgh and East of Scotland College of Agriculture). (*Farming Leader*, **8**, No. 34, 9, 1956).

The practical aspects are reviewed with reference to the extents of deficiencies, the needs of different crops, rates and methods of application, and the types of material available.

31. Nucleic acid derivatives in soils. By G. Anderson. (*Nature*, **180**, 287-288, 1957).

The purine and pyrimidine bases guanine, adenine, cytosine, thymine, and uracil have been identified in hydrolysates of humic acid from three mineral soils. The evidence suggests that deoxyribonucleic acid and a minute amount of ribonucleic acid are present in humic acid. The amount of deoxyribonucleic acid was greater than that likely to be present in soil microorganisms.

32. Metabolism of methoxylated aromatic compounds by soil fungi. By Moira E. K. Henderson. (*J. gen. Microbiol.*, **16**, 686-695, 1957).

The metabolism of methoxylated aromatic compounds by the soil fungi *Haplographium* sp., *Hormodendrum* sp. and *Penicillium* sp. has been investigated. A study of rates of decomposition of mono-methoxybenzoic acids by *Hormodendrum* sp. revealed that they are most rapidly attacked in the order para, meta, and ortho. In respiration studies with all three fungi the *p* form was again found to be metabolized most rapidly. In the initial stage of attack the methoxyl group is replaced by a hydroxyl group. *Penicillium* sp. also formed *p*-methoxyphenol from *p*-methoxybenzoic acid. A study of the rates of metabolism of monohydroxybenzoic acids revealed that they are attacked in the same order as the monomethoxybenzoic acids. *p*-Hydroxybenzoic acid formed from *p*-methoxybenzoic acid is further metabolized to protocatechuic acid by *Hormodendrum* sp. and *Penicillium* sp. When veratric acid (3 : 4-dimethoxybenzoic acid) is incubated with *Hormodendrum* sp. and *Penicillium* sp. the methoxyl group in the *p* position is replaced by a hydroxyl group to give vanillic acid. All three fungi formed two unidentified phenolic compounds from 2 : 4-dimethoxybenzoic acid. The possible significance of the results in the decomposition of lignin in soil is discussed.

33. Abnormalities in nutrient uptake by Corsican Pine growing on sand dunes. By T. W. Wright. (*J. Soil Sci.*, **8**, 150-157, 1957).

Monthly variations in foliar N, K, Ca, Mg, and P_2O_5 of young Corsican pine growing on the sand dunes of Culbin Forest, Morayshire, have been compared with monthly changes in the available moisture in the rooting zone, calculated with the aid of Penman's formula. A reversal of the normal seasonal trends has been observed in the second half of the growing season. In trees showing poor growth, heavy thinning delayed the drying out of the rooting zone and temporarily improved the K, Mg and N levels in the foliage.

34. The effects of different suckling frequencies on the quantity of milk consumed by young lambs. By Joan Munro and R. H. E. Inkson. (*J. Agric. Sci.*, **49**, 169-170, 1957).

An experiment was carried out to compare the amount of milk obtained by lambs suckling at 1-hourly intervals with that obtained by lambs suckling at 4-hourly intervals during a 24 hr. period. Statistical analyses of the figures showed that the milk consumption of lambs suckling at 4-hourly intervals was not greater than that of lambs suckling at 1-hourly intervals.

(B) *Submitted for Publication*—

35. The soil survey of Scotland. By R. Glentworth. (To appear in *Scot. Agric.*).

36. The geography and soils of north-east Scotland. By R. Glentworth. (To appear in *Agric. Progr.*).

37. Heather management. By R. A. Robertson. (To appear in *Scot. Agric.*).

38. Some observations on the ecology of an upland grazing in north-east Scotland with special reference to Calluneta. By I. A. Nicholson (Hill Farming Research Organization) and R. A. Robertson. (To appear in *J. Ecol.*).

39. Certain aspects of vegetational history in north-east Scotland. By S. E. Durno. (To appear in *Scot. geog. Mag.*).

40. A note on the dating of the Forth Valley carse clay. By S. E. Durno. (To appear in *Scot. geog. Mag.*).

41. Identification of fossil fruits of *Najas flexilis* in Scotland. By S. E. Durno. (To appear in *Trans. Proc. bot. Soc. Edinb.*).

42. The occurence of pollen of *Fraxinus* in northern Scottish peats. By S. E. Durno. (To appear in *Trans. Proc. bot. Soc. Edinb.*).

43. Studies on the basaltic soils of Northern Ireland. IV. Mineralogical study of the clay separates. By D. M. McAleese (University of Cambridge) and W. A. Mitchell. (To appear in *J. Soil Sci.*).

44. Studies on the basaltic soils of Northern Ireland. V. Cation-exchange capacities and mineralogy of the silt separates. By D. M. McAleese (University of Cambridge) and W. A. Mitchell. (To appear in *J. Soil Sci.*).

45. Modern methods for studying clays. By R. C. Mackenzie. (To appear in *Agrochimica*).

46. The illite in some Old Red Sandstone soils and sediments. By R. C. Mackenzie. (To appear in *Min. Mag.*).

47. The montmorillonite differential thermal curve. I. By R. C. Mackenzie. (To appear in *C. R. Groupe franç. des Argiles*).

48. Saponite from Allt Ribhein, Fiskavaig Bay, Skye. By R. C. Mackenzie. (To appear in *Min. Mag.*).

49. Differential thermal characteristics of peat. By B. D. Mitchell. (To appear in *Nature*).

50. The trace-element content of some soils and rocks from Macquarie Island, South Pacific Ocean. By D. J. Swaine. (To appear in *Australian Antarctic Reports*).

51. The alkaline nitrobenzene oxidation of soil organic matter. By R. I. Morrison. (To appear in *J. Soil Sci.*).

52. Esterification of the primary alcoholic groups of carbohydrates with acetic acid—a general reaction. By R. B. Duff. (To appear in *J. Chem. Soc.*).

53. Nutrient balance in plant leaves. By P. C. DeKock. (To appear in *Agric. Progr.*).

54. Stimulation of respiration by respiratory inhibitors. By P. C. DeKock and I. R. Macdonald. (To appear in *Physiol. Plant*).

55. Observations on the pedology of some Krasnozem soils of New South Wales. By J. D. Colwell. (To appear in *J. Soil Sci.*).

56 Some effects of thinning on the soil of a Norway spruce plantation. By T. W. Wright. (To appear in *Forestry*).

57. The nutrient content of Scots and Corsican pines growing on sand dunes. By T. W. Wright and G. M. Will. (To appear in *Forestry*).

APPENDIX 1

Soil series and symbols for the soil associations contained in the Soil Survey Memoir *The Soils of the Country round Banff, Huntly and Turriff* for Sheets 86 (Huntly) and 96 (Banff).

Association	Series					
	Freely drained		Poorly drained		Very poorly drained	
Whitehills	————		Whitehills	WH	————	
Leslie	Leslie	LE	Charleston	CL	Pitscurry	PC
Gartly	Gartly	GY	Culdrain	CI	————	
Insch	Insch	IN	Myreton	MR	Mosstown	MW
Tarves	Tarves	TR	Pitmedden	PD	Pettymuck	PK
Ordley	Ordley	OD	Boghead	BH	————	
Bogtown	————		Bogtown	BT	Broom	BR
Fraserburgh	Fraserburgh	FR	Whitelinks	WL	————	
Strichen	Strichen	ST	Anniegathel	AE	Hythie	HY
Foudland	Foudland	FD	Fisherford	FH	Shanquhar	SQ
Countesswells	Countesswells	CW	Terryvale	TV	Drumlasie	DM
Hatton	Hatton	HN	Blachrie	BZ	————	
Cuminestown	Cuminestown	CM	Culbyth	CJ	Woodside	WS
Boyndie	Boyndie	BY	Dallachy	DA	Ballindarg	BA
Corby	Corby	CY	Mulloch	MC	Mundurno	MO
Durnhill	Durnhill	DH	Kilbady	KY	Balloch	BD
Durnhill Gravel	Woodhead	WA	————		Monksburn	MK

APPENDIX 2

Comparison of freely and poorly drained soils from the Insch Soil Association.

Profile Location: Parkfield, Oldmeldrum.

Association: Insch. Freely drained. Brown forest soil of low base status. Cultivated.

Horizon	Depth ins.	%Loss on Ignition	Mechanical Analysis			Exchangeable Cations me/100g				% Base Saturation	pH	Organic Fraction		Phosphorus	
			% Sand	% Silt	% Clay	Ca	Mg	K	H			%C	%N	Total $\%P_2O_5$	Acetic Soluble mg/100g
S	0–6	11·5	58·9	15·6	21·3	8·5	0·98	0·11	10·6	47·6	6·2	3·97	0·46	0·53	7·6
S	12–15	10·1	59·0	15·5	22·8	8·2	0·85	0·06	10·1	47·5	5·8	3·25	0·31	0·53	3·5
B_2	17–21	7·3	63·1	16·1	17·4	2·6	0·39	0·06	7·9	27·9	6·0	1·56	0·21	0·46	4·3
B_3	24–30	4·3	73·8	15·9	11·1	1·7	0·25	0·08	4·0	33·4	5·8	0·44	0·05	0·15	5·2
C(g)	30–36	5·1	72·5	15·9	13·6	5·9	1·33	0·12	4·4	62·6	5·6	0·24	0·06	0·16	2·4
C(g)	45–48	N.D.	82·6	10·5	8·0	12·9	2·39	0·14	3·5	81·5	5·3	0·24	0·07	0·14	0·7
Insch. Poorly drained. Non-calcareous ground-water gley. Cultivated.															
S	0–6	8·0	58·1	18·3	21·2	11·2	2·55	0·44	6·6	68·2	5·8	2·49	0·26	0·18	11·9
A_2g	12–14	3·8	76·7	10·6	15·1	9·7	4·60	0·09	2·2	85·9	5·8	1·37	0·05	0·15	24·3
B_2g	20–24	5·1	57·0	14·7	26·4	11·3	8·10	0·10	2·2	90·4	7·7	0·33	0·04	0·12	9·1
B_3g	24–30	4·1	66·3	18·2	17·8	9·5	9·17	0·12	0·9	95·5	6·3	0·46	0·03	0·13	30·1
Cg	45–48	4·2	63·7	13·8	20·9	11·5	9·68	0·15	0·9	95·7	6·9	0·16	0·02	0·14	28·6

APPENDIX 3

Comparison of freely and poorly drained soils from the Foudland Soil Association.

Profile Location: Ythanwells

Association: Foudland. Freely drained. Podzol. Cultivated.

Horizon	Depth ins.	%Loss on Ignition	Mechanical Analysis			Exchangeable Cations me/100g				% Base Saturation	pH	Organic Fraction		Phosphorus	
			% Sand	% Silt	% Clay	Ca	Mg	K	H			%C	%N	Total %P_2O_5	Acetic Soluble mg/100g
S	0–6	14·8	44·0	26·1	22·1	5·9	0·45	0·06	19·8	24·4	5·0	8·07	0·49	0·28	0·9
B_2	8–10	8·7	48·8	23·8	23·0	1·3	0·09	<0·01	11·5	11·0	5·4	2·85	0·21	0·21	1·0
B_3	16–20	3·5	60·4	19·9	16·2	0·3	<0·01	<0·01	4·5	5·4	5·5	N.D.	N.D.	0·17	5·4
C	24–28	4·0	63·9	13·2	18·9	0·5	0·01	0·02	3·9	11·6	5·5	N.D.	N.D.	0·16	4·4

Foudland. Poorly drained. Non-calcareous ground-water gley. Cultivated.

S	0–8	12·3	37·5	30·1	26·3	6·0	0·66	0·05	11·1	38·0	5·3	5·64	0·37	0·19	4·5
A_2g	12–16	3·2	48·3	30·7	17·8	3·3	0·30	0·01	1·2	75·0	5·6	0·41	0·07	0·09	8·8
B_2g	22–24	3·2	52·7	23·2	20·9	4·5	0·69	0·01	1·4	79·5	5·7	N.D.	N.D.	0·12	2·8
Cg	28–32	2·3	53·1	28·3	16·3	4·0	0·81	0·03	2·0	72·0	6·0	N.D.	N.D.	0·13	12·0