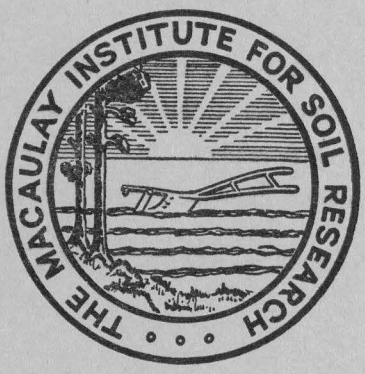
THE MACAULAY INSTITUTE FOR SOIL RESEARCH



ANNUAL REPORT 1948-1949

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

THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

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1948–1949

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* Appointed 1949.

RESEARCH WORKERS

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

Visiting . . . . . I. D. BLAIR (Canterbury Agricultural College, Lincoln, New Zealand).

I. K. WALKER (Department of Scientific and Industrial Research, Wellington, New Zealand).

W. WARD (Pilkington Bros. Ltd., St. Helens, Lancs.).

CONTENTS

THE MACAULAY INSTITUTE FOR SOIL RESEARCH

ANNUAL REPORT

1948–1949

THE Council of Management of The Macaulay Institute for Soil Research records with deep regret the death of Professor James Hendrick which occurred in Aberdeen on 25th February, 1949. Professor Hendrick had been associated with the Institute since it was established in 1930, and was the first Chairman of Council. To him, in great measure, the founding and establishing of the Institute in Aberdeen was due. After having served as Chairman for two terms he continued to give of his counsel, and had been Convener of the Staff Committee for many years.

COUNCIL CHANGES

Some changes in the personnel of the Council fall to be recorded. Professor W. O. Kermack, F.R.S., was appointed as one of the representatives of the University of Aberdeen to fill the vacancy caused by the death of Professor Hendrick.

Professor E. L. Hirst, F.R.S., was appointed as one of the representatives of the Department of Agriculture for Scotland to succeed Mr. A. McCallum, O.B.E., who resigned after many years of valued service. Consequent upon his appointment as Deputy Director General of the Forestry Commission, Mr. W. H. Guillebaud tendered his resignation. Mr. James Macdonald, Director of Research in the Forestry Commission, and Principal T. M. Taylor, C.B.E., K.C., Vice-Chancellor of the University of Aberdeen, were co-opted.

STAFF CHANGES

The following appointments to the Staff of the Institute were made during the year:

Pedology:	
Soil Survey Section:	W. M. Crooke, B.Sc., D. T. Davies, B.Sc., P. C. Harper, B.Sc. and M. J. Mulcahy, B.Sc.(For.).
X-ray Section:	Miss A. A. Milne, B.Sc.
Physico-Chemical Section:	Miss K. R. Farquharson, B.Sc.
Analytical Section:	H. G. M. Hardie, Ph.D., A.R.I.C.
Soil Organic Matter:	R. B. Duff, B.Sc., Ph.D. and S. E. Durno, B.Sc.
Soil Fertility:	N. M. Scott.

Visitors

During the past year many visitors were welcomed to Craigiebuckler. Included amongst these were representatives of Institutions in France, Netherlands, Norway, Sweden, Turkey, Australia, Canada, New Zealand and South Africa.

Visiting Research Workers

The following research workers spent short periods during the year studying the work being done in

(*a*) *The Department of Spectrochemistry*

Dr. I. K. Walker, Dominion Laboratory, Department of Scientific and Industrial Research, Wellington, New Zealand.
Mr. W. Ward, Pilkington Bros. Ltd., St. Helens, Lancs.

(*b*) *The Department of Soil Organic Matter*

Dr. I. D. Blair, Canterbury Agricultural College, Lincoln, New Zealand.

It is with pleasure that the Council reports that it has been possible to accept research workers for the coming academic year from Australia, South Africa, Italy, Chile and Switzerland.

New Laboratories

The Council reports with pleasure that the new laboratories for accommodating the Department of Soil Fertility have now been completed and additional space thereby secured will do much to alleviate congestion.

Consequent upon this the reconstruction and re-allocation of laboratories in the present building will proceed.

The Council further has pleasure in reporting that substantial progress was made in the Department of Spectrochemistry by the introduction of the new technique of direct flame photometry.

Policy

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

Representation on Committees

The Institute is represented on Committees of the following Departments :

(1) *Agricultural Research Council*

(*a*) Fertilizer Placement Conference.
(*b*) Mineral Deficiencies Conference.
(*c*) Land Drainage Conference.

(2) *The Department of Agriculture for Scotland*

(*a*) Technical Advisory Committee
(*b*) Sub-Committees on Grassland and Field Trials.
(*c*) Sugarbeet Committee.

(3) *Forestry Commission*

The Sub-Committee dealing with nutritional problems in tree nurseries.

(4) *Colonial Office*

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

Dr. A. B. Stewart was appointed to serve on the Development Commission Survey of Agricultural, Forestry and Fisheries Products and their Utilization.

The Secretary of State for Scotland appointed :

Dr. A. B. Stewart—Deputy Director—to be a member of The Hill Farm Research Committee ;

and

Dr. D. N. McArthur—Director—to be a member of

(1) The Scottish Standing Committee for the Calculation of the Residual Values of Fertilizers and Feeding Stuffs—of which Committee he was further appointed Chairman.

(2) The Scottish Peat Committee—and Convener of its Sub-Committee on the Survey of Peat Deposits in Scotland.

(3) The Nature Conservancy (Scottish Committee).

Acknowledgements

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

September, 1949.

PEDOLOGY

Soil Survey (Scotland)

Two teams of surveyors have been engaged in field work this year, one in Banffshire and the other in Roxburghshire. With the recent appointment of four more surveyors, there is now a field staff of eight officers, six of whom will undergo training in the technique of soil survey.

North-east Scotland—Banffshire

The country mapped on a reconnaissance scale of 2½ inches to 1 mile stretches from the Aberdeenshire-Banffshire border at Pennan west to Portsoy, and extends south from the Moray Firth coast to the county border near Keith. It covers approximately 150 square miles of rolling arable ground. There is a comparatively smooth plain covering the central coastal part, but the country tends to become hilly in the eastern and western areas.

The altitude of the arable ground ranges from 100 to 800 feet, while Knock Hill rises to 1409 feet. The valleys of the Deveron and the Boyndie cross the area, running in a north-south direction.

Highland schist rocks predominate, but there are intrusions of basic igneous rocks, serpentine and granite, and bands of crystalline limestone, while a conglomerate stratum of the Old Red Sandstone formation is found in the eastern part of the county.

The Soils of North-east Banffshire. Fourteen soil associations have been distinguished in this area. Seven of these are extensive :

(1) Insch, *see* Annual Report, 1939-40.

(2) Foudland, *see* Annual Report, 1940-41.

(3) Ordley, *see* Annual Report, 1941–42.

(4) Strichen, *see* Annual Report, 1942–43.

(5) Boyndie (formerly Memsie), *see* Annual Report, 1942–43.

(6) Tarves, *see* Annual Report, 1943–44.

(7) Durnhill, *see* Annual Report, 1945–46.

Five are found in small areas :

(8) Fraserburgh, *see* Annual Report, 1942–43.

(9) Leslie, *see* Annual Report, 1945–46.

(10) Countesswells, *see* Annual Report, 1945–46.

(11) Kemnay, *see* Annual Report, 1945–46.

(12) Hill and Basin Peat.

Two new associations have been identified :

(13) Whitehills—residual soil on black Jurassic clay.

(14) Unnamed—till with a high proportion of crystalline limestone.

The *Insch Association* is developed on basic igneous till containing a high proportion of large olivine norite (" blue-heathen ") erratics. The topography is undulating, and the natural drainage of the soil varies. The dominant soil is poorly drained,* and has a grey-brown loam surface on a strongly mottled yellowish loam to clay-loam, cloddy substratum. Considerable areas are excessively bouldery and are in permanent pasture.

The association forms a belt of from 1 to 3 miles wide running in a north-south direction on the east side of the Knock Hill, lying between Huntly and Portsoy.

About Whyntie, south of Boyndie Bay, an area of amphibolite till has been provisionally classed as Insch until chemical analyses are carried out.

The *Foudland Association*, developed on argillaceous schist till, extends from Gamrie Bay westwards to a point roughly 4 miles south-east of Portsoy and southwards into Aberdeenshire, with the exception of the coastal fringe. The soils vary in texture from silty, fine-sandy-loams to loams, and are underlain by a yellow-grey, fine-sandy-loam till. Most of the association consists of freely drained soils covering broad, rolling hills, but smaller areas of poorly drained soils are found in the valleys. The area is a good agricultural one, but shortage of water is often evident.

The *Ordley Association*, developed on till derived from an Old Red Sandstone stratum of conglomerate schist fragments, has loam-textured soils on a brown till with a noticeable reddish cast and with free to slightly-poor drainage.

This association extends south from Gamrie Bay and Pennan into Aberdeenshire, has a smooth rolling topography with an average altitude of 500 feet and, except near the coast, is fertile.

The *Strichen Association*, developed on till derived from quartz schist rocks, occurs mainly to the west of Aberchirder, and covers a belt approximately 4 miles wide in a north-south direction. Extensive areas of this deposit have a depressed basin-like topography, and have poorly to very poorly drained soils. The freely drained soils are loams developed on a greyish-yellow till of fine-sandy-loam texture. The soils with poor drainage vary from cloddy, brownish-grey loams—lying on a dull, bluish-grey, sandy-clay-loam till—to peaty-gley types where peat had been cut over.

The area is inherently one of low fertility, and any improvement would appear to depend upon an adequate drainage system.

The *Boyndie Association* is developed on fluvio-glacial sands with very little gravel, and covers the area to the south and east of Macduff. It is found extensively to the west of Banff, and terminates abruptly south-east of Portsoy. Below an altitude of 250 feet it extends inland for 2 to 3 miles. The dominant soil is freely drained and has a loamy sand surface horizon with a sand substratum. Generally the topography is smooth, but near

* Within each soil association the natural drainage varies, and for purposes of reference the various types are described in this report in the following order—(*a*) freely drained, (*b*) slightly-poorly drained, (*c*) poorly drained, (*d*) very poorly drained.

the Boyndie Hills, 1 mile south-west of Banff, it is dissected and moundy. In an area south of Whitehills large amphibolite erratics—often many tons in weight—seriously interfere with cultural operations. The soil is considered to be fairly fertile.

The *Tarves Association*, developed on a mixed acid and basic till, is found as transitional areas associated with the Insch Association. The topography and morphology are similar to that of the Insch Association.

The *Durnhill Association* is developed on a dominantly quartzite till, and occurs around Sillyearn Hill and Knock Hill. The topography is hilly. The till contains a proportion of basic igneous rocks, but these do not appear to ameliorate the extreme acidity of the soil. Considerable areas of this association are covered by heath and plantations. Podzol with iron pan, gleyed podzol with iron pan, and hill peat commonly occur. Only a small proportion of this association is cultivated, and the soils are of low fertility.

The *Fraserburgh Association*, developed on the 100-feet raised-beach, lies about Whitehills and Banff, and has relatively deep loamy-sand soils overlying sand. The topography is smooth. Shell fragments occur in these soils, but it is doubtful whether these are *in situ* or have been artificially added.

The *Leslie Association* is developed on serpentine till and covers only small areas at Drumagarach and south of the Knock Hill.

The *Countesswells Association*, developed on granitic till of a stony, loamy-coarse sand texture, covers two small areas—one south of Aberchirder and the other about 1 mile south of Cornhill. The latter has soils derived from granitic gneiss and boulders are commonly found. The till is thin and rock outcrops in both areas. Podzols, with and without iron pan, predominate.

The *Kemnay Association*, developed on alluvial deposits of recent origin, is found along drainage courses and in the flat ground adjacent to the railway line 4 miles south-west of Banff. Here the soils are clay loams overlying clay.

The *Whitehills Association* covers some 10 acres of black Jurassic clay close to the coast at Whitehills. The soils are grey, cloddy clays on yellow-mottled, dark-grey clay with poor drainage. A brickworks is situated on the deposit and occupies about a quarter of it. Black clays have been observed elsewhere, but are usually overlain by a later deposit of till.

Unnamed Association. A mixed till in which crystalline limestone is conspicuous forms the parent material of a number of small areas. This association has not yet been named as further investigation of its properties is necessary.

South-east Scotland—Roxburghshire

A detailed survey on a scale of 6 inches to 1 mile has been made of the hill farm of Sourhope, Roxburghshire, which is administered by the Edinburgh and East of Scotland College of Agriculture and covers an area of approximately 4 square miles. Its soils are typical of the hill areas and have been used as a basis for the reconnaissance survey *described* below.

The soils of this farm have been formed from a pinkish-brown till derived from porphyritic lava and can be grouped as follows :

(*a*) On the lower slopes, a range of soils on clay to clay-loam till—all with a mull humus A horizon.

The slightly-poorly drained soil carries an *Agrostis-Festuca* vegetation, the poorly drained soil carries *Deschampsia caespitosa* and *Nardus*, and the very poorly drained soil carries *Juncus communis* and *D. caespitosa*.

(*b*) On the upper slopes, a range of soils developed on shattered residual porphyritic lava and pockety, stony loam till.

The soils developed on the steep slopes carry an *Agrostis, Festuca* and short *Pteris* vegetation, while those on the very steep slopes are immature and have a complex vegetation.

(*c*) On the flattish hill tops, various podzolic soil types with mor humus and occasionally a thin iron pan, developed on stony loam till. These are associated with two common vegetational types—*Nardus-Molinia-Polytrichum* and *Calluna-Juncus squarrosus* with Sphagnum and other mosses.

(*d*) Hill peat, which can be divided into :

(i) Shallow peat of less than 2 feet carrying *Nardus*.

(ii) Cut-over peat carrying *Calluna-Eriophorum*.

(iii) Deep peat carrying *Calluna-Eriophorum*.

Thirteen soil profiles have been collected from this area.

A reconnaissance survey on a scale of 2½ inches to 1 mile has been made of an area extending from the Cheviot Hills northward to the vicinity of Kelso. Approximately 100 square miles have been surveyed. Five soil associations have been established :

1. Sourhope—on till derived from porphyitic lava of Old Red Sandstone Age.
2. Whitsome—on till derived from sandstone of Carboniferous Age.
3. Blakelaw—on light-textured till derived from sandstone of Old Red Sandstone Age.
4. Bowmont—on clay-loam to clay-textured till derived from sandstone of Old Red Sandstone Age.
5. Eckford—on water-sorted sand and gravel, mainly derived from Old Red Sandstone and Carboniferous material.

Sourhope Association. The soils of this association are as described in the detailed survey of Sourhope Farm. From Hoselaw Mains, situated 4 miles north-east of Yetholm, the association boundary runs west to Lardenlaw then south-west to Linton Farm near the River Kail opposite Morebattle. The association is known to continue into England, but the national boundary from Hoselaw Mains south to Netherhindhope is meantime being regarded as its eastern boundary. On the left bank of the Kail the association is bordered by the Eckford Association on the north and the Bowmont Association on the west. This area includes all the hilly part of the region.

The *Whitsome Association* is developed on a brownish- to yellowish-red sandstone till of Carboniferous Age which varies in texture from fine-sandy heavy-loam to sandy clay. The association borders the Sourhope Association at Hoselaw Mains and runs west to meet the Yetholm-Kelso road at Easter Softlaw. From here it extends northwards to the Tweed. The

association continues north of the river where it has still to be surveyed. The dominant soil is slightly-poorly drained, having 12 inches of a medium-brown, sandy, clay-loam surface soil on a yellowish-brown, red, stony, sandy, clay-loam till. Near the farm of Notylees there is an area of dark-red heavy-clay derived from calciferous Carboniferous sandstone. It extends for about 100 acres on the Scottish side of the border.

The *Blakelaw Association* is developed on brownish-red loamy-sand till of Old Red Sandstone origin. The area covered by the association forms a relatively thin strip of country between the Sourhope and Whitsome Associations. The dominant soil is freely drained, having 10 inches of red-brown sandy-loam on brown-red, loamy-sand till. Under natural vegetation this type is podzolized, having 3 inches of a bleached A_2 layer.

The *Bowmont Association* is developed on clay loam to clay till of the Old Red Sandstone formation. South of the River Kail this association borders the Eckford Association in the north and the Sourhope Association in the east. North of the river it is bounded by the Whitsome Association in the north and by the Sourhope Association in the east. The dominant soil is a surface water gley with 10 inches of brownish-grey, sandy clay-loam on 5 inches of grey, mottled, sandy clay-loam overlying reddish-brown, sandy, clay till. The soils with better drainage are more uniformly reddish-brown.

The *Eckford Association* is developed on alluvial sand and gravel, mainly of Old Red Sandstone origin but partly derived from Carboniferous sandstone and porphyritic lava material. The association covers an area on the south side of the River Kail in the vicinity of Eckford. The dominant soil is freely drained, having 14 inches of reddish-brown, loamy sand underlain by fine sand.

Laboratory Investigations and Collaborative Work

During the winter the survey officers have developed various lines of research in connection with the soil survey :

(*a*) A method of estimating total phosphate has been modified to reduce interference from silica.

(*b*) An investigation into the decomposition of stones found in soils with free and poor drainage has been started.

(*c*) Various methods for the removal and estimation of amorphous sesquioxides have been compared.

Close co-operation has been maintained with the X-ray and Physico-Chemical Sections, and sites for field trials have been selected in collaboration with the Department of Soil Fertility.

The second Soil Survey Conference between the officers of the Soil Surveys of England and Wales and of Scotland was held in Shropshire in April, 1949. At such conferences efforts are made to co-ordinate the work of the two Soil Surveys.

Analytical Section

The Analytical Section of the Pedology Department was formed in April 1949 with the primary object of conducting routine analyses (physical and chemical) of soils submitted in connection with the Soil Survey of

Scotland. The Section will also carry out chemical analyses of clay minerals and of other samples received from the various Departments of the Institute. When the Section is properly organized, it is hoped to engage in investigational work on analytical methods.

The determinations normally carried out for classification purposes on all soil profiles sampled are : (*a*) moisture, (*b*) loss on ignition, (*c*) mechanical analysis, (*d*) exchangeable calcium, magnesium, potassium and hydrogen, (*e*) *p*H, (*f*) total carbon and nitrogen, and (*g*) total phosphate and readily soluble phosphate. These determinations have been completed on thirty-eight soil profiles representative of the different hydrologic associates of the soil associations mapped during 1948. The mechanical analyses of the soil profiles sampled during 1947 have also been completed.

Typical wet and dry profiles from the main soil associations mapped since the commencement of the Soil Survey of Scotland have been selected for more detailed analysis.

Soil Geology and Mineralogy

A detailed geological and soil survey has been made of the farm of Lephinmore, Loch Fyne, Argyll, on behalf of the Department of Agriculture for Scotland and a map prepared on the scale of 6 inches to 1 mile. The farm lies in a belt of siliceous schistose rocks intruded by narrow bands of igneous rock. The lower arable ground is formed on alluvium and on glacial drift, which is a highly siliceous boulder clay largely derived from the local rocks. Most of the higher ground is covered by peat, some of it very deep. The soils on the sand and gravel areas of the lower ground are freely drained but the boulder clay areas are generally poorly drained with gleyed soils. On the hill ground the soils are thin humose loams on rock, peaty gleys and peat.

An area in the Tummel valley near Pitlochry, Perthshire, has been surveyed at the request of the Brown Trout Research Laboratory of the Scottish Home Department. The area is covered by river-alluvium and by fluvio-glacial sands and gravels. The soils were found to be fairly uniform and were mainly well drained, sandy loams with only small areas of gleyed types. They were found to be generally slightly podzolized. A detailed map on the scale of 6 inches to 1 mile was made and soil profile samples collected for further laboratory investigation.

A geological and soil survey for the Forestry Commission has been made of certain areas in Glen Isla, Angus. The areas lie in a belt of quartzose and micaceous schists, but only on the highest ground were residual soils found. The lower ground is on boulder clay, but on some of the higher ground patches of drift also occur. The freely drained soils are podzolized but a large part of the ground is poorly drained, so that gley and peaty gley soil types occur with patches of peat. A detailed map on the scale of 6 inches to 1 mile was prepared and profile samples from typical sites collected.

The fine sand fractions of the soils, from areas surveyed in the Soil Survey of Scotland, and the glacial drifts forming the parent materials were subjected to mineralogical examination with a view to their characterization.

X-Ray Investigations

A powder camera has been designed in collaboration with Messrs. Hilger and Watts Ltd., and the prototype is at present undergoing tests at the Institute. The principal feature of the camera is the collimating system, in which the width of the slits can be adjusted easily to any required size. With the slits at minimum separation and using Feα-radiation, high spacing reflections up to 50A or more can be recorded.

Further information concerning the mineralogy of local soil-clays, and the correlation of mineral type with soil-forming conditions, tend to support the preliminary conclusions mentioned in last year's report. A clay mineral, corresponding to the rock-forming mineral biotite, and the decomposition products are important constituents of these clays. The biotite-like mineral, hitherto undescribed, is classed as a trioctahedral illite, and a description of its properties and occurrence is in press.[17] An account of the weathering of macroscopic biotite in the soil—a process analogous in many ways to the breakdown of the trioctahedral illite in the clay fractions of the soils—has been read before a meeting of the Clay Minerals Group of the Mineralogical Society.[13]

Samples from other countries have been examined with a view to comparing the mineralogical nature of indigenous and foreign soil-clays. These include samples from Norway and from South and East Africa. Samples from Northern Ireland were found to be similar to Scottish types.

The common occurrence of vermiculites in local soil-clays led to an independent investigation of this group of minerals. Of special interest is the very high ion exchange capacity of these minerals and their tendency to fix certain ions, such as K^+, in exchange positions. Notes on the configuration of the inter-layer water in vermiculite,[15] and on the distinction of vermiculite from chlorite and montmorillonite in clays [14] have been published. A general account of the present state of knowledge on these minerals still awaits publication.[18]

Other work on vermiculite includes an attempt to determine the positions taken up by the exchangeable ions by means of an unidimensional Fourier synthesis. Facilities generously provided by Professor T. C. Phemister of the Department of Geology and Mineralogy at Aberdeen have enabled a number of single-crystal photographs of vermiculite to be made, with the object of determining the detailed structure of the crystal and the changes which take place on heat-treatment. A study of the effect of different exchangeable ions on the structure of the mineral is being made using the methods of both X-ray analysis and differential thermal analysis.

Several weathered rock and sedimentary clay samples from localities in north-east Scotland have been examined, and an occurrence of illite from Ballater, Aberdeenshire, formed by the alteration of felspar in granite has been described.[10] On the other hand, decomposed felspars from the Mourne Mountains granite were found to consist largely of kaolinite.

Little information on the amorphous component in clays can be obtained by means of X-ray diffraction, although such material may constitute a considerable proportion of some soil-clays. Free iron oxides make up the bulk of the amorphous component in local soil-clays and they seldom occur in crystalline form. A method is being developed to allow of the estimation

of the total free iron in a clay, based on the fact that hematite is formed by recrystallization from iron oxide on heating. The proportion of free iron in the clay is estimated by comparing the resulting diffraction photograph with standard photographs of artificial mixtures containing known amounts of hematite.

Physico-Chemical Investigations

Differential Thermal Analysis

The work carried out during the last 3 years with this method of investigating the mineralogical composition of clays has yielded useful information on the application and limitation of the method. It has proved, for example, very valuable for distinguishing different types of iron oxide occurring in soil-clays,[9] and for quantitative determinations. A study of the curves obtained has enabled more complete information to be gained than was originally expected. Some of the minerals found by X-ray examination, however, cannot be differentiated on the present curves, but a greater sensitivity may enable at least some of these to be distinguished. In view of the usefulness of the method, a new apparatus to give much greater output and sensitivity is being constructed. It will conform to the general recommendations of the *Differential Thermal Analysis Sub-Committee of the Comité International pour l'Etude des Argiles.* The complementary use of X-ray and differential thermal methods would seem to be desirable in investigating soil-clays.

The investigation of the clay mineralogy of Scottish soil-clays has *continued*, and some samples from other countries have also been examined, thus giving valuable information on the variations obtained on thermograms for clays developed under different conditions. With very few exceptions, the clays examined have contained some proportion of halloysite or kaolinite. Some quantitative determinations have been made and good agreement with X-ray results obtained.

A short account of the differences observed in the types of free iron oxide associated with soil clays has now been published.[9] Samples from various hydrologic sequences on various associations have been examined with a view to elucidating the conditions of formation of the " cold-precipitated " type. This type has proved to be very widespread, its occurrence being noted in several clays originating from other countries—for example, in some soil clays from Natal and in " montmorillonite " from Mexico. Under laboratory conditions it has been found, as expected, that the conditions of precipitation influence the curve considerably, material obtained by precipitation with sodium hydroxide, for instance, giving an entirely different curve from that obtained by precipitation with ammonium hydroxide.

In addition to soil-clays, over fifty minerals have been examined. These included the weathering products formed *in situ* from different rock types,[10] since a knowledge of the minerals formed under different weathering conditions should lead to a clearer understanding of the formation of clay minerals in the soil. In two samples of decomposed granite the clay mineral constitution was similar to that found at Ballater,[10] while the clay fraction of another consisted of a mixture of " cold-precipitated " hydrated ferric oxide,

kaolinite and illite. The residual material from a decomposed limestone gave the thermogram of a practically pure halloysite, although, from the colour, there was a slight contamination with iron oxides. The thermogram of the material from decomposed norite was somewhat unusual, and has not been completely interpreted, although X-ray examination has indicated biotite. The curve, however, shows an exothermic effect followed by a slight endothermic one at 450–500° C., and the clay sinters into an extremely hard mass on calcining. This sintering has been observed with only one soil-clay—derived from Old Red Sandstone till, possibly with some andesite contamination—and is being further investigated.

A differential thermal examination of dolomite from Duror was undertaken at the request of the North of Scotland Hydro-Electric Board. The material supplied proved to be a true dolomite with 12 per cent. insoluble in acid (mainly quartz, as shown by X-ray examination).

Some further work has been carried out on the vermiculites in collaboration with the X-ray Section, special attention being paid to the effects of saturation with various ions.

Other Studies

The study of the removal of free iron oxides from soil-clays and pure minerals has been continued throughout the year, especially with a view to developing a standard analytical procedure for the sodium hydrosulphite method. Optimum conditions for the removal of free iron oxide at varying *p*H values have been obtained, and work is proceeding on the effect of treatment on the clay lattice structure.

Some theoretical concepts of the hydration of montmorillonite formed the subject-matter of a paper presented at a meeting of the Clay Minerals Group of the Mineralogical Society.

SPECTROCHEMISTRY

THE Department of Spectrochemistry is engaged in the determination of those constituents of soils, plant materials and related substances, such as rocks, minerals, fertilizers, waters and animal organs, which can be estimated by spectrographic and allied physical methods. In recent years there has been, in spectrochemical work, a tendency to eliminate the photographic plate, and to measure the spectral line intensity directly. Developments in this direction are being made at The Macaulay Institute, and the general interest which other workers are showing in this technique is reflected in the number of enquiries which are being received. At present it can be applied only to some of the alkali and alkaline earth metals, as most trace constituents require arc excitation which is not amenable to direct measurement of spectral line intensity.

In addition to the work on direct photometry and the developments in methods mentioned below, investigations are in progress on the possibility of evolving a technique of using absorption spectra as a means of identifying the constituents of soil organic matter.

The Department has been responsible for the design and equipment of a workshop for the construction and maintenance of precision equipment of the type required in physical and physico-chemical determinations. The adoption of instrumental methods of analysis by this and other departments has created a demand for modifications to commercially available instruments, and for new designs, which is impossible to satisfy without a workshop and an adequately experienced instrument maker.

Several workers from other institutions have visited the Department for extended periods for training in spectrochemical methods. Contact with developments in methods has been maintained by visits to other centres carrying out spectrographic work, and through meetings of the Spectrographic Discussion Group, which is carrying out a joint investigation on the analysis of powder samples by arc methods, in which the Institute is collaborating. Liaison is also being maintained with other Institutes desiring facilities for trace element analysis by means of the Consultative Committee for the Development of Spectrographic Work, sponsored by the Department of Agriculture for Scotland. A memorandum on the technique for the sampling and subsequent treatment of samples has been prepared by the Technical Sub-Committee of this Committee.

FLAME EMISSION METHODS

The chief developments in flame emission work have been in the direction of flame photometry. As mentioned in the 1947–48 report, the initial investigations employed a selenium cell and an infra-red filter for the determination of potassium. This method has been in use throughout the year for the routine determination of potassium in acetic acid extracts of soils, the results being interpreted by the Soil Fertility Department for use in

agricultural practice. This technique requires a preliminary 10-fold concentration, as the sensitivity for potassium is the same as that of the Lundegårdh spectrographic method. It is not possible with a selenium cell to obtain a sensitivity sufficient to permit the elimination of the concentration process, nor can electronic or magnetic amplification be satisfactorily applied to the selenium cell output which amounts to a fraction of a microamp. It has proved possible to obtain greater sensitivity by the use of an electron photomultiplier tube as the photoelectric detector, and this, combined with an infra-red image converter tube to convert the red potassium emission to a wavelength to which the photomultiplier is sensitive, has enabled potassium to be determined at very much lower levels than hitherto. In addition to the infra-red filter (Ilford 207) it has been found necessary to incorporate heat filters (Chance ON 20) to reduce the background intensity to a reasonable value.

It has thus become possible to determine potassium directly in the filtrate obtained after shaking 20 g. soil with 800 ml. 2·5 per cent. acetic acid, and an extended trial of this technique for routine determinations of potassium has yielded satisfactory results. At the same time, direct determinations of calcium (in the absence of aluminium) and sodium can be obtained from the same solutions, using a wavelength spectrometer to isolate the spectral lines, and Cambridge Spot Galvanometers to measure the response of the photomultiplier tubes directly. It is hoped to publish a description of this equipment in the near future.

Determinations by the normal Lundegårdh method have included analyses of various types of plant materials—cereals, pasture grasses and turnips for the Soil Fertility Department, tomatoes, raspberries, agricultural crops and bracken for the Plant Physiology Department, as well as other miscellaneous plant samples. Analyses of exchangeable cations in soil profiles have been made in connection with pedological investigations arising out of the Soil Survey of Scotland.

Arc Emission Methods

The cathode layer arc emission technique is employed, in conjunction with a chemical concentration method using 8-hydroxyquinoline, tannic acid and thionalide [2] for the determination of cobalt, nickel, molybdenum, zinc, tin, lead, vanadium, chromium, titanium and silver in soil extracts and plant materials. This method is also capable of indicating the presence of gallium, germanium, beryllium and other elements should they be present. The method for the direct analysis of plant ash previously reported (*Ann. Rep.*, 1945–46) has been further developed and now permits the determination of copper, manganese, magnesium, barium, strontium and, if necessary, sodium and calcium, so that the use of these methods together with the flame photometer gives a reasonably complete picture of the metallic constituents, both major and trace, present in plant materials. Comparisons of results with those obtained by other methods have given reasonable agreement.

Work has been continued on the effect of alterations in electrode dimensions and other variable factors on the intensities of both trace element and internal standard lines. It appears that the main effect of such alterations

is to change the relative rates of volatilization of the elements, with a consequent shift in the standard curves. This work has been prepared for publication.

Trace Constituents in Soils, Plants and Biological Materials

A knowledge of the trace element status of the soil parent material is a valuable adjunct to the study of the trace element relationship of soil, plant and animal. This involves the rock and its constituent minerals, as well as the processes of weathering which lead to sedimentary rocks or to soil formation. A detailed study, made in collaboration with Professor L. R. Wager of the University of Durham, of the minerals of a suite of rocks is now almost ready for publication; an earlier account still awaits publication.[20] The immediate programme includes the study of trace element relationships in a number of soil profiles, typical of the north-east of Scotland, on which the Soil Survey Unit has carried out the normal investigations. Some analyses of such profiles have already been made, with results which suggest that further determinations may be profitable.

Numerous analyses of soils for trace constituents, cobalt in particular, have been made. Samples taken in the course of a survey of part of the Solway area, where cobalt deficiency in stock occurs, have extended the work in the area previously reported. A general account of the trace element status of soils, prepared for the XIth International Congress of Pure and Applied Chemistry, still awaits belated publication.[19]

Samples of soil and herbage from a series of plots in Caithness, where the molybdenum content of the soil is higher than usual, have been analysed for copper, molybdenum and other trace constituents. The Hannah Dairy Research Institute has submitted various samples of dried grasses for trace element analysis. Much of the work on trace element contents of soils and plants is related to animal disorders, and samples have been examined from several farms where such disorders are suspected to be due to trace element abnormalities. Interesting instances of combined low contents of copper and cobalt in the herbage have been discovered.

Animal organs from the Rowett and Moredun Institutes have been analysed for cobalt and other trace constituents, and arising from the work on rumen bacteria previously reported (*Ann. Rep.*, 1947–48) a series of different types of organisms grown in various culture media have been examined.

A number of seaweed ashes have been analysed on behalf of the Scottish Seaweed Research Association, whilst numerous samples of soils and plants from overseas, including sisal leaves and soils, and cocoa leaves and soils from East Africa and soils from Iceland have been examined. The latter were suspected of being deficient in cobalt, but high contents were found, as the basaltic nature of the rocks of the area would lead one to anticipate.

In certain disorders it is not trace element deficiencies which are involved; excesses are found in some instances, and in this connection various samples of plants, including vegetables from Long Ashton Research Station, have been examined. Further instances of nickel toxicity have been detected locally.

SOIL ORGANIC MATTER

THE work of the Department of Soil Organic Matter has proceeded along lines similar to those indicated in last year's Annual Report.

CHEMICAL INVESTIGATIONS

The study of the humus complex has been continued and techniques for the more exact separation and identification of constituents are being developed.

Carbohydrates

The original work on the composition of the soluble polysaccharide complex isolated from soil has been completed and a paper has been accepted for publication in the *Biochemical Journal*.[22] Ash-free polysaccharide complexes from a wide range of soils have been prepared. They have similar properties and contain the same sugars, namely galactose, glucose, mannose, arabinose, xylose, and glucuronic acid, although in variable proportions. The small amounts of ribose and of nitrogen compounds present in the complexes are probably of direct microbial origin. The detailed structure of these complexes has been investigated by means of controlled hydrolysis and oxidation, using the methods of paper chromatography for identification of structural changes taking place. A provisional unit structure has been suggested.

The co-operative work between the biochemical and micro-biological sections has continued upon carbohydrates.

Nitrogeneous Compounds

The application of paper partition chromatography to the identification of amino-acids hydrolysed from soils and organic soil constituents has also been continued. Progress has been made in improving the preparatory technique for the chromatographic investigation of such materials. Although most of the common amino-acids have been identified by chromatographic methods in the acid hydrolysates of various soils and in some humus fractions, it has not yet been found possible, when using these hydrolysates, to obtain the clear separation of amino-acids which can be obtained when using standard mixtures of pure amino-acids. This is due to interference by inorganic salts and non-nitrogenous organic matter, and the elimination of these from test solutions has not yet been satisfactorily achieved.

MICROBIOLOGICAL INVESTIGATIONS

A paper dealing with the impact of recent advances in microbiology on the study of soil organic matter has been read before a joint meeting of the Society of Chemical Industry Food Group (Microbiological Panel) and the Society of Applied Bacteriology.[5]

Compost

A second paper [1] in the series on the microbiology of composting has been published embodying the work on the aerobic thermophilic bacterial flora referred to in previous annual reports. The work on the mycological aspects of composting has been prepared for publication. It will be necessary to obtain more information on the physiology of the micro-organisms taking part in the decomposition of organic matter in compost or in soil before further advances in this study are made.

Physiology of Micro-organisms Isolated from Soil and Compost

Most of the experimental work on bacteria has been carried out on the synthesis of polysaccharides. In the first study [3] type cultures of aerobic mesophilic spore-forming bacilli capable of synthesizing polysaccharides were employed. The natural habitat of many of these organisms is decomposing organic matter. The strains studied were *Bacillus cereus, B. subtilis, B. megatherium, B. polymyxa, B. circulans-macerans, B. brevis* and *B. alvei*, which synthesize polysaccharides from sucrose and monosaccharides. The constituent sugars of these polysaccharides were identified and it was found that a relationship exists between the type of polysaccharide produced and the groups of the genus as classified by Smith *et al.* (*U.S. Dept. Agric. Misc. Pub. No.* 559, 1946). Thus the synthesis of levan from sucrose is confined to bacilli of Group I and *B. polymyxa*, while the synthesis of other polysaccharides from sucrose and monosaccharides is confined to bacilli of Group II and *B. megatherium*. *B. polymyxa* and *B. megatherium* may be regarded as intermediate types since they synthesize both levan and other polysaccharides from sucrose, depending on the medium. In addition it was found that bacilli of Group II synthesize from a variety of sugars polysaccharides containing (*a*) glucose and a uronic acid, (*b*) mannose and a uronic acid, (*c*) glucose, mannose and xylose and a uronic acid, the type of polysaccharide being characteristic of the organism and not of the substrate sugar. The claim of Kleczkowski and Wierzchowski (*Soil Sci.*, **49**, 193, 1940) that *B. krzemieniewski* produces a mannan composed of L-mannose units was not confirmed. The strains of this organism studied synthesized a complex polymer of glucose (3 parts) mannose (2 parts) on uronic acid (2 parts); the mannose was natural D-mannose.

A second paper [4] has been published giving a survey of gum-producing bacteria in various soils. Bacteria capable of synthesizing polysaccharides were well represented in all the soils tested. Investigation of the types of polysaccharides synthesized in pure culture by the organisms revealed the existence of a group of bacteria producing a polysaccharide containing rhamnose. Such a polysaccharide has not hitherto been isolated from a non-pathogenic bacterium. The data obtained from the spore-forming bacteria isolated from these soils were in accordance with the findings reported above for type cultures of this genus.

A paper is in preparation on the nature of the reducing sugars produced during the synthesis of polysaccharides from sucrose by certain bacteria.[23]

The physiology of two cellulose-decomposing fungi isolated from straw composts—namely *Coprinus lagopus* and *Chaetomium globosum*—is now being investigated. *C. lagopus* produced daily crops of sporophores in one

compost just after the disappearance of cellulose from the heap. It has now been shown that this organism will grow and fruit in liquid culture if supplied with mineral salts, cellulose and hot-water extract of straw. If the straw extract is omitted fruiting does not occur. This suggests that some factor or factors necessary for the growth and fruiting of this fungus is supplied by the straw extract. A note on this observation has been submitted for publication.[21] Attempts are in progress to determine the nature of the responsible factor or factors in the straw.

Chaetomium globosum produces perithecia (fruit bodies) abundantly on the surface of straw. This fungus has been found to be easily cultured in liquid medium containing a source of carbohydrate and its physiology is being studied.

Field and Glasshouse Experimental Work

Field work during this season has been confined to the Institute experiment started in 1941 (see *Ann. Rep.*, 1941–42). Differences in yield between the different treatments were less pronounced in 1948 than in previous years, and again this trend is apparent. Experiments were made in the glasshouse to study, amongst other things, the depressing effect produced by the addition of cellulose to the soil both upon the micro-organisms in the soil and upon plant growth.

Forestry Investigations

An intensive survey of the Culbin Forest has been completed. On the Culbins there is a wide variety of soil conditions varying from shingle beds to high sand dunes. The flattened summit of an immobile dune with unplanted areas and plantations of *Pinus laricio* ten and twenty years old was selected for detailed investigation. Quadrats were marked out in the three areas and tree measurements completed so that tree size and change in soil conditions can be observed together.

The soil profiles have been sampled to a depth of 4 feet. Generally it may be said that afforestation of the sand dunes leads to an increase in the fine sand fraction. Estimations of available phosphate, calcium, sodium, manganese, magnesium, and potassium have been completed. In the planted areas there is a cyclic movement of available nutrients with a depletion of nutrients in the lower sand layers and an increase in the upper layers. Soil acidity increases with afforestation. With the closing of canopy in the oldest plantation a continuous litter cover has formed.

A technique has been developed by which the percentage volumes of air, water and soil particles can be determined. The percentage volume of water present in the upper sand layers decreases markedly with afforestation. It has been demonstrated that the moisture present in the dunes is derived from rain-water which percolates slowly downwards. No evidence was obtained to suggest that water is supplied from the low lying water table. Investigations of the water relationships are being continued. On an average the soil particles occupy approximately 60 per cent. of the total soil volume.

Increased microbiological activity following the formation of continuous litter and humus layers in the older plantation has been demonstrated by

fungal and bacterial counts. Basidiomycetes form a large proportion of the fungal mycelium observed in the field.

The sand dunes are frequently stabilized by *Ammophila arenaria* (Marram grass), *Polytrichum spp.*, and other associated plants. As *Pinus laricio* becomes established and canopy closes, vegetational changes occur. Records of these plant successions have been completed.

Data regarding the mechanical composition of the sand have been supplied to the Road Branch of the East Conservancy in connection with the construction of cement roads. An experiment has been designed to determine the most suitable method of establishing secondary grass or heather roads on the Culbins. The first assessment of seed germination and tillering has indicated the importance of *Holcus lanatus*, *Dactylis* and *Festuca*.

An investigation of the Tentsmuir area based upon techniques developed at Culbin has been initiated for a similar range of tree age and size. Here *Pinus sylvestris* has been planted on low-lying sand flats with a relatively high water table. The area has been fixed naturally by vegetation for a longer period than the Culbins, and some visible profile development has occurred. Soil samples have also been collected at the Bin and Clashindarroch forests.

In association with members of the Forestry Commission, and with a view to extending this investigation to other soil types, several areas, including Allerston, Rannoch, Monaughty, Darnaway, Newcastleton, Achnasheen and Inchnacardoch, have been visited.

Routine and Consultative Work

General routine and consultative work has continued along the lines indicated in last year's report, directly and in association with other departments, in connection with composts, peats, and similar organic ameliorants. Much of this has involved *ad hoc* experiments or trials carried on in the glasshouse.

PLANT PHYSIOLOGY

THE investigation of the absorption and translocation of nutrients by plants has been continued by laboratory and field work and further study has been made of the relationship between plant composition and soil conditions.

PLANT NUTRITION

Samples obtained from field experiments on oats and swedes are being used to investigate ion antagonism, nutrient distribution within the plant, and the effect of soil treatment on tissue composition.

Experiments on raspberries, strawberries and gooseberries—designed to investigate the effect of nitrogenous and potassic fertilizers upon the composition of the plant tissue, upon bud formation and upon fruit yield—have been periodically examined and sampled. The investigations have now been extended to study the effects of phosphate fertilizers and late summer applications of nitrogenous, phosphatic and potassic fertilizers.

A paper reviewing British and American research on raspberry and strawberry nutrition and outlining the soil conditions considered satisfactory for these crops has been published.[7]

Glasshouse experiments have confirmed that heavy dressings of peat are useful in counteracting magnesium deficiency induced in tomato plants by a high potassium/magnesium ratio in the soil.

PLANT-ANALYSIS TECHNIQUE

The plant-analysis technique for determining the nutrient status of plants and soils has been further examined. Factorial field experiments have supplied material for investigating the effects and interactions of deficiencies of nitrogen, phosphorus and potassium in oats and swedes. Both actively metabolizing tissue (leaf laminae) and conducting tissue (stems and petioles) of growing, fully developed, and senescent types were sampled for the determination of nutrient ions therein. The results so far obtained indicate that both actively metabolizing and conducting tissues are satisfactory for the determination of nutrients other than nitrate. Nitrate must be determined in conducting tissue.

The plant-analysis technique has proved useful for the assessment of nutrient status of plants submitted for routine examination with a view to the adoption of remedial treatment.

ANALYTICAL METHODS

Analytical technique has necessarily received considerable attention. Chemical methods utilizing the Spekker Photoelectric Absorptiometer have been either developed or modified for the determination of nitrogen (nitrate or ammonium), phosphate, potassium, calcium and magnesium in plant material and are outlined below:

Nitrate: A technique using phenoldisulphonic acid.

Ammonium: Simple micro-diffusion followed by the use of Nessler's reagent.

Phosphate: A technique using sodium molybdate and hydrazine sulphate reagents.

Potassium: A rigidly standardized cobaltinitrite turbidimetric procedure.

Calcium: Precipitation with chloranilic acid (at *p*H 4·8) and subsequent estimation of the excess chloranilic acid (at *p*H 2·9).

Magnesium: A technique using thiazol yellow.[24]

Other elements in plant material are determined, as required, by the Department of Spectrochemistry.

The above methods, together with the interpretation of results obtained, have been described and discussed in a paper read to the 1st International Congress of Biochemistry, Cambridge, 1949.

SOIL FERTILITY—CHEMISTRY AND FIELD EXPERIMENTATION

Soil Fertility Investigations

The principal aims of the work of the Soil Fertility Department remain : (1) the improvement of fertilizer practice, (2) assessment of the agricultural significance of pedological differences, and (3) improvement of methods of assessing the nutrient status and requirements of soils. Field experiments with lime, organic manures, and various combinations of fertilizers on different crops and soils, therefore, form one of the main features of the work, most of which is inherently of a long-term character. The field experiment programme has been expanded along these lines during the year and, as in previous years, has been supplemented with pot experiments, crop analyses, and laboratory investigations on the soils.

General aspects of the work have been dealt with in addresses to various agricultural and scientific meetings, in both England and Scotland, and reviews of such specific problems as fertilizer placement and the improvement of marginal land have been given in leaflets prepared for the Department of Agriculture for Scotland.[11, 12]

General Manurial and Liming Experiments

These general experiments are gradually being extended to cover the main soil types so far distinguished in the Soil Survey and are designed to provide comprehensive information on such points as : (1) the crop producing capacities of different soil types under optimum management, (2) the nutritional requirements of different crops, (3) the rotational fertilizer and lime requirements of different soils, and (4) the responses to and interactions of lime, dung, and fertilizers. Included under this heading are the long-term experiments of the soil-substitution series, mentioned in last year's report, which are now in the second year of cropping.

An account has been accepted for publication [26] of the results of experiments carried out over a period of four years with a range of liming materials. These included ground burnt lime, ground burnt magnesian lime, dried paper works lime, calcareous shell sand, blast furnace slag, and ground limestones of varying degrees of fineness. All these forms have proved highly effective, the differences between them being small and quite unimportant compared with the large responses to lime. The results support the normal practice in a six-course rotation of roots, cereals, hay and pasture, of liming ordinary mineral soils to a *p*H of 6·0–6·2, and illustrate very clearly the need for adequate supplementary manuring. They also indicate that fine grinding of limestone is unnecessary and a product with about 45 per cent. finer than 100 mesh and the remainder finer than 20 mesh appears to be fully adequate under Scottish conditions. Further data are being

obtained from these experiments. New experiments have been started with particular reference to the effect of ground limestone and ground magnesian limestone on the magnesium content of crops.

Phosphate Relationships of Soils

Work on this subject has been continued along the general lines mentioned in previous reports, and a review of various aspects of phosphate fixation has been published.[16]

The field side of the work has been continued to gather information on points such as the yield response to phosphate, the uptake of phosphate by crops, and the interactions of phosphate with lime, dung and other nutrients. Experiments have also been started to obtain further information on the effect of particle size on the efficiency of superphosphate and to test the effectiveness of ammoniated superphosphates. Other field investigations started during the year include preliminary trials on the efficiency of dung-superphosphate mixtures compared with the same materials applied separately, and a long-term experiment to measure the rate of penetration of different phosphates in grassland on limes and unlimed plots. Existing long-term experiments covering residual effects and the relative merits of frequent light applications of phosphate compared with single heavy dressings are being continued.

Work is well advanced in a study of the significance of phosphate fixation in relation to phosphate availability in different soils. This work consists of pot experiments supplemented by laboratory estimations of the rate of fixation of different phosphates. In another investigation, an attempt is being made with the aid of pot experiments, to obtain by soil analyses a direct measure of the percentage utilization by oats of applied phosphate. Pot results showing the effect of acid pretreatment of soils (to remove the readily soluble phosphate) on plant growth have also been obtained.

Apart from standard soil and crop analyses associated with the field and pot experiments, work in the laboratory has been devoted mainly to the experiments on the rate of phosphate fixation, mentioned above, and to the fractionation of the phosphate present in different types of soil from field experimental areas. In the latter connection, considerable information has now been accumulated regarding acid-soluble, fluoride-soluble, and other categories of phosphate in various soils, and it is intended to make a preliminary assessment of their inter-relationships and significance in relation to field behaviour.

As mentioned in last year's report, Dr. Williams spent a year taking part in work on phosphate problems under the direction of Professor Sante Mattson in Sweden. Part of this work has now been published.*

* (*a*) "Phosphate relationships of Soil and Plant. I. Membrane Equilibria and Phosphate Uptake." By S. Mattson, E. Eriksson, K. Vahtras and E. G. Williams. (*Ann. Roy. Agric. Coll., Sweden*, **16**, 457–484, 1949.)

(*b*) "Membrangleichgewichte und Phosphataufnahme in Pflanzen." By S. Mattson, E. Eriksson, K. Vahtras and E. G. Williams. (*Ztschr. Pflanz. Dung.*, **45 (90)**, 23–37, 1949.)

Fertilizer Placement

A report on the 1948 experiments has been submitted to the Agricultural Research Council, under whose auspices these experiments were inaugurated. The cereal experiments provided further data on the advantages of combine-drilling phosphate with the seed. Although there is generally no difference between broadcast and combine drill application of sulphate of ammonia there may be isolated exceptions to this general conclusion. Previous experiments with 60 per cent. muriate as a source of potassium showed little or no difference between broadcast and drill applications of this fertilizer, but with 40 per cent. potash salts as a source of potassium in the 1948 experiments combine-drilling proved inferior to broadcast application. Further experiments are being carried out with oats and barley to obtain more data on this point under different seasonal conditions.

The results of the 1948 experiments on turnips and swedes, using a Storrie-Willett machine, supported the preliminary conclusion that superphosphate placed in bands near to, but not in contact with the seed is superior to broadcast application. Preliminary results for sulphate of ammonia show no marked differences between broadcasting and band placement about 1 inch below the seed, but with 40 per cent. potash salts broadcasting appears to be superior to band placement.

During the year a special experimental drill, which is being made with the co-operation of the National Institute of Agricultural Engineering, was delivered for testing purposes before final completion. This machine has been calibrated and used to lay down further experiments on swedes to study the effects of placing fertilizer in different positions relative to the seed. After suitable modifications have been made for ridge work this machine should be very useful for fertilizer placement investigations on root crops.

Advisory Work

In collaboration with the North of Scotland College of Agriculture advisory work has been continued and over 7,000 soil samples have been examined during the year. Most of the soil samples were taken from agricultural land, but soils from horticultural areas, forest nurseries, and sports grounds have also been examined. Analyses have also been carried out on such materials as limestones, calcareous sands, wood ashes, composts and various by-products likely to be of value on the land.

The grouping of advisory soil samples in terms of the various soil associations recognized in the reconnaissance soil survey of Aberdeenshire and Kincardineshire has been continued during the year. The analytical data for soils examined during 1948 have not significantly altered the general trends noted in the 1947–48 report. In all associations there are still widespread deficiencies of lime and phosphate. Potash deficiency, although generally less acute, also occurs quite extensively.

COLLABORATIVE WORK

The Animal Diseases Research Association

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

The Rowett Research Institute

Analyses of soils, pasture herbages, animal organs and other related materials, such as constituents of animal diets, have been carried out for trace constituents. Micro-organisms grown in various culture media have been analysed in order to ascertain the trace element uptake of the different types.

Differential thermal analysis examinations of bone-salt and various calcium-phosphorus compounds have been made.

An empirical investigation is being made by means of X-ray diffraction methods of the changes taking place in starch granules after various treatments.

The Hannah Dairy Research Institute

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

The Scottish Colleges of Agriculture

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

Department of Agriculture for Scotland

The Institute has undertaken to collaborate in the examination of samples submitted by officers of the Department of Agriculture for Scotland engaged in the survey of the peat deposits of Scotland.

Forestry Commission (Research Branch)

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

Scottish Raspberry Investigation and Strawberry Disease Investigation

Experiments on strawberries, raspberries and gooseberries to correlate soil treatments with vegetative development, fruit yield, tissue composition

and disease resistance, have been established in collaboration with the workers on Strawberry Disease Investigations (Department of Agriculture for Scotland) and on Small Fruit Diseases in Scotland (East Malling Research Station).

Consultative Committee on the Development of Spectrographic Work

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

Arrangements have been made to meet the demands of the bodies concerned as far as trace element analyses are concerned, and the Technical Sub-Committee has prepared a memorandum on the sampling and pretreatment of materials intended for trace element determinations.

PUBLICATIONS

(A) *Issued during the year—*

1. "The microbiology of composting. II. A study of the aerobic thermophilic bacterial flora developing in grass composts." By W. G. C. Forsyth and D. M. Webley. (*Proc. Soc. Appl. Bact.*, 34–39, 1948.)

   A study has been made of the thermophilic flora developing in composts made from lawn mowings. It has been shown that (i) there is a rapid development of a thermophilic flora during the high temperature phase of the process, (ii) this development takes place particularly in the upper layers where conditions are aerobic, (iii) aerobic thermophilic bacteria appear to be abundantly present and can be isolated with ease on nutrient agar, (iv) the presence of thermophilic actinomycetes is strongly indicated by direct microscopic methods, but difficulty is being experienced in isolating the organisms for further study, (v) the thermophilic bacteria readily attack the protein and hemicellulose fraction of the grass, leading to the production of abundant ammonia and a relative increase in the cellulose and lignin fractions.

2. "Applications of chemical concentration by organic reagents to spectrographic analysis." By R. L. Mitchell and R. O. Scott. (*Spectrochimica Acta*, **3**, 367–378, 1948.)

   In addition to extending the lower limit of determination of trace elements in soil extracts, plant materials, etc., a chemical concentration method may be useful in ensuring that all spectrographic determinations are made in similar matrices, so eliminating errors due to the variation in the major composition of materials such as plant ashes. Organic precipitants, particularly 8-hydroxyquinoline and mixtures containing this reagent, have proved satisfactory for this purpose. Results are quoted showing, with a mixture of 8-hydroxyquinoline, tannic acid and thionalide, complete recovery of Co, Ni, Mo, Sn, Pb, Zn, Cr, V, Ti, Be and Ge in a matrix of Al_2O_3, with combined spectrographic and chemical errors seldom exceeding ± 10 per cent. for quantities of the 2–100 microgram order. The normal major constituents of biological samples, namely alkalis, alkaline earths and phosphate, are satisfactorily eliminated.

3. "Polysaccharides synthesized by aerobic mesophilic spore-forming bacteria." By W. G. C. Forsyth and D. M. Webley. (*Biochem. J.*, **44**, 455–459, 1949.)

   The constituent sugars of polysaccharides synthesized by the genus *Bacillus* have been identified. Some relationship exists between type of polysaccharide synthesized and group classification proposed by Smith *et al.* (*U.S. Dept. Agric., Misc. Pub.*, 559, 1946). It was not confirmed that *B. krzemieniewski* produces a mannan composed of L-mannose units. A detailed study af the sugars of the polysaccharide synthesized by this organism was carried out.

4. "The synthesis of polysaccharides by bacteria isolated from soils." By W. G. C. Forsyth and D. M. Webley. (*J. Gen. Microbiol.*, **3**, 395–399, 1949.)

   Bacteria capable of synthesizing polysaccharides are present in various agricultural, moorland and forest soils and may form from 5–16 per cent. of the viable bacterial population as estimated by the plate dilution counting technique. Chemical examination of the polysaccharides synthesized distinguished four types: levans, glucose-uronic acids, glucose-mannose-uronic acids, and glucose-mannose-rhamnose-uronic acids. Bacteria synthesizing these polysaccharides are well distributed in the soils studied, those forming the first two types being by far the most common. There is no clear relationship between the morphology of the organisms and type of polysaccharide synthesized.

5. " Micro-organisms in relation to the production and degradation of soil organic matter." G. K. Fraser. (*Chem. and Ind.*, 375–377, 1949.)

A summary review is presented of the impact of microbiology on the study of the nature of soil organic matter, and of the activities of bacteria and fungi in the production and degradation of its major constituents. This leads up to the consideration of the part played by micro-organisms in the formation of the colloidal " humus " fraction and of the conclusions to be drawn as to possible lines of future investigation into this, the characteristic organic complex of soils.

6. " The association of hydrologic sequence in certain soils of the podzolic zone of north-east Scotland." By R. Glentworth and H. G. Dion. (*J. Soil Sci.*, **1**, 35–49, 1949.)

An account of a scheme of classification based on the association concept as used in the Scottish Soil Survey, with some discussion of its advantages and potentialities. The variations in soil properties resulting from different hydrologic conditions in the associations in the brown podzolic soils of Scotland can be shown to follow definite trends from one major profile to another, irrespective of the parent material of the association. These variations are discussed with respect to the distribution of nitrogen, phosphorus, amorphous sesquioxides, sesquioxide translocation, the indurated layer, *p*H, base saturation, and base exchange capacity and exchangeable magnesium and calcium.

From the regularity of these trends it is suggested that the character of a soil zone is best described by reference to the zonal association rather than by the characters of the normal freely drained soil, as is usually done.

7. " Raspberry and strawberry nutrition." By J. G. Hunter. (*Growers' Digest*, **1**, 51–65, 1949.)

The soil conditions leading to satisfactory growth of raspberries and strawberries are outlined and various methods of manuring are given. The research work done in Britain and America on the nutrition of these crops is reviewed.

8. " The Macaulay Institute for Soil Research." By D. N. McArthur. (*Chem. Prod.*, **12** (n.s.), 372–373, 1949.)

A short summary of work in progress at The Macaulay Institute for Soil Research.

9. " The nature of free iron oxides in soil clays." By R. C. Mackenzie. (*Nature*, **164**, 244, 1949.)

The differential thermal analysis technique has provided a method for distinguishing at least two types of free iron oxides occurring in soil clays—namely, goethite and " cold-precipitated " hydrated ferric oxide. Evidence is presented that the latter occurs naturally in the soil and is not formed by any pre-treatment of the clay.

10. " Illite occurring in decomposed granite at Ballater, Aberdeenshire." By R. C. Mackenzie, G. F. Walker and R. Hart. (*Min. Mag.*, **28**, 704–713, 1949.)

A clay occurring in an altered vein in a granite has been examined by optical, X-ray, chemical and thermal methods. The clay is classified as illite, although its thermal data are different from any so far described. The thermograms show two peaks—a broad one at 550–600° C. and a sharp one at 713° C., the former, on the basis of other evidence presented, being attributed to a small amount of montmorillonite, found as a contaminant, and the latter to illite.

11. " Fertilizer placement for arable crops." By A. B. Stewart. (Department of Agriculture for Scotland : Leaflet No. 3 (n.s.), 1949.)

A review leaflet covering existing knowledge on methods of applying fertilizers and the general aims of liming and manuring, and summarizing recent experimental work on comparisons between broadcast and drilled or placed applications of fertilizers on crops commonly grown in Scotland.

12. "Improving marginal land." By A. B. Stewart. (Department of Agriculture for Scotland: Leaflet No. 4 (n.s.), 1949.)

A review leaflet summarizing existing knowledge of methods of increasing the productivity of the poorer classes of land, with particular reference to the importance of such factors as drainage, cultivations, cropping including grassland improvement, liming and manuring.

13. "The decomposition of biotite in the soil." By G. F. Walker. (*Min. Mag.*, **28**, 693–703, 1949.)

A noticeable feature of many of the soils of north-east Scotland is the presence in them of glistening yellow flakes of decomposed biotite. The process of breakdown to vermiculite has been traced in the coarse soil fractions by means of X-ray diffraction supplemented by other methods. An analogous process is found to occur in the soil-clays of the area, and the present study throws light on their mineralogy.

14. "Distinction of vermiculite, chlorite and montmorillonite in clays." By G. F. Walker. (*Nature*, **164**, 577, 1949.)

A rapid X-ray technique is described for the positive identification of vermiculite, chlorite, and montmorillonite in clays.

15. "Water layers in vermiculite." By G. F. Walker. (*Nature*, **163**, 726, 1949.)

Vermiculite is shown to have a high ion exchange capacity with magnesium ions normally filling the exchange positions. Dehydration of the mineral takes place by steps; spontaneous rehydration can occur under certain conditions.

A hypothesis of the structure of the water layers and the mechanism of their removal is developed. From the theory, it can be predicted that the configuration of the water layers in vermiculite should be largely determined by the type of exchangeable ion present, and experiment shows that this is so.

16. "Phosphate fixation." By E. G. Williams. (*N.A.A.S. Quart. Rev.*, **1**, 147–155, 1949.)

The various reactions by which fixation can take place are reviewed and classified in a simplified form. Distinction is made between biological and chemical fixation in easily available and difficultly available forms.

Methods for combating fixation and increasing the efficiency of applied phosphate are reviewed. It is concluded that apart from applying phosphate to individual crops in accordance with their responsiveness, the chief measures at present available for increasing the efficiency of applied phosphate under British conditions are suitable placement and adequate liming.

(B) *Submitted for publication—*

17. "Trioctahedral minerals in the soil-clays of north-east Scotland." By G. F. Walker. (To appear in *Min. Mag.*)

18. "Vermiculites and some related mixed-layer minerals." By G. F. Walker. (*Monograph on Clay Minerals*, Chap. 7. To be published by the Oxford University Press.)

19. "The trace constituents of the soil." By R. L. Mitchell. (To appear in *Trans. XIth International Congress of Pure and Applied Chemistry*.)

20. "The distribution of chromium, vanadium, nickel, cobalt and copper during the fractional crystallization of a basic magma." By L. R. Wager (University of Durham) and R. L. Mitchell. (To appear in *Trans. XVIIIth International Geological Congress*.)

21. "The fruiting of *Coprinus lagopus* in pure culture." By D. J. Eastwood. (To appear in *Nature*.)

22. " Studies on the more soluble complexes of soil organic matter. 2. The polysaccharides." By W. G. C. Forsyth. (To appear in *Biochem. J.*)

23. " The nature of the reducing sugars produced from sucrose during the synthesis of polysaccharides by certain bacteria." By W. G. C. Forsyth and D. M. Webley. (To appear in *J. Gen. Microbiol.*)

24. " The absorptiometric determination of magnesium." By J. G. Hunter. (To appear in *The Analyst.*)

25. " Placement of mineral nutrients in soils." By A. B. Stewart. (To appear in *Trans. XIth International Congress of Pure and Applied Chemistry.*)

26. " The effectiveness of various liming materials." By E. G. Williams and J. W. S. Reith. (To appear in *Emp. J. Expt. Agric.*)

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