THE MACAULAY INSTITUTE FOR SOIL RESEARCH

FOUNDED 1930

1968-1969 ANNUAL REPORT

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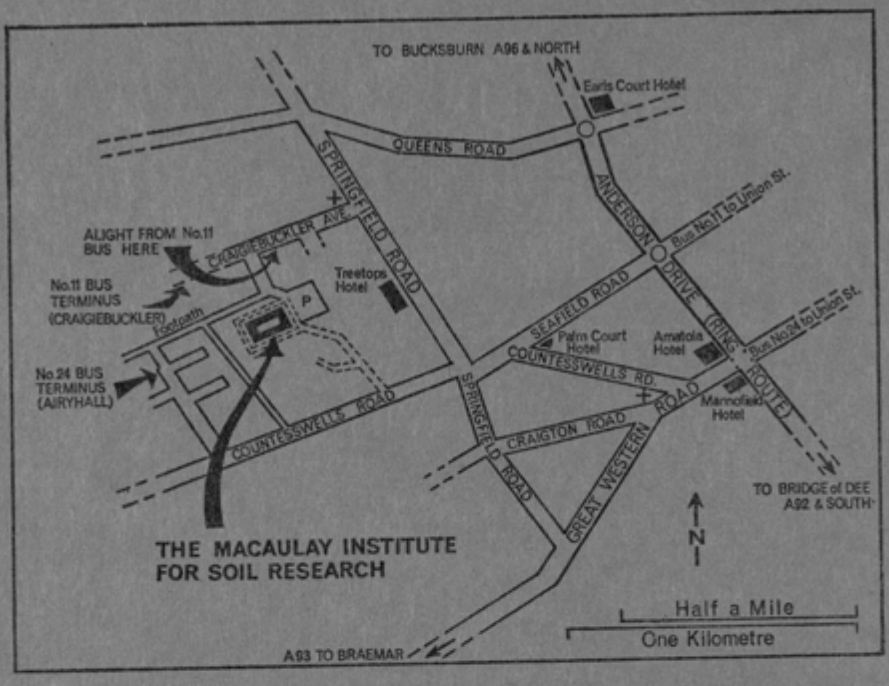

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN AB9 2QJ

(Founded 1930)

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1968-1969

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1968-1969

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Miss K. Reid—appointed 1/6/69.
B. Shirriffs.
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N. A. Duncan, B.Sc.—appointed 1/9/69.
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R. S. Rae—appointed 1/8/69.
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Miss L. K. Benson.
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Miss R. H. Greig.
Miss A. Keen—appointed 25/8/69.
Mrs K. A. Law—resigned 31/12/68.
Mrs J. McKenzie—resigned. 30/4/69
Mrs N. S. C. Mackie.
Mrs F. K. Nicol.

Mrs N. Nicol.
Mrs H. J. Shamsuddin, M.Sc.—appointed 11/8/69.
Miss W. M. Stein—appointed 11/8/69.
Miss S. J. Watt—1/11/68-16/5/69.
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I. M. Still.

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D. J. Linehan, B.Sc., Ph.D.
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P. N. Green—1/8/69-19/9/69.
Miss P. Lorimer.
B. G. Ord—appointed 18/8/69.
A. Reid.
A. Sim—appointed 22/9/69.
W. B. Sinclair—1/11/68-30/9/69.

Radioactivity . . . A. H. Knight, B.Sc., A.R.I.C.
H. Shepherd, L.R.I.C.

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A. A. Liddell—11/11/68-4/9/69.
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Miss J. I. Normington—resigned 31/10/68.

Miss D. Y. Robertson—appointed 1/10/69.
Miss J. S. Warsop—appointed 1/11/68.
Mrs A. P. Watt, R.G.N.
Mrs J. V. Dunbar.

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G. Anderson, B.Sc., Ph.D.
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W. E. Simpson, B.Sc.
R. E. Malcolm.
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J. A. M. Ross, N.D.A.
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Miss C. Ireland.
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Miss E. Pithie—appointed 7/1/69.
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Mrs E. C. Stewart—resigned 31/12/68.
Mrs E. B. Still—resigned 31/10/68.
Miss J. A. Turnbull—1/11/68-31/8/69.
A. R. Douglas.
J. S. Wilson.
R. Strachan.
A. G. Gall.
S. A. Duncan.

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Miss F. M. Strachan, B.Sc.
Miss L. M. Carr—appointed 1/11/68.
Miss A. McDonald—appointed 1/11/68.
Mrs C. McIntosh—resigned 31/10/68.
Mrs M. A. Sutherland—resigned 31/10/69.
Miss S. I. D. Walker.

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M. G. Riddell.
A. I. A. Wilson—appointed 1/9/69.
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Private Secretary to Director . . . Miss M. H. F. B. Nicol.

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Miss M. J. Dunbar.
Mrs D. M. Forbes—resigned 23/5/69.
Miss R. C. M. Gribble.
Miss S. M. Maxwell—appointed 28/7/69.
Miss E. W. M. Murray—resigned 25/7/69.
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Mrs E. E. Rettie—resigned 25/7/69.

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Driver-Handyman . . I. Findlay—appointed 10/2/69

Attendant . . . . J. Christie.

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A. Mutch.
A. W. Gordon.
G. A. Reid.
J. Shaw.
H. Shaw.

Caretakers . . . Mr and Mrs W. Ryder.

VISITING RESEARCH WORKERS

D. van Dam (Afdeling voor Regionale Bodemkunde, Landbouwhogeschool, Wageningen, Netherlands).

A. S. de Endredy (F.A.O., Rome, Italy).

E. G. Kukovskii (Institute of Geochemistry and Physics of Minerals, Academy of Sciences of Ukrainian SSR, Kiev, Ukr. S.S.R.).

O. G. Oniani (Department of Chemistry, Georgian Agricultural Institute, Tbilisi, U.S.S.R.).

J. Quakernaat (Nederlandse Organisatie voor Zuiver-Weternschappelijk Onderzoek, The Hague, Netherlands).

E. M. Sequeira (Estacao Agronomica Nacional, Oerias, Portugal).

Volkan Solen (Orman Fakultesi, Universitesi Istanbul, Turkey).

C. B. Smith (College of Agriculture, Department of Horticulture, Pennsylvania State University, U.S.A.).

CONTENTS

INTRODUCTION

The fundamental objective of the Institute is the maintenance and improvement of soil fertility in all its aspects. The complexity of soil is such that many scientific disciplines are required for the understanding of the factors that control its development and behaviour, particularly as man has imposed his requirements in respect of agriculture, forestry and urban development on the natural processes. It is in this context that the many diverse investigations reported herewith must be viewed. Before turning to these, a few more general matters concerning the Institute should be mentioned.

Two official visits of very different character fall to be recorded. The Chairman of the Agricultural Research Council, The Hon. Mr J. J. Astor, accompanied by the Secretary of the Council, Sir Gordon Cox, visited the Institute on 10th June 1969 and met senior members of staff. On the occasion of his official visit to the Presbytery of Aberdeen, the Moderator of the Church of Scotland, the Right Reverend Dr T. M. Murchison, came to the Institute in order to learn, as a native of the Western Isles, something of the Institute that bears the name of a Lewis man.

A grant from the A.R.C. Underwood Fund permitted Dr Alan Walsh, F.R.S., of the Division of Chemical Physics of the Australian C.S.I.R.O. Chemical Research Laboratory, who was responsible for the introduction and development of atomic absorption methods of analysis, to spend two weeks at the Institute and other agricultural research organizations in Scotland discussing the applications of the technique.

The Institute has been pleased to provide facilities for visiting research workers from The Netherlands, Portugal, Turkey, U.S.A. and U.S.S.R., and to receive short-term visitors from some twenty-four overseas countries.

Various members of staff have participated in international meetings. The Director was invited to present the first Plenary Paper at the Fifteenth International Spectroscopy Colloquium in Madrid, at which Dr R. O. Scott also read a paper. Dr R. Glentworth attended a meeting of the F.A.O. Working Party on Soil Survey and Classification in Bulgaria and, after a study tour, attended the First National Congress of the Bulgarian Soil Science Society. Dr J. F. Darbyshire attended the Third International Congress of Protozoology in Leningrad. The Council are most grateful to the Department of Agriculture and Fisheries for Scotland and the Agricultural Research Council for making it possible for these members of staff to take part in these proceedings and contributing towards their expenses in whole or in part.

Dr R. C. Mackenzie and Dr V. C. Farmer attended a meeting of rapporteurs of the O.E.C.D. Project on Non-metallic Minerals in Paris, their expenses being met by O.E.C.D. Mr E. L. Birse received a D.A.A.D. (German Academic Exchange Service) grant to enable him to spend six weeks at the Plant Sociological Centre at Rinteln, Weser, Hanover, and on field work, to study Professor Tüxen's methods of classifying and mapping vegetation.

Mr C. J. Bown was granted leave of absence for one year from 1st April 1969 to work with the Soil Survey of Saskatchewan, in the field and in their laboratories, at the invitation of Professor D. A. Rennie, Director of the Saskatchewan Institute of Pedology.

The Council of Management, at their meeting in November 1968, decided that departmental status should be accorded to Statistics and that Mr R. H. E. Inkson should be designated Head of the Department.

Members of staff have served on technical committees appointed by such official bodies as the Department of Agriculture and Fisheries for Scotland, the Agricultural Research Council and the Forestry Commission, as well as on various other scientific panels and groups.

PEDOLOGY

The properties of the soil system and its components, with special reference to the manner in which those of individual components influence the soil as a whole, continue to be the major field of interest of the department.

For many years systematic mineralogical analyses of clay fractions separated from soils provided by the Soil Survey have been carried out in the department and it has been possible to associate the predominance of certain clay minerals with specific rock types. Clay minerals in soil have, however, several sources, particularly inheritance from the parent material, degradation of minerals originally present and synthesis of new minerals. The last two processes are often difficult to disentangle since degradation of one mineral may well lead to synthesis of another. Inheritance, on the other hand, is more readily assessable by examination of the clay mineralogy of parent rocks and systematic studies on certain rocks, particularly sedimentary species, are now in progress.

Another aspect of the work of the department is illustrated by studies on the afforestation of peat. Peat and highly organic soils cover approximately one-tenth of the area of Scotland and are therefore of considerable importance with regard to future land development. One of the major uses of such land at present is for afforestation, but peat, because of its inherently high water content and low nutrient status, is not an ideal medium for plant growth and many problems have to be overcome before its full potential for agriculture or forestry can be realised. Field experiments have been in progress for some years to assess the effect of drainage on the physical characteristics of peat and on tree growth. Responses so far obtained indicate that lowering of the water table leads to considerable site improvement and to very much more vigorous trees. Such experiments, although only indirectly applicable to agriculture, are nevertheless yielding results of fundamental importance.

Close collaboration has continued with the Forestry Commission. In addition, contact has been maintained with the Highlands and Islands Development Board in connection with peat survey, with the Natural Environment Research Council on the conservation of northern peatlands, and with the British Standards Institution on the standardization of peat and peat products.

Collaborative studies have been carried out with other departments of the Institute and various samples have been examined for the Forestry Commission, F.A.O., the Organization for Economic Cooperation and Development (O.E.C.D.), the Universities of Aberdeen, Edinburgh, Glasgow, Heidelberg, Rome and Cairo, and the British Standards Institution.

A number of post-graduate workers have been welcomed during the year. Professor E. G. Kukovskii, Institute of Geochemistry and Physics of Minerals, Academy of Sciences of the Ukrainian S.S.R., Kiev, studied the clay mineralogical techniques in use in the department, Dr J. Quakernaat, Nederlandse Organisatie voor Zuiver-Wetenschappelijk Onderzoek, The

Hague, Netherlands, has commenced studies on the physical chemistry of clay minerals, and Dr V. Sölen, Forestry Faculty, University of Istanbul, Turkey, is studying the thermal characteristics of soil organic matter. Dr A. S. de Endredy, F.A.O., Rome, is also assisting in the work of the department.

Members of staff have attended, *inter alia*, meetings of the Clay Minerals Group of the Mineralogical Society, the Thermal Analysis Group of the Society for Analytical Chemistry, British Standards Institution Panel M79/2/5 on propagation pots fabricated of peat, the A.R.C. Working Party on Methods of Soil Analysis, the Quaternary Research Association, and a joint meeting of the British Ceramics Society and the Institute of Physics and Physical Society. At these meetings several papers were read.

Mr R. A. Robertson attended meetings of the Praesidium and Council of the International Peat Society in Helsinki and Dublin and also, as Chairman of the B.S.I. Panel M79/2/5, accepted an invitation to visit Norway to discuss the production of standards for peat propagation pots. Dr R. C. Mackenzie attended a meeting of rapporteurs in Paris in connection with the O.E.C.D. project on Non-Metallic Minerals.

Surface Properties of Soils and Soil Clays

Methods for effectively dispersing soils have been further investigated with particular reference to soils containing carbonate and to those with appreciable amounts of montmorillonite and allophane[1]. An assessment of techniques for measuring the cation-exchange capacity of such soils is also in progress.

There is increasing evidence of the value of specific surface-area measurement by gas adsorption techniques in studies on soils and soil clays and improvements have been made in the design of the apparatus employed. Water-vapour adsorption has now been adopted for measurement of surface areas of natural and synthetic gel systems.

Soils and clays react with fluoride ions releasing hydroxyl ions. The rate of release and amount released depend on the degree of crystalline order in the clay components, particularly at the surfaces. This reaction has been shown to provide a basis for a method of readily differentiating poorly-ordered from well-ordered material in soil clays and a technique suitable for systematic investigations has been devised.

Soil Mineralogy

The study of crystallographically poorly-ordered inorganic materials in soil clays continues to be a major subject of research, and development of selective chemical dissolution methods for qualitative and quantitative assessment continues. The effects of dilute alkali solutions on silica polymorphs[34] and on poorly-ordered and well-ordered aluminium oxides have been investigated. The value of sodium pyrophosphate in extracting 'free' iron oxides from soils was tested on a number of Scottish soil clays but this reagent was found to be less effective than the sodium dithionite–sodium bicarbonate method currently in use. The latter was therefore used in examination of a

number of mineral samples in connection with the establishment of an international 'minerals bank' under the auspices of O.E.C.D. The value of chemical and thermoanalytical techniques in the study of poorly-ordered aluminosilicates in soil clays was discussed at a joint meeting of the Clay Minerals Group of the Mineralogical Society and the Thermal Analysis Group of the Society for Analytical Chemistry.

The requirement for total chemical analyses of minerals and soil clays continues to increase. During the year the methods of 'wet' analysis in use were tested on reference samples supplied by the British Ceramic Research Association in connection with their second survey of accuracy in ceramic analysis. Methods for determinations of major elements in mineral specimens by X-ray fluorescence techniques are being developed using fusion with lithium tetraborate, lanthanum oxide being the heavy absorber.

A system for simultaneous differential thermal analysis or differential scanning calorimetry and mass spectrometry has been constructed, in which the evolved gases from the former are analysed by the latter. This enables changes in energy and in decomposition products to be recorded simultaneously as the temperature is varied according to a specific programme. For clay minerals, especially smectites and allophanes, it has been possible by this system to measure accurately the amounts of water evolved at each stage, using prior calibration with salt hydrates. From the results, information has been derived as regards the energy required to release water molecules from clay minerals at different temperatures and consequently as regards the nature of the bound water.

A microthermobalance system capable of recording weight losses of the order of 0·5 μg and of simultaneously recording thermogravimetric and derivative thermogravimetric curves has been constructed. Samples can be examined *in vacuo* (to 10^{-6} mm Hg) or in any desired static or flowing gas atmosphere. Initial tests of this equipment have proved very satisfactory.

A chapter on the differential thermal analysis of clay minerals[43] has been compiled for a forthcoming volume.

Mineralogy of Scottish Sedimentary and Metamorphic Rocks. A paper on the clay minerals of Dalradian limestones[44] has been submitted for publication. Over 100 samples of Old Red Sandstone rocks have been collected to investigate their clay and fine-sand mineralogy in order to establish the extent of the inheritance of these minerals in the derived soils. Different parts of the sequence are characterized by different clay-mineral assemblages. In the Lower Old Red Sandstone the Downtonian stage almost invariably contains kaolinite, illite and sometimes chlorite, while the overlying Dittonian rarely contains kaolinite but has a variety of interstratified minerals including chlorite-vermiculite, chlorite-montmorillonite and illite-montmorillonite. These minerals appear to be related to the volcanic rocks which are abundant in the sequence. The clay fractions of the Middle Old Red Sandstone of Caithness usually contain illite and chlorite while the Middle Old Red Sandstone of other areas and the Upper Old Red Sandstone invariably yield

Hague, Netherlands, has commenced studies on the physical chemistry of clay minerals, and Dr V. Sölen, Forestry Faculty, University of Istanbul, Turkey, is studying the thermal characteristics of soil organic matter. Dr A. S. de Endredy, F.A.O., Rome, is also assisting in the work of the department.

Members of staff have attended, *inter alia*, meetings of the Clay Minerals Group of the Mineralogical Society, the Thermal Analysis Group of the Society for Analytical Chemistry, British Standards Institution Panel M79/2/5 on propagation pots fabricated of peat, the A.R.C. Working Party on Methods of Soil Analysis, the Quaternary Research Association, and a joint meeting of the British Ceramics Society and the Institute of Physics and Physical Society. At these meetings several papers were read.

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Surface Properties of Soils and Soil Clays

Methods for effectively dispersing soils have been further investigated with particular reference to soils containing carbonate and to those with appreciable amounts of montmorillonite and allophane[1]. An assessment of techniques for measuring the cation-exchange capacity of such soils is also in progress.

There is increasing evidence of the value of specific surface-area measurement by gas adsorption techniques in studies on soils and soil clays and improvements have been made in the design of the apparatus employed. Water-vapour adsorption has now been adopted for measurement of surface areas of natural and synthetic gel systems.

Soils and clays react with fluoride ions releasing hydroxyl ions. The rate of release and amount released depend on the degree of crystalline order in the clay components, particularly at the surfaces. This reaction has been shown to provide a basis for a method of readily differentiating poorly-ordered from well-ordered material in soil clays and a technique suitable for systematic investigations has been devised.

Soil Mineralogy

The study of crystallographically poorly-ordered inorganic materials in soil clays continues to be a major subject of research, and development of selective chemical dissolution methods for qualitative and quantitative assessment continues. The effects of dilute alkali solutions on silica polymorphs[24] and on poorly-ordered and well-ordered aluminium oxides have been investigated. The value of sodium pyrophosphate in extracting 'free' iron oxides from soils was tested on a number of Scottish soil clays but this reagent was found to be less effective than the sodium dithionite–sodium bicarbonate method currently in use. The latter was therefore used in examination of a

number of mineral samples in connection with the establishment of an international 'minerals bank' under the auspices of O.E.C.D. The value of chemical and thermoanalytical techniques in the study of poorly-ordered aluminosilicates in soil clays was discussed at a joint meeting of the Clay Minerals Group of the Mineralogical Society and the Thermal Analysis Group of the Society for Analytical Chemistry.

The requirement for total chemical analyses of minerals and soil clays continues to increase. During the year the methods of 'wet' analysis in use were tested on reference samples supplied by the British Ceramic Research Association in connection with their second survey of accuracy in ceramic analysis. Methods for determinations of major elements in mineral specimens by X-ray fluorescence techniques are being developed using fusion with lithium tetraborate, lanthanum oxide being the heavy absorber.

A system for simultaneous differential thermal analysis or differential scanning calorimetry and mass spectrometry has been constructed, in which the evolved gases from the former are analysed by the latter. This enables changes in energy and in decomposition products to be recorded simultaneously as the temperature is varied according to a specific programme. For clay minerals, especially smectites and allophanes, it has been possible by this system to measure accurately the amounts of water evolved at each stage, using prior calibration with salt hydrates. From the results, information has been derived as regards the energy required to release water molecules from clay minerals at different temperatures and consequently as regards the nature of the bound water.

A microthermobalance system capable of recording weight losses of the order of 0·5 μg and of simultaneously recording thermogravimetric and derivative thermogravimetric curves has been constructed. Samples can be examined *in vacuo* (to 10^{-6} mm Hg) or in any desired static or flowing gas atmosphere. Initial tests of this equipment have proved very satisfactory.

A chapter on the differential thermal analysis of clay minerals[43] has been compiled for a forthcoming volume.

Mineralogy of Scottish Sedimentary and Metamorphic Rocks. A paper on the clay minerals of Dalradian limestones[44] has been submitted for publication. Over 100 samples of Old Red Sandstone rocks have been collected to investigate their clay and fine-sand mineralogy in order to establish the extent of the inheritance of these minerals in the derived soils. Different parts of the sequence are characterized by different clay-mineral assemblages. In the Lower Old Red Sandstone the Downtonian stage almost invariably contains kaolinite, illite and sometimes chlorite, while the overlying Dittonian rarely contains kaolinite but has a variety of interstratified minerals including chlorite-vermiculite, chlorite-montmorillonite and illite-montmorillonite. These minerals appear to be related to the volcanic rocks which are abundant in the sequence. The clay fractions of the Middle Old Red Sandstone of Caithness usually contain illite and chlorite while the Middle Old Red Sandstone of other areas and the Upper Old Red Sandstone invariably yield

kaolinite and interstratified illite-montmorillonite. A supporting study of the heavy fraction of the fine-sand minerals is also being made.

Greensands from Mull and Morvern, which were known to have a high P_2O_5 content, were found by X-ray diffraction examination to contain minerals of the plumbogummite group. X-ray fluorescence analysis showed variable amounts of strontium, lanthanum, cerium, yttrium and barium[45].

Rock-Weathering Studies. Studies on the weathering of a biotite-hornblende rock in a soil at Rehiran, Inverness-shire[46, 47], showed that the hornblende contains an intergrowth of another amphibole which weathers selectively to an interstratified chlorite-saponite.

The formation of gibbsite from an ultrabasic rock in Rhum[2] has been described, and a paper relating to the alpine podzols on the Ben Lawers chlorite schists[48], previously reported on, is in press.

Clay Fractions of Soils. Systematic examination of soil clays by X-ray, thermal and electronoptical methods represents a significant part of the year's work. An account of the clay mineralogy of the dominant soil series in the Perth and Arbroath areas (Sheets 48 and 49) has been prepared for the Soil Survey memoir of that area. A detailed study of allophane- and gibbsite-containing podzolic soils of north-east Scotland developed on epidiorite is continuing. X-ray diffraction examination of the clay fractions of soils of the Loch Awe area formed on epidiorite indicate that, unlike those of the north-east, chlorite is the dominant clay mineral.

A combined electron and X-ray diffraction study of various size fractions of a natural sepiolitic clay from Tanzania indicated the presence of very fine crystals of illite and high-potassium felspar. Carbon replicas revealed the felspar crystals to be rhombs. This combination of techniques has also been used to index the reflections of a natural mixture of minerals of the alunite-jarosite series. Three phases have been identified, the X-ray data for which correspond closely to those for natroalunite, natrojarosite and jarosite. Imogolite, a fibrous aluminosilicate occurring in many Japanese soils developed on volcanic ash, has been shown by infrared absorption, electronoptical and electron diffraction techniques to have a unique structure[3]. The manganese mineral lithiophorite has also been subjected to a detailed electronoptical examination[49].

The transformation of goethite to hematite in tropical and temperate soils has been further investigated and it has been found from a comparison of X-ray data for pure goethite samples and soil goethites that substitution of aluminium for iron in the lattice affects all three unit-cell parameters. A study of the transformations occurring in synthetic iron oxides is also in progress. It would appear that the products of the oxidative breakdown of ferric iron–catechol chelates with hydrogen peroxide at 30°C are magnetite, lepidocrocite and goethite, depending on the ratio of ferric iron to catechol. When oxidation is carried out in the presence of OH-saturated anion resin, well-crystallized hematite is produced.

The clay mineralogy of alluvial soils from Rajistan and West Pakistan has been determined: illite and/or muscovite predominates and palygorskite is

present throughout. Soil and mineral samples from organizations in Canada, West Germany, Ghana, Japan, New Zealand, Nigeria, Norway, Sweden, Sudan, U.A.R., U.S.A. and U.S.S.R. have also been analysed. The X-ray diffraction, differential thermal and electronoptical characteristics of some reference minerals supplied by O.E.C.D. have been determined. A review of techniques used in soil-clay mineralogy[4] has appeared.

Clay-Organic Complexes. The collaborative study with Microbiology on the adsorption of nucleic acids by montmorillonite has shown that randomly interstratified complexes are formed with both DNA and RNA[51]. A paper on a naturally occurring organometallic–clay mineral complex[5] has been published.

Organic and Biological Materials

The simultaneous differential thermal analysis and mass spectrometry apparatus has been extensively used in the examination of a range of biological materials, including pollens, spores, peat, humic acids, cellulose and tryptophane. In many instances the distinctive differential thermal analysis pattern is reflected in the simultaneous evolution of carbon monoxide, carbon dioxide and water. Characteristic patterns for these compounds can be observed, particularly for carbohydrates.

Chapters on organic compounds[52] and biological material[53] have been compiled for a forthcoming book on differential thermal analysis.

Soil Analysis

Systematic analytical determinations have been completed on all soils collected by the Soil Survey during 1967 and examination of those collected during 1968 is almost complete. New techniques for certain determinations are being assessed. An autoanalyser for carbon and nitrogen is now in continuous operation. Iron, aluminium and carbon in pyrophosphate extracts from soils are also being determined. Some 100 soil samples have been examined for other departments of the Institute and for outside bodies. In collaboration with Soil Survey, separation and identification of the polyphenolic constituents of the neutral fraction of aqueous extracts of pine needles, which can complex with sesquioxides, has continued. The statistical evaluation, in collaboration with Soil Survey and Statistics, of field and laboratory information for four Scottish soil series has now been completed[54].

Peat

Systematic surveys, documentation and evaluation of Scottish peat resources have been continued and extended. The results of this work, which provide information of practical as well as of scientific value, are incorporated in appropriate Soil Survey memoirs and in more detailed maps and reports on selected deposits which have development potential either as land for agriculture or forestry or as sites for the commercial production of peat for horticulture and related purposes. The acquisition of a tracked vehicle has greatly facilitated field work, particularly in areas inaccessible to wheeled transport.

In the past year surveys of representative areas of high-level blanket bog

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In the past year surveys of representative areas of high-level blanket bog

in the southern part of the Nairn district (Sheet 84) have been completed and examination and characterization of deposits in the Wick and Latheron areas (Sheets 116 and 110) are well advanced. Apart from a section of Methven Moss, which impinges on the western part of the area, no peat deposits of any size or significance have been located in the Perth and Arbroath areas (Sheets 48 and 49).

A number of surveys related to regional and other developments have been completed and maps and reports prepared. A survey of Machrie Bog on the Island of Arran, undertaken at the request of the Arran Council of Social Services, has been completed and a survey of peatland in North Uist is in progress. An assessment has been made of the horticultural value of peat deposits in Shetland and at Ochtertyre Moss near Stirling. In all this work close collaboration has been maintained with the Department of Agriculture and Fisheries for Scotland, the Colleges of Agriculture, the Forestry Commission, the Highlands and Islands Development Board, the Nature Conservancy, local authorities, landowners and farmers.

Standard physical and chemical determinations on peat, including over 500 samples taken in the course of field survey, have continued along the lines previously reported. In association with the British Standards Institution, specifications and test procedures proposed by the Association Française de Normalisation for propagation pots made of peat and other biodegradable materials are being examined and assessed; alternative test procedures for inclusion in an International Standards Organisation standard are under review. With regard to standards for peat for horticultural purposes, close contact is being maintained with the American Society for Testing and Materials, the German Standards Institute and national standards organizations in Scandinavian countries.

An English edition of the Transactions of the Second International Peat Congress[6] and a brief review of peat resources and their development in Britain and the U.S.S.R.[7] have been published. Two papers[55, 56] presented at the Third International Peat Congress in Quebec in 1968 are still in press. In collaboration with the Peat Research Institute, Hanover, Germany, work is currently in progress to produce a comprehensive German-Russian-English glossary of scientific and technical terms with specific reference to the fields of peat research and development.

Root and Moisture Studies. Investigations on the oxygen requirements, in culture solution, of tree roots have continued and a comparison made between lodgepole pine and sitka spruce. Spruce is the more demanding species, with root growth falling off rapidly below 10 per cent oxygen, whereas for lodgepole pine appreciable growth occurs at oxygen concentrations as low as 3 per cent. Earlier studies on the effect of different cultural treatments on root development in a grass sward on deep peat[8] have been described.

The downward and lateral movement of water in peat has been studied, using water enriched with tritium to indicate the rate and extent of movement. Results obtained over a 12-month period are currently being assessed.

Pollen Analysis and Quaternary Research. The study of vegetational history has continued, with investigations at sites in Argyll, Isle of Arran, Nairnshire, Perthshire and the Cairngorm Mountains. Results from these and other sites have led to an assessment of altitudinal zonation of climate since the Boreal period[9] and are providing evidence on the distribution and composition of vegetation during the Flandrian stage of the Quaternary period. The Cairngorm work, carried out in collaboration with the Department of Geography, University of Aberdeen, is concerned with discovering whether or not there is any palynological evidence of a cold phase of short duration, which it is thought may have occurred in the second half of the sub-Atlantic period. The geomorphological significance of peat exposed by the Wooler Water, Northumberland, has also been investigated[57].

Pollen diagrams from several sites in the southern Highlands have revealed information on the former extent and nature of the Caledonian Forest; as a result, the relationship, in both space and time, between pine and birch in this area is becoming more fully understood. The influence of prehistoric human activity on vegetational history and soil development is now widely recognized and consequently a number of sites of archaeological significance have been examined in order to establish more precise datings and correlations.

Investigations on structural variations in peat[10] are continuing and methods whereby the relatively new technique of fluorescence microscopy can be applied to palynological studies and to the examination of plant remains in peat are being developed.

Studies on Forest Soils

The experiment at Lon Mor, Inverness-shire, on the response of lodgepole pine to water-table height[38] is still in progress. The five treatments have now been maintained for six years and in the current season their effect on root development has been investigated. The method used was to excavate individual plants and to record the lateral and downward penetration, the degree and type of branching, and the general morphology of the root system. In the waterlogged plot root growth is stunted and die-back is a characteristic feature. In the driest plot, where the water in the surrounding ditch is maintained at 0·5 m from the surface, roots extend to a depth of 0·43 m and have a lateral spread of at least 2·6 m.

Tree Nutrition. Investigations into the nitrogen nutrition of coniferous trees, carried out in collaboration with the Forestry Commission, continue. Examination of the distribution of organic matter and nitrogen within a pine forest has illustrated the extent to which immobilization of nitrogen in mor humus is associated with site degradation and declining tree growth[11], a condition that is rapidly alleviated by the application of nitrogen fertilizer. Detailed analysis of the component parts of a forest ecosystem (a 38-year-old plantation of Corsican pine) sampled following a period of fertilizer application has now been completed. The proportion of the fertilizer nitrogen recovered in the tree crop was found to be greater than that retained

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in the soil organic layers, and it seems that coniferous trees have a considerable ability to store nitrogen within their tissues. This storage probably accounts for the relatively long time-span (seven to eight years) over which such trees show increased growth in response to a single application of nitrogen fertilizer. Two-dimensional paper chromatography suggests that appreciable storage of nitrogen occurs as free amino acids, there being marked differences in the concentrations of these between untreated and fertilized trees. Of the amino acids identified in needle extracts of Corsican pine α-alanine, γ-aminobutyric acid and arginine were present in greatest amounts.

In a series of greenhouse experiments with Corsican pine, it has been found that the form of nitrogen supplied to the tree roots has a marked effect on both total nutrient uptake and tree growth, ammonium nitrogen being the preferred form. The nature of the nitrogen supplied also alters the amount and pattern of free amino acids present in fresh foliage. These experiments continue and during the past year new equipment has been developed to provide a continuous-flow nutrient culture system in which each plant is grown in a separate pot. Such a system enables the use of larger plants (up to 0·4 m) than has hitherto been possible, so overcoming the difficulties of working with small seedlings that carry varying proportions of adult, juvenile and cotyledon needles.

A new field experiment has been laid out in a stand of nitrogen-deficient 40-year-old Scots pine at Culbin Forest, Morayshire, to examine the effect of form of nitrogen fertilizer on both tree growth and transformations of nitrogen in the soil organic layers. Fertilizer forms of ammonium (sulphate of ammonia), nitrate (Chile nitrate of soda), ammonium nitrate (I.C.I. 'Nitram') and urea have been applied at a single rate (250 kg N per ha) and these treatments have been partially factorialized with phosphorus (100 kg P per ha as triple superphosphate) and lime (2·5 tonnes ground limestone per ha). Clear differences between the effects of the different forms of nitrogen applied were apparent by the end of the first growing season. Needle weight and needle nitrogen concentration were highest in those plots given ammonium nitrate (29 mg and 2·5 per cent N as against 20 mg and 1·4 per cent N in the untreated control) and both these parameters were significantly greater in the ammonium nitrate plots than in those given either sodium nitrate or urea (24 mg and 1·8 per cent N), with ammonium sulphate occupying an intermediate position (25 mg and 2·0 per cent N). Application of phosphate or lime tended to increase needle weight for any given foliar nitrogen concentration but, at least in the first year of application, had no significant effect on nitrogen concentration.

A thesis on the effect of nitrogen fertilizer on the growth and nutrient uptake in a stand of Corsican pine, submitted by Mr H. G. Miller to the University of Aberdeen for the degree of Ph.D., was sustained.

Mineralization of Nitrogen in Peat and Forest Humus. The rate of release of nitrogen in an assimilable form from organic matter may be critical for successful tree growth on peat bogs or in forests where there is a marked

accumulation of mor humus. Incubation studies are now being carried out on these materials, using incubation times varying from two days to nine weeks and temperatures varying from 22 to 30°C. As yet, there is little information available for peat although it has been found that the amount of mineral nitrogen present in fresh samples, prior to incubation, varies greatly between peat types and that within any one peat type the quantity of mineral nitrogen increases with increasing moisture content.

For studies with forest humus, samples were taken in May from the Scots pine experiment at Culbin Forest that has been described above. Only 0·2-4·4 per cent of the nitrogen in these humus samples could be extracted with 2N KCl prior to incubation. However, on being incubated at 30°C for nine weeks, this rose to between 3·3 per cent and 8·6 per cent of the total nitrogen. More than 90 per cent of the extracted nitrogen was in the ammonium form, the quantity of which after incubation varied from 32·5 to 106·1 mg nitrogen per 100 g organic matter as against only 2·5-8·6 mg present in the nitrate form. The fertilizer treatments previously given to the plots from which these humus samples were taken had a profound influence on the rate at which mineralization proceeded during incubation. Nitrogen fertilizers increased the production of mineral nitrogen in the order urea > ammonium nitrate > ammonium sulphate > sodium nitrate ⩾ untreated control. Phosphate also increased the net production of mineral nitrogen; indeed, in those plots given phosphate alone the mineral nitrogen present after incubation amounted to 86·3 mg nitrogen per 100 g organic matter as against 38·7 mg in the untreated control and 97·4 mg in the plots given urea. The effect of lime was less marked than that of phosphate, although when given together with a nitrogen fertilizer it did tend to increase the net production of mineral nitrogen on incubation over the values found for the samples treated with the nitrogen fertilizer alone. However, in the plots given only lime there was, relative to the untreated control, a decrease in the quantity of mineral nitrogen present after incubation; indeed, in these samples prior to incubation no mineral nitrogen could be detected at all.

Classification of Peatland Sites for Afforestation. The work described under this heading in the previous report has been completed[59, 60].

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Mineralization of Nitrogen in Peat and Forest Humus. The rate of release of nitrogen in an assimilable form from organic matter may be critical for successful tree growth on peat bogs or in forests where there is a marked

accumulation of mor humus. Incubation studies are now being carried out on these materials, using incubation times varying from two days to nine weeks and temperatures varying from 22 to 30°C. As yet, there is little information available for peat although it has been found that the amount of mineral nitrogen present in fresh samples, prior to incubation, varies greatly between peat types and that within any one peat type the quantity of mineral nitrogen increases with increasing moisture content.

For studies with forest humus, samples were taken in May from the Scots pine experiment at Culbin Forest that has been described above. Only 0·2-4·4 per cent of the nitrogen in these humus samples could be extracted with 2N KCl prior to incubation. However, on being incubated at 30°C for nine weeks, this rose to between 3·3 per cent and 8·6 per cent of the total nitrogen. More than 90 per cent of the extracted nitrogen was in the ammonium form, the quantity of which after incubation varied from 32·5 to 106·1 mg nitrogen per 100 g organic matter as against only 2·5-8·6 mg present in the nitrate form. The fertilizer treatments previously given to the plots from which these humus samples were taken had a profound influence on the rate at which mineralization proceeded during incubation. Nitrogen fertilizers increased the production of mineral nitrogen in the order urea>ammonium nitrate>ammonium sulphate>sodium nitrate⩾untreated control. Phosphate also increased the net production of mineral nitrogen; indeed, in those plots given phosphate alone the mineral nitrogen present after incubation amounted to 86·3 mg nitrogen per 100 g organic matter as against 38·7 mg in the untreated control and 97·4 mg in the plots given urea. The effect of lime was less marked than that of phosphate, although when given together with a nitrogen fertilizer it did tend to increase the net production of mineral nitrogen on incubation over the values found for the samples treated with the nitrogen fertilizer alone. However, in the plots given only lime there was, relative to the untreated control, a decrease in the quantity of mineral nitrogen present after incubation; indeed, in these samples prior to incubation no mineral nitrogen could be detected at all.

Classification of Peatland Sites for Afforestation. The work described under this heading in the previous report has been completed[59, 60].

SOIL SURVEY

The main emphasis of the Soil Survey continues to be the systematic study and mapping of the soils of Scotland. A recent development has been the publication of a Technical Monograph describing a land use capability classification of the land of Britain made in collaboration with the Soil Survey of England and Wales[12]. In this classification the limitations imposed by soil, site and climate are considered. Seven main classes of land are recognized: Class 1 land has the fewest limitations and has the widest use range for arable crops, whereas Class 7 land is high-lying above the plantable limit, is unimprovable and is only suitable for sporting and amenity purposes. The first four classes are applicable to arable land and have progressively increasing limitations of soil, site and climate. Classes 5 and 6 are applicable for grazing or forestry, but Class 5 is capable of improvement by mechanical means. In preparing the experimental maps based on this classification, the officers of the soil advisory services of the Scottish agricultural colleges and officials of the Lands Branch and Inspectorate of the Department of Agriculture and Fisheries for Scotland are consulted.

Systematic soil survey on a scale of 2·5 inches to 1 mile has continued in the ten areas detailed below. During the period April to September 1969 approximately 405 square miles have been surveyed, 75 on Sheet 115 (Reay), 30 on Sheet 85 (Rothes), 70 on Sheet 75 (Tomintoul), 30 on Sheet 74 (Grantown), 17 on Sheet 47 (Crieff), 63 on Sheets 43, 44, 51 and 52 (Island of Mull), 30 on Sheet 45 (Oban), 38 on Sheets 40/41 (Kinross/Elie) and 48 on Sheet 31 (Airdrie). In addition, revision, correlation and sampling have been carried out on Sheets 116 (Wick), 110 (Latheron), 84 (Nairn), 33 (Edinburgh) and 24 (Peebles). Extensive use continues to be made of aerial photographs at both 1:10,000 and 1:25,000 scales as an aid to mapping.

One hundred and ninety soil profiles have been described and sampled for analysis, many with the aid of a Smalley 360 Mechanical Excavator that has now been brought into use. This machine has been found capable of dealing with extremely stony and compacted soils.

Dr R. Glentworth attended the Seventh Session of the Working Party on Soil Classification and Survey of the F.A.O. European Commission on Agriculture at Varna, Bulgaria, and subsequently was the guest of the Bulgarian Soil Science Society at their First Congress in Sofia. In collaboration with the Soil Survey of England and Wales, an agreed draft of the United Kingdom Section of the Soil Map of the World (1:5 million) has been prepared and submitted to F.A.O./U.N.E.S.C.O., Rome.

The Survey continues to be represented on the Agricultural Research Council Technical Committee on Soil Fertility, and on the A.R.C. Soil Survey Research Board Technical Working Party on Soil Analysis.

Mr E. L. Birse visited Professor R. Tüxen at Rinteln, West Germany, and participated in an excursion of the International Society for Plant

Geography in both Germany and the Netherlands. Members of staff attended the spring and autumn meetings of the British Society of Soil Science and the meeting of the Quaternary Research Association in Wales.

Mr C. J. Bown, at the invitation of the Saskatchewan Institute of Pedology, University of Saskatchewan, Saskatoon, Canada, is spending one year from 1st April 1969 with the Saskatchewan Soil Survey.

Mr D. van Dam, post-graduate student from the Department of Soil Science, The Agricultural University, Wageningen, Holland, spent six months with the Soil Survey of Scotland.

Sheets 116 and 110 (Wick and Latheron)

Mapping of these two sheets was completed at the end of last season. The earlier part of this season was spent on revision work, collection of further profile descriptions and samples, and in correlation of previously unnamed associations and soil series. Sheet 110 is now complete and Sheet 116 should be completed by the end of the season.

The following new associations have been defined:

Berriedale Association on drift derived from Middle Old Red Sandstone Barren Red Series sandstones and conglomerates.

Braemore Association on drift derived from Middle Old Red Sandstone Barren Red Series mudstones.

Dunnet Association on sandstones of Upper Old Red Sandstone age.

Shielton Association on sand and gravel derived from Middle Old Red Sandstone Caithness Flagstone Series strata.

The Reiss Association has been renamed the *Thurso Association* and comprises soils developed on drift derived from Middle Old Red Sandstone Caithness Flagstone Series strata.

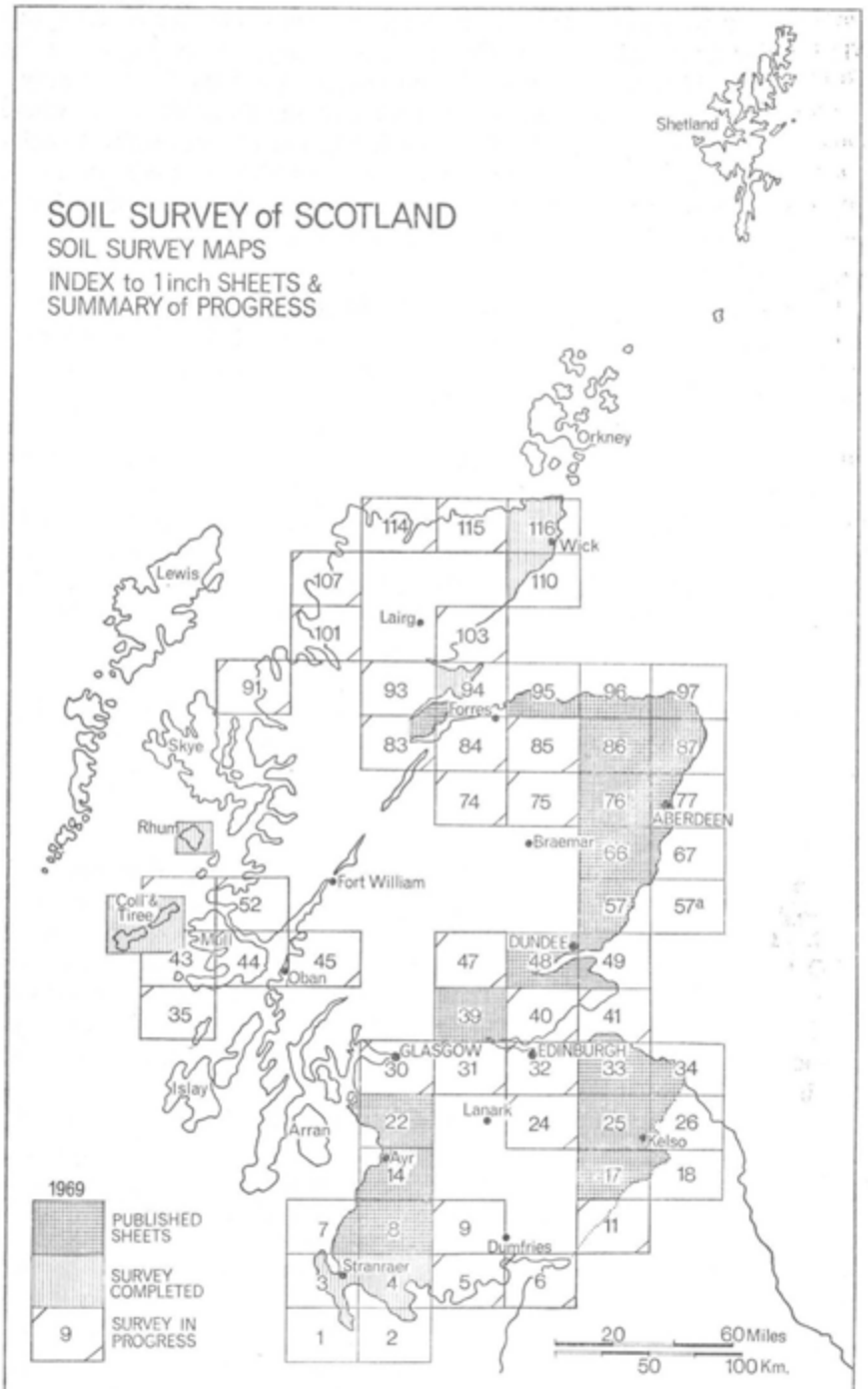
A preliminary summary of the findings in this area is given later in the report.

Sheet 115 (Reay)

Mapping was commenced on Sheet 115 (Reay) during the middle part of the season. Briefly, the area comprises two main regions, namely (a) the westward continuation of the Caithness Plain underlain by Middle Old Red Sandstone Caithness Flagstone Series strata, and (b) the Moine Plateau composed of Moine Schist and Strath Halladale Granite, mainly peat covered but more rocky towards the west, and dissected by Strath Naver and Strath Halladale, where outwash gravels occur.

A broad reconnaissance indicates that in the first region soils of the Thurso Association will occur, while in the second soils of the Strichen and Countesswells and, to a lesser extent, Berriedale and Corby Associations will be present, but peat will predominate.

Preliminary survey of an area of some 40 square miles was undertaken in the Strathy district to establish the mapping units likely to be encountered over the Moine Schist region. Peaty podzols of the Strichen Association,


SOIL SURVEY of SCOTLAND
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SUMMARY of PROGRESS
Shetland
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GLASGOW
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Kelso
Ayr
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1969
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20 60 Miles
50 100 Km.

together with thin and deep peat are dominant, but complexes covering five types of soil-landscape relationship will be necessary. Peaty podzols of the Corby Association occur on mounds and terraces along the River Strathy.

Some 20 square miles were mapped west of the Sandside Burn, where soils are mainly peaty podzols of the Berriedale and Countesswells Associations together with thin and deep peat. On the Caithness Plain 15 square miles were mapped in the Shebster district. All soils belong to the Thurso Association and comprise Thurso, Olrig and Bilbster series.

Sheet 85 (Rothes)

During the field season approximately 30 square miles have been surveyed. The area extends from the southern edge of the sheet, where it crosses Glen Avon, to Cross of Knockando, and includes much of Knockando, with parts of Ballindalloch and Glen Livet.

The greater part consists of moorland and forest, with arable land confined to the valley terraces and lower hillslopes of the Avon and Spey. Creag an Tarmachain (2121 feet) is the highest point, with most of the lower hills ranging from 1700 to 1200 feet. The afforested land mostly lies below 1000 feet but extends locally above 1200 feet. The upland soils are developed on till or soliflucted till derived from acid schists and granulites, and have been included within the Strichen Association. The soils include podzols, peaty podzols, peaty gleys, sub-alpine podzols, hill peat, and to a very limited extent alpine soils. The valley soils include podzols, brown podzolics, humus podzols, and gleys, with their cultivated analogues; they are developed on till, moraine, and moraine terraces, the latter including gravel, sand and silt. Soil associations identified include Strichen, Corby and Boyndie.

Sheet 75 (Tomintoul)

About 70 square miles have been mapped on hill ground in two main areas, one situated in the north-east of the sheet, the other in the south-west. In the north-eastern area the country surveyed ranges from about 1500 to 2500 feet and extends from upper Glenfiddich eastwards to The Buck and Glenkindie. Hill peat is widespread, especially in the central part of the area. Other soils found include iron and peaty podzols and sub-alpine podzols belonging mainly to the Foudland, Durnhill, Strichen and Insch Associations.

The country surveyed in the south-west of the sheet includes part of Glen Avon and the greater part of the upper catchment area of the Water of Caiplich; Ordnance Survey air photographs on the scale of approximately 2·5 inches to the mile proved satisfactory as a basis for mapping. In the Water of Caiplich catchment area slopes are usually moderate and hill peat is extensive below about 2300 feet, the remaining soils being peaty and sub-alpine podzols belonging principally to the Strichen Association. Glen Avon is more rugged and elevated, with altitudes ranging from 1500 to 3850 feet, and hill peat occupies a much smaller area. The mineral soils are peaty and sub-alpine podzols and rankers belonging mainly to the Countesswells Association.

Sheet 74 (Grantown)

Survey has been started in the Mid-Strathspey and Strathdearn region. Approximately 30 square miles have been mapped in two localities, Abernethy and north-west of Grantown-on-Spey.

The whole sheet area is underlain by crystalline metamorphic rocks of the Moine Series and associated igneous intrusions. Whereas severe glaciation has denuded most of the hill tops, the lower hill slopes and valleys are mantled with thick deposits of fluvioglacial sands and gravels.

Around Grantown stony sandy loam soils, characterized by intense induration, have been identified within the Strichen and Countesswells Associations. Where the schistose rocks have been considerably permeated by granitic material the resultant parent material has given rise to soils of the Aberlour Association. The dominant soils are peaty podzols, although peaty gleys or humic gleys on induration are frequently found below the spring lines.

The Abernethy district consists of a fluvioglacial outwash plain about 730 feet above sea level, which slopes gently from the River Spey towards the Kincardine Hills. These gravel or sandy gravel deposits form the parent material of the Corby Association soils. On the hummocks and ridges which support a natural or semi-natural pine forest the dominant soil is an iron podzol. In depressed sites and on open moorland, however, the dominant soil is a peaty podzol. Most of the kettle-holes have been infilled with peat which may be 20 feet thick. Along the River Spey haughs the alluvium has been differentiated on a textural and drainage classification. A silt capping up to 15 inches thick and overlying poorly drained sand, appears to be associated with old meander channels.

Sheet 47 (Crieff)

The mapping in the two upland districts south of Aberfeldy and east of Killin, described in last year's report, has been further extended by the completion of another 17 square miles of this exceedingly dissected and mountainous terrain. Soils encountered were similar to those described previously and are all included in the Strichen Association. Twelve soil profiles were described and sampled to provide basic information on the range of major soil groups in this highland district, and to assist in an assessment of the effects of minor igneous intrusions and calcareous bands of rock on the dominantly acid Highland Schist parent material.

Sheet 31 (Airdrie)

Some 48 square miles of systematic soil survey, north of the Forth and Clyde Canal, have been completed this year. This includes approximately 8 square miles of the Lennoxtown district which were the subject of a special detailed survey at a scale of 6 inches to 1 mile mentioned under Special Surveys.

The north-western portion consists of the major part of the Campsie Fells and Kilsyth Hills, which are underlain by basic lavas of Carboniferous age, overlooking to the south the drift-covered Kelvin Valley, largely under-

lain by Carboniferous sediments. Mapping has been restricted to the area bounded by the western margin of the sheet from Fintry southward to Torrance and eastward as far as the Kilsyth to Carronbridge road.

The lava hills are predominantly grassy south of the Carron Valley and the vegetation reflects the very heavy annual rainfall of the district, which in the hill area exceeds 60 inches, with several of the higher tops receiving over 70 inches. Altitude ranges from about 300 feet in the Endrick Valley at Fintry, through 700 feet at the surface of Carron Valley reservoir, to over 1800 feet on several of the higher tops. The soil pattern forms an altitudinal sequence of major soil groups and sub-groups from acid brown soils and gleys at the lowest altitudes below 900 feet, through podzolic brown soils to peaty brown soils, peaty podzols, peaty gleys and peats at the higher altitudes, with some of the rocky hill slopes and tops supporting ranker and skeletal soils. Most of the soils will be included in the Darleith Association, although some of the associated morainic soils will be included in the Kirktonmoor Association. There is a high proportion of peat and peaty soils as a direct result of the climatic conditions.

The drift plain below the spectacular lava hill scarp overlooking Lennoxtown and Kilsyth has a drumlinoid appearance, with several large drumlins, innumerable small ones and some similarly shaped basic igneous intrusions in the predominantly boulder clay covered terrain. The boulder clay, lying mainly between 200 and 800 feet, is derived principally from a mixture of Carboniferous sediments (sandstones, shales, coals and occasional limestones and mudstones), with sandstone tending to be the dominant component over much of the area. The soils are predominantly gleys of the surface-water type with associated gleyed brown soils and some acid brown soils, and are included in the Giffnock Association.

The Kelvin Valley has frequent alluvial flats of sandy, gravelly or silty material among the moundy gravel deposits which flank either side of this low ground area between 50 and 200 feet. The soils of the flats are frequently gleyed and intermixed with peaty soils or peat deposits; they have been mapped as undifferentiated alluvium or peat-alluvium complex. The moundy sand and gravel deposits are derived from the neighbouring underlying Carboniferous sediments and lavas and develop free draining acid brown soils which are included in the Darvel Association. The gravels dominate the deposits, and to date the sandy phase has not been found sufficiently important or extensive to separate.

Sheets 43, 44, and parts of 51 and 52 (Island of Mull)

Two periods have been spent on the island; during the first the survey of the northern part of the island was completed, and during the second survey was carried out in the more mountainous southern areas around Loch Buie and the Croggan and Laggan Deer Forests. A total of 65 square miles have been mapped on the island since 1968, mostly complexes of brown forest soils, flush soils and rock (Knockan* complex), peaty podzols, peat and rock (Mishnish* complex), peaty gleys, peat and rock (Airigh*

* Provisional names.

complex) and various small areas of indurated raised beach gravels (Gruline* Association) and estuarine silty clays (Ensay* Association). In the southern area large areas of complexes of rock, flush peat, peat (both deep and shallow) and small areas of peaty gleys and peaty podzols (Cruachan* complex) occur from sea level to 1400 feet where the mountain soils, rock and hagging peats of Drise* complex start to occur. The botanical survey in co-operation with the British Museum (Natural History) has been continued.

Sheet 45 (Oban)

During July and August survey was commenced to the east of Oban. Approximately 30 square miles have been completed. The bedrock is chiefly Lower Old Red Sandstone andesites and conglomerates. Since the latter are derived from the former no differences in soils were found. Drift deposits are very thin but widespread and comprise mixed andesite and granite with some schist, due to the influence of the Loch Etive glacier which overspread this area and had its sources in the hills of the Ben Cruachan granite massif.

Freely drained brown forest soils (Sourhope series) and podzols (Cowie series) have been identified. The gley soils are not similar to those previously described for the Sourhope Association, being considerably lighter in texture (loams and sandy loams rather than clays and clay loams). The soils again occur in complexes and, although it is possible to identify individual soils within a complex, it is rarely possible to map them. The major map units are therefore complexes of brown forest soils, flush gleys and rock (Sourhope* complex), peaty gleys, peat, podzols and rock (Glenamachrie* complex). There are also areas of indurated morainic soils.

The major arable ground of the region is developed upon gravelly raised beaches and kame terraces derived from andesite and granite, giving in the main brown forest soils of the Etive Association on gravel (Etive* series) and on sand (Ardconnel* series).

Sheets 40 and part 41 (Kinross and Elie)

A further 38 square miles have been mapped — 12 square miles on the rising ground bordering the coastal fringe of Fife between Elie and Anstruther, 10 along the Leven Valley between Loch Leven and Markinch and 16 around and to the north of Dunfermline. Twenty-eight soil profiles have been described and sampled during the season, the majority of the pits being dug using a mechanical excavator.

Apart from the seaward edge of the coastal fringe area where raised beach sands and gravels form the parent material of soils of the Dreghorn Association, the major portion of the area surveyed is overlain by glacial till. While Carboniferous sediments are the major rock components of these deposits, the complicated nature of the underlying solid formations has, in many cases, resulted in a somewhat complex series of parent materials. Soils of the Rowanhill Association are dominant, with smaller areas of the Giffnock Association. In the vicinity of the igneous intrusions

which occur throughout the area, the till frequently contains a notable proportion of igneous material and the derived soils have been included in the Hindsward Association; in this area the imperfectly drained Reidston series is most extensive.

Because of the fine texture of the Carboniferous till, the dominant soils are imperfectly drained brown forest soils with gleyed B and C horizons and poorly drained non-calcareous gleys. The frequent occurrence of *Juncus*-infested pasture land and the marked contrast with limited areas which have been drained and reseeded emphasizes the necessity for a sound drainage system of these soils.

The igneous intrusions are mainly of teschenite and of quartz dolerite. The teschenite yields freely drained residual soils of the Darleith series, while the quartz dolerite gives rise to the freely drained Drumain series, first named last season. Further examination of the latter series and comparison with similar soils from other areas suggests the possibility that Drumain might be more correctly included in the Sourhope than in the Darleith Association.

Sheets 32 and 24 (Edinburgh and Peebles)

Field work during the past season has been confined to sampling, revision and correlation. Samples have been taken for routine chemical analysis, bulk density and moisture measurements and micromorphological studies. It has been necessary to re-locate and re-sample some of the 102 profile sites that have been studied within the area during the last eight years for this purpose.

Most of the soil correlation was carried out on the low ground between Penicuik and Biggar, but also extending westwards to Lanark (Sheet 23). Soils of the Mountboy Association have been identified between West Linton and Biggar on drifts derived solely from Lower Old Red Sandstone arenaceous rocks which are rich in lava fragments. Due to the extensive partial sorting of the parent materials, however, these are of coarser texture than the Angus soils and new series will have to be nominated.

Between Stirling and Lanark, soils of the Glenpark series of the Sorn Association have been encountered. Around Biggar, soils of the Sourhope series are associated with those of the Glenpark series, that is, soils from two different associations. This poses a problem of classification. Further north, around Carnwath, Walston and Dunsyre, the drifts are red to pale yellow and correlate with those of the Lanfine Association. Once again there has been considerable sorting of the upper layers of the till and soils with sandy loam surface horizons will have to be assigned new series names. Where there is strongly water-sorted material, soils of the Eckford series occur.

Special Surveys

Lennoxtown Development Area, Stirlingshire. At the request of the Planning Department of Stirling County Council a soil survey at a scale of 1:10,000 was carried out on the 8 square mile Lennoxtown and Milton of Campsie Development Area and a detailed soil map prepared. Addi-

tional maps were derived showing (a) land use capability, (b) soils requiring drainage and (c) depth of topsoil.

Glen Feshie (part of Sheet 64). The survey of the Glen Feshie area was completed by mapping (1:25,000) the remaining 20 square miles and collecting 12 profiles for analysis. Much of the ground surveyed ranges from 3000 to 4000 feet, the soils belonging to the Strichen and Countesswells Associations.

Glen Beg, Morayshire. A detailed survey (1 : 10,000) was carried out on a 5 square mile area for afforestation purposes. The soils are mainly peaty podzols of the Countesswells, Strichen, Aberlour and Corby Associations. A map and report are in preparation.

Cononbank Farm, Inverness-shire. At the request of the Inspectorate of the Department of Agriculture and Fisheries for Scotland, a detailed survey (1 : 2500) was made of 280 acres scheduled for drainage and reclamation. Maps showing (a) peat depth contours and (b) thickness of alluvial overlay were prepared.

Maps, Memoirs and Cartographic Work

Soil maps on a scale of 2·5 inches to 1 mile (1:25,000) for Glenbuchat and Candacraig, Aberdeenshire, and for the Island of Rhum, on the 1 inch to 1 mile scale (1:63,360) for the Black Isle, and on the quarter inch scale (1 : 250,000) for North-east Scotland, have been published.

The final colour proofs for the experimental land use capability maps (1 inch to 1 mile) of Sheets 7/8 (Girvan/Carrick), Sheet 39 (Stirling), Sheets 48/49 (Perth/Arbroath) and the Black Isle have been checked and corrected and the completion of these sheets is awaited. The line copy for the soil map of combined Sheet 1/2/3/4 (Kirkmaiden, Whithorn, Stranraer, Wigtown) has been submitted to the Ordnance Survey for printing and the first colour proof is awaited.

Two maps for which the bulk of the cartographic process work has been done in the department are nearing completion—The Assessment of Climatic Conditions in Scotland, on an approximate scale of 10 miles to 1 inch (1 : 625,000) and The Soils of the Bush Estates, Midlothian, on a scale of about 6 inches to 1 mile (1:10,000). Work is in progress on maps of The Soils of Scotland (1:625,000) and The Vegetation of the Nairn and Cawdor District. It is anticipated that these maps will be printed locally.

The preparation for restricted circulation to advisory officers of uncoloured 2·5 inches to 1 mile field sheets has been initiated, and two sheets are now available; these are Sheets NJ 81 and NJ 91, parts of 1 inch Sheets 77 (Aberdeen) and 87 (Peterhead). Progress on this project has been delayed while alterations were made to the darkroom facilities.

The memoir covering Sheets 7/8 (Girvan/Carrick) has been submitted to H.M. Stationery Office for printing. Bulletins to accompany the Glenbuchat and Candacraig and the Black Isle maps have been prepared. A report to accompany the map of the soils of the Bush Estates is being written.

Vegetation Surveys

The first map for the assessment of climatic conditions in Scotland, based on accumulated temperature and potential water deficit, has been modified, and the units of measurement are now metric. It will shortly be in the hands of the printer. The preparation of a second climatic map, based on the measurements of winter cold and wind pressure, has now commenced.

The account of the vegetation of Sheets 48/49 (Perth/Arbroath) is nearing completion. The permanent vegetation quadrats at Scare Hill, Monymusk, Aberdeenshire, have been remapped, in collaboration with Peat Ecology.

A new system of record cards for vegetation analysis has been designed to facilitate the print-out of tables by computer. A computer programme for this has been written and is now in operation.

Micromorphological Work

Over thirty sites were visited during five weeks' field work, and monoliths were collected for soil thin section work or inclusion in the Soil Library. These included bench mark soils from the Lothians and Borders, alpine and sub-alpine soils from north-east Scotland, and soils developed on Old Red Sandstone from Angus. Over 200 soil thin sections have been produced.

Other Work

Further attention has been given to the transfer of field information to a punched card system. Several computer programmes have been compiled, tested and run on the IBM 1130 computer at the Rowett Research Institute. These include analysis of data from multi-cell field tensiometers, rearrangement of phytosociological array tables and analysis of data required for the production of maps of climatic regions.

Collaboration with Soil Fertility and with the three Scottish Colleges of Agriculture has continued, with advice and assistance given on drainage and improvement schemes and experiments and in the selection of sites for field trials. Soil information was supplied to the Scottish Horticultural Research Institute and the Scottish Plant Breeding Station in connection with their investigations and experiments, and to several local authorities.

Five meetings of the Eastern Border Development Association on the development of horticulture in the Borders and Northumberland were attended. The suitability of soils in the counties of East Lothian, Berwickshire and Roxburghshire for horticultural crops has been considered and an estimate made of the potential acreage suitable for specific crops.

Liaison with the Lands, Inspectorate and Engineering Branches of the Department of Agriculture and Fisheries for Scotland has been maintained. At the request of the Engineering Branch, seven sites for possible estuarial reclamation in the Highlands and Islands were examined and reports submitted.

Co-operation with the Forestry Commission, particularly the Research Branch, has involved talks and demonstrations on soils and survey techniques and visits to a number of forests where soils were examined and discussed.

Requests for soil information and enquiries on the published work of the Survey continue to increase, reflecting the growing awareness of its value.

Lectures and demonstrations on various aspects of the work of Soil Survey have been given to numerous organizations, including the Institute of Landscape Artists, the Hill-land Use and Ecology Discussion Group, and the Department of Geography of the University of Glasgow. Assistance was given to the Biological Records Centre at Monks Wood Experimental Station, the British Bryological Society and the Royal Commission on the Ancient and Historical Monuments of Scotland.

THE SOILS OF EASTERN CAITHNESS

The preliminary summary of the findings in an area in which the survey has been completed deals this year with an area situated wholly within the county of Caithness. It lies to the east of a line extending approximately from Thurso to the Ord of Caithness and covers almost 450 square miles.

The area includes the major part of the Caithness Plain. This is a smooth low tableland formed of Middle Old Red Sandstone sedimentary rocks with an average elevation of about 200 feet in the north-east, rising gently to 600 to 800 feet in the south-west. It can be subdivided into three broad morphological regions: a lower plateau, a middle plateau, and a foothill region. The lower plateau in the north and east lies mainly below 200 feet, but rising from this to just over 400 feet are a few smooth rounded hills. The middle plateau extends from east to west across the country at between 200 and 600 feet, and for the most part is covered in blanket peat. The foothill region in the southernmost part of the Plain again has a general elevation of 200 to 600 feet, but includes ground up to 800 feet; it is more dissected and the drift cover is extremely thin.

The south-west of the area consists of the edge of the Moine Plateau, an extensive region of the Northern Highlands, and is formed of Moine schists together with injection-complex and intrusive granites. It lies mainly between 600 and 1000 feet, but is deeply dissected by the valleys of the Berriedale and Langwell Waters and includes the eastern end of the Scaraben ridge which rises steeply to almost 2000 feet.

The solid rocks of the area are mainly Middle Old Red Sandstone sediments, with granite and Moine schists present in the south-west.

The general succession is:

Upper Old Red Sandstone	Dunnet Sandstones
Middle Old Red Sandstone	John o' Groats Sandstones
	Caithness Flagstone Series
	Barren Red Series
Intrusion of Helmsdale Granite	
Strath Halladale Injection-complex Granite	
Moine Series	Moine Schists

The Moine Schists are regionally metamorphosed sediments and comprise quartzites, mica-schists and granulitic quartz-biotite schists. The Strath Halladale Granite forms part of an injection-complex with the schists,

while the Helmsdale Granite is an intrusion of Newer Igneous Rocks age; these granites are described as mainly pink biotite-granites.

The Barren Red Series forms the basement beds of the Middle Old Red Sandstone in Caithness and it consists of a sequence of unfossiliferous and predominantly red-coloured sandstones and conglomerates with occasional arkoses, breccias and mudstones. The Caithness Flagstone Series comprises a succession of sandstones, mudstones, calcareous flags and occasional limestones. In contrast to other rocks of the Old Red Sandstone formation in Scotland, the Caithness Flags are not red, but vary from pale to dark browns and greys, and the succession is rich in fossil fish remains. The John o' Groats Sandstones are yellow and red calcareous sandstones and they occur in the extreme north-east of the area. The Upper Old Red Sandstone or Dunnet Sandstones, present only at Dunnet Head, consist mainly of pink and yellow unfossiliferous false-bedded sandstones.

The superficial deposits of the area are mainly the various drift deposits associated with the Pleistocene Glaciation. Two main types of till occur. The most widespread is the Shelly Boulder Clay, a dark grey till of moderately fine texture derived mainly from rocks of the Caithness Flagstone Series. It is of variable thickness; the average is some 3 to 4 feet, but deeper sections occur where valleys and bays have been infilled, while on steeper slopes and on higher ground the till may be either thin or absent. The deeper sections are calcareous below about 4 to 6 feet and contain fragments of shells.

The second main type of till consists of brown or reddish brown material of moderately coarse texture derived from the Moine schists, granites, and Barren Red Series sandstones and conglomerates. This till occurs in the south and west of the area. In addition, a trail of moderately coarse textured moraines and associated gravel deposits is present in the northern part of the county.

Recent drift deposits consist of windblown shelly sand, which occurs around the margins of the wider shallow bays, and of alluvium, present along most river and stream channels and at old lake sites. Peat development is extensive and deep blanket bog covers about half the area.

The climate of the area under review is cool and equable. Mean daily temperature for the winter months is 3·9°C (39°F) and for the summer months 11·4°C (52°F). Although winter temperatures are not very low, there is only a slow build up of temperature and winter and spring tend to be rather prolonged. Annual rainfall is fairly evenly distributed throughout the year and averages vary from about 750 mm (30 inches) along the east coast to 900 mm (35 inches) in the west, and from 900 to 1000 mm (35 to 40 inches) on the higher ground in the south. Strong easterly winds are common in spring, while winds from the north-west to north-east sector occur throughout the winter months. Haar is especially prevalent along the east coast during the spring and summer months.

Twenty-nine soil series and five soil complexes have been mapped and they represent the following eleven soil associations:

Association	*Parent Material*
Berriedale	Drift derived from Middle Old Red Sandstone Barren Red Series sandstones and conglomerates
Braemore	Drift derived from Middle Old Red Sandstone Barren Red Series mudstones
Canisbay	Drift derived from Middle Old Red Sandstone John o' Groats Sandstones and Caithness Flagstone Series strata
Corby	Sand and gravel derived from granite and Moine schists
Countesswells	Drift derived from granite
Dunnet	Sandstones of Upper Old Red Sandstone age.
Durnhill	Drift derived from quartzite
Fraserburgh	Shelly sand
Shielton	Sand and gravel derived from Middle Old Red Sandstone Caithness Flagstone Series strata
Strichen	Drift derived from Moine schists
Thurso	Drift derived from Middle Old Red Sandstone Caithness Flagstone Series strata

In addition, thin peat, deep peat, alluvium, peat-alluvium complex and mixed bottom lands have been delineated.

The soil series mapped represent six major soil sub-groups, of which the most widespread are non-calcareous gleys, peaty gleys and peaty podzols. Brown calcareous soils, brown forest soils and humus-iron podzols are of limited occurrence.

The Thurso Association is the most extensive in the area. It comprises soils developed on parent materials derived from rocks of the Caithness Flagstone Series. The dominant soil, Thurso series, is a poorly drained non-calcareous gley which is developed on till of sandy clay loam texture, and it forms the main arable soil of much of the Caithness Plain. Profile morphology in the Thurso series is typically that of surface-water gleys; grey colours predominate, with associated coarse ochreous and pale brown mottling, while structure in the B_2g horizon is usually coarse prismatic, the ped faces having grey sandy coatings. Texture in the B and C horizons is generally in the sandy clay loam class, the clay content being between 20 and 25 per cent, although the overall range of clay in soils sampled is from 17 to 30 per cent.

Analyses usually indicate exchangeable cations to be at medium levels, although high amounts of exchangeable calcium are occasionally recorded in some C horizons. Similarly, pH values are slightly acid, generally pH 6 to pH 6·5 in the S horizon increasing to pH 7 in the C horizon, but where calcareous till is encountered at the base of the soil profile, pH 8 is usual, with values for exchangeable calcium of up to 45 me/100 g being recorded. Total P_2O_5 is generally very low in the B and C horizons, values recorded being in the order of 40 to 80 mg P_2O_5/100 g.

Olrig series, a peaty gley also developed on till, is less extensive, and it

occurs under a wet *Calluna* moor vegetation. The profile is characterized by a peat horizon, a dark brown organic-stained A horizon immediately below, a grey-brown A_2g horizon with a few drab mottles, and a B_2g horizon of blocky or prismatic structure with frequent ochreous mottles occurring within the peds. Some of this series has been reclaimed, in which case there is a dark coloured humose loam S horizon replacing the peaty horizon. Otherwise the original profile features are largely retained. Uncultivated peaty gleys have pH values which increase from about pH 3·9 to 4·5 in the organic surface horizon to pH 5 to 5·5 in the C horizon, while cultivated versions have a higher value, between pH 5 and pH 6, at the surface. Total P_2O_5 content is usually low throughout the profile, and amounts recorded are similar to those in Thurso series.

Bilbster series is a freely drained soil which has been derived from a peaty podzol by cultivation. It is developed on moundy moraines and on thin drift usually associated with steep slopes or rock ridges. The main feature of the profile is the presence of a strongly indurated horizon immediately below a 6 to 8 inch S horizon. Typically the indurated layer is brown or yellowish brown loam or sandy clay loam, with sandy loam textures occurring on the moraines. Coarse platy structure, sometimes with iron staining present on the faces, is usual, and an iron pan or trace of one frequently occurs on the upper surface of the indurated material. The induration decreases in intensity with depth. Low levels of exchangeable calcium generally occur in B and C horizons, while pH values are strongly to moderately acid throughout the profile. Total P_2O_5 is moderate to low.

Camster series, a peaty podzol, is mainly developed on thin drift of sandy loam texture with rock present at 24 inches or less, but it also occurs on moraine mounds. Vegetation is usually a wet *Calluna* moor. Profile characteristics are an organic layer at the surface, a thin A_2g horizon, an iron pan, occasionally a friable B_2 horizon, and an indurated B_3 horizon. The reaction in the organic horizon is about pH 4 or slightly more, while the mineral horizons vary from about pH 4·6 in the A_2g horizon to over pH 5 in the B_3 and C horizons. Below the organic horizon the values for exchangeable calcium are less than 0·01 me/100 g.

Rock is frequently encountered within profile depth in all the soil series of the Thurso Association. Occasionally extremely shallow soils occur and in particular a profile consisting of a 6 to 8 inch S horizon overlying rock is often present in areas of Bilbster series.

Soils of the Canisbay Association are developed on reddish brown drift derived from rocks of the John o' Groats Sandstones with some admixture of Caithness Flagstone Series. Textures are usually in the sandy loam to sandy clay loam range. Canisbay series, the dominant series, is a peaty gley, much of which is under cultivation, and Warth series is a peaty podzol. These soils are of minor extent, and occur only in the extreme north-east of the county.

Soils of the Fraserburgh Association are developed on windblown shelly sand deposits which occur locally around some of the bays. They are

characterized by extreme sandiness, loose consistence and high pH. Fraserburgh series, a brown calcareous soil, occurs on freely to excessively drained low stable dunes, usually under a pasture vegetation containing *Festuca rubra*. Below the dark brown A horizon of sand and organic matter there is a brown B horizon and a slightly paler-coloured C horizon. Whitelinks series is a calcareous groundwater gley and it occurs where there is a drainage impedance due to underlying till or peat at 3 feet or so. Characteristic of this profile are a Bg horizon of brown sand with coarse rusty mottles and a Cg horizon of wet grey sand. Vegetation is commonly a pasture rich in plant species. In addition, skeletal soils under marram grass occur on unstable sand dunes.

Analyses of soils of the Fraserburgh Association indicate that the pH may be variable in the surface horizons, values from pH 6 to pH 7·5 being recorded, while in the lower horizons the pH is always high, ranging up to pH 9. Exchangeable calcium in the lower horizons is usually at levels between 30 and 60 me/100 g, while total P_2O_5 is at very low levels throughout the profile, amounts present usually ranging from 30 to 60 mg P_2O_5/100 g.

Soils of the Dunnet Association occur on the Upper Old Red Sandstone sandstones of Dunnet Head. They are peaty podzols, and are developed on soft friable sandstones. Texture is in the loamy sand class, and a characteristic feature of the profile is the black layer of humus-stained material towards the base of the A_2g horizon. Sometimes hard sandstone occurs within profile depth.

Soils of the Corby and Shielton Associations are developed on the sand and gravel deposits which are of minor extent and occur in the lowland part of the area. Peaty podzols with iron pan are the dominant soils.

Soils of the Strichen and Countesswells Associations are developed on moderately coarse and coarse textured drifts derived from Moine Schist (Strichen Association) and granite (Countesswells Association). In both associations the dominant soil is a peaty podzol which occurs on moderate to steep slopes under a wet *Calluna* moor vegetation. Profile features are those of the typical peaty podzol, namely, a peaty surface horizon, a well-developed A_2g horizon, a thin iron pan, and an indurated B_3 horizon. The pH is about 4 at the surface, and increases down the profile to about 5 to 5·5, while amounts of exchangeable bases are low.

In the Countesswells Association, humus iron podzols occur locally under birchwood on steep valley slopes, while in the Strichen Association there is a limited occurrence of brown forest soils developed under acid grassland, also on steep slopes.

In the Durnhill Association, only one series occurs. This is a montane podzol and it is developed in frost-shattered quartzite debris under a *Rhacomitrium* or *Calluna*-lichen heath.

Soils of the Berriedale Association are developed on reddish brown drift derived from the sandstone and conglomerates of the Barren Red Series. Berriedale series, a peaty podzol, is the dominant series and occurs as drift of sandy loam texture. Strong induration immediately below the iron pan

is a feature of this series. A brown forest soil and a cultivated podzol are also developed on this parent material. On till of sandy clay loam texture, peaty gleys and, less frequently, non-calcareous gleys occur.

Soils developed on drift derived from fine sandstones and mudstones of the Barren Red Series are grouped into the Braemore Association. The textures of the soils are clay loam or clay, and colours in B and C horizons vary from reddish brown to weak red. A peaty gley is the dominant soil, but a non-calcareous gley and a peaty podzol also occur. Soils of this association are only local in extent.

Peat is extensively developed and probably covers half the area. Most of it occurs as deep blanket bog (>36 inches) which forms the continuous and unbroken stretches over much of the central and western districts, where it is associated with the formation of dubh-lochans and flowe features. Commonly it supports a *Calluna-Eriophorum-Trichophorum* moor. The pH values range from pH 4·3 to 4·6 at the surface to pH 4·6 to 4·9 at about 36 inches.

Shallow peat (18-36 inches) occurs on steeper slopes, generally under a wet *Calluna* moor, and flushed peat occurs along stream channels where it usually supports a *Juncus*-rich pasture.

Farming in the area is predominantly of the upland stock rearing type. The main arable belt lies between Wick and Thurso where the larger farms occur, while smaller holdings and crofts are found along the east and north-east coast. Oats accounted for most of the cereal acreage until five years ago, but now more barley is being grown, particularly on the better ground. Although the growing season is short, reasonable crop yields can be obtained; average yields are: oats, 24 to 27 cwt/acre and barley, 30 cwt/acre. Except on very large farms where cereal cropping is an economic venture, there is a move away from cropping to grass. Hay and silage is cut later than in districts farther south, but yields of 30 to 40 cwt/acre for hay and 5 to 7 tons/acre settled silage are nevertheless common. The basic crop rotation is oats, oats, roots, oats undersown followed by four or five years of grass, although the second oat crop is going out and roots are sometimes being replaced by grass.

The main farming income is from sheep, the breeds being the North Country Cheviot and the Half-bred. A large acreage of hill land or outrun is used in conjunction with the arable ground; there are only a few hill farms proper in the area. Stocking is at the rate of one ewe per arable acre.

The trend in cattle is towards the weaned calf market. Dairying is declining in importance, the tendency being for smaller units to go out and bigger ones to increase in size.

Forestry is of minor extent. The Forestry Commission have one sizable plantation at Rumster, where the dominant species are lodgepole pine and sitka spruce, planted on organo-mineral soils and peat. In addition, there are one or two very small blocks in the area which have been planted for shelter or for experimental purposes. Otherwise, the area is extremely sparsely wooded with only occasional belts of hardwood species which were planted last century for shelter around the large estate properties.

SPECTROCHEMISTRY

In laboratories concerned with trace element investigations on soils, plants and related materials, direct reading, emission and absorption methods of spectrochemical analysis are being increasingly employed. Related techniques, such as X-ray fluorescence, appear to have only limited applications for the determination of trace elements at the levels occurring in agricultural materials. Spark-source mass spectrometry, however, is capable of lowering the limits of detection of elements already being determined spectrochemically and would also permit the detection of other elements of biological importance.

The application of the multi-channel direct reader installed in 1968 to the determination of trace elements in non-conducting powder samples such as the ashes of plant materials, soils and chemical concentrates derived from plants and soil extracts is proceeding satisfactorily. The limits of detection and determination are generally as good as those by the spectrographic methods previously employed. As the punched tape output from the direct reader has not yet been installed, time-consuming transference of the typed output to card or tape suitable for the IBM 1130 computer at the Rowett Research Institute is still necessary.

A period of four months was spent in the department by Professor Cyril B. Smith of Pennsylvania State University, who studied the methods employed for the determination of trace elements, especially in plant materials, and investigated the use of synthetic powder standards for the alternating current arc rotating-disk method for the analyses of plant ashes in place of the normally employed analysed standard plant materials. Dr A. Walsh, F.R.S., of the Division of Chemical Physics, C.S.I.R.O., Australia, visited the department for one week, during which fruitful discussions of possible developments in atomic absorption and fluorescence were held. He also gave a talk at the Institute on these developments, at which most of the users of these techniques in the north-east of Scotland were present. Numerous other visitors from Britain and overseas have spent short periods in the department, mainly for the study of techniques involved in emission, atomic absorption and infrared spectroscopy.

Various members of staff have presented papers at conferences concerning either the spectrochemical determination of trace elements or their application to nutritional problems. Three international conferences have been attended: Dr R. O. Scott and the Director presented papers at the Fifteenth International Spectroscopy Colloquium in Madrid[65, 66]. Members of staff gave lectures at the International Symposium on Trace Element Metabolism in Animals, held in Aberdeen[67, 68] and at the International Atomic Absorption Spectroscopy Conference at Sheffield, at which a short paper on the determination of molybdenum was presented. Other lectures by members of staff were to the 131st Annual Meeting of the British Association for the Advancement of Science, at Exeter, and to a Conference on Modern Analytical Techniques: Ceramics and Geochemistry, at Leeds.

Trace Elements in Soils, Plants and Biological Materials

While no significant changes have been made in the laboratory methods for assessing soil status, many of the research soil samples have been analysed for EDTA-soluble trace elements as well as for those more usually determined in acetic acid or ammonium acetate extracts. In view of the various plastic and other synthetic materials now commonly employed both during the production and during the preparation, storage and analysis of samples of agricultural interest, many of these materials have been analysed for contaminating metallic impurities. Practically every material was found to contain one or more metals of biological importance, including copper, zinc, lead, magnesium, cadmium, chromium and titanium, while one adhesive embossing tape contained a significant amount of molybdenum. It should be emphasized that in trace element investigations any such materials being employed should be checked for undesirable metal content prior to use. These possible sources of contamination were discussed in one of the above-mentioned papers[67].

Soils and Soil Parent Materials. Six further profiles with iron or other pans have been examined, in addition to the nine reported last year. One of these profiles, developed on trachyte and rhyolite, has a manganese pan containing 3 per cent total manganese and is of particular interest in that the pan shows also a marked accumulation of cobalt but not of nickel. The contents of EDTA-soluble manganese, cobalt and nickel confirm other indications that manganese and cobalt can be associated in the same mineral form, as similar findings have been reported in manganese nodules and concretions in some Australian soils. The previously reported study of the manganese-rich minerals lithiophorite and cryptomelane from the Lecht Mines, Tomintoul[49], has been submitted for publication and a general paper on trace element balance in soils[15] has appeared. Another general paper[69] is still awaiting publication.

Trace element studies on soils and selected soil profiles from areas sampled by the Soil Survey of Scotland have been continued, those from the areas covered by Soil Survey Sheets 57 (Forfar), 66 (Banchory) and 67 (Stonehaven) being nearly completed.

Soil Status and Plant Uptake. The analyses of samples examined in collaboration with Soil Fertility from areas where animal or plant nutritional disorders are suspected have continued on a scale similar to that of previous years. With the increasing experience available regarding such problems, many of these samples require to be analysed for only a limited number of elements and, as described later, techniques are being investigated for more rapid determination of these. Research samples analysed on behalf of Soil Fertility have been mainly from a field experiment designed to test the effect of change in soil pH on the trace element content of such agricultural crops as pasture species (rye grass, cocksfoot and clover), cereals (oats and barley) and root crops (swedes and potatoes). Ammonium acetate-, acetic acid- and EDTA-soluble trace elements in the soils associated with the experiment

have also been determined. In conjunction with Soil Fertility, an investigation has been started to examine more fully the effect of soil drainage conditions on the trace element uptake by pasture species growing on a range of soil types. Studies have continued on the increases in the apparent lead content of vegetation that occur in winter, and in the second season it has again been shown that cloche-protected herbage shows smaller increase in the lead content than unprotected herbage. As part of a longer term investigation of the lead content of various plants, analysis of cocksfoot from a sand culture experiment has continued. Ways in which plant trace element contents are affected by factors other than soil conditions have been described[68].

Other collaborative work has included the examination of radish, red-beet, sugar-beet, carrot and lettuce from the National Vegetable Research Station, pasture from the National Agricultural Advisory Service, taro and yam from Tahiti, sugar-cane from the Sugar Industry Research Institute, Mauritius, and lucerne from the Animal Health Research Centre, Uganda.

Spectrochemical Methods of Analysis

Few changes have been made in the basic methods of analysis employed, although work is nearing completion on both the transference of the direct current arc methods from spectrographic to direct reading and the greater employment of flame methods for the determination of such elements as copper, magnesium, manganese, molybdenum and zinc.

It is occasionally more convenient to employ non-spectrochemical techniques, and during the year the determination of chloride by means of a specific-ion electrode has been investigated. Work has continued on the spectrofluorometric determination of selenium.

Arc Emission. For the determination of trace elements in ashed plant materials a carbon cathode of external diameter 3·18 mm and bore 1·6 mm diameter by 5·5 mm deep is now being employed. A 9 amp direct current arc with 10 mm gap is used, the ash : K_2SO_4 : carbon-powder ratio of 1 : 1 : 2 being the same as with the wider, shallower cathodes previously employed. The coefficients of variation for the unreplicated determination of the elements with a single narrow type electrode are almost as good as those from the duplicate exposures previously used, while there is a very considerable saving in time.

The cathode ray display microphotometer continues to be employed in the arc spectrographic determination of very low contents of several elements, notably cobalt, lead and molybdenum, in soils, plants and chemical concentrates derived from plants and various types of soil extracts.

Direct Photometry. Various modifications have been made to the Hilger and Watts E789 3-metre Polychromator installed last year to improve its performance for cathode layer direct current arc methods of analysis. It has not yet proved possible to determine caesium using the 8521Å line, as no suitable infrared photomultiplier has been found. Some problems have arisen with the use of second order lines, especially Zn 2138Å and Be

2349Å. Quartz cells filled with bromine vapour have proved suitable as filters, passing the zinc and beryllium ultraviolet lines and rejecting coincident first order visible light. A description of this, along with some other modifications and applications, has been submitted for publication[65]. The report of the use of a double-exit slit for the easily reversed K 7665Å line[16] has now been published.

The determination of copper, manganese, iron, barium and strontium in plant ash is now being carried out by means of the Hilger and Watts E789 Polychromator, using the narrow bore carbon cathode electrodes described above. The simultaneous determination of other elements such as molybdenum, nickel and lead when present at abnormally high levels is being investigated. The transfer of this method from spectrographic to direct reading has entailed a detailed study to establish the calculations required for background correction, especially for the determination of elements near their detection limits. For instance, a change in the calcium content of a plant ash from about 2 to 20 per cent Ca causes an apparent increase of the copper content (using Cu 3274Å) of about 50 ppm, and correction must be applied. The transfer of other arc emission methods for the determination of trace elements in soils and in chemical concentrates of soil extracts and plant materials to the direct reader is proceeding, and the use of palladium and indium as internal standard elements is being investigated.

The complex calculations required to convert the output data of the Polychromator to the trace element content of a sample have demonstrated the necessity for a digital computer of similar size to the IBM 1130 at the Rowett Research Institute. One programme written in the department has been to enable functions representing sigmoid working curves to be evaluated[17].

The small and medium direct readers described in earlier reports continue to be used for porous-cup solution-spark and triggered alternating-current arc methods of excitation. The calculations required for the rotating-disk analysis of plant ash for a number of elements are now being carried out by computer.

Flame Emission. During the year about 27,000 samples have been analysed for calcium and potassium and 13,000 for sodium, using the laboratory-built three-channel flame photometer. A historical review of the development of flame techniques[18] has now been published.

Investigations into the use of various types of burners and gas mixtures have been carried out. A nitrous-oxide : butane flame used in conjunction with a 10 cm long Techtron (AB 41) air : acetylene burner has proved advantageous for the flame emission determination of calcium and magnesium, with limits of detection of better than 0·1 ppm. Interference from any phosphorus present in samples is negligible, while that from aluminium is less than with an air : acetylene flame. Lower limits of determination of some elements have been achieved by the use of a separated flame, which is produced when silica side-plates are fitted parallel to the long slot of an atomic-absorption type burner. An air : acetylene flame of this type has proved safe

and reliable, but nitrous-oxide:butane and nitrous-oxide:acetylene combustion mixtures tend to overheat the burner top and a water-cooled top is being tested.

Atomic Absorption and Fluorescence. The determination of copper, zinc and manganese directly in EDTA extracts of soils by atomic absorption, employing a separated air:acetylene flame, has been compared over a period of some six months with their determination by the more time-consuming porous-cup solution-spark method. Results show satisfactory agreement; for zinc the atomic absorption technique is both more sensitive and more accurate than the spark method employing the Hilger medium direct-reader.

A flame method for the determination of molybdenum in ammonium-acetate extracts of soil is being developed. A preliminary concentration of the molybdenum from the soil extract is carried out by extraction with tri-n-octylamine in petroleum ether, followed by transference of the molybdenum to an aqueous solution by the action of gaseous ammonia. A limit of detection of 0·1 ppm Mo is achieved with a nitrous-oxide:acetylene flame, using either flame emission or atomic absorption. With a laboratory-built, integrating, two-channel flame photometer in which the cyanogen band head at 3862Å is employed as a form of internal standard for the Mo 3903Å line, increased precision and limit of detection as compared with single beam operation has been achieved.

A microwave power supply unit with two resonant cavities is being used to investigate the possibilities of microwave-excited electrodeless discharge lamps as atomic absorption and atomic fluorescence light sources. Although the intensity produced by these lamps is very high, difficulty has been experienced in obtaining sufficient long-term stability to enable them to be used in routine applications.

Absorption Spectrometry of Soil Constituents

As collaborative work with Microbiology and Biochemistry has led to the development of infrared spectroscopy as a powerful tool for characterizing the components of the cell walls of fungi and yeasts, and for tracing the course of lysis of these walls, it may be useful to summarize here the peculiar contributions of the technique in this field. Not only can the common constituents of such cell walls—glucan, chitin and melanin—be readily distinguished by their infrared spectrum, but the various types of glucan differing only in the type of glucose-glucose linkages can also be distinguished. Generally, minor glucan components in a wall containing a mixture of different glucans can only be recognized after isolation by chemical or biochemical procedures, as in the recognition of a $\beta(1\rightarrow6)$ glucan as a component of yeast cell wall[19]. But α-glucans can be recognized in the presence of β-glucans, and this has proved of value in following the lysis of soil yeasts which contain both α- and β-glucans in their walls[20]. The advantages of the infrared technique include the small size of sample required, the speed with which results can be obtained and the ability of the technique to reveal the presence of totally unexpected constituents.

Other cooperative studies in progress include the examination of soil organic matter fractions (with Biochemistry) and the characterization of soil phosphate fractions (with Soil Fertility); this work has led to the identification of inorganic pyrophosphate in soils[21]. Collaborative work with Pedology on imogolite, a partially ordered aluminosilicate found in volcanic ash soils, has now been published[3]. This material promises to be suitable for studies on the surface properties of the allophanic family of aluminosilicates, which often predominate in the clay fraction of Scottish soils. Studies on the interaction of ammonia with imogolite and vermiculite, now in progress, have been facilitated by the adaptation of a highly sensitive colorimetric method for determining ammonia. A note on the use of this procedure to measure cation exchange capacities of clay minerals[70] has been accepted for publication.

Other soil minerals which have been intensively investigated include biotite and amphiboles, and this work has contributed to studies on the weathering of these minerals carried out in Pedology[47]. A discussion of the use of infrared spectroscopy to detect the reactivity of montmorillonite surfaces with weak organic bases[71] has been accepted for publication. Two reviews[4, 22] of the application of infrared spectroscopy to characterize clay minerals, mentioned in last year's Annual Report, have now been published, but a third more extensive treatment[72] still awaits publication.

BIOCHEMISTRY

In October 1968 Dr H. A. Anderson and Dr D. J. Linehan joined the staff of the department. Dr Linehan, who came from the A.R.C. Food Research Institute, is to develop biochemical studies of aseptically produced plant material, especially that derived from roots. Dr Anderson, formerly I.C.I. Fellow in the Department of Organic Chemistry at Liverpool University, is continuing some of the late Dr R. I. Morrison's work on soil lipids, and will use some of the powerful analytical methods now becoming available to re-examine some aspects of the chemistry of humic substances.

Metabolism of Carbohydrates in Soil

The department has a continuing interest in the origins of the organic fraction of soils. It is possible to speculate about this from a knowledge of its chemistry and of the chemistry of the various residues of living organisms that enter the soil (*see* Annual Report 1959/60), but in the long run speculation is no substitute for direct experimentation.

One difficulty here is the time-scale of the processes involved. At Rothamsted it has been found that when ryegrass, labelled with radioactive carbon, is incorporated into soil it first undergoes rapid decomposition, the decay curve suggesting a half life of 100 days or so; later the process slows down and a half life of the order of four years may be calculated. The organic matter in the top 23 cm of the unmanured plot of the Broadbalk continuous wheat experiment has a mean residence time of about 50 years, assuming that all fractions behave alike, but radio-carbon dating gives a figure of 1400 years.

It is therefore clear that, among the chemical transformations involved, some must be very slow and thus difficult to follow adequately in a single human lifetime. However, it has recently been possible, with the help of Dr D. S. Jenkinson, Rothamsted Experimental Station, and Professor R. D. Haworth, University of Sheffield, to examine humic acids from soil samples collected more than 80 years ago. The electron spin resonance signal from one of these samples provided evidence for a change in this property of the humic fraction since the plot concerned was allowed to revert to wilderness in 1883.

If radioactively-labelled whole plant material is added to soil, label may be found at once in all the classical fractions of soil organic matter (humic acid, fulvic acid, etc.) and interpretation of subsequent change is difficult, so a series of experiments in which relatively simple substances have been added to moist soils under laboratory conditions has been carried out, and the appearance of label has been followed in specific, identifiable constituents of the organic matter fraction. Because of the long experience of soil carbohydrates in the department, the sugars of the soil polysaccharide fraction have been examined particularly. Some reference to preliminary work has been made in previous Annual Reports (No. 35, 1964/65; No. 37, 1966/67).

When a labelled carbohydrate (glucose, xylose, starch) is added to soil, far more of the label appears in soil carbohydrates than is the case when a non-carbohydrate (acetate) is used, suggested that the sugars are not fully degraded before being rebuilt into microbial polysaccharides. As would be expected, a large part of the added material is oxidized completely and lost as carbon dioxide. Of the remainder the biggest proportion is found in glucose, and this is true even when another sugar (xylose) is added. Of the six other sugars commonly found in soil hydrolysates two hexoses, mannose and galactose, acquire significant amounts of label, but the pentoses, arabinose and xylose, do not. The methyl pentoses, fucose and rhamnose, also became labelled, but not as strongly as the hexoses.

This pattern of labelling was found originally with starch and glucose added to a soil from the Countesswells series, derived from acid igneous parent material and having an acid pH (4·6), and it seemed possible that it reflected conditions favourable to fungal growth[23]. However, the same soil limed to pH 7·5 gave a similar result.

Further, the addition of a labelled pentose (xylose) to this latter soil, or to an Insch series soil (pH 5·7), derived from a basic igneous rock, led to a rapid disappearance of label from xylose, and the establishment of a pattern similar to that found with glucose. It would thus seem that this pattern is characteristic of the microflora established when easily-metabolized carbohydrate is added to soil. The presence of pentoses in the soil polysaccharide fraction could be the result of the failure of the soil microflora to metabolize some pentose-containing polysaccharides of higher plants. Experiments are at present being designed to test this hypothesis. Alternatively the soil pentose might be a product of much slower microbial processes; the transformations referred to here are relatively quick, taking only a few days when glucose is the substrate, and a month or so with starch.

It does not necessarily follow that these fast transformations are of less importance than long-term ones, because there is some evidence that the improvements in soil structure conferred by additions of organic matter and attributed to polysaccharides are seen chiefly during the first year after their application.

Other evidence has recently been obtained which at first sight supports the idea that plant material may persist relatively unchanged in the soil. A chromatographic investigation has shown that the hexuronic acid mixture liberated by acid hydrolysis of the soil polysaccharide fraction consists mainly of galacturonic acid, with smaller amounts of glucuronic. The most likely source of the galacturonic acid is the pectic fraction of the plant cell walls. Two minor sugar components recently identified, 2-0-methyl and 3-0-methyl xylose, are both likely to be of plant origin[24]. If this was the case they would not be expected to acquire label in the experiments described above, but unfortunately the techniques so far employed are not sensitive enough to measure radioactivity in the very small amounts of sugar involved.

Other Research in Progress

The imino acid, L-hydroxyproline, stimulates the growth of segments from

pea roots, but simultaneously inhibits protein and nucleic acid synthesis. This phenomenon is being investigated further in collaboration with Plant Physiology, using radioactive proline and hydroxyproline, on the assumption that the synthesis of cell-wall protein is involved.

Work has continued on the effects of humic acids and fungal pigments on the metabolism of root tissue[25].

Studies of the enzymic degradation of fungal cell walls have been continued in collaboration with Microbiology[19, 20, 26].

Both this department and Plant Physiology have for some years been interested in copper deficiency in plants, particularly in relation to the binding of copper in soils of high organic matter content. A paper with a direct bearing on this problem, based on earlier work by Dr Cheshire with R. I. Davies and I. J. Graham-Bryce, has recently been published in the Journal of Soil Science.

In collaboration with Microbiology a fluorimetric method for the determination of nucleic acids has been used to follow the production of nucleases by a soil myxobacterium[75].

Visiting Workers

As mentioned above, the successful identification of two xylose derivatives in the soil polysaccharide fraction, to which Mr J. -F. Bouhours made a substantial contribution in 1967, has been published[24].

Mr F. Megusar, of the University of Llubljana, contributed to the symposium of the International Atomic Energy Agency on Isotopes and Radiation in Soil Organic Matter Studies, held in Vienna in 1968. His paper, on the depressing effect on mineralization caused by the addition of mineral nitrogen to soil, was based on his work in this department in 1967.

PLANT PHYSIOLOGY

Fundamental aspects of absorption of trace and major elements by plant roots and tissues constitute the major research interests of the department. The ultra-structure of plant tissues is assuming increasing importance in the work in hand.

Collaboration continues with a number of other departments within the Institute as well as with outside bodies. Members of staff presented papers to a joint meeting of the Agriculture and Pesticides Groups of the Society of Chemical Industry[50] and to an Edinburgh Botanical Society Symposium.

Copper Deficiency in Oats grown on Peat

Further work has been carried out on copper deficiency in oats induced by nitrogen fertilization of peat in pot culture. Anatomical investigations of copper-deficient plants have shown numerous tillers and also buds developing at the nodes. The nodes contain more copper than the internodal tissue, but the buds contain very little copper and soon cease growth. Investigations of the stem in copper deficiency showed that the growing point does not abort at an early stage, but a number of nodes are formed with no terminal inflorescence,, the stem tissue dying back and producing a typical white tip. Electron micrographs of copper-deficient leaves show chloroplasts well filled with stroma, but few grana, all of which are located to one side of the plastid. Other chloroplasts display arrested development. None of these features is visible in oat plants with adequate copper. Investigations of the enzyme content of such plants showed that no copper-containing enzymes could be detected in leaves of copper-deficient oat plants, whereas they were easily detected in leaves of plants with adequate copper.

Iron could be found in the protein of copper-deficient oat leaves separated on Sephadex columns, but not in similar separations of copper-sufficient leaves. Using wheat leaves grown with ^{59}Fe, iron could easily be demonstrated as a component of leaf proteins, and this technique will be employed in subsequent studies. The proteins of the potato were also studied on Sephadex columns. Separations between copper-containing, iron-containing (phytoferritin) and molybdoproteins could be repeatedly achieved. These fractions showed polyphenolase, peroxidase plus catalase and xanthine oxidase plus nitrate reductase activity respectively. Preliminary reports[27, 28] of some of this work have appeared.

A batch of wheat containing ^{59}Fe was successfully grown for experiments in human nutrition, in collaboration with the Epidemiological Research Unit (South Wales). Although the bran contained twice as much iron as the flour per unit weight, specific activities were similar, indicating similar pathways. The phosphorus distribution was similar to that of iron, indicating that iron is probably bound to a phosphoprotein.

Recently attention has been focused on the importance of chelating agents of low molecular weight in the absorption of iron. Using the duckweed *Lemna gibba* in sterile culture, it has however been found that chelates such

as salicylic acid and galactose may profoundly affect growth. A paper on the toxicity of D-galactose to *L. gibba* was presented at the Edinburgh Botanical Society Research Symposium at Ayr in September.

A collaborative study of a soil toxicity on lucerne, commenced by Dr DeKock while on leave of absence in Canada, has been accepted for publication[94] and his studies on nitrogen metabolism of tobacco, carried out at the University of California in Los Angeles, are also to be published[95].

Ion Flux Studies

Further examination of influx and efflux of chloride ions in cells of potato tuber disks, begun last year, has been frustrated by a widespread tendency of tissue from the current year's crop to become flaccid during aging. It was found that this newly encountered problem could be eased by adding 0·1 mM $CaSO_4$ to the KCl incubating solution. However, this measure could not be wholly relied upon to maintain the tissue in a healthy condition, and it became impracticable to continue meaningful studies. This work will continue with the new crop.

Onion roots have been used successfully for the study of ion fluxes at cellular level. By the addition of 1 per cent sucrose, onion root segments can be maintained in a phase of high (linear) ion absorption rate for a sufficient time to enable satisfactory study of influx and efflux in the manner described in an earlier report. A second paper[96] describing similar work with pea epicotyls, carried out in the Department of Botany, Washington State University, in 1967, has been accepted for publication. Construction of improved equipment to further studies of the electrochemical aspects of ion transport has been completed.

Ion Absorption and Protein Synthesis

A paper, referred to in last year's report, characterizing amino acid incorporation by beet storage tissue ribosomes[29] has been published. Ribosomes are the protein synthesizing particles within the cell, and in an attempt to assess the directness of the relationship between protein synthesis and ion absorption the effect of some recently available antibiotics has been tested on these processes. Because of their inhibitory properties, these antibiotics, which include lincomycin, spectinomycin and cycloheximide, are valuable for identifying the operation of different metabolic pathways; their usefulness, however, is dependent on their specificity, that is to say, if they are known to interfere with several metabolic processes then obviously it is impossible to conclude that any given pathway is more involved than another. Because of the apparent absence of side effects, cycloheximide has until now been the preferred inhibitor of protein synthesis in plants, but when tested on beet storage tissue disks it was found to stimulate oxygen uptake, suggesting that it may interfere with energy transfer. A preliminary report of this work[30] calling into question the specificity of cycloheximide as a protein synthesis inhibitor has been published, and further experiments are in progress. Its effectiveness as an inhibitor of ion absorption processes has been studied in some detail, and it would appear to be inhibitory to ion

absorption in all but green tissue. This finding has led to the initiation of some comparative studies on the absorption of both organic and inorganic ions by leaf and root tissue.

Radioactivity

Measurement of the distribution of tritiated water in peat and water movement studies has been continued until after more than twelve months from the date of placement. Work with Soil Fertility involving the measurement of ^{32}P to determine L values in soils in pot experiments has now been facilitated by adoption of the Čerenkov method in which counting can be done in an automatic sample change scintillation counter. This method has the advantage of ease of sample preparation over the usual precipation method as magnesium ammonium phosphate, with which comparisons have been made. A barium isotope method for cation exchange capacity of soils has been investigated in Soil Fertility. A paper has been published on collaborative work with Biochemistry[23], and work with the Rowett Research Institute for which ^{65}Zn labelled ryegrass was produced has been accepted for publication[81]. Joint work with Soil Fertility on the cation exchange capacity of plant roots is being prepared for publication.

MICROBIOLOGY

The general aim of the work of the department is to obtain a deeper understanding of the role of micro-organisms in the organic matter cycle in soil and of their effect on the roots and on the healthy development of higher plants of economic importance. For this purpose it is necessary not only to study material taken directly from the field but also to develop and improve techniques used in the laboratory. In addition, because of their predominance in a particular soil or plant rhizosphere or because of a special interest arising from their characteristics, micro-organisms have often to be investigated in detail in relation to their isolation, cultivation, ultrastructure and production of enzymes or metabolic products. Further work is then necessary to determine the factors which influence their function, establishment and survival in the soil or rhizosphere, a more complex study but extremely important if understanding of the activities of soil micro-organisms in their micro-habitats is to be achieved. Collaboration is being maintained with other departments of the Institute and is proving invaluable in certain studies, and some collaboration with outside bodies has also been undertaken. An account of the progress made in the investigations during the year is given below.

Members of staff attended a variety of meetings and visited organizations with allied interests. Dr J. F. Darbyshire was present at the Third International Congress of Protozoology, held in Leningrad in July.

Interrelationships between Plant Roots and Micro-organisms

A detailed account of the apparatus developed for growing plants to the fruiting stage with shoots exposed to the atmosphere and with axenic roots has been accepted for publication[82]. This apparatus could be used to study plant nutrition and root exudates, but is at present being used in an attempt to reach an understanding of the nature of microbial competition between soil protozoa and bacteria on plant roots. These studies should also yield information on any effects these micro-organisms may have on plant growth and development. Up to the present only soil amoebae and a few soil bacteria have been used in these investigations, but recently new techniques have been developed for the isolation and culturing of soil flagellates and ciliates. A demonstration entitled *Techniques used in axenic or monaxenic culture of soil amoebae* was given at a meeting of the British Section of the Society of Protozoologists at Chelsea College of Science and Technology, London, in April. These techniques involve the use of an inverted microscope, a micromanipulator and laminar airflow equipment, all of which have been specifically modified for this purpose, and they should considerably extend the range of these studies.

Microbial Decomposition of Organic Phosphates

The account of the study of the microbial degradation of *myo*inositol hexaphosphate in sand and soil[31] has now been published.

The study of nucleic acid degradation by soil micro-organisms has been

continued, using the non-fruiting myxobacterium *Cytophaga johnsonii*. It was found that this organism could not utilize nucleic acids as sole sources of carbon, nitrogen or phosphorus, but in the presence of readily available sources of these elements, the nucleic acids were rapidly attacked and inorganic orthophosphate and purine and pyrimidine bases released. The nucleases involved in this degradation have been isolated from the culture fluids by gel filtration and their activities measured by a fluorimetric method. The results of this investigation[75] have been submitted for publication.

An account of the study of adsorption of nucleic acids by montmorillonite carried out in collaboration with Pedology[51] has been accepted for publication. This investigation is being extended to cover aspects of the microbial degradation of montmorillonite-nucleic-acid complexes, and preliminary results have shown that nucleases produced by pure cultures of bacteria or mixed soil populations can attack the adsorbed nucleic acid. The degradation results in some degree of collapse of the lattice spacing of the complex.

Lytic Soil Micro-organisms

A paper describing the results of a study of the microbial lysis of the cell walls of two soil yeasts, *Cryptococcus albidus* and *C. terreus*,[20] has now been published.

The work on parasitic fungi occurring in sclerotia of *Sclerotinia sclerotiorum* (Annual Report No. 38, 1967/68) has been expanded. *S. sclerotiorum* occurs widely in temperate and subtropical areas of the world where it attacks a very wide range of fleshy plants, including nearly all vegetables. Two fungi, *Coniothyrium minitans* and *Trichoderma viride*, have been isolated from sclerotia collected from infected potato stems in the north-east of Scotland. When applied as spore suspensions, these fungi attack sclerotia buried in soil. Preliminary results have shown that wall-lysing enzymes are responsible for the decay of the sclerotia, and concentrated crude enzyme preparations have been produced which bring about rapid lysis of the living cells. The results are incorporated in a joint paper with the Mycology Division, School of Agriculture, Aberdeen,[83] which has been accepted for publication.

In collaboration with Biochemistry and Spectrochemistry, a chemical analysis of the cell walls of the three morphologically different cell structures of *S. sclerotiorum* has been carried out and a study made of their ultrastructures. It has been shown that chitin and β-glucan occur in the hyphal walls and in the pseudoparenchymatous and outer rind walls of the sclerotium. A melanin component is also present in the outer rind walls.

A systematic investigation is in progress on the incidence of lytic microorganisms present on the root surface of winter wheat (*Triticum aestivum* var. *champlein*) during the life cycle of the plant. Samples of the wheat at various stages during growth have been taken directly from a field-grown crop. Techniques developed in the department have been used to enumerate the numbers of organisms on the root surface of the wheat and the presence of those with ability to lyse fungal walls. For the latter, two media containing walls of *Saccharomyces cerevisiae* are being employed—one with anti-

microbial substances present to suppress fungi, actinomycetes and certain bacteria. The other medium, containing only soil extract and the yeast walls, is being used for comparison. The predominant lytic organisms appearing throughout the growth period of the plant are being isolated.

A comprehensive account of the biological transformation of microbial residues in soil[84] has been prepared.

Ultrastructure of Fungi

Although the technique of preparing ultra-thin sections of biological tissue has made possible many advances in our knowledge of microbial cell organelles, artifacts may be introduced by the chemical fixation and embedding methods used. These methods are not required in the freeze-etching technique. Freeze-etched pycnidiospores of *Coniothyrium minitans* (referred to above) have been prepared at the Botany Department, University of Aberdeen, and three-dimensional views of the cell structures—surface, walls and internal organelles—have been obtained. The ultrastructure of the surface features of the pycnidiospores and the internal organization of the pycnidia of various species of *Coniothyrium* have been studied by examining carbon replicas and ultra-thin sections. This work has been undertaken in collaboration with the Commonwealth Mycological Institute with a view to establishing a sounder basis for the classification of the genus.

Various preparations from the cell walls of baker's yeast have been examined by conventional means in the Institute's electron microscope for the department of Biochemistry. Two joint papers[19, 26] have now been published.

Microbial Production of 2-Ketogluconic Acid

During the year it has been possible to resume work on the microbial production, under controlled culture conditions, of potassium 2-ketogluconate. Crystalline samples suitable for detailed X-ray studies and larger amounts for preliminary tests as a possible extractant have been obtained.

SOIL FERTILITY

The research programme continues to be directed towards improvement of manurial practices and crop production through better understanding of the factors regulating the performance of different soil series. The main emphasis remains on the implications of parent material and drainage conditions in terms of soil chemical properties, nutrient relationships, fertilizer requirements, and laboratory methods for evaluating nutrient status. Studies in these areas, involving a variety of chemical and physico-chemical laboratory investigations integrated with field and pot experiments, have been continued and intensified. In addition, developments have been initiated in two other directions. On the field side the first requirement was to characterize the general performance of contrasting soil series by extensive experimentation over a range of sites and seasons, with the main emphasis on the effects of fertilizers on the mature yields and total nutrient contents of the common agricultural crops. In several ways this information provides foundations for the laboratory studies, and remains essential. The stage has now been reached, however, where it is desirable to examine in detail the growth and development of crops at selected individual sites, and to assess more specifically the implications of soil physical conditions, moisture, root systems, site characteristics and environmental factors, in addition to soil chemical properties and nutrient supply. The recent appointment of Dr P. W. Dyson as Crop Physiologist enables these developments to be actively pursued. Similarly, on the laboratory side, attention is being given not only to the amounts of nutrients in crops but also to the forms of occurrence, partly as a logical extension of studies on the cation-exchange properties and mineral composition of plants.

Advisory soil testing in collaboration with the North of Scotland College of Agriculture, and related activities designed to further practical application of research findings, have been continued. Normal contacts and co-operation have also been maintained with the Hill Farming Research Organisation, the Rowett Research Institute, and other research and technical bodies. Under the last head comes membership of the Technical Committee on Soil Fertility of the Agricultural Research Council, the Working Party on Soil Analysis set up by the Soil Survey Research Board, the Grassland Committee of the Scottish Agricultural Improvement Council, and the Scottish Sub-committee of the Sugar Beet Research and Education Committee. The department is now represented also on the Scottish Standing Committee for the Calculation of Residual Manurial Values. Members of staff have visited relevant Institutes and University departments to discuss research developments, and have taken part in meetings of the British Society of Soil Science, the Agricultural Group of the Society of Chemical Industry, and the Society of Applied Biologists. A paper[85] was contributed to the Symposium on Trace Element Metabolism in Animals held in Aberdeen in July 1969. Dr G. Anderson has been elected to the Council of the British Society of Soil

Science, and Dr E. G. Williams has become a member of the Editorial Board of *Communications in Soil Science and Plant Analysis*.

Dr O. G. Oniani, head of the Department of Chemistry, Georgia Agricultural Institute, U.S.S.R., visited the department for a month, mainly to gain practical experience of the methods which have been developed for identifying and estimating organic phosphates in soils.

Autoanalyser procedures have been standardized and brought into routine use for colorimetric estimations of phosphate in soil and crop extracts, and the equipment will shortly be used also for crop nitrogen determinations, by replacing the final distillation of the Kjeldahl extract with a colorimetric estimation. The review of physico-chemical aspects of soil research mentioned in last year's report has now appeared[32].

Effects of Fertilizers on Crop Yields and Composition. Striking features which have emerged from the field programme over the years are the large differences in yield levels and calculated optimal NPK dressings that occur between experiments. Such variations emphasize the desirability of the developments mentioned above concerning assessment of soil, site and environmental factors, coupled with detailed studies of crop growth and development. As a first step in these directions three NPK experiments on barley and three on swedes, representing contrasting soils and sites, have been sampled at intervals throughout the season. At each stage of growth measurements have been made not only of total dry matter and nutrient uptake but also of nutrient distribution within the plant, including roots. The main immediate aims are to determine which growth indices influence the final yield and to make a preliminary assessment of the effects of nutrient supply, soil series, site characteristics and environment on these indices. A further aim has been to establish suitable experimental procedures.

Annual and long-term field experiments and laboratory analyses of crop and soil samples have been continued to measure the effects of various N, P, K and Mg treatments on the yield and mineral composition of potatoes, roots, cereals and herbage, and on the nutrient levels in the soils.

Methods of Applying Fertilizers. Broadcast and combine drill applications of phosphate for cereals have been tested at row widths of 3·5 and 7 inches in three experiments on barley and one on oats. With broadcast phosphate, only in one of the barley experiments did seed drilled in 3·5 inch rows produce higher yields, the others giving the same results at both row widths. Phosphate combine drilled with seed in 3·5 inch rows was not clearly superior to the broadcast treatments. With 7 inch rows, however, there was a consistent trend for phosphate combine drilled with the seed to give higher yields. At this row width, therefore, it is still advisable to combine drill fertilizers containing phosphate in soils rated as low or slightly low in this nutrient. Two experiments on cereals have been carried out to compare broadcast and placed applications of liquid and solid NPK fertilizers using the experimental drill made by the National Institute of Agricultural Engineering.

Trace Elements. The paper presented to the Symposium on Trace Element Metabolism in Animals summarized the main findings from field and laboratory work in collaboration with Spectrochemistry on trace elements in herbage[85]. Soil factors, including geological nature of the parent material, pedological drainage conditions, lime status and fertilizer treatment can directly affect the trace element content of mixed herbage in temporary leys by influencing uptake by individual species. In addition, the proportions of the various grasses and clovers present can be altered by lime and fertilizer dressings, thereby producing indirect effects. Soils derived from basic igneous rocks usually have higher readily soluble contents of the important trace elements than corresponding soils from acid igneous or metamorphic parent materials. The trace elements in herbage grown on these soils normally show similar trends. The amounts of most trace elements, particularly cobalt, manganese and molybdenum, in plants grown on soils with poor pedological drainage conditions, even when field drains are installed to remove excess water, are normally higher than in plants grown on corresponding freely drained soils. Lime dressings normally reduce the cobalt and manganese contents in herbage, but increase molybdenum. The influence of lime on copper and zinc is generally small. High rates of fertilizer N reduce or eliminate clovers and this can lower the contents of cobalt, copper and molybdenum in mixed herbage, because clovers are usually richer in these three elements than the associated grasses. Applying N seems to have very little influence on the contents of cobalt, copper and zinc in the individual grasses and clovers separated from mixed herbage grown on soils with adequate supplies, but the contents of molybdenum and manganese have been consistently reduced. The limited information available for P and K fertilizers suggests that normal rates are unlikely to produce any large changes, but more information is being obtained and the field work has been completed in an experiment to measure the effects of N, P and K treatments on the trace element contents of mixed herbage and some of its constituent species.

A series of plots, covering various soil parent materials and drainage categories, have been established on young leys to provide herbage and soil samples to investigate, again in collaboraion with Spectrochemistry, the relationship between various laboratory soil values and contents of trace elements, especially molybdenum, in herbage. Three samples are being taken during the growing season to examine influences of stage of growth and time of sampling.

Inorganic Phosphate. The joint paper with Statistics on the usefulness of conventional laboratory extraction methods in predicting the phosphate requirements of swedes[33], summarized in last year's report, has now appeared. Two other papers mentioned last year are in press, one dealing with the residual effects of phosphate[86] and the other with the phosphate status of some Nigerian soils[87].

Further detailed studies are in progress to examine the intensity and quantity aspects of soil phosphate status and laboratory extraction values, and to

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see what improvement is possible in the level of correlation between crop responses and laboratory values by eliminating seasonal differences and minimizing soil and site variations. To these ends, an integrated field-pot-laboratory project is being carried out in the current season, based on twenty experimental sites confined to the Tarves Association and representing relatively well-drained soils formed on till derived from mixed acidic and basic igneous rocks. In the field, phosphate responses are being measured with swedes, relevant soil characteristics are being observed, and measurements of mean temperature are being obtained by the cane sugar inversion method. Parallel responses have been measured with oats in all-soil and soil-sand media in pots, with supplementary determinations of labile phosphate using ^{32}P, in collaboration with Plant Physiology. In the laboratory a range of phosphate intensity and quantity indices and relevant other soil properties, selected in the light of previous studies, are being determined for each area.

Further pot work has also been done on the availability of rock phosphates at particle-size less than 1 μ and on growth effects of organic phosphorus compounds. Physico-chemical studies of phosphate adsorption isotherms have also been continued, with particular reference to the development of an improved method for characterizing the phosphate retention capacity of soils.

Organic Phosphorus and Sulphur. As mentioned in previous reports, chapters on soil organic phosphorus[88] and organic sulphur[89] have been prepared for an *Encyclopedia of Soil Science*. A joint paper with Spectrochemistry on the identification of inorganic pyrophosphate in alkaline extracts of soil[21] has now appeared.

Two more phosphorus compounds occurring in alkaline extracts of soil have been identified and purified by ion-exchange and paper chromatography. Each was found to contain deoxyribose, phosphorus, and a pyrimidine base, which in one case was thymine and in the other uracil. The ratio of P to pyrimidine was 2:1, and the esters were shown to be the nucleotides thymidine-3′:5′ diphosphate and deoxyuridine-3′:5′ diphosphate. They may have been formed by hydrolysis of polynucleotides during extraction, but their isolation confirms, for the first time, the existence in soil of characteristic structural units of DNA. An account of this investigation[90] has been accepted for publication.

In a joint investigation with the Soil Research Institute, Canada Department of Agriculture, Ottawa, the organic phosphorus in a number of Canadian and Scottish soils was extracted with contrasting reagents and the extracts fractionated by ion-exchange chromatography. Sodium hydroxide was a more effective extractant than hydrochloric acid or aqueous acetylacetone, but there was evidence that the latter caused less change in the extracted phosphate, a considerable proportion of which seemed to be present in complex form, or as large molecules. The nature of the material extracted by sodium hydroxide has been investigated and an account of the work has been prepared for publication.

Further work is being carried out on the extraction with aqueous acetylacetone of organic forms of P and S, and of related soil constituents, including aluminium and iron.

Nitrogen. Variable effects of recent crop residues make laboratory evaluation of soil nitrogen status particularly difficult under Scottish conditions, but a reliable method would be of much practical value. Tests have therefore been started to examine the usefulness of a number of recently suggested chemical methods for assessing available nitrogen. Compared with incubation procedures these are relatively simple to carry out and correspondingly more suitable for possible routine use.

Soil Acidity and Liming. An account of the work on measurement of pH, lime potential and aluminium hydroxide potential[91] described in last year's report has been accepted for publication. Subsequent developments have been concerned with the relationship between these measurements of the intensity of acidity in equilibrium soil suspensions and the total acidity, using incrementally limed samples of a range of contrasting acid soils. The reactions of aluminium ions are central to this theme and the current emphasis is on equilibria between adsorbed and soluble aluminium. A simple and reliable estimate of soil negative charge, represented by the cation exchange capacity at the natural acidity of the soil, was required for this work, and was obtained by saturating a soil sample with 0·5 M barium chloride to replace all exchangeable cations with Ba^{2+} and then bringing it to equilibrium with 0·0025 M barium chloride solution containing the radioactive isotope ^{133}Ba. The cation exchange capacity was then calculated from the distribution of the isotope between the solution and the solid phase. Experimental variables affecting the accuracy of the determination were investigated, and an account of the method has been submitted for publication[92].

Cation-exchange Properties and Mineral Composition of Plants. Progress has been made in processing the comprehensive data which have been gathered over several seasons on the cation-exchange properties and detailed mineral composition of a wide range of plant species. Two papers have been prepared for publication in collaboration with Plant Physiology. The first deals with the effects of soil pH on the root cation-exchange capacity (C.E.C.) and mineral composition of oats, barley, wheat, swedes and potatoes sampled at an early stage of growth from demonstration plots maintained by the North of Scotland College of Agriculture. These cover the pH (water) range 4·5 to 7·5 in 0·5 unit steps, and the results show numerous marked effects of pH on the major and trace element contents of the different crops. There are also distinct differences in the pattern of cation uptake and translocation between the dicotyledenous swedes and potatoes compared with the monocotyledenous cereals. These differences probably hinge to some extent on the marked difference in C.E.C. between the two classes of plant. The level of C.E.C. is much higher for the swedes and potatoes, and unlike that of the cereals is not significantly affected by soil pH. The second paper

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In a joint investigation with the Soil Research Institute, Canada Department of Agriculture, Ottawa, the organic phosphorus in a number of Canadian and Scottish soils was extracted with contrasting reagents and the extracts fractionated by ion-exchange chromatography. Sodium hydroxide was a more effective extractant than hydrochloric acid or aqueous acetylacetone, but there was evidence that the latter caused less change in the extracted phosphate, a considerable proportion of which seemed to be present in complex form, or as large molecules. The nature of the material extracted by sodium hydroxide has been investigated and an account of the work has been prepared for publication.

Further work is being carried out on the extraction with aqueous acetylacetone of organic forms of P and S, and of related soil constituents, including aluminium and iron.

Nitrogen. Variable effects of recent crop residues make laboratory evaluation of soil nitrogen status particularly difficult under Scottish conditions, but a reliable method would be of much practical value. Tests have therefore been started to examine the usefulness of a number of recently suggested chemical methods for assessing available nitrogen. Compared with incubation procedures these are relatively simple to carry out and correspondingly more suitable for possible routine use.

Soil Acidity and Liming. An account of the work on measurement of pH, lime potential and aluminium hydroxide potential[91] described in last year's report has been accepted for publication. Subsequent developments have been concerned with the relationship between these measurements of the intensity of acidity in equilibrium soil suspensions and the total acidity, using incrementally limed samples of a range of contrasting acid soils. The reactions of aluminium ions are central to this theme and the current emphasis is on equilibria between adsorbed and soluble aluminium. A simple and reliable estimate of soil negative charge, represented by the cation exchange capacity at the natural acidity of the soil, was required for this work, and was obtained by saturating a soil sample with 0·5 M barium chloride to replace all exchangeable cations with Ba^{2+} and then bringing it to equilibrium with 0·0025 M barium chloride solution containing the radioactive isotope ^{133}Ba. The cation exchange capacity was then calculated from the distribution of the isotope between the solution and the solid phase. Experimental variables affecting the accuracy of the determination were investigated, and an account of the method has been submitted for publication[92].

Cation-exchange Properties and Mineral Composition of Plants. Progress has been made in processing the comprehensive data which have been gathered over several seasons on the cation-exchange properties and detailed mineral composition of a wide range of plant species. Two papers have been prepared for publication in collaboration with Plant Physiology. The first deals with the effects of soil pH on the root cation-exchange capacity (C.E.C.) and mineral composition of oats, barley, wheat, swedes and potatoes sampled at an early stage of growth from demonstration plots maintained by the North of Scotland College of Agriculture. These cover the pH (water) range 4·5 to 7·5 in 0·5 unit steps, and the results show numerous marked effects of pH on the major and trace element contents of the different crops. There are also distinct differences in the pattern of cation uptake and translocation between the dicotyledenous swedes and potatoes compared with the monocotyledenous cereals. These differences probably hinge to some extent on the marked difference in C.E.C. between the two classes of plant. The level of C.E.C. is much higher for the swedes and potatoes, and unlike that of the cereals is not significantly affected by soil pH. The second paper

reports a study of the relationship between yield of dry matter and root C.E.C. of a number of leek varieties.

Further small field experiments have been carried out on oats, barley, potatoes and beans, to provide material for examining the forms of nutrients in plants. To facilitate work on organic constituents a Cenco Freeze Drier with three trays has been obtained, giving a total capacity of about 1 kg of fresh plant material.

Advisory Work. Analyses of soil and crop samples, concerning problems of animal health as well as crop production, have been continued, with the assistance of Spectrochemistry, especially in trace element estimations. Over 12,000 soil samples were dealt with during the year. As usual most of these were taken from agricultural land by the staff of the North of Scotland College of Agriculture, but about 1000 came from horticultural areas and several hundred from forest nurseries. The latter are processed in collaboration with Pedology. The main demand continued to be for assessments of lime, phosphate and potassium requirements, but trace element problems were again a major feature, involving analyses of about 100 samples of crops, and herbage, together with over 800 soil cobalt and nearly 700 soil copper determinations.

STATISTICS

In providing a service for the other departments of the Institute, the use of available computing facilities has become increasingly important. Grateful acknowledgement is made to the Rowett Institute for the regular allocation of time on their IBM 1130 computer and to Dr G. E. Thomas of the Edinburgh Regional Computing Centre for advice and discussions regarding future computer projects.

Members of staff have attended seminars and courses on computer programming, meetings of the Royal Statistical Society and the Biometric Society, Datafair 69 organized by the British Computer Society, and the 37th Session of the International Statistical Institute.

The library of computer programmes, located on a magnetic disk backing store, has been extended during the year by translating from previous ALGOL versions and by writing new FORTRAN programmes as required. Programmes have now been written for the statistical analysis and presentation of results from the following types of designed experiments: randomized blocks, factorial experiments with three factors and 3^3 design, semi-balanced and balanced lattice squares, and a central composite design. Subroutines are available to examine in detail the effects of treatments. Other general programmes provide facilities for correlation and regression analysis, data processing, conversion and tabulation.

In addition to the routine design of field experiments and the analysis of results for Soil Fertility, work is continuing on a number of aspects of the estimation of optimum combinations of nutrients for various crops. Different models of the response function and the question of experimental design are both being investigated. In the case of a single nutrient, results from an investigation into the phosphate requirements of swedes[33] have been published. A regular service is now in operation for the processing and tabulation of the results of chemical analyses of soil and crop samples. Other Soil Fertility investigations required the application of correlation analysis, linear and multiple regression analyses, and the combination of experimental results over a period of years.

Factorial designs, correlation and regression analysis have been used in Plant Physiology greenhouse and growth chamber experiments which have been concerned with the growth of lemna and with physical and chemical properties of oat plants[79].

Methods of multivariate analysis have been applied to Soil Survey problems and acknowledgement is made to Rothamsted Experimental Station for collaboration and computer facilities. An investigation into the relationship between botanical composition of natural vegetation and soil characteristics used both regression and clustering techniques. Methods of numerical taxonomy were applied to the classification of soil profiles, using the classification programme ORION/17. A brief account of the procedure appears in a review of some of the statistical methods in soil research in use at the Institute[17], and the results of the numerical classification have been

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A new programme in FORTRAN was written to process a further set of results in terms of 2-hourly measurements of head of water from the catchment area at Blacklaw Moss, Lanarkshire. The computer output lists the discharge rate at 2-hourly intervals and the mean for each 2-hour period, the 2-hourly run-off, and the daily and weekly run-off in cubic feet per acre and equivalent inches of rainfall. Other Pedology studies have included the use of the angular transformation in a vegetation survey from a water level experiment, the analysis of variance of physical and chemical measurements on needle samples from factorial experiments, and regression analysis in the comparison of methods of estimation.

The analysis of results has been completed for a shrub growth experiment which had been planned for the Horticultural Department of the North of Scotland College of Agriculture. A split-plot factorial design was used and measurements of height and spread over two seasons were examined.

Collaboration with the Crop Husbandry Department of the West of Scotland Agricultural College continues and the combination of results from two series of factorial experiments is being carried out. Factorial designs have been provided for further experiments on potatoes, swedes and rape. The analysis of variance of 30 variates from eight experiments was carried out. Since most of these were of a 3^3 design a FORTRAN programme was written for the purpose and has been added to the programme library.

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The library holds an extensive collection of literature on soil science and related subjects and, although the service is primarily for members of staff, loans can be obtained by individuals and institutions either on direct application or through inter-library lending schemes. A list of periodical holdings is available on request.

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PUBLICATIONS

(A) *Published—*

1. Effects of particle size, pH and organic matter on the thermal analysis of allophane. By A. S. Campbell (Lincoln College, Canterbury, New Zealand), B. D. Mitchell and J. M. Bracewell. (*Clay Miner.*, **7**, 451-454, 1968.)

   This investigation examines the effects that can be produced on differential thermal analysis curves by the methods normally used to separate the clay fraction from soils containing amorphous colloids. The influence of the pH of the dispersion medium and of the nature of the organic matter are shown to be of considerable importance.

2. A gibbsitic soil derived from the weathering of an ultra-basic rock on the island of Rhum. By M. J. Wilson. (*Scott. J. Geol.*, **5**, 81-89, 1969.)

   The mineralogy of a soil derived from the weathering of an ultra-basic rock near the summit area of Askival on the island of Rhum was investigated by optical, X-ray diffraction and differential thermal techniques. The fine sand fraction is dominated by olivine and anorthitic plagioclase felspar, while the clay fraction contains gibbsite and chlorite. General weathering reactions in the soil are discussed and the origin of the gibbsite is considered in detail.

3. Imogolite: a unique aluminosilicate. By J. D. Russell, W. J. McHardy and A. R. Fraser. (*Clay Miner.*, **8**, 87-99, 1969.)

   The fibrous aluminosilicate imogolite, which is found in association with allophane in volcanic ash soils, and which is thought to have a surface similar to that of allophane, has been studied by electron-optical and infrared absorption methods. Electron diffraction indicates a unique structure in which chains of Al-O octahedra are cross-linked through isolated Si_2O_7 groups. Infrared spectra support this view and suggest three different types of OH group in the structure. The OH groups appear to be more widely separated than in allophane.

4. Techniques in soil-clay mineralogy. By R. C. Mackenzie and V. C. Farmer. (*Rep. Prog. appl. Chem.*, **52**, 269-279, 1968.) *No reprints.*

   A review of the current position in so far as preparation of samples, chemical examination, X-ray diffraction, thermal methods, electronoptical methods, infrared absorption spectroscopy, and some other subsidiary techniques are concerned.

5. Effects of pretreatment on a 14Å swelling mineral from Gartly, Aberdeenshire. By J. Perez-Rodriguez and M. J. Wilson. (*Clay Miner.*, **8**, 39-45, 1969.)

   A 14Å swelling mineral, interlayered with what is probably an organometallic complex, occurs in the surface horizon of a gleyed soil near Gartly, Aberdeenshire. The effects of various commonly used pretreatments are described and the possible nature of the interlayer material is discussed.

6. Transactions of the Second International Peat Congress, Leningrad, 1963. Edited by R. A. Robertson. 2 vol. 1968. H.M.S.O., £12.

   This English edition of the Transactions contains 113 scientific and technical papers on many aspects of peat research and development, including peat resources, classification and ecology; production, transportation and industrial utilization; agriculture, horticulture and forestry; physics, chemistry, microbiology and balneology. The two volumes comprise 1090 pages of text and contain 234 tables, 250 figures, 171 photographs and approximately 1000 references.

7. Peat resources and their development. By R. A. Robertson. (*Proc. N. Engl. Soil Discuss. Grp Meeting, Southport, 1967.* **No. 4**, 1-4, 1968.) *No reprints.*

The nature and extent of peat resources in Britain are reviewed and various forms of utilization discussed. With regard to future research and development, reference is made to the technical achievements of the Soviet peat industry.

8. Effect of different cultural treatments on root development in a grass sward growing on a deep peat. By R. Boggie. (*J. Br. Grassld Soc.*, **23**, 280-284, 1968.)

Previous work had shown that on deep peat the root systems of sown grasses are shallow. In order to study the effect of cultivation on root development, an experiment was laid down in an area of deep peat where sown grass swards were established on plots which had been subjected to different cultivation treatments. Root development is shown to be affected by depth of cultivation and this is discussed in relation to surface seeding of peatland areas.

9. Evidence for variations in the altitudinal zonation of climate in Scotland and northern England since the Boreal Period. By S. E. Durno and J. C. C. Romans. (*Scott. Geog. Mag.*, **85**, 31-33, 1969.)

The altitudinal difference between the zones in which initiation of blanket peat development took place in Scotland and northern England is shown to vary from 1200 feet (366 m) in mid-Boreal time to nil at the beginning of the sub-Atlantic Period. This indicates that climatic conditions in upland Britain have tended to become progressively more uniform since the Boreal Period.

10. Structural variations in peat. By J. M. Stewart (McMaster University, Hamilton, Ontario, Canada) and S.E. Durno. (*New Phytol.*, **68**, 167-182, 1969.)

The macro- and microscopic structure of an upland peat bog in east Aberdeenshire has been examined and quantitative assessment of identifiable plant tissues and pollen carried out. Results indicate that structural components of peat can provide useful supplementary information on the stratigraphy of bogs in which pollen is poorly represented.

11. Nitrogen nutrition of pines on the sands of Culbin Forest, Morayshire. By H. G. Miller. (*J. Sci. Fd Agric.*, **20**, 417-419, 1969.)

Investigations into the dynamics of nitrogen within Corsican pine plantations on the sand dunes of Culbin Forest have shown that development of post-establishment deficiency conditions can be ascribed to a marked persistence of nitrogen in organic matter deposited on the forest floor. There is reason to believe that as other new forests on poor land pass middle-age a similar deficiency may develop and it can be anticipated, therefore, that nitrogen fertilizers will play an increasingly important role in Scottish silviculture.

12. Land use capability classification. By J. S. Bibby and D. Mackney (Rothamsted Experimental Station). (*Tech. Monogr. Soil Surv. Gt Br.*, **No. 1**, 1969. 27 pp.)

A classification to evaluate the soil, site and climatic factors in land use has been developed for Great Britain. Land is graded according to the severity of its limitations for crop growth into seven use capability classes. Class 1 land has a wide range of uses with few limitations, while the remaining classes suffer from increasingly severe limitations and are progressively less flexible. Capability sub-classes are defined on the particular limiting physical factors.

13. A natural system of classification. By J. W. Muir. (*J. Soil Sci.*, **20**, 153-166, 1969.)

The proposed natural system of soil classification is based on three principles of soil formation. The first principle emphasises the three-dimensional nature

of soil bodies. The second principle, known as the Principal of Developmental Sequences, is concerned with stages of soil development. The many developmental sequences identified by pedologists are correlated by means of a small number of constituents which are lost and gained during soil formation. These constituents, in an order of eluviation/illuviation, are used to rank the properties on which the proposed system is based. Soil horizons are defined according to the ranked properties and the classes of the system are, in turn, defined in terms of the horizons, with the result that the central statement of the system is the Principle of Developmental Sequences. The third principle points out that the horizon immediately under the A horizon is the most suitable horizon for classifying a profile.

14. Hill-land vegetation in Scotland. By E. L. Birse. (pp. 16-19 of *Hill-land Productivity: Proc. Symp. Eur. Grassld Fed.;* Edited by I. V. Hunt; *Occ. Symp. Br. Grassl. Soc.*, **No. 4**, 1968.)

The climate of Scotland is oceanic, but the degree of oceanicity varies from the humid western to the drier eastern areas. The parent materials of the soils are mainly derived from acid rocks and this, in conjunction with high precipitation, means that the soils developed are acid and often podzolized. In general the hill-land vegetation is moorland—*Calluna* moor and *Calluna-Eriophorum vaginatum-Trichophorum* moor—or acid grassland. The grassland ranges from *Molinia* grassland on peaty soils to *Agrostis-Festuca* acid grassland on dry mineral soils. On small areas of base-rich soils is found *Agrostis-Festuca* basic grassland.

15. Trace element balance in soils. By M. L. Berrow. (*Technology in Agriculture*, **2**, 131-2, 1969.) *No reprints.*

The release of trace elements by weathering and their behaviour in soils is discussed. Soil drainage status, pH, organic matter content and treatment with certain additives are soil factors which affect trace element uptake by plants.

16. Direct photometry of self-reversed lines using a double exit slit. By J. C. Burridge and R. O. Scott. (*Spectrosc. Lett.*, **1**, 379-385, 1968.)

A double exit slit, made in the Institute workshop, and suitable for the direct photometry of the broad self-reversed K 7665 Å line using the Hilger and Watts E 789 3-metre polychromator, is described. This enables total potassium to be determined directly in rocks and soils by direct current arc excitation, at contents which would otherwise have required dilution.

17. Statistics in soil research. By R. H. E. Inkson. (*Appl. Statist.*, **17**, 216-225, 1968.)

Some applications of statistics to soil research at the Macaulay Institute are reviewed. The paper deals with such topics as: the place of soil testing and field experiments in providing a basis for fertilizer recommendations; model-fitting and data processing in peat and forest soil investigations and in emission spectrographic analysis; and multivariate analysis in soil classification and botanical surveys.

18. Flame methods: their development and application. By R. L. Mitchell. (Chap. 1 of *A Handbook of Flame Emission and Absorption Methods.* Edited by J. A. Deans and T. C. Rains. New York: Dekker. 1969.) *No reprints.*

A historical review of the development of flame methods and a brief comparison of their performance with that of other analytical techniques.

19. The glucan components of the cell wall of baker's yeast (*Saccharomyces cerevisiae*) considered in relation to its ultra-structure. By J. S. D. Bacon, V.C. Farmer, D. Jones and Irene F. Taylor. (*Biochem. J.*, **114**, 557-567, 1969.)

Polysaccharides composed of glucose (glucans) are constituents of the cell walls of many fungi. Advantage is taken in the present work of the fact that each yeast cell is totally enclosed in glucan so that the extraction of certain constituents is dependent upon a partial degradation of the glucan. The yeast glucan, hitherto believed to be a single chemical entity, has in this way been shown to consist of several components. Recognition of this complexity helps to explain the action of bacterial enzymes on yeast walls, and the study is being extended to cover the degradation of cell walls of fungi by various soil organisms.

20. A study of the microbial lysis of the cell walls of soil yeasts (Cryptococcus spp.). By D. Jones, J. S. D. Bacon, V. C. Farmer and D. M. Webley. (*Soil Biol. Biochem.*, **1**, 145-151, 1969.)

In studies on microbial cell walls as components of the soil organic matter complex, little attention appears to have been devoted to soil yeasts. An examination has been made of the chemistry and ultra-structure of cell walls of two soil yeasts *Cryptococcus terreus* and *C. albidus*. The difference in the ability of soil micro-organisms to degrade this material has been examined. One important finding was that the wall composition varied according to the nature of the culture medium in which the yeasts were grown, and this in turn determined the extent to which walls were degraded. The mode of action of the enzymes involved in the degradation of the walls has been studied in detail since some of the organisms used in these experiments are potential tools for controlling fungal plant pathogens.

21. Identification of inorganic pyrophosphate in alkaline extracts of soil. By G. Anderson and J. D. Russell. (*J. Sci. Fd Agric.*, **20**, 78-81, 1969.)

The phosphorus compounds of natural origin which have hitherto been identified in soils are all orthophosphates, in either inorganic or organic form. Recent investigations on the nature of the phosphate present in sodium hydroxide extracts of soil have revealed the presence of another phosphorus compound, inorganic pyrophosphate. It was isolated and purified by ion-exchange and paper chromatography, and its identity was confirmed by its chromatographic properties, its rate of hydrolysis in dilute acid, and by infra-red spectroscopy. The amounts found ranged up to 2·6 ppm P in the soil, but losses may have occurred during the fractionation procedure. It may occur in the soil in the form identified, or it may be present as a pyrophosphate ester which is mineralized during extraction.

22. Infrared spectroscopy in clay mineral studies. By V. C. Farmer. (*Clay Miner.*, **7**, 373-387, 1968.)

The application of infrared spectroscopy to the characterization of clay mineral structures, of their thermal reactions and of their interactions with adsorbed organic and inorganic molecules is reviewed. (154 references.)

23. Transformation of ^{14}C glucose and starch in soil. By M. V. Cheshire, C. M. Mundie and H. Shepherd. (*Soil Biol. Biochem.*, **1**, 117-130, 1969.)

Carbohydrate in soil is important mainly for two reasons: firstly in promoting aggregation, and secondly in providing a source of food for the microbial population. The origin of the carbohydrate may be plant residues or microbial synthesis. Incubation of a soil of pH 5 with ^{14}C glucose and starch has shown that hexoses and methylpentoses are synthesised in soil, but not pentoses.

24. The occurrence of 2-O-methylxylose and 3-O-methylxylose in peat. By J.-F Bouhours (Catholic University, Toulouse, France) and M. V. Cheshire. (*Soil Biol. Biochem.*, **1**, 185-190, 1969.)

Soils and peat contain small amounts of methylated sugars which show greater mobility than the parent sugar on paper chromatograms. Using a peat derived from *Calluna vulgaris* one group of these substances moving 30 per cent faster than rhamnose and having the characteristic reactions of pentose has been shown to be an approximately equal mixture of 2-O-methylxylose and 3-O-methylxylose, together amounting to about 4 mg/100g peat. 2-O-methylxylose is already known to occur in higher plants, but 3-O-methylxylose, although suspected to be present in larch hemicelluloses, has not been positively identified in nature before.

25. The stimulation of invertase development in aseptic storage tissue slices by humic acids. By D. Vaughan. (*Soil Biol. Biochem.*, **1**, 15-28, 1969.)

Humic acid solutions, at concentrations as low as 5 mg/litre, stimulated by 80-100 per cent invertase development in beet storage disks aged under aseptic conditions. However, changes in respiration, RNA content and cell-wall nitrogen were stimulated by less than 20 per cent. Invertase development was not stimulated in the stem storage organs of artichoke and potato. The amount of humic acid taken up by the disks was only 15-20 μg/g fresh weight of tissue after three days of ageing. Some model humic acids stimulated invertase development, but examination of infrared and ESR spectra failed to show any correlation between the basic structure and effect on invertase stimulation. Several humic acid-like fungal pigments were also active in stimulating invertase development.

26. Cell wall residues in yeast protoplast preparations. By J. S. D. Bacon, D. Jones, and P. Ottolenghi (Carlsberg Laboratory, Copenhagen, Denmark). (*J. Bact.*, **99**, 885-887, 1969.)

Techniques and knowledge developed at the Macaulay Institute have been used to confirm an observation made at the Carlsberg Laboratory. Snail digestive juice, which is commonly used to solubilize the wall of the living yeast cell, while the protoplast is protected by a medium that matches its internal osmotic pressure, does not remove the wall completely. This has implications both for studies of the regeneration of the wall by the living protoplast, and for work in this Institute on the enzymic degradation of fungal cell walls.

27. Mineral balance in plants. By P. C. DeKock. (*Technology in Agriculture*, **2**, 161-162, 168, 1969.) *No reprints.*

The functions of the nutrient elements are discussed in relation to known cell constituents, and reasons for their interaction are considered.

28. The relationship between trace elements in soils and plants. By P. C. DeKock and M. V. Cheshire. (*Rep. Welsh Soils Discuss. Grp.*, **No. 9**, 98-108, 1968.)

The content of a particular element in plants does not depend only upon its availability but also on the availabilities of other elements. The adverse effect of nitrogen on copper deficient oat plants is due not to the reduced availability of copper in the peat but to a greater requirement within the plant. Increased growth will not account for this. Interactions between elements suggest a common form or complex within the plant. The possible nature of such complexes is discussed in relation to nitrogen and phosphorus.

29. Characterization of amino acid incorporation by subcellular fractions from sterile beet disks. By R. J. Ellis (University of Aberdeen) and I. R. MacDonald. (*Planta*, **83**, 248-256, 1968.)

The development of an ion uptake capacity in storage tissue disks is dependent upon protein synthesis. This study provides evidence that in beetroot tissue this synthesis is initiated by the formation of messenger RNA, the protein template formed in the cell nucleus.

30. Does cycloheximide inhibit protein synthesis specifically in plant tissue? By I. R. MacDonald and R. J. Ellis (University of Aberdeen). (*Nature*, **222**, 791-792, 1969.)

Cycloheximide is extensively used in plant research as a metabolic inhibitor which is assumed, on the basis of work with animal cells, to act *via* interference with protein synthesis. This report demonstrates that while cycloheximide severely inhibits ion uptake, this may be due to interference with energy transfer.

31. The hydrolysis of *myo*inositol hexaphosphate by soil micro-organisms. By M. P. Greaves and D. M. Webley. (*Soil Biol. Biochem.*, **1**, 37-43, 1969.)

Inositol polyphosphates, which form the major part of the organic phosphorus identified in soils, exist as insoluble salts in soils and may be associated with clay minerals. In these forms they are believed to be unavailable to plants. In this study no hydrolysis of sodium *myo*inositol hexaphosphate added to soil could be detected, but in sand it was rapidly mineralized by an inoculum of mixed soil micro-organisms. In the presence of clay minerals the hydrolysis of the sodium salt was reduced, particularly with montmorillonite. The results suggest that adsorption of both substrate and enzyme are involved and illustrate the complex relationships between enzymic processes in soil and their chemical and physical environments.

32. Soils: some physico-chemical aspects. By B. W. Bache. (*Rep. Prog. appl. Chem.*, **52**, 259-269, 1967.) *No reprints.*

A report of recent work on soil physical chemistry, under the following headings: surface area and charge; cation adsorption and exchange; anion sorption; soil acidity; equilibria relating to soil solution; and ion mobility in soils.

33. Prediction of phosphate requirements of Swedish turnips from soil phosphate values. By J. W. S. Reith, R. H. E. Inkson and E. G. Williams. (*J. Sci. Fd Agric.*, **20**, 265-271, 1969.)

Yields from 199 field experiments on six soil groups in north-east Scotland were used to calculate correlation coefficients between the responses of swedes to 120 lb P_2O_5 per acre and readily soluble phosphate values determined by six methods. There were marked effects of soil parent material and drainage conditions on the correlations which ranged from $-0{\cdot}05$ to $-0{\cdot}74$. By fitting a Mitscherlich equation to the yields, calculations for four combinations of fertilizer and root prices were made of the profit from optimal economic dressings, from standard dressings and from rates for individual experiments based on four methods of extracting soil phosphate. Attention is drawn to factors, particularly variations in site characteristics, limiting the usefulness of soil phosphate values in predicting the requirements for a single crop. There was no convincing benefit from using soil values to recommend phosphate dressings for individual soils, and their main practical usefulness is in the periodic checking of phosphate status as a guide to rotational manuring.

(B) *Awaiting Publication at 30th September, 1969—*

34. The application of alkali dissolution techniques in the study of Cretaceous flints. By S. S. J ørgensen. (Submitted to *Geochim. cosmochim. Acta.*)

35. The classification of soil silicates and oxides. By R. C. Mackenzie. (To appear in *Encyclopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2. Section D. Berlin: Springer.)

36. Heavy minerals. By W. A. Mitchell. (To appear in *Encyclopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2. Section D. Berlin: Springer.)

37. Oxides and hydrous oxides of silica. By B. D. Mitchell. (To appear in *Encyclopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2. Section D. Berlin: Springer.)

38. The thermal characteristics of soil minerals and the use of these characteristics in the qualitative and quantitative determination of clay minerals in soils. By R. C. Mackenzie and S. Caillère (Paris, France). (To appear in *Encyclopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2. Section D. Berlin: Springer.)

39. Basic principles and historical development. By R. C. Mackenzie. (To appear as Chap. 1, pp. 3-30, of *Differential Thermal Analysis*, Vol. 1. Edited by R. C. Mackenzie. London: Academic Press.)

40. Instrumentation. By R. C. Mackenzie and B. D. Mitchell. (To appear as Chap. 3, pp. 63-99, of *Differential Thermal Analysis*, Vol. 1. Edited by R .C. Mackenzie. London: Academic Press.)

41. Technique. By R. C. Mackenzie and B. D. Mitchell. (To appear as Chap. 4, pp. 101-122, of *Differential Thermal Analysis*, Vol. 1. Edited by R. C. Mackenzie. London: Academic Press.)

42. Oxides and hydroxides of higher-valency elements. By R. C. Mackenzie. (To appear as Chap. 9, pp. 271-302, of *Differential Thermal Analysis*, Vol. 1. Edited by R. C. Mackenzie. London: Academic Press.)

43. Simple phyllosilicates based on gibbsite- and brucite-like sheets. By R. C. Mackenzie. (To appear as Chap. 18, pp. 497-537, of *Differential Thermal Analysis*, Vol. 1. Edited by R. C. Mackenzie. London: Academic Press.)

44. The clay mineralogy of the Scottish Dalradian limestones. By M. J. Wilson and D. C. Bain. (Submitted to *Contr. Miner. Petrogr.*)

45. Plumbogummite-group minerals from Mull and Morvern. By D. C. Bain. (Submitted to *Mineralog. Mag.*)

46. A study of weathering in a soil derived from a biotite-hornblende rock. Pt. I. The weathering of biotite. By M. J. Wilson. (Submitted to *Clay Miner.*)

47. A study of weathering in a soil derived from a biotite-hornblende rock. Pt. II. The weathering of hornblende. By M. J. Wilson and V. C. Farmer. (Submitted to *Clay Miner.*)

48. Alpine podzol soils on the Ben Lawers massif, Perthshire. By J. H. Stevens and M. J. Wilson. (Submitted to *J. Soil Sci.*)

49. Lithiophorite from the Lecht Mines, Tomintoul, Banffshire. By M. J. Wilson, M. L. Berrow and W. J. McHardy. (Submitted to *Mineralog. Mag.*)

50. The oxides of iron, aluminium and manganese. By R. C. Mackenzie, E. A. C. Follett and R. Meldau (Gütersloh, Germany). (To appear in *The Electron-optical Investigation of Clays*. Edited by J. A. Gard. London: Mineralogical Society.)

51. The adsorption of nucleic acids by montmorillonite. By M. P. Greaves and M. J. Wilson. (*Soil Biol. Biochem.*, **1**, 317-323, 1969.)

52. Organic compounds. By B. D. Mitchell and A. C. Birnie. (To appear as Chap. 22, pp. 611-641, of *Differential Thermal Analysis*, Vol. 1. Edited by R. C. Mackenzie. London: Academic Press.)

53. Biological materials. By B. D. Mitchell and A. C. Birnie. (To appear as Chap. 24, pp. 673-704, of *Differential Thermal Analysis*, Vol. 1. Edited by R. C. Mackenzie. London: Academic Press.)

54. The classification of soil profiles by traditional and numerical methods. By J. W. Muir, H. G. M. Hardie, R. H. E. Inkson and A. J. B. Anderson (Rothamsted Experimental Station). (Submitted to *Geoderma.*)

55. Peat resources and development in the U.K. By R. A. Robertson and P. C. Jowsey. (Submitted to *Trans. III int. Peat Congr., Quebec, Canada, 1968.*)

56. The chemical status of an exposed peat face. By J. M. Stewart (McMaster University, Hamilton, Ontario, Canada) and R. A. Robertson. (Submitted to *Trans. III int. Peat Congr., Quebec, Canada, 1968.*)

57. The geomorphological significance of a peat exposed near Wooler, Northumberland. By C. M. Clapperton (University of Aberdeen) and S. E. Durno. (Submitted to *Scott. Geogr. Mag.*)

58. Effect of water table height on growth of *Pinus contorta* on deep peat. By R. Boggie and H. G. Miller. (Submitted to *Proc. N.E.R.C. Symp. Peatland Forestry, Edinburgh, 1968.*)

59. Evaluation of peatland sites according to their physical and chemical characteristics. By H. G. Miller, R. A. Robertson and B. L. Williams. (Submitted to *Proc. N.E.R.C. Symp. Peatland Forestry, Edinburgh, 1968.*)

60. Physical and chemical factors influencing the cation-exchange capacity of peat under field conditions. By B. L. Williams. (Submitted to *Proc. N.E.R.C. Symp. Peatland Forestry, Edinburgh, 1968.*)

61. The soils (of Caithness). By D. W. Futty. (To appear in *The Caithness Handbook.*)

62. The photography of soils and associated landscapes. By J. M. Ragg. (Submitted to *Soil Survey Handbook.*)

63. Soil bulk density measurement in the field by gamma-ray transmission method. By J. M. Ragg. (Submitted to *Soil Survey Handbook.*)

64. Soil temperature. By J. M. Ragg. (Submitted to *Soil Survey Handbook.*)

65. Geochemical analysis with a multi-channel direct reader employing direct current arc excitation. By R. O. Scott, J. C. Burridge and R. L. Mitchell. (Submitted to *Boln. Geol. Min., Madrid.*)

66. Trends in applied geochemical and biogeochemical analysis. By R. L. Mitchell. (Submitted to *Proc. XV Colloq. Spectros. int., Madrid, 1969;* also *Boln. Geol. Min., Madrid.*)

67. Problems in trace-element analysis. By R. O. Scott. (Submitted to *Proc. W.A.A.P. I.B.P. Symp. Trace Eelement Metabolism in Animals, Aberdeen, 1969.*)

68. Vegetational factors affecting the trace element content of plants. By J. C. Burridge. (Submitted to *Proc. W.A.A.P. I.B.P. Symp. Trace Element Metabolism in Animals, Aberdeen, 1969.*)

69. Trace elements in soils. By R. L. Mitchell. (Submitted to *Proc. N.A.A.S. Conf. Trace Elements in Soils and Crops, London, 1966.*)

70. A spectrophotometric method for determination of cation-exchange capacity of clay minerals. By A. R. Fraser and J. D. Russell. (*Clay Miner.*, **8**, 229-230, 1969.)

71. Reactivity of montmorillonite surfaces with weak organic bases: comment on a paper of Swoboda and Kunze. By M. M. Mortland (University of Michigan), V. C. Farmer and J. D. Russell. (*Proc. Soil Sci. Soc. Am.*, **33**, 818, 1969.)

72. The characterization of soil minerals by infrared spectroscopy. By V. C. Farmer and F. Palmieri. (To appear in *Encyclopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2. Section D. Berlin: Springer.)

73. Soil lipids. By R. I. Morrison. (Chap. 19 of *Organic Geochemistry: Methods and Results*. Edited by G. Eglinton and Mary T. J. Murphy. Berlin: Springer, 1969.)

74. Effect of humic acid on the development of invertase activity in slices of beet-root tissue washed under aseptic conditions. By D. Vaughan. (*Proc. Symp. Humus et Planta, IV, Prague, 1967*, 268-271, 1969.)

75. The degradation of nucleic acids by *Cytophaga johnsonii*. By M. P. Greaves, D. Vaughan and D. M. Webley. (Submitted to *J. appl. Bact.*)

76. The metabolism of nitrogen in plants. By P. C. DeKock. (*Tech. Bull. Minist. Agric. Fish. Fd*, **No. 15**, 1-6, 1969.)

77. Uptake of nitrogen by plants. By P. C. DeKock and E. A. Kirkby. (*Tech. Bull. Minist. Agric. Fish. Fd*, **No. 15**, 7-14, 1969.)

78. Fundamental aspects of iron nutrition of plants. By P. C. DeKock. (Submitted to *Proc. N.A.A.S. Conf. Trace Elements in Soils and Crops, London, 1966.*)

79. An investigation into the effect of varied phosphorus and iron concentrations in the nutrient medium on the cation and anion content of oats. By Linna Bentley (University of London), P. C. DeKock and R. H. E. Inkson. (Submitted to *Pl. Soil.*)

80. Electrochemical aspects of ion transport in plants. By A. E. S. Macklon. (Submitted to *J. Sci. Fd Agric.*)

81. The complexes of zinc, copper and manganese present in ryegrass. By I. Bremner (Rowett Research Institute, Aberdeen) and A. H. Knight. (Submitted to *Br. J. Nutr.*)

82. An improved method for the study of the inter-relationships of soil micro-organisms and plant roots. By J. F. Darbyshire and M. P. Greaves. (Submitted to *Soil Biol. Biochem.*)

83. Parasitism and lysis by soil fungi of *Sclerotinia sclerotiorum* (Lib.) de Bary, a phytopathogenic fungus. By D. Jones and D. Watson (School of Agriculture, Aberdeen). *Nature*, **224**, 287-288, 1969.)

84. Biological transformation of microbial residues in soil. By D. M. Webley and D. Jones. (To appear as Chap. 17 of *Soil Biochemistry*. Vol. II. Edited by A. D. Maclaren and J. J. Skujins. New York: Dekker.)

85. Soil factors influencing the trace element content of herbage. By J. W. S. Reith. (Submitted to *Proc. W.A.A.P. I.B.P. Symp. Trace Element Metabolism in Animals, Aberdeen, 1969.*)

86. Residual effects of phosphate and the relative effectiveness of annual and rotational dressings. By E. G. Williams and J. W. S. Reith. (Submitted to *Proc. N.A.A.S. Conf. Residual Value of Applied Nutrients, London, 1968.*)

87. Soil phosphate values in relation to phosphate supply to plants from some Nigerian soils. By B. W. Bache and N. E. Rogers (Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria). (Submitted to *J. agric. Sci., Camb.*)

88. Other organic phosphorus compounds. By G. Anderson. (To appear in *Encyclopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2. Section C. Berlin: Springer.)

89. Sulphur in soil organic substances. By G. Anderson. (To appear in *Encyclopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2. Section C. Berlin: Springer.)

90. The isolation of nucleoside diphosphates from alkaline extracts of soil. By G. Anderson. (Submitted to *J. Soil Sci.*)

91. Determination of pH, lime potential and aluminium hydroxide potential of acid soils. By B. W. Bache. (Submitted to *J. Soil Sci.*)

92. A barium isotope method for measuring cation exchange capacity of soils and clays. By B. W. Bache. (Submitted to *J. Sci. Fd Agric.*)

(C) *Papers by Members of Staff on Leave of Absence: Published or Accepted for Publication. (No reprints)*—

93. Soil survey of part of the Taieri Uplands, Otago, New Zealand. By J. M. Ragg and R. B. Miller (New Zealand Soil Bureau). (To appear as *Rep. N.Z. Soil Bur.*)

94. Nutrient status of alfalfa showing poor growth on some Alberta soils. By G. W. Webster (University of Alberta) and P. C. DeKock. (Submitted to *Can. J. Pl. Sci.*)

95. The mineral nutrition of plants supplied with nitrate and ammonium nitrogen. By P. C. DeKock. (*Proc. Symp. Nitrogen Nutrition of the Plant, University of Leeds, 1968.*)

96. Active and passive transport of potassium in cells of excised pea epicotyls. By A. E. S. Macklon and N. Higinbotham (Washington State University, U.S.A.). (Submitted to *Pl. Physiol., Lancaster.*)

(D) *Thesis*—

The following thesis has been accepted for the degree of Ph.D. by the University of Aberdeen:

Effect of nitrogen fertilizer on tree growth and nutrient uptake in a stand of Corsican pine. By H. G. Miller.