THE MACAULAY INSTITUTE FOR SOIL RESEARCH

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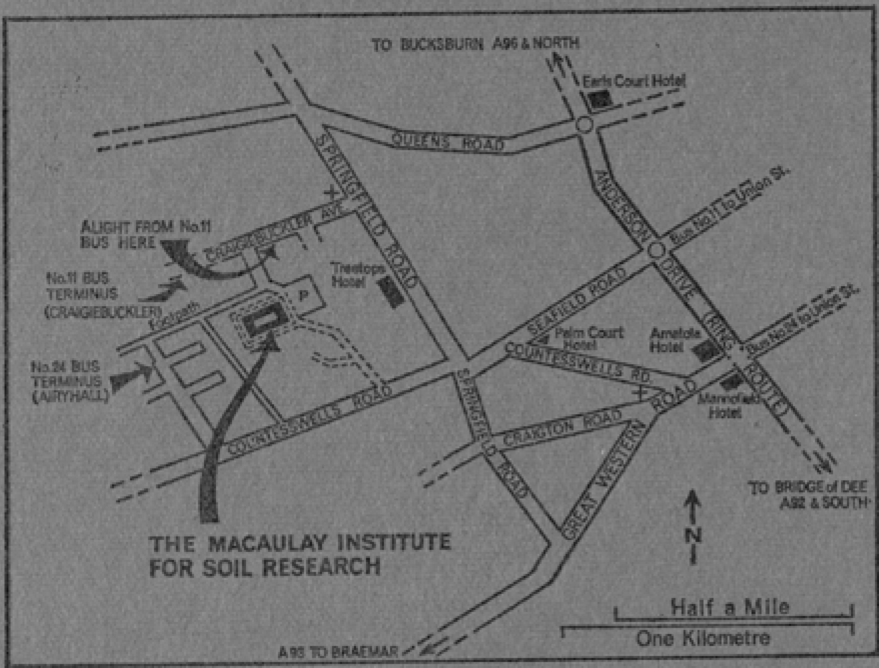

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

(Founded 1930)

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1971-1972

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1971-1972

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Deputy Director—

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B. Shirriffs.
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Miss S. K. Davidson—appointed 12/10/71.
G. J. Ewen.
Miss H. W. Farquhar.
Miss E. M. Glass—appointed 8/5/72.

Mrs A. G. Grant—resigned 31/10/71.
Miss L. Gray.
Mrs R. B. Islam, M.Sc.—resigned 11/10/71.
Miss A. Keen.
Mrs V. MacPherson.
Mrs F. K. Nicol.
Mrs A. Peace—8/11/71-29/2/72.
Miss E. E. Picken—appointed 1/2/72.
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Miss C. L. Robertson.
Mrs H. J. Shamsuddin, M.Sc.
Miss R. Slicher.
Miss W. M. Stein.
Mrs L. K. Stephen—resigned 24/8/72.
Miss A. R. Walker—appointed 28/8/72.
Miss R. S. Wyllie.
G. Bruce.
I. M. Still.

BIOCHEMISTRY

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D Vaughan, B.Sc., Ph.D.
H. A. Anderson, B.Sc., Ph.D.
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W. Bick, L.R.I.C., F.I.L.
Miss E. Cusens, L.R.I.C.
A. H. Gordon, L.R.I.C.—resigned 31/8/72.
A. Hepburn.
Mrs D. Bower—resigned 31/12/71.
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Mrs P. A. Reid—resigned 31/8/72.
Mrs L. M. Smith.
Miss L. A. J. Stefani.
Miss K. M. Willox.
Miss C. A. Woolley—appointed 11/9/72.

PLANT PHYSIOLOGY

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A. Hall.
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Mrs A. E. Naylor, M.Sc.—resigned 30/4/72.
R. W. G. MacLeod, B.Sc.—appointed 18/9/72.
Miss F. B. Grabowska, B.Sc.—appointed 25/9/72.
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R. J. Cumming.
Miss F. Davies.
Miss M. C. McFarlane—appointed 15/5/72.
B. G. Ord.
Miss R. M. Paterson—appointed 18/10/71.
A. Sim.
Mrs A. C. Watt—resigned 15/10/71.

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

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Head of Department: D. M. Webley, M.Sc., Ph.D., F.I.Biol., F.R.S.E.
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D. Jones, M.Sc., Ph.D., M.I.Biol., F.R.M.S.
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M. S. Davidson.
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Mrs C. A. Christie.
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Mrs B. C. Henderson—resigned 18/8/72.
Mrs L. A. Johnston.
Miss M. G. Sherriffs—appointed 1/9/72.
Mrs J. S. Wood—resigned 31/7/72.
Mrs J. V. Dunbar.

SOIL FERTILITY

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J. W. S. Reith, B.Sc.(Agr.), Ph.D., F.R.I.C.
G. Anderson, B.Sc., Ph.D.
W. M. Crooke, B.Sc., Ph.D.
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K. S. Caldwell, S.D.A., S.D.D.H.
R. E. Malcolm.
J. A. M. Ross, N.D.A.
G. S. Sharp, L.R.I.C.
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Miss J. O. Moir.
J. Munro.
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Miss C. J. Anderson—appointed 1/8/72.
Miss G. Barber—appointed 5/1/72.
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Mrs H. M. Duncan.
Mrs R. Firmin—resigned 21/7/72.
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Miss C. Ireland.
Miss M. E. Leith.
Mrs N. I. McFadyen.
Miss E. A. Mackay.
Miss S. E. Masson.
Mrs E. Pirie.
Miss D. B. Thomson—appointed 5/1/72.
R. Strachan.

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A. R. Douglas.
J. A. M. Anderson.
S. Harris.

STASTISTICS

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Miss J. M. Cooper, B.Sc., Dip.Stat., A.I.S.
Mrs D. E. G. Paterson, B.Sc.
G. J. M. Stephen, B.Sc.—appointed 1/2/72.
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Miss P. L. Parton.
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M. G. Riddell.
A. I. A. Wilson.
R. Riddell.

Photographer J. Mitchell.

ADMINISTRATION

Secretary and Treasurer Miss E. J. Dey, M.B.E.—retired 30/11/72.
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Attendant E. M. S. Cruickshank.
Outdoor Staff H. Gordon.
A. Mutch.
J. S. Morrison.
G. A. Reid—retired 29/10/71.
J. Shaw.
C. J. Benzie—appointed 1/5/72.
H. Shaw.

VISITING RESEARCH WORKERS

A. K. Dale (A.R.C. Bursar from N.I.A.E., Silsoe, attending Birmingham University).

*Nancy M. Darrall (Department of Agricultural Botany, University of Reading).

B. Davey (Department of Soil Science, University of Sydney, N.S.W., Australia).

H. K. El-Kholy (7 Al-Shaik Al-Amir Street, Kobba Gardens, Cairo, Egypt).

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

L. Gabris (Department of Soil Science, University of Agriculture, Nitra, Czechoslovakia).

Y. Henis (Department of Plant Pathology and Microbiology, Faculty of Agriculture, Hebrew University, Rehovot, Israel).

B. Khazai-Nejad (Soil Science Institute, Shiraz, Iran).

*Judith E. Longland (Trent Polytechnic, Nottingham).

*D. G. McInnes (Napier College of Science and Technology, Edinburgh).

M. Maeda (Section of Marine Microbiology, Ocean Research Institute, University of Tokyo, Japan).

Nahid Manteghi (Laboratory Division, Soil Institute of Iran, Tehran).

*N. A. Mogul (Hatfield Polytechnic, Hatfield, Herts).

H. W. Morgan (I.C.I. Post-Doctoral Fellowship).

A. Negro (Faculty of Architecture, Institute of General and Applied Chemistry, Turin Polytechnic, Turin, Italy).

Z. A. Omer (Cartographic Section, Soil Survey Division, Sudan).

R. L. Parfitt (Department of Chemistry, University of Papua and New Guinea, Boroko, T.P.N.G.).

L. P. Raikov (Nikola Pushkarov Institute of Soil Science, Sofia, Bulgaria).

A. Salehabadi (Geological Survey of Iran, Tehran).

P. L. Searle (Soil Analysis Section, Soil Bureau, D.S.I.R., Lower Hutt, New Zealand).

*C. A. Shand (Robert Gordon's Institute of Technology, Aberdeen).

Esme Velagic (Department of Agriculture, University of Sarajevo, Yugoslavia).

*S. Whittaker (John Dalton College of Technology, Manchester).

**Sandwich-Course student.*

CONTENTS

INTRODUCTION

The past year has seen preparations being made for considerable administrative changes in the organization of the agricultural research service institutes. These are concerned with the implementation of the simplified career structure for members of the scientific staff recommended in the Fulton Report 'A Framework for the Future' (Cmnd 3638) and the acceptance of many of the principles propounded in the Green Paper by Lord Rothschild entitled 'A Framework for Government Research and Development' (Cmnd 4814), and in the White Paper 'Framework for Government Research and Development' (Cmnd 5046). The implications of these changes will become obvious in the course of the next twelve months.

During the year the forthcoming retirement of Miss E. J. Dey, M.B.E., who has been Secretary of the Institute since 1941, was announced and Miss E. A. Piggott, Assistant Secretary of the Scottish Plant Breeding Institute, was appointed to succeed her in November 1972. Miss Dey has been associated with the Institute since its inception and joined the staff in 1935. The Council have minuted their sincere appreciation of her services to the Institute over the past 37 years, during 31 of which she has undertaken the onerous duties of Secretary with highly commendable efficiency and responsibility. They wish her a long and happy retirement.

Dr J. S. D. Bacon, who had been Head of Biochemistry since 1956, resigned to take up an appointment as Head of the Department of Carbohydrate Biochemistry at the Rowett Research Institute. During his 16 years at the Institute, Dr Bacon built up a department which achieved an international reputation and attracted numerous workers from overseas, and the Council desire to express their appreciation of his contribution to the development of the Institute.

During the year the research programme of the Institute has progressed steadily, as the Reports of the individual departments, prepared by their respective Heads, will indicate. Some 29 publications have been issued and a further 53 papers have been submitted and await publication. Volume IX of the Collected Papers of the Institute, covering the period 1967/69, has now been issued and includes 87 publications.

Towards the end of the year the research programme of the Institute for the forthcoming six years was reviewed by an ARC Visiting Group comprising Professor J. L. Harley, M.A., Ph.D., F.R.S. (Chairman), Professor of Forest Science, University of Oxford; Professor D. H. Everett, M.B.E., M.A., D.Phil., D.Sc., F.R.S.E., Leverhulme Professor of Physical Chemistry, University of Bristol; Professor E. W. Russell, C.M.G., M.A., Ph.D., F.Inst.P., Emeritus Professor of Soil Science, University of Reading; Professor E. A. Vincent, B.Sc., Ph.D., M.A., Professor of Geology, University of Oxford, and Professor L. Fowden, B.Sc., Ph.D., F.R.S., Professor of Plant Chemistry, University College, London The report of the group is awaited.

The Hon. Mr J. J. Astor (Chairman) and four other members of the Agricultural Research Council, accompanied by Sir Ronald Baskett (Secretary), visited the Institute in June 1972 on the occasion of a Council Meeting in Aberdeen.

Mr A. L. Buchanan-Smith, Joint Parliamentary Under-Secretary of State for Scotland, paid a visit to the Institute in October 1971. Other visitors have included Mr M. Joughin, Chairman of the Scottish Agricultural Development Council, and Mr I. M. Whitelaw, Secretary. Among larger groups, visits from parties from the Annual Conference of British Geographers and from the Scottish Peat and Land Development Association may be mentioned.

Scientific workers from twenty-one different countries paid short visits to the laboratories during the year, and facilities were provided for longer term workers from Australia, Bulgaria, Czechoslovakia, Egypt, Iran, Israel, Italy, Japan, New Zealand, Nigeria, Papua and New Guinea, Portugal, Sudan and Yugoslavia.

Contacts with fellow research scientists working on related topics is particularly valuable for workers with several years' experience of their subject and as many members of staff as possible are given facilities to attend appropriate scientific meetings and visit laboratories in Britain and overseas. For the latter, thanks are due to the Agricultural Research Council and the Department of Agriculture and Fisheries for Scotland for making such visits possible. During the past year Dr H. A. Anderson (Biochemistry) attended a small international conference on Humic Substances in The Netherlands; Dr V. C. Farmer (Spectrochemistry) attended an International Clay Conference in Madrid, Spain; Dr I. R. MacDonald (Plant Physiology) visited various research stations and university departments in Israel; Dr H. G. Miller (Pedology) visited various centres working on forest soils in Norway, Sweden and Finland; Dr J. W. S. Reith (Soil Fertility) attended the Seventh World Fertilizer Congress in Vienna, Austria, and Mr R. A. Robertson (Pedology) attended the Fourth International Peat Conference in Helsinki, Finland. In addition Dr G. Anderson (Soil Fertility), Dr M. L. Berrow (Spectrochemistry) and Mr J. S. Bibby, Mr J. M. Ragg and Mr J. S. Robertson (Soil Survey) attended a special meeting of the British Society of Soil Science in The Netherlands and had the opportunity of making contact with their Dutch colleagues and seeing something of their work.

Dr R. C. Mackenzie (Pedology) was invited by the Italian Group of the International Confederation for Thermal Analysis to address a meeting in Rome and by Nordforsk to deliver the opening lecture at the first meeting of their Committee on Thermal Analysis in Helsinki. In both cases Dr Mackenzie took the opportunity of visiting relevant research establishments: the costs of these visits were defrayed by the organizers.

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

It is perhaps desirable to remind readers of this report that while the Institute is a company limited by guarantee, registered in Edinburgh in 1930, and managed by a nominated Council of Management, it is wholly government financed, funds to support the work being provided by the Department of Agriculture and Fisheries for Scotland, the research programme being co-ordinated by the Agricultural Research Council: a grant towards work on forest soils is received from the Forestry Commission.

PEDOLOGY

The purpose of the work of the department continues to be to obtain a comprehensive understanding of the genesis, nature and properties of the soil system, thus enabling fuller evaluation of its functions as a substrate for plant growth. The studies being undertaken to this end are described in detail below.

During the year the scanning electron microscope and microprobe system, referred to last year, has yielded valuable information on both mineral and biological materials and it is clear that much more can be expected over the next few years. Mass spectrometry has also demonstrated its value in several areas of investigation in both this and other departments. The glasshouse too is proving its worth, not only by enabling more ambitious experiments to be undertaken but also by permitting better control over experimental conditions than was previously possible: one tangible result is the establishment of several clones of Sitka spruce.

Collaboration with other departments of the Institute has continued and some samples relevant to the programme of work have been examined for outside bodies. Close connections have been maintained with the Forestry Commission, the Department of Agriculture and Fisheries for Scotland and the Highlands and Islands Development Board on questions relating to the survey and utilization of peat. Information and advice on matters concerning peat have also been sought by many bodies and individuals.

During the year Professor A. Negro, Istituto di Chimica Applicata, Facoltà di Architettura, Politecnico di Torino, Italy, a visiting research worker, completed his studies on compounds of lime with ferric oxide. Dr A. S. de Endredy, F.A.O., Rome, two sandwich-course students—Mr D. McInnes from Napier College of Science and Technology, Edinburgh, and Mr S. Whittaker from Manchester Polytechnic—and one A.R.C. Bursar—Mr A. K. Dale from the National Institute of Agricultural Engineering, Silsoe, currently reading Mechanical Engineering at the University of Birmingham—have also assisted in the work of the department.

Members of staff have attended, *inter alia*, meetings of the British Ecological Society, the British Society of Soil Science and the Clay Minerals Group of the Mineralogical Society.

Mr R. A. Robertson presented a paper at the Fourth International Peat Conference in Helsinki, Finland, and participated in a post-Congress excursion in the USSR. He also attended a Peat Symposium in Poland at the invitation of the Ministry of Agriculture, Warsaw, and participated in a meeting of an International Working Group on Peat Standards at Aalsmeer, the Netherlands. Dr H. G. Miller visited Norway, Sweden and Finland to study various aspects of forest soils research in these countries, with special reference to nitrogen nutrition on mineral soils. At the invitation of Nordforsk (the Scandinavian Council for Applied Research), Dr R. C. Mackenzie delivered the opening lecture at the first meeting of their Committee on Thermal Analysis at Helsinki, Finland, and, also by invitation, addressed the Gruppo Italiano, International Confederation for Thermal Analysis, at their meeting in Rome, Italy.

CHEMISTRY AND MINERALOGY

Analytical Studies

Despite some difficulties arising from the number of samples (over 2400) received from Soil Survey for systematic physical and chemical analysis in 1971, work is progressing satisfactorily, all determinations on 1970 samples having been completed and those on 1971 samples being under way. Analyses have also been performed on samples from other departments and on samples from outside bodies relevant to the programme of work.

In connection with studies on the aeration of peat and organic soils being carried out by Peat and Forest Soils, techniques for field sampling of soil atmosphere for subsequent mass spectrometric study are being investigated with a view (a) to increasing the sensitivity of determinations into the parts-per-million range for certain components and (b) to handling a large number of samples. The gases of especial interest in connection with their effect on root development are oxygen, carbon dioxide, methane, ethene and other hydrocarbons. At the request of Microbiology gas analyses have been carried out on incubated peat samples to test whether gaseous nitrogen is directly utilized by micro-organisms; results to date, however, merely show consumption of oxygen and release of carbon dioxide. In conjunction with Microbiology and Plant Physiology an apparatus has been devised for mass spectrometric determination of the isotope of nitrogen of mass 15.

X-ray fluorescence spectroscopy has been further developed during the year and it is now possible to determine sodium in pressed powder samples. Analyses have been made of saponite-bearing andesitic rocks, clays containing interstratified minerals, and montmorillonitic clay fractions of vertisols and entisols (cracking and non-cracking soils, respectively).

The laboratory-built differential thermal analysis apparatus has been reconstructed to improve temperature control and sensitivity; the latter is now such that it is possible to examine soil samples without the necessity of particle-size separation. Two chapters — one recounting the uses of differential thermal analysis in soil science[35] and the other considering general applications in industry with special reference to dusts[36]—have been compiled for a forthcoming book.

Soil Mineralogy

Because the minerals present in the soil form a major part of its nutrient capital and are important in relation to its behaviour and properties, pure minerals likely to occur in soils, parent materials and clay minerals continue to receive considerable attention. The non-crystalline or poorly ordered inorganic material that is associated with particle surfaces is particularly important since, because of its mode of occurrence, it can influence soil properties disproportionately to the amount present. Although the principal methods used for studying such poorly ordered material are chemical and thermoanalytical, electronoptical techniques, and particularly electron diffraction, are being increasingly used in identifying and studying material amorphous to X-rays[38].

The scanning electron microscope and microprobe system is proving very valuable in soil mineralogy since it enables study of the surfaces of soil particles in sub-micron detail. So that a sample can be examined with as little disturbance as possible, a technique involving freeze-drying of the soil ped and subsequent coating with an electrically conducting material has been devised. This appears to have little effect on micromorphology since features—such as surfaces of cracks, root channels or mineral grains—that have been identified by a hand lens or under the optical microscope can readily be located under the scanning electron microscope and examined in much greater detail than previously possible. Thin sections of soil prepared for optical study also yield further information when examined by scanning electron microscopy. The value of the electron microprobe system in qualitative and quantitative studies has been thoroughly assessed during the year: a computer programme correcting results for inter-element effects has been written and tested and optimum operating conditions for quantitative determination of the major elements, together with the accuracy obtainable, are being evaluated. As an example of the usefulness of this technique, the centres of some biotite flakes from a soil profile have been found to be depleted in potassium compared with the edges; moreover, treatment of such flakes with a solution of cesium chloride shows the core to be accessible to cesium.

Parent Materials. Investigations on soils derived from andesite, which frequently show a high cation-exchange capacity (c.e.c.) but low clay content, have shown that the c.e.c. of the silt and sand fractions can in some instances account for two-thirds that of the soil; moreover, most of the exchangeable calcium and magnesium is associated with the coarse fractions and potassium with the clay fraction. These observations can be accounted for by the widespread occurrence in the coarse fractions of aggregates of saponite derived from the parent rock, the exchangeable calcium and magnesium in these fractions probably originating from weathering of felspar and saponite, respectively. It is hoped that a recently developed method for quantitative clay-mineralogical analysis by X-ray diffraction[1] will assist in solving apparent anomalies such as these.

Following earlier studies on Old Red Sandstone (Devonian) rocks[2], the clay mineralogy of Scottish Carboniferous sediments has been examined[3] as part of a study on the relative importance of inheritance and pedogenic processes in determining the clay-mineralogical constitution of Scottish soils. Studies on weathering of granite and granulite boulders in an Upper Old Red Sandstone conglomerate, mainly by X-ray diffraction, optical and electron-optical methods, suggest that the weathering occurred in an almost closed alkaline system[4].

Clay Fractions. The systematic examination, principally by X-ray diffraction, thermoanalytical, electronoptical and selective chemical techniques, of soil clays from the Peebles and Edinburgh areas (Sheet 24/32) has been completed and fine sand fractions from the same soils have also been examined. The usual suites of clay minerals have been observed and some profiles have a relatively high content of non-crystalline inorganic material.

To obtain a better appreciation of the characteristics of soils from widely different areas, clay mineralogical studies have also been performed on soils from Cyprus, New Guinea, New Zealand, Nigeria and Zambia.

In connection with the assessment of the effects of inheritance and pedogenic processes on soil-clay mineralogy, soils derived from marl, sandstone, conglomerate and andesitic lava of Lower Old Red Sandstone age have been examined[39] and results correlated with those for the parent rocks[2]. This work has substantiated the trends noted in last year's report.

Further investigations have been performed on soils developed on till derived from chloritic schists in the Loch Awe area and it has been established that soil chlorites frequently show anomalous thermal characteristics because of oxidation of ferrous iron in the lattice[5]. An interesting feature of some of these soils, revealed by X-ray fluorescence spectroscopy, is that they have titanium contents which, for the soils themselves can be as high as 3·3 per cent TiO_2. Most of the titanium is located in the clay fraction which, in the A horizon of one podzolic soil, contains as much as 25 per cent TiO_2. Although no titanium mineral could be detected by X-ray diffraction, electronoptical study has shown the presence of cryptocrystalline aggregates of anatase which may originate from weathering of sphene in the coarser fractions. Not only are the anatase aggregates amorphous to X-rays, they also dissolve in the hydrofluoric acid digestion method commonly used to concentrate oxide minerals.

The characterization and quantitative determination of interstratified clay minerals, which frequently occur in Scottish soils, raises many problems. However, a computer programme has now been written to calculate the one-dimensional diffraction functions for such minerals allowing for variations in both the proportion of each component and the type of ordering of the layer stacking. This programme has been applied to kaolinite-montmorillonite systems[40], several samples of which have now been identified in Scottish soils[41].

Vertisols and entisols from the Sudan have been mentioned in several recent department reports; from a more detailed study it would appear that the mineral of the montmorillonite group present is a ferriferous beidellite.

Clay-Organic Complexes

Studies on the decomposition of iron-phenolic chelates have established that iron can undergo valency changes during the formation and decomposition of these chelates; moreover, when in combination with phenolic substances ferrous iron can be reoxidized even in the absence of oxygen. These observations are being related to the oxidation-reduction cycles of iron oxides in gley and pseudo-gley soils.

In collaboration with Microbiology, X-ray diffraction has been used to characterize montmorillonite-polysaccharide complexes. It has also been demonstrated that complexes of montmorillonite with adenine are resistant to microbial attack[42].

Surface Properties of Soils and Soil Clays

An examination has been made of the relationship between rate of release of hydroxyl ions on treatment with sodium fluoride solution and the composition of sodium carbonate and sodium dithionite extracts of soils from the major soils series of the Kirkmaiden, Whitburn, Stranraer and Wigtown areas, the Stirling area and the Forfar, Banchory and Stonehaven areas (Sheets 1/2/3/4, 39 and 57/66/67, respectively). For freely drained soils (excluding organic horizons) the fluoride activity is significantly related to the amounts of alumina and silica extracted by 5 per cent sodium carbonate solution and the amount of ferric oxide extracted by buffered sodium dithionite solution.

The degree of polymerization of silica tetrahedra in poorly ordered materials is being studied by converting the sample to volatile trimethylsilyl derivatives that can be separated and determined by gas-liquid chromatography. By applying this method to synthetic aluminosilicate gels of different compositions systematic relationships governing the proportions of monomeric and dimeric silica have been derived.

The cation-exchange capacity of clays separated from allophanic Scottish soils varies with the pH of the dispersing agent used for separation—an effect that is being further studied to assess its usefulness in the quantitative determination of poorly ordered aluminosilicates.

The heat of displacement of *n*-heptane by *n*-butanol from surfaces of synthetic aluminosilicate gels has been measured by a flow microcalorimeter and has been shown to be a function of specific surface area and independent of the chemical composition of the gel. Similar measurements on a naturally occurring ferric oxide colloid have established that sorbed water can markedly affect heat of replacement; this effect is receiving further attention.

In an attempt to assess the extent, if any, of clay movement in gley and pseudo-gley soils, detailed particle-size analyses are being performed on the $<5\mu m$ fraction of 50 such soils. A wet-sieving technique is also being used to determine aggregates in the same soils. Systematic variations have been observed in a few samples, but detailed analysis must await completion of experimental work.

Organic and Biological Materials

Rapid pyrolysis of small soil samples *in vacuo* with mass spectrometric detection and determination of the volatile products[6] has been applied with success to the problem of distinguishing mull and mor types of humus in uncultivated freely drained soils[43]. Computer analysis of the results have shown that compounds of most value in discrimination are carbon dioxide, methanol and the alkenes. Preliminary trials to effect separation of the complex mixture of pyrolysis products using gas-liquid chromatography before passing in the mass spectrometer have been most encouraging and should enable the study eventually to be extended to cultivated soils.

In collaboration with Microbiology, Biochemistry and Spectrochemistry various constituents of fungal cell walls have been successfully characterized by X-ray diffraction[7].

PEAT AND FOREST SOILS

Peat Survey and Evaluation

Survey, classification and evaluation of Scottish peat resources[8] have continued to provide both practical and scientific information. Survey techniques and expertise are also employed to assist field and laboratory investigations—particularly those concerned with Quaternary studies, drainage[45], cultivation[47], afforestation and the winning and utilization of peat for horticultural and other purposes.

In the Kirkmaiden, Whitburn, Stranraer and Wigtown areas (Sheet 1/2/3/4) a range of profiles representative of some 1000 ha (2500 acres) of deep peat have been sampled for both standard and trace-element analyses. Sampling for trace-element determinations has posed particular problems and a modified sampler and sampling technique have been devised in order to reduce, as far as practicable, the possibility of contamination. Representative samples for trace-element investigation have also been taken at 0·5 m intervals of depth from several profiles in the Stirling area and the Latheron and Wick areas (Sheets 39, 110/116), all profiles being located on deposits previously surveyed and sampled according to standard procedure.

In collaboration with Soil Survey, an area of some 3250 ha (8000 acres) on the Glenborrodale estate in the Ardnamurchan peninsula (Sheet 52) has been examined as part of a comprehensive evaluation of the area being carried out on behalf of the Highlands and Islands Development Board. Reconnaissance of deposits covering about 1400 ha (3500 acres) in the Cromarty area (Sheet 94) has been completed and a special topographical survey of Greenhead Moss near Wishaw has established the reserves of horticultural peat and the extent to which further extraction is feasible. Currently, work is in progress to complete the survey and characterization of selected peat deposits in the Peebles and Edinburgh areas (Sheet 24/32); the total area involved is estimated to be in the region of 1600 ha (4000 acres).

Air photographs continue to be employed as a source of topographical detail not available on published maps and as an aid in differentiating bog types, particularly in inaccessible areas. Cartographic work and documentation have progressed satisfactorily and laboratory analyses of survey samples continue to provide information on the chemical and botanical characteristics necessary for purposes of classification and evaluation.

The close liaison established with all national and international organizations responsible for peat science and technology has proved invaluable in fulfilling responsibilities for the recording, provision and exchange of information on many aspects of peat research and development[48].

Pollen Analysis and Quaternary Research

Investigation into the late-Weichselian (before 8000 B.C.) and Flandrian (after 8000 B.C.) vegetational history of Scotland, largely based on a programme of regional comparison of pollen analytical data, has reached a stage when broad conclusions can be drawn[49]. These mostly refer to the distribution and composition of woodland and of certain non-arboreal species that have formed an important part of the post-glacial vegetation. Forest distribution appears to have been influenced more by exposure than by extremes of climate. Thus the most extensive areas of forest occurred in the more sheltered glens and valleys and, conversely, the most exposed regions such as the northern and western isles were largely bereft of significant woodland. Tree cover was most widespread in the Boreal and Atlantic periods (approximately 7000-3000 B.C.) but subsequent climatic deterioration and deforestation, the latter accelerated by increasing human settlement, led to a great decline which has continued to the present. Forests composed predominantly of Scots pine—the Caledonian Forest—were largely restricted to the northern half of the country, particularly to mountainous areas such as the Cairngorms. Taking the country as a whole, birch appears to have been the most widespread tree throughout Flandrian time. In Lowland Scotland alder occurred plentifully, reaching abundance in the Atlantic period. In non-montane regions, trees of the deciduous woodland, mainly oak and elm, were of considerable importance, especially in parts of coastal Argyll, the Central Lowlands, and the Southern Uplands. In the same regions hazel became very abundant in the Boreal period but never reached such high frequency in the mountainous regions and in the far north.

Non-arboreal vegetational history is dominated by heather, which contributed vast quantities to the pollen record after the Boreal period, and in the more recent Sub-Atlantic period heather became dominant over large tracts of formerly wooded terrain throughout Scotland. Grasses and sedges were most abundant mainly before the Boreal period and again in the Sub-Boreal and Sub-Atlantic periods. There is also evidence of early agriculture, in the form of pollen of plantain and other weeds of cultivation, and this together with parallel evidence from archaeologists has proved to be of considerable mutual interest.

Pollen analysis and stratigraphical studies continue to provide evidence for purposes of dating and chronological correlation[50, 51].

Root and Moisture Studies in Peat

The broad objectives of this investigation are to assess factors of soil environment that affect root development and distribution and to isolate and quantify those that directly influence plant growth.

The experiment at Lon Mor, Inverness-shire, designed to investigate the effect of water-table height on the growth of lodgepole pine[9, 52] has been extended by planting Sitka spruce seedlings (1 + 1) on the hitherto unplanted areas of each of the five plots in which water levels in the perimeter ditches are maintained at 0, 10, 20, 30 and 50 cm below the surface. It is already apparent that Sitka spruce is less tolerant of a high water-table than lodgepole pine. In the wettest plot, where the water-table is kept at the surface, establishment of the seedlings has been extremely poor, mortality exceeding 90 per cent, whereas in the driest plot, where the water-table at the centre is 35 cm below the surface, all the transplants have established successfully. Further assessment and comparison of soil conditions and growth responses are in progress.

Work on the aeration status of peat profiles has made further progress. As reported previously, redox potential measurements were initially used for comparative evaluation, but it has been possible this year, using a portable commercial oxygen electrode and analyser, to measure directly the oxygen content of the soil solution and the soil atmosphere. A cell fitted with a silicone rubber membrane, which covers perforations in the wall, is filled with water and placed in the profile; after the oxygen concentrations inside and outside have attained equilibrium it is withdrawn and the oxygen concentration in the solution measured. Although this technique is applicable both above and below the water-table, the soil atmosphere above the water-table is being sampled separately and analysed by the mass spectrometer, thus not only providing a check on the cell measurement but also giving the levels of nitrogen and carbon dioxide. Using the same sampling procedure coupled with gas chromatography, it is hoped to obtain a more complete analysis of the atmosphere in peat under different conditions.

Peat Standards

Investigation of the properties of horticultural peats has been extended to include most of the types commercially available in this country. The primary object is to establish the physical and chemical determinations that best characterize the peat for practical purposes[10], and several analytical methods are currently being evaluated. Although structural characteristics, which largely determine air-moisture relationships, are of great importance, it is recognized that a fully comprehensive specification must await evaluation of many other factors and the development of suitable analytical techniques. In collaboration with representatives of National Standards Organizations in Finland, Norway, Germany, Poland and the Netherlands, considerable progress has been made towards the drafting of an international standard for peat and peat products.

In conjunction with laboratory studies, experiments are being conducted in the glasshouse to establish relationships between growth of a variety of plants and the physical properties of different peats. The complete water and nutrient economies of the organic substrates are also being studied and related to the botanical composition, degree of decomposition and particle-size distribution of the peats employed.

The glasshouse experiment, in collaboration with Plant Physiology, on the assessment of different horticultural peats and blends of selected types as substrates for the growth of tomatoes has continued and has been extended. In addition to nutritional aspects, particular attention is being paid to the relative stability of substrate structure under intensive cropping conditions.

Nutrient Uptake from Forest Soils

Development work continues in preparation for a new series of experiments in pole-stage Sitka spruce to investigate the relationship between tree growth and nutrient uptake, the rate of uptake being subjected to a degree of controlled variation through the application of fertilizers. Two experiments will be started in each of the years 1973, 1974 and 1975, and the eventual total of six will provide a coverage of the main areas where this species is planted in Scotland. In locating these experiments, only stands of approximately 25-year-old Sitka spruce that will probably respond to added fertilizers and have no obvious soil physical factors limiting growth have been considered. In co-operation with the Forestry Commission, 18 such stands were selected throughout Scotland and foliage samples from a total of 185 trees subsequently taken for analysis. The levels of major nutrients in these samples varied greatly and were sometimes exceptionally high, particularly from forests in the extreme west of the country. Surprisingly, the stands appeared to group into geographical regions on the basis of their foliar N : P and K : P ratios, although the significance of this is not clear. Ultimately, four suitable experimental sites were located, of which two, at Leanachan Forest near Fort William and at Fetteresso Forest near Stonehaven, will be fertilized in the spring of 1973 and two, at Strathyre Forest near Lochearnhead and at Elibank Forest near Peebles, in 1974. Sites for the 1975 series have still to be located, but it is proposed that one will be in the extreme west and the other in the extreme south.

At each site, nutrient uptake investigations are to be concentrated in three replicates each of an untreated control and a complete NPK fertilizer treatment (200 kg/ha N, 100 kg/ha P and 150 kg/ha K). To isolate the effects of individual nutrients in this comparison a concurrent fertilizer experiment will be laid out using a 'central composite rotatable' design, which permits use of a very much smaller number of plots than would be required for a full factorial experiment.

Methods for the collection of litterfall, throughfall and stemflow have been devised and have been tested in a small stand of Sitka spruce within the grounds of the Macaulay Institute. Although the equipment uses simple, readily obtained and inexpensive components, extensive tests suggest that no contamination will be introduced. Attention is also being given to the collection and analysis of aerosols entering an area of woodland. In collaboration with Spectrochemistry, sufficiently precise methods of water analysis have been developed for this study. From the preliminary samples collected in the stand at the Institute, Sitka spruce clearly releases larger amounts of some nutrients into rainwater than the Corsican pine previously studied at Culbin Forest, where rainwater was of virtually no importance in the release of nitrogen and phosphorus from the trees; indeed for nitrogen, foliar absorption was found to be the dominant process in all plots but those with the heaviest nitrogen dressing. With spruce, throughfall contains twice as much nitrate and twenty times as much ammonium, and stemflow about seventeen times as much nitrate and sixty times as much ammonium, as the original precipitation. These increases in concentration should more than compensate for interception loss, which is possibly around 40 per cent. Increases in phosphorus concentration seem to be just as large and, as with pine, large amounts of potassium, calcium and magnesium are released into rainwater.

The growth response of pole-stage Corsican pine at Culbin Forest to varying rates of ammonium sulphate can be correlated very closely with foliar nitrogen levels in the previous autumn—a relationship that apparently remains largely unchanged from year to year. However, the relationship for growth in basal area is different from that for height growth, maximum basal-area growth culminating at 2·1 per cent N and height growth at 1·6 per cent N.

Also at Culbin Forest, the efficacy of ammonium sulphate, urea, ammonium nitrate and sodium nitrate as nitrogen fertilizers is being compared in a crop of pole-stage Scots pine. From the outset, maximum response has been to ammonium nitrate and by the end of 1971 (three growing seasons after application) foliar nitrogen levels were in the treatment order ammonium nitrate (2·4 per cent)>ammonium sulphate (2·1 per cent)>urea (1·9 per cent)>sodium nitrate (1·8 per cent), the comparable value for the untreated control in this year being 1·2 per cent. These values were apparently little affected whether or not phosphorus or lime was applied together with the nitrogen fertilizer.

During the past year, three ten-year-old experiments in young conifer crops have been closed. In two of these there has been a response to nitrogen, although on an upland heath soil this only became apparent after an application of phosphorus.

In the glasshouse, work continues on locating and propagating easily rooted clones of Sitka spruce, the object being to provide a source of genetically identical material for future pot experiments. Further cuttings have been taken from the most successful source tree located in the previous year's work; six so far untried trees are also being tested.

Nitrogen Mineralization in Peat and Mor Humus

For peat, the main emphasis has been on examining the effect of phosphorus and potassium fertilizer applications on the rates of mineral nitrogen production during incubation. To enable study of the effect in field-treated material, samples from an established Forestry Commission experiment at Durris Forest, Kincardineshire, have been chemically analyzed and duplicate samples have been incubated at 15°C and 30°C, both in the unaltered wet condition (aerobic) and in an artificially waterlogged state (anaerobic). The stimulating effect of an application of phosphorus and potassium on mineral nitrogen production during aerobic incubation (which has previously been observed in peat from Achray Forest, Stirlingshire, and Inchnacardoch Forest, Inverness-shire) has been detected only for samples from two of the four replicate blocks in this experiment. These two particular blocks are located on deep peat, the others being on shallow hill peat where absence of response may reflect the higher ash and total phosphorus contents of the material (10-20 per cent and 0·1 per cent, respectively, as against 4 per cent and 0·05 per cent for the deep peat). About 35 mg N per litre was obtained by aerobic incubation at 30°C of samples from untreated plots on deep peat; this increased to 84 mg in samples from plots given phosphorus and potassium fertilizer and to 56 mg where nitrogen had been applied. At 15°C, production was much slower, samples giving 35 and 76 mg N per litre at 30°C yielding only 18 and 19 mg N per litre, respectively. Fertilizer treatment did not affect mineral nitrogen production in samples incubated under anaerobic conditions, irrespective of the block sampled. However, about twice as much mineral nitrogen accumulated in the anaerobic samples during 130 days incubation at 30°C as in any of the aerobic series.

Peat samples from the untreated control plots in this field experiment have been used to study the separate and combined effects of additions of phosphorus and potassium on nitrogen mineralization at incubation temperatures of 2°C, 15°C and 30°C. The results suggest that phosphorus is primarily responsible for stimulating the rate of nitrogen production, but there are indications of qualitative as well as quantitative differences between the short-term effect detected in laboratory experiments and the long-term effect of phosphorus and potassium applied in the field.

Samples of humus continue to be taken from the fertilizer experiment in pole-stage Scots pine at Culbin Forest. Results of chemical and incubation studies on samples taken at intervals during the first three years of this experiment have now been collated[53].

In conjunction with Microbiology, the rate of production of mineral nitrogen in peat is being compared with the numbers and types of bacteria in both fresh and incubated samples from different horizons of a deep basin bog at Lyne of Skene, Aberdeenshire.

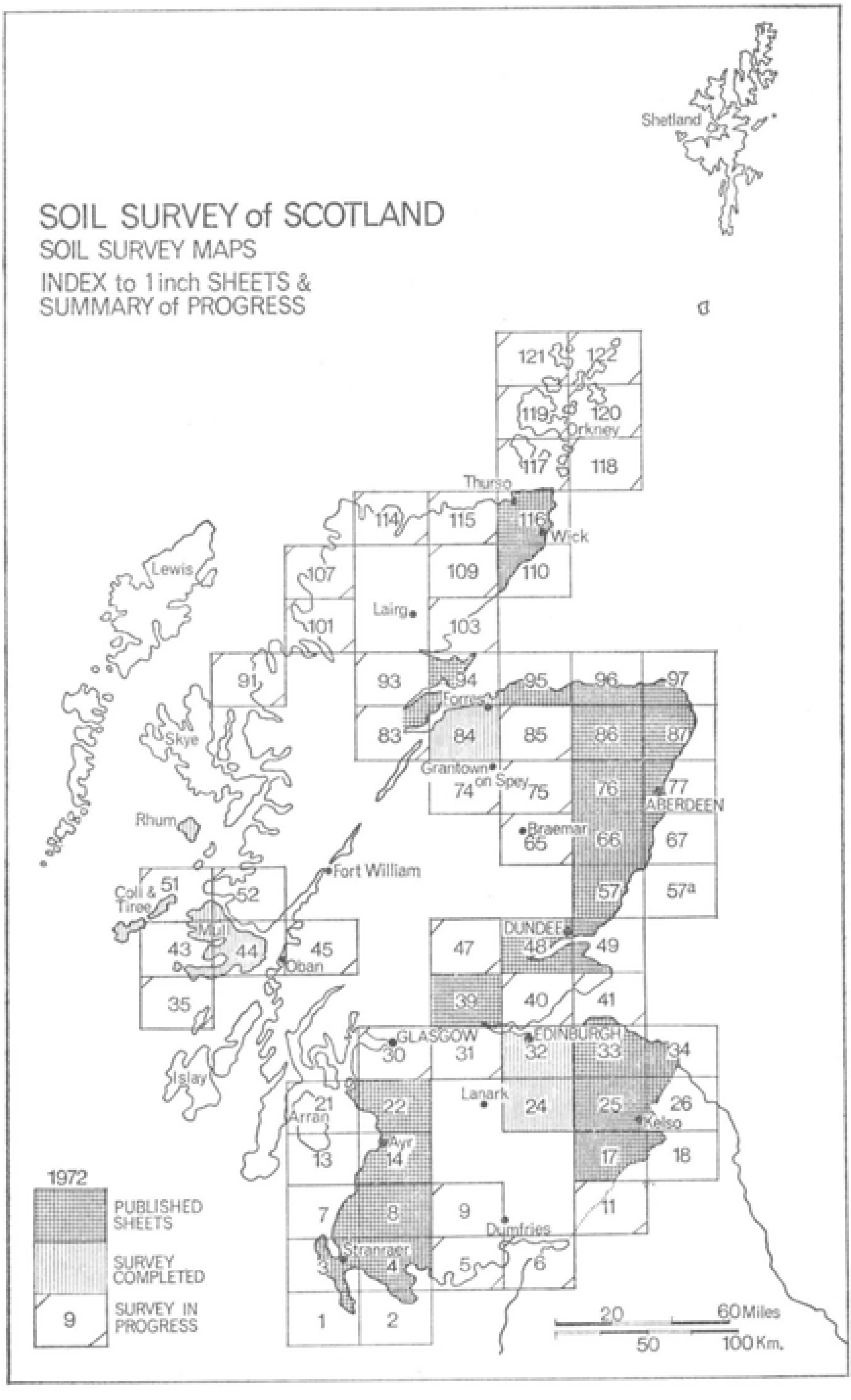
SOIL SURVEY

Soil Survey activities have formed an increasingly important feature of the Institute's programme since its foundation in 1930, and it is now 25 years since the Soil Survey Research Board was formed by the Agricultural Research Council, in 1947, to co-ordinate the systematic survey of the soils of England and Wales and of Scotland. During this period the Soil Survey of Scotland has expanded greatly and there have been significant administrative and technical developments. The total staff is now 28, comprising, in addition to the Head of the Survey, two senior soil correlators, two ecologists, one micromorphologist, three cartographers, one recorder and 18 field surveyors who are currently covering ten areas. Four of these areas are operated from the Institute and the remainder from six decentralized regional offices. The introduction of the latter has had a beneficial stabilizing effect on the staffing position. Excluding five surveyors appointed since 1970, the average length of service of the present field staff is sixteen years, and this provides valuable continuity.

In the pre-war years mapping was done on a scale of 1:10,000, but following the introduction of the Wartime Edition of maps on a scale of 1:25,000 this scale has been used for recording the systematic survey, whether compiled from air photographs or not. A system of classification based on profile morphology has been and is being used which puts emphasis on the geology of the parent material, on the hydrologic conditions, and on soil genesis. The soil key for the published maps has been arranged in a co-ordinate system in which the genetic soil groups and drainage classes are in vertical columns and the different soil associations based on parent material are listed horizontally. The individual units distinguished are soil series, which are given names from the localities where they were first mapped. The soil association name is usually that of the dominant series. Most soil associations include representatives of two or more genetic soil groups and two or more drainage classes. The association can frequently be equated with a geomorphological landscape unit with the soil series and their differing drainage classes forming a hydrologic sequence related by a common parent material in a recurrent pattern over the landscape.

Coloured soil maps on a scale of 1 inch to 1 mile are printed by the Ordnance Survey, using the sheet areas of their Third Edition projection to correspond with the maps published by the Institute of Geological Sciences. The accompanying descriptive memoirs are printed by Her Majesty's Stationery Office. To date, the soils of 32 sheet areas have been surveyed and published on 20 soil maps. Six corresponding land use capability maps have been published. Field work has been completed on another ten sheets and the soil and land use capability maps are at various stages of production. Those for Sheets 24 (Peebles), 32 (Edinburgh) and parts of Sheets 43, 44, 51 and 52, covering the Island of Mull, are at the Ordnance Survey.

Soil maps covering 8700 square miles (22,000 km^2) have been published, or are being printed, and with a further 2000 square miles (5200 km^2) of survey completed on current sheets rather more than one-third of Scotland has now been surveyed.


SOIL SURVEY of SCOTLAND
SOIL SURVEY MAPS
INDEX to 1 inch SHEETS &
SUMMARY of PROGRESS
Shetland
Orkney
Thurso
Wick
Lewis
Lairg
Skye
Rhum
Forres
Grantown on Spey
Braemar
ABERDEEN
Fort William
Coll & Tiree
Mull
Oban
DUNDEE
GLASGOW
EDINBURGH
Islay
Arran
Lanark
Kelso
Ayr
Dumfries
Stranraer
1972
PUBLISHED SHEETS
SURVEY COMPLETED
SURVEY IN PROGRESS
20
60 Miles
50
100 Km.

The vegetation of each sheet area has been surveyed and recorded. Accounts of the various communities, with component plant lists, and their relationship to the soils, have been prepared for inclusion in the accompanying memoirs.

A series of three maps under the general title of Assessment of Climatic Conditions in Scotland has been published on a scale of 10 miles to 1 inch.

Thin sections have been prepared of the soils of 15 of the more important associations, covering most of the genetic soil groups. Many others have been prepared to help to elucidate specific problems of soil genesis, or to characterize profile features.

The Soil Library now contains more than 300 preserved monoliths of the more commonly occurring soil series.

During the current season systematic survey on the scale of 2·5 inches to 1 mile has continued in the ten areas listed below. Some 540 square miles (1400 km^2) have been surveyed, 50 on Sheets 117, 118, 119 and 120 (Orkney), 75 on Sheets 109 and 115 (Auchentoul and Reay), 50 on Sheet 85 (Rothes), 50 on Sheet 75 (Tomintoul), 20 on Sheet 74 (Grantown), 42 on Sheets 51, 52 and 53 (Coll, Tobermory and Ben Nevis), 25 on Sheet 47 (Crieff), 27 on Sheets 40 and 41 (Kinross and Elie), 135 on Sheet 31 (Airdrie) and 70 on Sheets 5 and 9 (Kirkcudbright and Maxwelltown).

Two hundred and ten soil profiles have been described and sampled for analysis.

Successful use has been made of a six-wheeled cross-country vehicle with low pressure tyres for traversing wet peaty moorland and uncultivated hill ground.

The department was represented on the Working Group on Drainage Investigations set up by the Department of Agriculture and Fisheries for Scotland and on the Working Group on Soil Physical Conditions set up by the Agricultural Research Council. Members of the staff attended meetings of the British Society of Soil Science, the annual meeting of the Ordnance Survey Committee on Survey and Mapping, a meeting of the North of England Soils Discussion Group, and the conference on Land Use Capability, at Sutton Bonington, sponsored by the Ministry of Agriculture, Fisheries and Food and the Agricultural Development and Advisory Service.

Sheets 118, 119, 120, 121, 122, part 117 (Orkney Islands)

Approximately 50 square miles (130 km^2) have been surveyed and 36 profiles described and sampled. The soils of the island of Sanday have been mapped and on the Mainland of Orkney survey continued in the parishes of St Ola, Orphir, Firth, and Stenness.

On Sanday two major soil parent materials occur. Soils of the Bilbster series (Thurso Association) have been found on a brown, commonly indurated, stony, sandy loam to loam drift. This drift is patchy and variable in thickness, and soils developed more or less directly on rock (Bilbster series, shallow phase) have been encountered. About a third of the island is covered with wind-blown shelly sand and soils of the Fraserburgh Association ranging from skeletal to very poorly drained have been mapped.

In the parish of St Ola soils of the Kirkwall Association have again been encountered, non-calcareous gleys and peaty gleys being dominant. It now appears necessary to distinguish both poorly drained and very poorly drained peaty gleys. In the West Mainland, however, the dominant soils are those of the Thurso Association, mainly Bilbster series but with areas of the Camster and Olrig series. Poorly drained soils of the Canisbay Association have also been found, and peaty podzols developed on red and yellow sandstones of the Lower Eday Sandstones were met for the first time.

Extensive areas of blanket peat have been mapped as shallow or deep peat, much of the peat having been cut over and, on hill summits, quite severely hagged. Basin peat occurs locally.

Sheets 109 (Auchentoul) and 115 (Reay)

An area of approximately 75 square miles (195 km^2) lying between Strath Naver and Strath Halladale has been mapped and 25 profiles have been described and sampled. All the soils belong to the Strichen, Corby and Berriedale Associations. Those of the Strichen Association are the most widespread, peaty gleyed podzols and peaty gleys being the commonest, with brown forest soils occurring locally. The mapping units are largely complexes of peaty soils and shallow peat, further differentiated on the basis of presence or absence of rock outcrops and deep peat. Soils of the Corby Association are confined to the sand and gravel deposits of the straths and consist of humus-iron podzols (Corby series) and peaty podzols (Tarbothill series). Soils of the Berriedale Association are peaty gleyed podzols (Berriedale series), peaty gleys (Knockally series) and subalpine podzols, and they occur on the new outliers of Middle Old Red Sandstone conglomerates and sandstones. Deep blanket peat is common throughout the area.

Sheet 85 (Rothes)

Approximately 50 square miles (130 km^2) have been surveyed and 34 profiles described and sampled. The ground surveyed lies in the north central part of the sheet and includes the greater part of the Gedloch and Rothes estates between Glen Latterach and the Glen of Rothes, together with Elchies Forest by Archiestown, Ben Aigan, and some parts of Carron estate on both sides of the River Spey south of Archiestown. Most of the land lies below 1200 feet, although the summit of Ben Aigan exceeds 1500 feet.

The soil parent materials encountered range from fluvioglacial sands and gravels, underlying the arable land just south of Elgin, through mixed drifts derived from sandstones and schists, at the edge of the moor between Glen Latterach and the Glen of Rothes, to till derived from acid schists spread over much of the moorland and hill ground on the Gedloch and Rothes estates. Further south at Elchies and Carron mixed till derived from schist, granite and syenite occurs, while on Ben Aigan and in Elchies Forest the subsoil often has a reddish cast, generally associated with red staining of the joint faces of the underlying rock. This feature is believed to be a residual effect from a former covering of Old Red Sandstone strata, and not caused by the pink coloration of the feldspars from the Ben Rinnes granite.

The soils have been grouped within the Corby, Boyndie, Orton, Strichen, Aberlour, Countesswells and Durnhill Associations. On the arable land cultivated humus-iron podzols and non-calcareous gleys predominate. To the east of the Glen of Rothes the moorland pattern includes peaty podzols, peaty gleys and hill peat, with podzols only around the fringes. On Ben Aigan, podzols are developed on the lowest slopes, with peaty podzols with strong thin iron pan between 500 and 1250 feet. Peaty gleys are restricted to concave catchment slopes around gully head areas. Above 1250 feet the thin iron pan is no longer present and subalpine podzols are developed on the summit plateau.

Sheet 75 (Tomintoul)

About 50 square miles (130 km^2) have been surveyed and 18 profiles described and sampled. The majority of these profiles were exposed by the Smalley excavator. This machine was also used to confirm that, in the Tomintoul area, parent materials derived from Old Red Sandstone rocks occur at a considerable distance from the outcrops shown on the geological map. In part this is a consequence of the transfer of drift, but in some places, for instance the Braes of Glenlivet, the parent materials appear to be derived locally from seams of conglomerate and sandstone.

The greater part of the mapping was done in the south-east quarter of the sheet, in the Morven district, where the Insch Association is extensive. The parent materials of this association are formed from basic rocks, mainly norites and gabbros, and their derived drifts. Brown forest soils, gleys and peaty gleys are dominant on the lower ground. Above about 1400 feet the most extensive mapping unit is a freely drained peaty soil which lacks a distinct A_2 horizon. This soil is suitable for improved grazing where slope, stoniness and climate permit. Peaty podzols having a gleyed A_2 horizon, iron pan and ochreous B_2 horizon are not common, but were mapped on the north-facing slopes of Morven. The indurated B_3 horizon is not confined to freely drained soils, although in gleys it may be partly softened, and it is absent where the texture is clay loam or finer. Induration fades as elevation increases, but this may be related to the prevalence of coarse-textured stony drifts on the higher ground.

About 20 square miles (50 km^2) have been surveyed in the south-west quarter of the sheet, where the parent materials are derived from granite and the soils belong to the Countesswells Association. The country is rugged and elevated, rising to over 3500 feet on Bynack More and the slopes of Beinn a' Bhuird. Soil complexes have been mapped where rock outcrops, screes and boulder lobes are extensive and on the morainic topography of the valley floors. As elevation increases, peaty podzols give way to podzols with only weakly-developed iron pan and B_2 horizons, and finally to soils having black humose horizons below a thin surface organic layer. Although samples from the latter soils show greater amounts of pyrophosphate-extractable iron in the humose horizon relative to layers above and below, the enrichment with humus is a more obvious feature. A variant found under the *Nardus*-dominant sward on the rims of depressions has a grey, mainly mineral, horizon immediately above the humose layers, which suggests that there is intense leaching during the main thaw of snow patches in early summer.

Sheet 74 (Grantown)

Systematic soil survey of the northern part of Sheet 74 has been continued in the Dulnain Valley. Approximately 20 square miles (50 km^2) have been mapped between Dulnain Bridge and Inverlaidnan.

Alluvial soils similar to those reported in 1970 were again identified. A complex system of old meander channels is characterized by an infilling of peat alluvium or poorly drained sand overlain by a silt capping. The common hazard of flooding and breaching of the old levees in this area is illustrated by occasional superficial deposits of sandy gravel up to 60 cm thick.

Gravels and sandy gravels, forming the parent material of the soils of the Corby Association, flank both sides of the valley. On excessively drained morainic ridges, situated either on or above the terrace system, the natural profile is an iron podzol. Elsewhere, on more subdued topography, humus-iron podzols and peaty podzols are the dominant soils. Cultivation is largely confined to the terraces.

Soils belonging to the Strichen, Dulsie and Aberlour Associations are found above approximately 900 feet on the slopes bordering the southern limit of the Dulnain Valley. Podzolization is widespread. In addition to the well established Strichen and Gaerlie series, humus-iron podzols and peaty podzols occur on very stony shallow soils associated with rankers and outcropping Moine schists. Where possible these soils have beeh mapped as the Derraird and Kichanroy series respectively, otherwise they have been included in a complex.

Sheets 51 (Coll), 52 (Tobermory) and 53 (Ben Nevis)

Reconnaissance of the area has been completed and mapping carried out principally in the parishes of Ardnamurchan, Morvern and Ardgour. Approximately 42 square miles (110 km^2) have been mapped. Bad weather and restriction of access by sporting activities have been limiting factors.

The basalts of Morvern give rise to soils which are identical with those of the Isle of Mull and can be mapped using the same complexes. New soil complexes will be necessary for soils derived from the gabbros of Ardnamurchan and from the granites and psammitic gneisses. Although some previously described soils, chiefly the freely drained and peaty podzol series of the Strichen, Insch and Countesswells Associations, can be recognized, many soils are variants peculiar to the western climatic zone. The cool, wet environment has caused an accumulation of partially decomposed organic material which, together with the coarse stony regolith and steep slopes, influences both soil processes and water regime. Further study is necessary before such soils can be characterized successfully.

Soils derived from rocks of the thin Mesozoic succession of the Western Highlands, chiefly sandstones and sandy limestones, have been encountered in Ardnamurchan and Morvern. They tend to be shallow and highly variable but brown forest soils, non-calcareous gleys, iron podzols, peaty podzols, and peaty gleys have been recognized. A reddish brown clay or clay loam till developed in small patches between 800 and 1200 feet on Rahoy Estate, Morvern, supports a peaty gley with many patches of peat. Some podzols and non-calcareous gleys also occur in the complex. Soils allied to those but with better drainage characteristics have been described as the Inchkenneth Association in western Mull.

Sheet 47 (Crieff)

Approximately 25 square miles (65 km²) of new mapping has been completed in the south-west corner of the area of Sheet 47 between Glen Artney and Loch Earnside. This area lies mainly north of the Highland Boundary Fault and includes a large proportion of very dissected mountainous country with Ben Vorlich (3224 feet) prominent. The soils encountered include all those described in previous reports on this area, namely the Callander and Gourdie Associations in Glen Artney (both of which have soils deficient in cobalt and copper), the Foudland Association in a narrow belt north of and parallel to the Highland Boundary Fault, and the Strichen Association bordering Loch Earn.

Sheet 40 and Part 41 (Kinross and Elie)

The survey of this district is now almost complete. Approximately 25 square miles (70km²) have been mapped in the Cleish-Saline area to the west and north-west of Dunfermline and mapping has been completed in several smaller areas in the East Neuk of Fife, in the Howe of Fife, and on Benarty Hill. In addition, the survey of much of the district has been checked and where necessary revised.

Twenty-five soil profiles have been described and sampled. Several soil series not previously mentioned in the reports for this district have been recognized. Although they cover relatively small areas, and in some cases are of insufficient extent to allow separation on the soil map, they are of interest genetically and morphologically and warrant a brief description.

The Devilla series of the Giffnock Association has already been mapped on Sheet 39 (Stirling) to the west. It is an imperfectly drained podzol developed on residual sandstone of the Calciferous Sandstone Measures and occurs under a heath vegetation.

The other four series have not yet appeared on published maps and have been given provisional names.

The Outh series of the Rowanhill Association is a peaty gley developed on till of clay loam or clay texture derived from Carboniferous sediments with a dominance of shale. Occurring under a *Juncus* flush vegetation, it is poorly drained in contrast to the Glaisnock series which is a peaty gley with very poor drainage.

The Dullmoir series of the Giffnock Association is a freely drained brown forest soil tending, in some cases, to a brown calcareous soil. It is developed on calciferous sandstone with occasional bands of limestone and occurs in small areas, generally in the vicinity of former limestone quarries.

The Aldie series of the Sourhope Association is an imperfectly drained brown forest soil with gleying, developed on water-sorted till derived from intermediate lavas of Old Red Sandstone age. It occurs in small areas throughout the Bellshill series. Because of the coarser texture of the upper horizons, resulting from water-sorting, the Aldie series is generally in a higher land use capability class than the Bellshill.

The Innerdouny series of the Sourhope Association is a peaty brown soil developed on drifts derived mainly from intermediate igneous rocks. It occurs commonly under *Nardus* grassland and is imperfectly drained with a peaty A horizon, 10 to 15 cm thick, overlying brown or pinkish brown drift. A thin gleyed horizon sometimes underlies the peat layer.

Sheet 31 (Airdrie)

Approximately 35 square miles (90 km²) of new ground has been surveyed, almost completing the mapping of the area of Stirlingshire north of the Forth-Clyde canal. The soils encountered include all those described in previous reports on this area — notably the Darleith Association in the Kilsyth Hills and on Denny Muir, the Giffnock and Rowanhill Associations on the drumlin country north of the Forth-Clyde canal, the Darvel Association in the Kelvin Valley and Carron Valley and the Stirling Association near Grangemouth and Carronshore. Systematic sampling of many of these soils has still to be carried out.

Mapping has also been carried out around Kirkintilloch, Coatbridge and Airdrie and on the eastern environs of Glasgow. About 80 square miles (200 km²) have been mapped in these areas and a further 20 square miles (50 km²) to the south of Falkirk and Linlithgow. The dominant soils are those of the Caprington and Rowanhill series with the Aberdona, Bargour and Darvel series and peat of secondary importance. To the north-east of Airdrie peat and soils of the Rowanhill Association are in complex with derelict mining bings and disturbed ground. As it is anticipated that this type of complex will be encountered elsewhere it has been delineated but not yet named.

Sheets 5 and 9 (Kirkcudbright and Maxwelltown)

Mapping has continued this season in an area lying to the east of Castle Douglas and extending northwards through the strip of land between the Water of Urr and the River Dee to comprise a total of 70 square miles (175 km²). In addition 60 soil profiles from areas mapped during previous seasons have been described and sampled.

The underlying rocks are entirely Ordovician and Silurian greywackes and shales, on which the distribution and nature of the soil parent materials is occasioned by the pattern of glacial erosion and deposition. The till deposits in the area near Castle Douglas carry freely and imperfectly drained brown forest soils, which are similar to the soils of the Ettrick and Rhins Associations and most closely resemble those soils indicated as intergrades of these types on the soil map of the Wigtown-Stranraer area. The establishment of a Castle Douglas Association to accommodate the soils in this area is being considered.

To the north, around Corsock, and northwards to Loch Urr and Lochinvar the parent material and soils closely resemble the modal types of the Ettrick Association.

The separation of freely and imperfectly drained soils on drumlin features occurring in the lowland areas, and of peaty podzol and peaty gley soils on similar features in the hill area, is continuing to prove laborious and time-consuming. As yet no resort has been made to mapping complex units in these situations, partly in order to avoid adding to the already considerable number of complexes in the Ettrick Association and partly because the areas delineated are usually greater than the two acres or so regarded as the minimum size for representation on maps at the scale of 1 inch to 1 mile. Nevertheless, the common occurrence in a locality of such separations of near limiting size is a cause for concern.

Vegetation Surveys

Further revision of the plant community tables of lowland Scotland was carried out prior to a private visit by Mr E. L. Birse to Professor R. Tüxen, Arbeitsstelle für Theoretische und Angewandte Pflanzensociologie, Todemann, Rinteln, West Germany. Much fruitful discussion was had with Professor Tüxen on the naming of Scottish plant communities and on their position in the European classification. Because of the higher degree of oceanicity in Scotland when compared with most of Europe, not all communities could be placed in their relevant alliance. For instance, vegetation dominated by *Juncus acutiflorus* and provisionally named Potentillo-Juncetum acutiflori can be regarded as part of the alliance Juncion acutiflori or of the alliance Molinion. Other communities, such as the small sedge communities, cannot be given definite association names until more records have been collected. The major woodland, pasture and moorland communities, however, have been named and characterized by the diagnostic species of the alliance, order and class and, where possible, by diagnostic species of the association.

Drafts of the introductory chapters on methods, climate and geology for the bulletin on the plant communities of the lowland and Southern Uplands of Scotland have been prepared.

The transfer of field and analytical information on soils and other habital conditions for some 600 releves has now been completed and the resulting data bank has been stored on an exchangeable disc cartridge for rapid information retrieval. The disc will be updated each year as new records are collected. The information will be used primarily to relate vegetation to soil types.

The third climatic map of Scotland, The Bioclimatic Sub-regions, has been published[11]. Each vegetation releve is now being placed in its appropriate thermal sub-zone, moisture sub-division and oceanicity sub-sector. At this stage the influence of warmth and, to some extent, of moisture status on the distribution of plant communities is evident. The more subtle influence of oceanicity is less clear, but additional recordings should help to elucidate it.

Recording of the mountain and moorland vegetation of Sheet 75 (Tomintoul) was carried out in April 1972 and that of Sheet 74 (Grantown) in May. Lowland vegetation was recorded on Sheets 40 and 41 (Kinross and Elie) during July and August. Several records were made of the weed communities of arable land as a first step towards characterizing them.

Soil Micromorphology

Examination of soil thin sections prepared from freely drained soils of the Ettrick Association has been completed and a draft paper drawn up. The interrelated morphological and micromorphological characteristics suggest a pattern of progressive soil profile development from brown forest soil to podzol or peaty podzol at lower altitudes, and a parallel evolution from weakly developed subalpine brown earths to alpine soils above the forest zone.

A fossil soil from below a barrow of Neolithic age has been examined, and a short paper[51] prepared. Although the present day semi-natural soils on the site are strongly podzolized, the evidence suggests that the profile was a brown forest soil developed under deciduous woodland.

Soil thin sections have been prepared from soil samples from Iceland and Elephant Island (Antarctica) made available by other workers, and these are helping to confirm the distinctions between current soil-forming processes and earlier periglacial processes, which have been made on the basis of micromorphological studies of Scottish soils.

To minimize alteration in soil structure which occurs during the preparation of soil thin sections, new techniques are being examined. In particular, the freeze-drying of soil samples prior to impregnation with polyester resin has proved satisfactory on an experimental basis. The purchase of equipment to enable impregnation of soil samples under vacuum to be carried out on a bulk basis has been approved and it is hoped to have this operational in the near future.

With the co-operation of Pedology, the application of scanning electron microscopy to the interpretation of soil micromorphology is being examined.

Other Work

Collaboration has continued with the three Scottish Colleges of Agriculture in such matters as drainage problems, selection of crop trial sites, investigations on the effects of subsoiling and moleing, and studies on water relationships in selected soil series.

An account of areas of Scotland requiring drainage for the successful production of arable crops and rotational grass has been prepared for the Working Group on Drainage set up by the Department of Agriculture and Fisheries for Scotland, and assistance has been given in the selection of sites for investigation.

Liaison has also been maintained with the Forestry Commission, the Nature Conservancy and the Highlands and Islands Development Board, and with other departments of the Institute.

Information on soils has been supplied to a number of University departments and assistance on field excursions given to the British Geomorphological Society, the Royal Scottish Forestry Society and the Hill Land Use and Ecology Group. Advice on the soils at several archaelogical excavations has been given. The publication of soil and land use capability maps has led to many requests for further information and a number of talks and lectures on the work of the Soil Survey have been given. An exhibit was supplied for the 'Search' Exhibition organized by the Department of Education and Science at the Science Museum, London.

Chapters on soils and land use capability have been contributed to three books to be published by the Nature Conservancy[54], the British Museum[55], and Glasgow University[56, 57], respectively. A monograph on the classification of some British soils according to the comprehensive system of the United States[58] is also in press.

Maps, Memoirs and Cartography

Soil maps on the scale of 1 inch to 1 mile have been published for combined Sheets 110/116 (Latheron/Wick) and 1/2/3/4 (Kirkmaiden/Whithorn/Stranraer/Wigtown). Land use capability maps of combined Sheets 110/116 (Latheron/Wick) and Sheet 94 (Cromarty and Invergordon) have also been published on the 1 inch scale.

The colour proof of the soil Sheet 94 (Cromarty and Invergordon) has been corrected and returned to the Ordnance Survey for final printing.

Scribed negatives and completed colour models for the soil maps of combined Sheet 24/32 (Peebles/Edinburgh) and part Sheets 35/36/43/44/51/52 (Island of Mull) have been submitted to the Ordnance Survey for printing and colour proofs are awaited.

The total of uncoloured 2·5 inches to 1 mile soil survey field sheets for restricted circulation now stands at 78. The recent additions are 11 sheets from the north-east area—six from Angus and Kincardine, eight from north Ayrshire and two from Midlothian and Peeblesshire.

The third climatic map on the 10 miles to 1 inch scale has now been published, with its accompanying pamphlet, under the title of The Bioclimatic Sub-regions of Scotland[11].

A map of the vegetation of the Nairn and Cawdor area on the 2·5 inches to 1 mile scale has reached line proof stage, but due to the complexity of the line work it will be some time before a decision can be reached on the feasibility of colour printing.

Publication of the memoir to accompany Sheet 7/8, The Soils of Carrick and the Country round Girvan[59], is awaited, and drafts of memoirs for Sheet 48/49 (Perth/Arbroath) and Sheet 110/116 (Latheron/Wick) have been completed.

SOILS OF THE COUNTRY ROUND PEEBLES AND EDINBURGH

The soil map, on the 1:63,360 scale, of combined Sheet 24/32 (Peebles/Edinburgh) has been completed and a preliminary summary of the findings is given below.

The area covers about 750 square miles (1935 km^2) of Midlothian, Peeblesshire, West Lothian and the eastern border of Lanarkshire. The landform can be split into three broad categories.

1. The Southern Uplands to the south and east.
2. The Pentland and Biggar Hills running north-east to south-west across the map.
3. The Lowlands, comprising the Coastal Plain, West Lothian Plain, Lothian Platform and Basin, etc.

The Southern Uplands, formed from Ordovician and Silurian shales and greywackes, range in altitude from 450 feet to 2700 feet (105 m to 860 m). The Pentland and Biggar Hills are underlain by sedimentary and igneous rocks of the Old Red Sandstone age while the low-lying region surrounding the Pentland Hills is formed from Carboniferous rocks.

The geological succession is:

Recent		Peat and alluvium.
Post-glacial		Low raised beach deposits.
Pleistocene		Solifluction deposits, fluvioglacial sands and gravels, till and high raised beach deposits.
Carboniferous	Upper	Coal Measures: sandstones, mudstones.
		Millstone Grit: shales and coals.
	Lower	Lower Limestone Group: sandstones, limestones.
		Calciferous Sandstone Measures: oil shales, lavas and tuffs.
Old Red Sandstone		Upper: red sandstones, cornstones, conglomerates and marls.
		Lower: sandstones, conglomerates, lavas and tuffs.
Silurian		Downtonian: red sandstones and conglomerates.
		Ludlow: mudstones, shales and greywackes.
		Wenlock: green, grey and reddish shales.
		Llandovery: greywackes and shales.
Ordovician		Ashgill: conglomerates, shales, greywackes.
		Caradoc: limestones and lavas.
		Arenig: shales, churts and lavas.

Three climatic regions occur within the area under review: (1) the Coastal Plain, (2) the Lothian Plain, Lothian Platform and Carnwath Drift Plain, (3) the Southern Uplands and Pentland Hills. The rainfall rises from 635-750 mm (25-30 inches) along the Forth coast to 890-1015 mm (35-40 inches) on the Lothian Platform and to above 1270 mm (50 inches) in the Pentland Hills and Southern Uplands. Temperature variations follow a similar pattern. Although winter temperatures are not very low in the lowlands, the rise in air temperature during spring tends to be slow, due to cold easterly winds. These winds often bring haar off the North Sea during the spring and early summer months, but this does not penetrate far inland. The prevailing wind is from the south-west quadrant.

Eighty-eight soil series and 17 soil complexes have been mapped and are represented by the following 20 soil associations:

Association	*Parent Material*
Ashgrove	Drift derived from carbonaceous shales.
Bemersyde	Drift derived from rhyolite and trachyte.
Biel	Drift derived from shales and sandstones of Carboniferous and Upper Old Red Sandstone age.
Darleith	Fine and medium textured basic igneous rocks and derived drifts.
Darvel	Fluvioglacial sand and gravel derived mainly from Carboniferous sediments.

Dreghorn	Raised beach sand derived mainly from Carboniferous sandstones.
Eckford	Fluvioglacial sand and gravel derived from sandstones of Upper Old Red Sandstone age.
Ettrick	Silurian and Ordovician greywackes, shales and their derived drifts.
Fraserburgh	Raised beach windblown shelly sand.
Giffnock	Drift derived mainly from Carboniferous sandstones.
Hobkirk	Red Sandstone of Upper Old Red Sandstone age and derived drifts.
Lanfine	Drift derived from red sandstones, marls and basic lavas.
Mountboy	Drift derived from Lower Old Red Sandstone grits, sandstones and conglomerates with some basic and intermediate lavas.
Rowanhill	Drift from Carboniferous shales, sandstones, cementstones and coals.
Sorn	Drift derived from Carboniferous sandstones and shales with some Old Red Sandstone marls, sandstones and lavas.
Sourhope	Drift derived mainly from andesitic lavas.
Stirling	Raised beach silts and clays.
Symington	Sand and gravel derived mainly from andesitic lavas.
Tynehead	Drifts from Carboniferous sandstones and Ordovician greywackes.
Yarrow	Gravels derived from greywackes of Silurian and Ordovician age.

In addition the following miscellaneous soils have been mapped:

Links (stabilized blown sand).

Blanket peat.

Basin peat.

Peat alluvium complex.

Alluvium.

Mixed bottom land.

The alluvium derived from the Ettrick and Rowanhill Associations has been subdivided on a basis of texture and drainage class. Where the parent material or soil pattern is complex the alluvial soils are undifferentiated.

The most extensive group of soils, the Ettrick Association, accounting for about 40 per cent of the area, comprises nine soil series and eight soil complexes, developed on parent materials derived from Ordovician or Silurian shales and greywackes. The dominant soil, the Linhope series, is a freely drained brown forest soil occurring mainly on the slopes of the Southern Upland valleys. It has a dark brown friable A horizon under natural vegetation, but when cultivated much of the organic matter is oxidized and colour values are reduced. The B horizon has a strong brown colour and passes down into a massive stony drift which is usually dense and often very compact. The soil reaction is generally strongly acid, pH (water) 4·5-5·0 at the surface under natural or semi-natural vegetation, rising to 5·0-5·5 in the

C horizon. When cropped or when pasture improvement has been carried out the pH of the surface soil is higher. Except in organic-rich A horizons, the cation-exchange capacity tends to be rather low. The total phosphorus content is low in the B and C horizons (70-100 mg P_2O_5/100 g), but in many surface horizons values exceeding 300 mg P_2O_5/100 g have been recorded, due to the application of phosphatic fertilizers—often as basic slag.

On the lower, more gently sloping valley sides imperfectly drained gleys and gleyed brown forest soils are found. On the coarser textured parent materials the Altimeg series is mapped, whilst the finer textures give rise to the Kedslie series. The coarser textured parent materials are confined mainly to the western parts of the Southern Uplands, while to the east clay loams or sandy clay loam tills predominate. The principal morphological features of the Kedslie series are a dark grey brown A horizon with subangular blocky structure, a greyish brown, prismatic B horizon, with prominent ochreous mottles and grey ped faces, merging into a less gleyed C horizon. Apart from its texture the Altimeg series is similar, but has a diffusely mottled, massive, compact B or BC horizon at about 40 cm. The cation exchange capacity of the Kedslie series is moderate and changes little down the profile, as does the pH, which is slightly acid—6·0-6·5. In the unfertilized soil the phosphorus content is moderate to low in the surface horizon and declines with depth. The Altimeg series, being a sandier soil, tends to have a lower exchange capacity in the B and C horizons.

The poorly drained soils are comparable with the Kedslie and Altimeg series in that the Ettrick series occurs on the fine textured clay loam tills while the Littleshalloch series, confined mainly to the south and west, occurs on the coarser textured tills. In receiving sites, but of minor extent, is the peaty gley Hardlee series.

In the more elevated regions, associated with blanket peat, is the peaty podzol Dod series. This soil predominates on the Moorfoot Hills and on the higher southern parts of the Southern Uplands with a high rainfall. Although the Moorfoot Hills do not occur in the high rainfall area, they have flat tops which shed water slowly and aid peat formation. The principal morphological features of the Dod series are a surface horizon of greasy peat on an eluviated A horizon, which is generally of fine sandy loam texture with a subangular blocky structure, and beneath this, usually at around 10-15 cm, a thin iron pan overlying a strong brown B horizon with a firm subangular blocky structure, over a compact, stony C horizon. The soil reaction is strongly acid, pH 3·5-4·0 rising to 4·5-5·0 with depth. The cation exchange capacity is high above the iron pan and drops markedly below it.

The other important soil in elevated regions is the Minchmoor series, a humus iron podzol which is very stony and in many places occurs on steeply sloping sites. The soil is characterized by 5-10 cm of black fibrous humus over a sandy loam A horizon with abundant angular stones, beneath which is a dark reddish brown B horizon containing much translocated humus. This overlies a strong brown stony B horizon, merging into a very stony and often compact C horizon. The soil reaction, as with the Dod series, is very acid, pH 3·3-3·6 rising to 4·5-4·8 with depth. The cation exchange capacity is high, falling markedly below the zone of humus translocation.

The Merrick series, an oroarctic podzol, occurs on the summits of the Southern Uplands above 2000 feet (600 m).

In the major valleys of the Southern Uplands the alluvium has been classified on the basis of texture and drainage class. The two main mapping units, the Peebles and Dryburn series, are both freely drained, but the former is stone free while the latter is gravelly. In old silted up drainage channels, where silty clay loam occurs, the poorly drained Heavyside series is developed.

The Yarrow series occurs on raised terraces in the Clyde, Tweed, Lyne, Manor and Eddleston valleys and is developed on a fluvioglacial gravel derived from greywacke. As the parent rock is almost entirely greywacke, this soil has many properties in common with the Linhope series.

The soils of the Mountboy Association are developed on the Lower Old Red Sandstone rocks, sedimentary and volcanic, occurring on the southern part of the Lothian Platform and the southern end of the Pentland Hills. The Garvock series, a freely drained brown forest soil, occurs on the Lothian Platform to the south of the Pentland Hills. The principal morphological features of this series are a dark reddish brown A horizon with a sandy loam texture and a fine subangular blocky or coarse crumb structure, developed on a brown B horizon with a sandy loam texture and, usually, very weak structure. The reddish brown C horizon, depending on the colour of the underlying rocks, is also of sandy loam texture, but is usually very gritty. Analyses available show the soil to have a slightly acidic reaction, with pH ranging from 5 to 6. The degree of base saturation at the surface is about 40 per cent and rises gradually with depth. High values for exchangeable calcium and total phosphorus in the surface reflect the agricultural treatment, as these values drop significantly with depth.

The other main soil series in this area is the Netherurd series, also a freely drained brown forest soil, but with partially sorted surface horizons. The morphological features and chemical properties of this soil are similar to those of the Garvock series, but the structure at the surface is very weak while the B horizon is generally firm and compact.

The Mountboy series, an imperfectly drained non-calcareous gley soil of minor extent, has a clay loam or sandy loam surface horizon overlying a mottled B horizon with a clay or clay loam texture and coarse prismatic structure. The C horizon is again a clay loam, but with many stones. When there is a large amount of weathered sandstone present the texture is usually sandy clay loam. The soil reaction is slightly acid, with a pH varying from 5·5 to 6·5. Medium to high values of exchangeable calcium and total phosphorus in the topsoil, decreasing with depth, indicate regular applications of lime and fertilizer.

Within the wet hollows of the Lothian Platform to the south of the Pentland Hills, the poorly drained Longstruther series has been mapped, but is of limited importance. On the higher ground of the Pentland Hills, the most widespread soil of the Mountboy Association is the Byrehope series, a peaty podzol with thin iron pan. This soil is characterized by a surface horizon of black greasy peat, overlying an eluviated A horizon with a sandy loam texture and weak blocky structure. Beneath, at around 10 cm, there is usually a thin iron pan overlying a reddish brown B horizon with weak blocky structure. The C horizon is usually stony and compact. The soil reaction is strongly acid throughout the profile, rising only slightly with depth, and the cation exchange capacity is high above the iron pan but falls markedly below it. Associated with the Byrehope series, but occurring in the wetter hollows, are the poorly drained peaty gley Hareshaw series and the non-calcareous gley soil Barras series, neither of which is extensive.

At the western end of the Pentland Hills are the soils of the Hobkirk Association developed on drifts derived from red sandstone of Upper Old Red Sandstone age. The two soils occurring in the upland region are the humus iron podzol Harelaw series and the peaty podzol Faw series. The Harelaw series is the more extensive soil and is characterized by a horizon of friable raw humus, overlying a pinkish grey eluviated sandy horizon which in turn overlies a black or very dark brown humus B horizon with a loamy sand texture; beneath this humose layer is a horizon with a strong yellowish red colour and a sandy loam texture, passing into a stony C horizon or rock.

The soil reaction is very acid in the surface and humose B horizons, about pH 3·5, but rises with depth to about 4·5. The cation exchange capacity is low, except in the humose B horizon where it is markedly higher.

The peaty podzol Faw series is distinguished by having a surface horizon of greasy peat and an eluviated A horizon of sandy texture overlying an undulating thin iron pan, beneath which is a strong yellowish red B horizon on a stony, compact C horizon. Chemically the Faw series is very similar to the Harelaw series and has a high cation exchange capacity in the organic rich horizons.

In the lower areas of the Carnwath Drift Plain the Hobkirk series, a freely drained brown forest soil, has been mapped. The principal morphological features are a dark reddish brown A horizon with a sandy loam texture and weak blocky structure, a reddish B horizon, again with a weak blocky structure, and a red C horizon which is often dominated by sandstone fragments. The Hobkirk series has a moderately acid reaction, with a pH of 5·5 throughout the profile. On cultivated land the exchangeable calcium content in the surface horizon is high and the total phosphorus is moderately high as a result of lime and fertilizer applications; both values decrease markedly down the profile. The organic matter content is moderate in the surface horizon but very low beneath.

Of limited importance in the wet hollows of the Carnwath Drift Plain are the Cessford series, a poorly drained gley, and the Wauchope series, a peaty gley.

On the Biggar Hills and north end of the Pentland Hills, soils of the Sourhope Association have been mapped. The only soils occurring to any extent are the Sourhope and Elsrickle series, both brown forest soils. Humus iron podzols and non-calcareous gley soils have been distinguished but are of minor extent.

The Sourhope series occurs over a wide altitudinal range and has a sandy loam to loam texture throughout the profile, usually reddish brown in colour from the underlying andesitic rocks. There is often a high stone content, increasing with depth. The chemical properties depend largely on its agricultural use, altitude and ease of access. At 1150 feet (350 m) on the Pentland Hills the reaction is acid, pH 4·8-5·0, while at 60 feet (20 m) on the footslopes, as a result of liming, the pH is 6·0-6·5. On the footslopes the cation exchange capacity, exchangeable calcium and total phosphorus are usually high in the surface layers and decrease with depth, while on the upper slopes of the Pentland Hills the values are much lower.

The Elsrickle series, confined to the Biggar Hills, is an imperfectly drained brown forest soil derived from stony andesitic drift overlying a clay loam till of mixed origin. The series is characterized by a dark brown A horizon with a loam texture and weak structure, overlying a very firm, compact, weakly mottled B horizon with a platy structure. Below this compact horizon is a dark grey brown clay loam. Few chemical analyses are available at present, but the indications are medium pH and high values for exchangeable calcium, cation exchange capacity and total phosphorus in the surface horizon, decreasing in the B horizon. In the clayey till, however, there are again high values for exchangeable calcium and exchange capacity, but not for total phosphorus.

The soils of the Eckford Association have been mapped extensively in the Carnwath Drift Plain and southern portion of the Lothian Platform, but are confined to the South Medwin river system. The Eckford series is a freely drained brown forest soil developed on fluvioglacial sand and gravels derived mainly from Old Red Sandstone sediments. Where limed its chemical properties are a pH of 6·0-6·5 and a high exchangeable calcium content in the surface horizons but moderate to low values beneath. The total phosphorus content is moderate at the surface but decreases with depth. A poorly drained gley soil and humus iron podzol have been distinguished but are of minor extent.

Soils of the Rowanhill Associations are dominant on the Lothian Plain and are developed on a clay till derived from Carboniferous sediments. To the east of Edinburgh the Winton series, an imperfectly drained non-calcareous gley soil, is dominant, while to the west the poorly drained Rowanhill series is more prevalent because of the higher rainfall. The Macmerry series occurs widely in both areas. The principal morphological features of the Winton series are a dark grey brown A horizon with a sub-angular blocky structure and a prismatic mottled B horizon, which is reddish brown around Penicuik and Rosewell but much browner and greyer to the west. The C horizon is a dark brown, less prominently mottled, massive clay loam, often with a high coal and shale content. The soil reaction is generally slightly acid, pH 6·3-6·5, changing little down the profile, but below two metres the till is often weakly calcareous. Except under woodland the degree of base saturation is high throughout and the high values for exchangeable calcium content and moderate values for total phosphorus on arable land are indicative of liming, for these values decrease with depth.

The Rowanhill series has been mapped west of the Pentland Hills in a broad strip running due west from Balerno through West Calder and in the Bathgate Hills. This series is a poorly drained non-calcareous gley with chemical properties very similar to the Winton series. The differences between these soils depend mainly on the length of time they are waterlogged. The Rowanhill series is generally saturated with water to within a few centimetres of the surface for more than half the year and exhibits a higher degree of hydromorphism than Winton series. The peaty gley Glaisnock series also occurs in this area but is of small extent.

The freely drained Greenside series, a brown forest soil developed on till derived from the underlying sandstones and shales, is mapped mainly on the eminences of the Lothian Plain and Platform where clayey till is absent. On the upper slopes the deposits are relatively shallow, but on footslopes they are generally thickened by the build-up of colluvium. The principal morphological features are a dark brown A horizon with a blocky structure and loamy B and C horizons which can have a heavier texture if argillaceous sediments occur locally.

The Macmerry series is an imperfectly drained soil, generally associated with soils of the Darvel Association, and has partially sorted surface horizons of sandy loam texture merging into sandy clay loam or clay loam within the B or C horizons. Mottling increases in intensity with depth in the solum, but, as in the Winton series, begins to fade in the C horizon. The chemical properties are very similar to those of the Winton series.

The soils of the Darvel Association, referred to above, occur on the fluvioglacial deposits, mainly terraces of rivers such as the South Esk, North Esk and Almond. The Darvel series, a freely drained brown forest soil, has been mapped as two phases, a stone-free phase and a gravelly phase. It has a dark brown A horizon with a weak crumb structure over a reddish brown B horizon with a very weak crumb structure, merging into a single grain loamy sand C horizon. The main chemical properties are a medium cation exchange capacity decreasing with depth to low values (about 5-6 me/100 g), a pH value between 6 and 7 where limed, and a high total P_2O_5 content ($>$230 mg/100 g) decreasing in the subsoil horizons.

A humus iron podzol, a peaty gley and an imperfectly drained brown forest soil have been distinguished as series in the Darvel Association but are of minor extent.

The Queensferry complex has been mapped west of Edinburgh as far as Linlithgow. This complex includes the Greenside, Darvel and Macmerry series as well as their intergrades.

Soils of the Darleith Association have been delineated on the basaltic lavas of the Bathgate Hills and the quartz dolerite intrusions in and to the west of Edinburgh. The Darleith series is the most extensive soil in the Association and comprises a dark brown loam A horizon on a strong brown weakly structured B horizon, which merges into a strong brown C horizon with abundant weathered stones. The values for exchangeable calcium are high throughout the profile, as is the cation exchange capacity. The total phosphorus content is high in the surface horizons and decreases with depth. Where the drift is thin and rock outcrops are common, the Dalmahoy complex has been mapped.

The Dreghorn series, mapped around Musselburgh, supports the larger part of the horticultural industry within the area. The morphological features of this series are a sandy loam A horizon, a lightening of texture down the profile, and weak structure throughout. The exchangeable calcium values are high in the surface horizons, as are the total phosphorus values; this can be attributed to the long period of cultivation and liming that these soils have experienced. The soil reaction in the surface horizons is slightly acid, pH 5·5-6, and the pH increases with depth to 6·3-6·8.

The agriculture of the area can be split broadly into three categories: arable, mixed arable and stock farming, and hill farming. The areas of each conform broadly to the climatic regions outlined above.

Along the coastal plain, in the warm dry lowland area, arable agriculture is practised almost exclusively, while around Musselburgh horticulture is dominant. To the south of this belt mixed arable and stock farming is common on the warm moist lowland and foothill regions, while in the cool wet hill regions of the Pentland Hills, Southern Uplands and Moorfoot Hills hill farming is the main form of agriculture.

The forestry of the area is mainly confined to the Tweed valley where the Forestry Commission have four forests, namely, Tweedsmuir, Cardrona, Glentress and Traquair. The Commission have also planted an area in Midlothian around Camilty. Apart from these, areas of woodland are small and privately owned.

SPECTROCHEMISTRY

At the present stage of development of spectrochemical techniques for the determination of trace elements in soils and plant materials, adequate reproducibility can be achieved for most of the biologically important elements at the concentration levels normally encountered, especially when photoelectric recording of the line intensities is employed. The limits of determination of some elements, however, are not sufficiently low. Molybdenum, for instance, cannot readily be determined at deficiency levels. To lower the limits of determination requires either the adoption of a different technique, such as mass spectrometry, or the refinement of existing methods. Since a mass spectrometer is not yet available in the department the capabilities of flame emission and atomic absorption methods are being further studied for elements which have low limits of determination by these techniques. Investigations are also being carried out into lowering the limits of determination by methods using direct current arc sources.

Several visiting workers came during the year to study the spectrochemical techniques currently employed. Mr Ali Salehabadi, Geological Survey of Iran, concentrated on the determination of the total amounts of trace elements, particularly noble metals, in soils and rocks, while Mrs N. Manteghi of the Soil Institute of Iran was mainly concerned with the arc and flame emission methods and the atomic absorption techniques for the analysis of soils and plants. Miss E. Velagic, Department of Agriculture, University of Sarajevo, Yugoslavia, studied in detail the flame emission and absorption methods for the analysis of soil and plant extracts. Dr R. L. Parfitt, Department of Chemistry, University of Papua and New Guinea, Boroko, is pursuing a six-month infrared study of the hydrous oxide surfaces in clays, while Dr B. G. Davey, Department of Soil Science, University of Sydney, New South Wales, Australia, has commenced a nine-month investigation of zinc in soils. Mr El-Kholy, a former student of Ain Shams University, Cairo, Egypt, who has been working in the department for the past three years, has been awarded the degree of Doctor of Philosophy by the University of Aberdeen for a thesis dealing with source conditions in spectrochemical analysis[84].

The department was represented at three international conferences. Dr V. C. Farmer participated in the 1972 International Clay Conference in Madrid, while Mr J. C. Burridge attended the Sixteenth International Spectroscopy Colloquium in Heidelberg and Dr A. M. Ure took part in the Third International Congress on Atomic Absorption and Fluorescence Spectrometry in Paris. Members of the staff also attended a London meeting of the Agriculture Group of the Society of Chemical Industry on Trace Elements in Plant and Animal Nutrition, a meeting of the Society of Analytical Chemistry on Selectivity in Trace Analysis, in Stirling, and the Third Annual Techtron Symposium, in London. Lectures were contributed to these gatherings, and the department was also represented at meetings of the British Society of Soil Science.

Trace Elements in Soils, Plants and Biological Materials

The main extracting agents in use for evaluating the trace element status of soils continue to be 0·5N acetic acid, neutral N ammonium acetate, and neutral 0·05M EDTA, but as mentioned in last year's report the possible use of the potassium salt of 2-ketogluconic acid is being investigated.

Lectures on trace elements in soils[14] and the factors that affect their availability[15], presented at a NAAS conference in 1966 and to a Symposium on Minor Metals of the Geochemical Environment held in Chicago in 1970, have now been published. A review of the factors affecting the availability of cobalt in the soil and its uptake by plants[64] is in press.

Soils and Soil Parent Materials. Studies on the behaviour of trace elements during the process of podzolization have been continued. Seven more profiles with iron pans, representing different parent materials, have been examined for total contents of trace elements and fractions extracted by various reagents. The total number of such profiles investigated is now over 30 and includes replicates from soil series belonging to the Corby, Ettrick, Darleith, Strichen, Hobkirk and Sourhope Associations. Compared with acetic acid, EDTA shows greater differences between horizons, presumably because it is more effective in extracting organically bound elements in the surface soil and the iron pan horizon. This effect is most clearly shown in the results for lead mentioned in Annual Report 40, 1969/70. Further work has also been done on the association which exists between cobalt and manganese in certain horizons where manganese has accumulated. Contrary to what might be expected, there does not appear to be a similar association between nickel and manganese. A report, in collaboration with Pedology, on clay minerals in some Carboniferous sediments in Scotland[3] has been published.

Determinations of trace elements in selected soil profiles sampled by the Soil Survey of Scotland have been continued. The study of profiles from Sheet 39 (Stirling) has now been completed, and work on parts of Sheets 83, 84, 93 and 94, covering the Black Isle area of Cromarty, and on Sheet 110/116 (Latheron/Wick) is in progress.

The distribution of the total contents of trace elements in peat profiles from basin and blanket bogs sampled by Pedology is being investigated. To minimize contamination, a carbon steel sampling borer was used in place of the normal stainless steel sampler with brazed fittings.

With the aid of facilities provided by the Departments of Natural Philosophy and Chemistry of the University of Aberdeen, application to soil studies of Mössbauer and electron spin resonance spectroscopy has continued. Mössbauer spectroscopy shows that the major component in iron pans from some of the profiles mentioned above appears to be either poorly crystalline goethite or amorphous ferric oxide, depending on the drainage conditions. Weathering of the iron components of a biotite and a hornblende has also been studied by Mössbauer spectroscopy. The technique is also valuable in determining the amounts of iron clay minerals that can be reduced by hydrazine and sodium dithionite, because removal of the excess reducing agent is not necessary and the problem of reoxidation, which makes use of chemical methods difficult, is avoided.

In collaboration with Biochemistry, the types of bonding between soil organic matter and metals such as vanadium, iron, manganese and copper have been investigated employing electron spin resonance. In a copper-humic acid system evidence of the direct bonding of nitrogen to the copper has been obtained.

Soil Status and Plant Uptake. The number of samples analysed on behalf of Soil Fertility from areas with suspected nutritional disorders of plants or animals has continued on the same scale as in previous years.

A large proportion of the analyses this year has been concerned with samples from the long-term field experiments laid down by Soil Fertility to examine the effects of soil drainage conditions. Top soils from all the sites have been analysed for EDTA-extractable copper, manganese and zinc in samples taken at three times in each of three successive seasons, and soil profile samples from each of the plots are now being examined. All the plant samples (mixed herbage, ryegrass, cocksfoot, timothy and clover) taken during the three-year period have now been analysed for copper, iron and manganese, and a large number of the mixed herbage samples have been more fully examined for elements such as cobalt, molybdenum and zinc. The results are being evaluated.

The analyses of different parts of cereal plants sampled throughout the growing season in 1964 have now been completed. Diagrams illustrating seasonal changes in the trace element distribution in these samples have been produced on the Institute computer-controlled graph plotter and have greatly facilitated assessment of the data.

A report on the trace element content of sewage sludges[16], in collaboration with the Agricultural Development and Advisory Service, Leeds, has now been published. Collaboration is continuing on the effects of soil additions of sewage sludges high in zinc, nickel, copper and chromium on trace element uptake by red beet, cauliflower, French beans, celery and lettuce. This investigation is now in its fifth year and has involved analysis of over a thousand samples. Miscellaneous samples analysed have included humic and fulvic acids prepared by Biochemistry, conifer samples from Forestry Commission plots (Northern Research Station, Midlothian) and nurseries (Alice Holt Lodge, Farnham, Surrey), feeding-stuffs from the Rowett Research Institute, Aberdeen, and cereals from the Scottish Horticultural Research Institute, Mylnefield, Dundee.

The provision of departmental glasshouse facilities in 1971 has made possible the development of pot culture studies, and an investigation has been commenced into the uptake of mercury by plants.

Spectrochemical Methods of Analysis

Under the auspices of the Consultative Committee for the Development of Spectrochemical Work, a bulletin detailing the techniques employed at the Macaulay Institute, the East of Scotland College of Agriculture and the West of Scotland Agricultural College[17] has been published. A modification to the method of ashing potato tubers, which makes the ash more suitable for the direct determination of trace elements, has since been introduced. A sulphated ash which does not stick to the mortar on grinding is obtained when 0·1 g of ammonium sulphate is added to a 1-5 g oven-dry sample prior to ashing at 450°C.

Arc Emission. The limits of determination of several trace elements in non-conducting powders have been lowered significantly by a new direct-current arc technique[84]. Anode excitation is employed, the sample, mixed 1:1 with graphite powder containing palladium as internal standard, being filled into a boring in a 6·15 mm diameter graphite anode. Excitation is carried out using a 20 amp d.c. current, a carbon counter electrode (cathode) and a 5 mm arc gap, light from the 2 mm portion of the gap near the anode being utilized. A specially designed twin jet around the sample electrode provides an argon:oxygen atmosphere around the tip and the arc plasma, and at the same time reduces the consumption of electrode material by surrounding the stem with pure argon. The use of a large sample weight and high current increases the line intensities, while the twin jet reduces background emission. To decrease the background further, and also to stabilize the arc by preventing wandering of the cathode spot, a sheath of downward flowing argon is used around the counter electrode. Analyses of United States Geological Survey standard rocks by this technique show that it has considerable potential. Further work on the method awaits the completion of a stabilized high current source.

Direct Photometry. The analyses of most plant ash samples are now being carried out using the Hilger E789 3-metre Polychromator. The determination of those elements in soils previously carried out spectrographically in the 3500-8500 Å region has also been transferred to this instrument, but matrix, background, and line interference corrections have not been fully developed for all the elements for which ultraviolet lines are employed.

It has now been established that for a large number of elements the simultaneous use of two internal standard elements (indium and palladium) which have quite different arc characteristics can provide a basis for matrix corrections in soil and rock analysis. The signal for a given concentration of an element, for example barium, can vary by as much as fourfold, depending on the rock type, but calculations based on the change in the In/Pd signal ratio with matrix composition can be used to make an adequate correction. Another problem, which has delayed transfer to the Polychromator of the analyses of rocks and soils, has been the difficulty of establishing suitable background corrections for several biologically important elements which have unfavourable signal to noise ratios, which can be as adverse as 1 to 20. A method using multiple regression based on nine predictor channels (major constituents and background channels)) is being evaluated and would appear to provide the corrections required under these conditions.

The simultaneous use of the two internal standards indium and palladium has also proved an advantage in the determination of copper and manganese directly in plant ashes. When results obtained for these elements in a single burn are calculated employing each of the internal standards they usually agree within five per cent of the mean. Results differing by more than this indicate a bad burn and can be rejected.

The medium direct-reader is now being employed mainly for the analysis of plant ash by the rotating pressed-disk technique. The 15-year old valve electronic console is obsolescent and any fault developing is now almost impossible to rectify. A replacement transistorized console would, however, extend the use of the instrument for several years.

Flame Emission. The number of analyses by the three-channel laboratory-built flame photometer has remained at about the same level as last year, although the demand for sodium determinations has increased.

The four-channel instrument, for the simultaneous determination of calcium, sodium and potassium by flame emission, and magnesium by atomic absorption, has been extensively tested with an air:acetylene flame and a 5 cm slot burner head. A suitable programme for performing all the calculations by computer has been developed and tested, and is now operational. Analyses of acetic acid extracts of soils carried out with this instrument produce results which for calcium, sodium and potassium agree with those obtained by the three-channel flame photometer, and for magnesium with those by the Techtron AA4 instrument. The use of a mixture of air and nitrous oxide as a support gas for an acetylene flame is being investigated with a view to obtaining greater freedom from aluminium interference in the determination of calcium and magnesium. To obviate the time-consuming addition of an ion suppressor to both the sample and the standard solutions, a burner has been designed which incorporates two nebulizers. One of these, using air, introduces the sample to the flame, while the other, using nitrous oxide, supplies a mist of an easily ionizable element.

The Techtron AA4, in the emission mode, has been employed for the determination of such elements as aluminium, lithium, barium and strontium.

The suitability of flame emission for the determination of aluminium in solutions of ashed plant material, using an air:acetylene flame, was investigated by Miss Velagic during her period of study. In plant materials, aluminium in the range of 15 to 800 ppm can be determined successfully using 500 ppm of sodium as an ion-suppressor in the sample and the standard solutions. Under these conditions interference from variations in the potassium, calcium and phosphorus contents is negligible.

An account of the determination of the alkali metals by flame photometric and atomic absorption methods[65] has been submitted for publication.

Atomic Absorption. The number of magnesium and copper analyses performed by atomic absorption using the Techtron AA4 instrument continues to increase: for magnesium from 12,000 last year to 14,000, and for copper from 800 to over 1000. Cobalt, manganese and zinc determinations have continued at the same level as in previous years.

The cold-vapour atomic absorption method for the determination of mercury in soils, mentioned in last year's report, has been further developed. The mercury is brought into solution by HNO_3-H_2SO_4-$KMnO_4$ treatment and reduced to metallic form by addition of hydroxylamine hydrochloride and stannous chloride. In place of the usual bubbling technique, the metallic mercury is partitioned between the liquid and the air phases by shaking the sample solution in a closed vessel. The mercury-laden air is then blown through a tube where the atomic absorption measurement is made. The advantage of this is that no frothing occurs, and the decrease in water vapour and spray permits elimination of a drier between the sample vessel and the absorption tube.

Since no standard samples of known mercury content are available, the validity of the wet digestion method was checked by developing an alternative method of sample preparation. The sample, mixed with cellulose powder, was suspended and burned in an atmosphere of oxygen in a closed flask containing an absorbing solution. The liberated mercury was reduced, partitioned and determined as described above.

Comparative analyses of a wide range of soils and peats by these two methods of sample preparation show excellent agreement. Mercury in the range 0·01 and 0·5 ppm in the soil can be determined in a 1 g sample. Other samples, such as rocks and plant materials, can also be analysed and the method can be easily adapted to determine mercury in air or gases.

An investigation into the distribution of total mercury and EDTA-extractable cadmium in peat profiles is being conducted using the cold-vapour atomic absorption method for mercury and the conventional atomic absorption technique for cadmium.

Possible sources of contamination from a wide range of laboratory materials have been investigated, with special reference to elements which can be readily extracted from plastics[66]. Flame emission and atomic absorption techniques were employed for the determination of many of the elements. Many plastics were found to contain soluble barium, cadmium and zinc, while laboratory grade paper tissues had 120 ppm extractable zinc and a self-adhesive label 1·2 per cent soluble barium.

Absorption Spectrometry of Soil Constituents

Anhydrous ammonia is now an important nitrogen fertilizer, and the nature of its interaction with soil constituents is of practical importance. An earlier study (Annual Report 36, 1965/66) of ammonia adsorption on the clay minerals montmorillonite and saponite had established that the principal mechanisms of adsorption involved either co-ordination to the exchangeable cation or formation of ammonium ion with concomitant precipitation of the original cation as hydroxide. This work has now been extended to include vermiculite[18], which is an important component of many temperate soils, appearing in size fractions ranging from clay to coarse sand. Vermiculite is structurally related to saponite, examined in the earlier work, but, because of its higher surface charge, it holds ammonium ions very much more strongly in its interlayer by forming a mica-like, almost anhydrous, structure. Consequently, on treatment with anhydrous ammonia substantially more ammonium and less co-ordinated ammonia was formed in vermiculite than in saponite for all exchangeable cations other than copper, which in both minerals preferentially formed a copper-ammonia co-ordination complex. The ammonium ions formed decomposed by reaction with water, liberating ammonia, and were more readily released than ammonium ions introduced by ion exchange. It would appear that the capacity of vermiculite to absorb and release nitrogen is greater when the nitrogen is applied as anhydrous ammonia than when it is applied as ammonium salts. Samples of ammoniated vermiculite of different particle size were supplied to Soil Fertility for pot culture evaluation of the effectiveness of the nitrogen.

Although expanding layer silicates play an important role in adsorption processes in soil, they are not the only active mineral surfaces. Aluminium and iron hydroxides and mixed silica-alumina gels of high surface area are also involved. These species are more likely to interact with acidic than with neutral or basic molecules, and exploratory studies on their reactivity are in progress. Pure silica gels are not very reactive under moist conditions, but in the course of a collaborative investigation with Pedology it was noticed that silica readily adsorbed boric acid and boric esters which were released into the vapour phase from the borosilicate glass vessels used[19].

In addition to these studies on surface reactions, development and application of infrared techniques to characterize mineral structure continues. A study of structural influences on hydroxyl stretching frequencies in layer silicates still awaits publication[67], and a paper on hydroxyl vibrations in amphiboles[68] has been submitted. A tubular structure consistent with the infrared spectrum and other physical characteristics of imogolite has been proposed[38]. A study of the cell wall composition of some plant pathogenic fungi[7] has now been published. The section continues to support several lines of investigation on soil minerals and soil organic matter initiated in other departments.

BIOCHEMISTRY

Following his departure at the end of August to take up a new senior post at the Rowett Institute, this report marks the end of the 16 years during which Dr J. S. D. Bacon has guided and developed the department, which was established in its present form on his appointment as Head in 1956. During this period fundamental studies have been successfully initiated and encouraged on various aspects of soil organic matter, covering the more labile components, especially polysaccharides, as well as the more stable humified fractions. As illustrated by the reviews of current topics below, these studies can be broadly divided into those concerned with the nature and transformation of soil organic constituents and those concerned with their effects on plant growth. Two developments which reflect Dr Bacon's personal expertise, initiative and foresight, have been the introduction of a wide range of modern sophisticated instruments and techniques, mentioned in last year's report, and the encouragement of inter-departmental collaboration, especially with Microbiology and Plant Physiology. Dr Bacon's personal research activities have concentrated mainly on elucidation of the mechanisms whereby cell walls are biologically degraded, and the main features were reviewed in some detail in last year's report. Under Dr Bacon's leadership, the department has grown and prospered, and a total of 90 scientific papers and articles of various kinds have been published since 1956.

Enzymic Degradation of Cell Walls

Research on this topic has continued, in collaboration with Microbiology[7].

Coniothyrium minitans, a fungus parasitic on sclerotia of *Sclerotina sclerotiorum*, has been found to produce a mixture of endo- and exo-β-glucanases capable of degrading sclerotan, the major component of the sclerotial cell wall (Annual Report 41, 1970/71). It has now been established that the endo- and exo-enzymes must act simultaneously if degradation is to be complete. The reasons for this are not yet clear, but it seems possible that irregularities in the structure of the sclerotan impede the action of the exo-enzyme, and that the endo-enzyme is able to remove these as they are exposed.

Some difficulties have been met in fractionating the glucanases of *Trichoderma viride*, another fungus parasitic on the sclerotia, but it appears that this organism also produces a mixture of exo- and endo-glucanases. Successful parasitism of sclerotia would thus seem to depend upon the production of several β-glucanases, but in particular of an exo-$\beta(1\rightarrow3)$-glucanase, which is needed to dissolve the very thick cell walls in the sclerotia.

Dr J. S. D. Bacon gave an invited paper on the lysis of fungal cell walls to a session on fungal and higher plant protoplasts at the Third International Symposium of Yeast Protoplasts, in Salamanca. Another contributor reported that *Schizophyllum commune* synthesizes a sclerotan-like polysaccharide, previously recognized only as a $\beta(1\rightarrow3)$-glucan. It therefore appears that sclerotan is not confined to sclerotia-forming fungi and that, as reported last year, considerable complexity exists in the structure of fungal cell walls, even within a single category of constituents, the glucans.

Research has also begun on the enzymic degradation of cell walls from higher plant tissues. A method for achieving a partial separation of the many enzymes present in snail digestive juice has been found. The unfractionated juice is capable of digesting plant cell walls almost completely *in vitro*, but it is unlikely that all the enzymes known to be present are involved. The ultimate intention is to purify and characterize those enzymes which are essential for wall lysis. This information would increase understanding of the degradation of plant material in soil, and also aid studies on the production of protoplasts from higher plant cells, which are expected to have important applications in plant breeding.

Nature and Origin of Soil Polysaccharides

Studies have continued on the transformations of plant materials added to soils. About 50 per cent of a ^{14}C labelled rye straw which had been milled to pass a 1 mm screen was degraded during incubation in soil for 14 months[72, 73] (Annual Report 40, 1969/70). Grinding the rye straw to a particle size twenty times smaller did not greatly increase the rate of decomposition, but polysaccharide material extracted from the straw by alkali (hemicellulose) was rapidly degraded.

The incubation of soil caused little observable change in the polysaccharide already present, but when the fraction of soil polysaccharide soluble in alkali, and separable as Forsyth's Fraction C, was added it was almost completely degraded within a few weeks. As it occurs in soil, this polysaccharide is protected against microbial attack. The characteristics of soil polysaccharide thus resemble those of plant material and support the hypothesis that a large proportion of it consists of undegraded plant polysaccharides.

Nature of Soil Organic Matter

Soil organic nitrogen occurs mainly as amino acids in the form of polypeptide derived from plant and microbial protein. A study of hydrolysates of humic acids isolated from horizons within soil profiles has revealed that the proportion of nitrogen identifiable as amino acids varies with depth. Special interest is centred on the immobilization of nitrogen in the organic horizons of forest soils and humus podzols, which occurs in conjunction with the appearance in the B_h layers of relatively large amounts of easily hydrolysed peptide. Analysis of humate fractions shows some correlation between the percentage of nitrogen released as amino acids and the amounts of aromatic derivatives produced by oxidation, providing some support for the hypothesis that the resistance to hydrolysis of the immobilized nitrogen is due in part to the nucleophilic substitution of phenolic compounds by the N termina of peptides.

Interaction between Soil Organic Matter and Mineral Constituents

Soil and peat profiles have been examined to characterize the organic matter in various soil types. Several striking features have been observed, particularly the thermal instability of the fulvic polysaccharide fraction. At one time it was thought that such structural collapse was initiated by the pepide present in the fraction, but this was not the case in some podzols, where only the translocated material showed thermal breakdown while fractions from contiguous horizons were stable. The occurrence of polysaccharide, peptide and polyphenols in these podzols has been investigated, but none of these easily characterized fractions has the capacity for chelation of iron and aluminium shown by the dark coloured fulvic polymers. Similarities between fractions from podzols on granitic parent material have been noted in profiles taken at latitudes between sea level and 1200 metres. This study will be continued with the aim of identifying the organic constituents involved in podzolization.

Effects of Soil Organic Matter on the Growth of Excised Tomato Roots

Various soil organic matter extracts have previously been shown to inhibit the growth of excised tomato roots cultured for seven days under axenic conditions. It has now been found that when the apices of these roots are excised and cultured for a further seven day period in fresh medium, growth is stimulated by concentrations of soil organic matter which were without effect or were growth inhibitory during the first seven day culture period. Thus the response of the excised tomato roots to organic matter extracts depends on the physiological age of the primary root meristems. The increased growth occurring in the presence of soil organic matter results from an increase in expansion of the root cells, and since the dry matter and protein contents of the cells are also substantially increased it does not merely reflect an increase in the water content of the cells. There is also an increase in the number of lateral roots. Fractionation of the alkaline extracts of soils by membrane ultra-filtration has shown that the physiological activity exists in humate components of molecular weights up to 100,000 and also in fulvate fractions of molecular weights between 1000 and 10,000. A particularly active fulvate fraction with a molecular weight in the region of 1000 has been isolated from a number of soils.

Since synthetic auxin antagonists, such as 1-naphthoxyacetic acid, also stimulate the growth of subcultured root apices, it was thought that the growth stimulation might result from an 'auxin antagonist' property of soil organic matter, but this does not appear to be so. The growth stimulation produced by 1-naphthoxyacetic acid results from an increase only in the fresh weight of the root cells, dry matter and protein contents being unchanged, and development of lateral roots depressed. Furthermore, while the effects of 1-napthoxyacetic acid are prevented by the auxins 2-naphthoxyacetic acid and 1-naphthalene acetic acid, those of soil organic matter are not.

Any growth regulatory effect that soil organic matter may exert, however, is liable to be obscured by influences on the availability and uptake of cations, especially iron. In the above experiments, ferric citrate was used as the source of iron with the view to avoiding this complication, but it cannot be ruled out and further work has been done to clarify the position. A membrane ultra-filtration method has been used to examine the effects of pH and humate additions on the molecular weight of iron species in ferric citrate solutions. At pH 5 a high proportion of the iron was found to be ultra-filterable, but additions of humate decreased this proportion, due to attachment of iron to high molecular weight organic matter. When the pH of the ferric citrate solution was raised, the proportion of ultra-filterable iron fell, probably due to hydrolytic polymerization. This fall appears to be partly counteracted by the presence of humate, and the significance of this effect in relation to the iron nutrition of excised tomato roots is being studied. The preliminary results indicate a relationship between the cation contents of the roots and the concentrations of ultra-filterable cations in the growth media. Addition of humate appears to have no effect on the uptake of potassium and calcium, but substantially decreases the iron content of the roots, and the implications of this are being further investigated.

Cell Elongation in Pea Roots

It has been found that natural amino acids have no effect on cell elongation in excised pea roots segments cultured under aseptic conditions, whereas their corresponding analogues p-fluorophenylalanine, ethionine and azetidine-2-carboxylic acid are inhibitory. These analogues also inhibit the development of several enzyme activities and of protein synthesis in general, in agreement with the concept that continuous protein synthesis is necessary for cell elongation. Unfortunately, because of this general interference, it has not been feasible to use these analogues for relating any particular aspect of protein synthesis to cell elongation. An account of this work[74] has been submitted for publication.

Hydroxyproline, which may be regarded as an analogue of proline, stimulates cell elongation in pea root segments, but does not affect protein synthesis measured in terms of incorporation of ^{14}C leucine or ^{14}C proline. Naturally occurring hydroxyproline (i.e. *trans*-4-hydroxy-L-proline) is confined almost exclusively to the cell-wall proteins where it is formed by hydroxylation of proline. It has been established that when cell elongation is slowing down there is a four-fold increase in the hydroxyproline content of the cell walls. Addition of hydroxyproline delays this increase and prolongs the period of rapid cell elongation. It seems probable, therefore, that cell wall proteins containing hydroxyproline play an important role in controlling cell elongation. Further support for this view is provided by the finding that 2,2′-bipyridyl both prevents conversion of proline into protein-bound hydroxyproline and enhances cell elongation. The key factor is the ability of the bipyridyl to complex iron, which is a cofactor in the conversion of proline into hydroxyproline. This mechanism may also account to some extent for the ability of humic acid to enhance cell elongation, not only in these pea systems but also in the tomato systems discussed above. Reports of these studies are in preparation and further work is in progress.

Other Activities

Dr Ludovite Gabris of the University of Agriculture, Nitra, Czechoslovakia, spent two months in the department studying the techniques used for characterizing soil polysaccharides.

Dr H. A. Anderson attended a symposium on Humic Substances held in May 1972 at the Limnology Institute, Nieuwersluis, Netherlands. A paper on the configuration of soil arabinose was presented at a meeting of the Biochemical Society in Aberdeen in June 1972.

In collaboration with Pedology, a glossary of German, English and Russian terms[48] covering a wide field of peat research and development has been compiled.

PLANT PHYSIOLOGY

The work of the department falls into two categories; the mineral nutrition and trace element balance of plants and the processes of salt absorption. In the mineral nutrition studies the functions of the trace elements and their interactions with the major elements are being elucidated, together with the function of chelating agents. Ion absorption is being investigated at cellular level under two interrelated themes, the characterization of the fluxes across cell membranes and the nature of the energy source for active uptake.

During a 12-day tour in Israel, Dr I. R. MacDonald studied current research in plant nutrition in research institutes and university departments, especially the Hebrew University, the Volcani Centre, and the Negev Institute for Arid-Zone Research.

Dr L. P. Raikov, Deputy Director of the Nikola Pushkarov Institute of Soil Science, Sofia, Bulgaria, came for two months to study radioisotope techniques.

Iron Deficiency

Work on iron deficiency in pear leaves[20] has established that there is no relationship between chlorosis and the contents of individual elements, including iron, but that a significant relationship exists between chlorosis and the phosphorus-iron ratio. The relationship between the phosphorus-iron and potassium-calcium ratios is also highly significant. Further investigations have supported these findings and the study has been extended to include citric and malic acids.

Nitrate Reductase

It has been reported by other workers that nitrate is not metabolized when calcium is deficient. This finding was investigated in a sand culture experiment using cauliflower, and also chinese cabbage, which has a very rapid growth rate. Two levels of calcium, two levels of nitrogen and three levels of molybdenum were used. At the higher level of nitrate, deficiency of both calcium and molybdenum became very pronounced. It was found that the activity of the enzyme nitrate reductase was much lower in the leaves with low calcium supply and that their nitrate content was accordingly high. Detailed statistical analysis of the results is in progress.

Trace Elements Studies on Peat

Tomatoes have been grown in bag culture in the new glasshouse to study the development of mineral deficiencies under intensive cultivation. Both iron and manganese deficiencies have developed and have been successfully controlled by foliar sprays. Blossom-end rot has still occurred in plants given a calcium supplement, but to a lesser extent than in plants not receiving the supplement. Electron micrographs have been made on these tomatoes and other tissues under study and earlier work[21] has been published.

Light-stimulated Ion Uptake in Wheat Laminae

The use of vacuum-infiltration as a method for facilitating studies on ion uptake by leaf tissue is described in a paper[22] now published. Vacuum-infiltration, by circumventing the cuticular resistance of the leaf, permits a much higher rate of ion uptake by wheat laminae. Ion uptake by this tissue is also enhanced three- or four-fold by light in both vacuum-infiltrated and non-infiltrated tissue, suggesting that there is a light-stimulated component of ion uptake which is powered by energy released from photosynthetic reactions. Attempts to relate this uptake to photosynthesis have revealed that the high rate of oxygen evolution characteristic of photosynthesizing wheat laminae is completely suppressed by vacuum infiltration. The apparent paradox that ion uptake is light-stimulated in tissue in which exergonic photochemical relactions are apparently inoperative is now being investigated.

Soil Organic Compounds and Plant Nutrition

A method has been developed for growing wheat seedlings in solution culture under aseptic conditions. The seeds are supported on a stainless steel grid in a crystallizing dish, above which is inverted a slightly larger dish that can be raised as the coleoptiles elongate. Wheat seedlings can be grown under these conditions for one to two weeks, during which time there is good root development. This method is being used to study the effect of calcium on root growth and, in conjunction with Biochemistry, the effect of humic acid, which has been found to stimulate elongation and branching of wheat roots in aqueous solution. Particular attention is being given to the interaction between calcium and other salts present in aqueous solution. Root growth is inhibited in the absence of calcium, but this inhibition is not attributable to a nutritional deficiency in the usual sense since the roots grow well in moist air. It appears that calcium is able to detoxify a solution which otherwise, because of its mineral constituents, is inhibitory to root growth. This effect is currently under investigation.

Ion Flux Studies

Earlier reports have explained how measurements of transmembrane electrical potentials together with ion flux data, particularly from isotope elution studies, are used to identify ion pumps at the cellular level, and their location within the cell. Data for onion root segments, in which cortical parenchyma cells predominate, show that at the outer cell membrane (plasmalemma) potassium and chloride are accumulated against the electrochemical gradient, and thus must be metabolically pumped into the cytoplasm. Entry of sodium is down the electrochemical gradient, but there is some evidence that it is at the same time removed from the cytoplasm by pumps working both in the direction of the vacuole and across the plasmalemma to the outside. Potassium and chloride diffuse through the tonoplast to enter the vacuole passively. Transport of calcium appears to be passive across both cell membranes, and accumulation is limited by an efflux pump.

In analysing isotope elution data three phases are normally identifiable, relating to loss of isotope at different rates from the cell wall, cytoplasm and vacuole. However, from the calcium efflux data, a fourth phase was apparent, intermediate between the rates characteristic of the wall and cytoplasm. It was considered that this was most likely due to exchange in the Donnan free space or, alternatively, to transport of isotope in a radial direction from the cortex into the vascular tissue of the root and its subsequent leakage from the cut ends.

To assess whether leakage from the cut ends of root segments was sufficient to affect significantly estimates of cortical cell efflux, a three-compartment perspex vessel was designed to enable the efflux of isotope from the surface of the segments to be measured separately from the loss from each end. Analysis of the results indicated that the 'fourth phase' was still present in the curve for cortical calcium efflux, strengthening the view that there is a measurable Donnan effect. Nevertheless, there was at the same time a continuing leakage of isotope from the cut ends of the segments at a rate that assumed significance towards the latter part of the elution experiments. Once free space isotope was removed, loss from the vascular tissues became constant, reflecting transport into the xylem from a large pool of isotope in the root, the exact pattern depending on the ion studied. For calcium, the steady state loss from the stele was exclusively from the proximal ends of the root segments, whereas for sodium this loss was exclusively from the tip ends of the segments. For chloride the steady state efflux was predominantly from the tip end, but not exclusively so. These patterns are very reproducible and are not affected by variation of the nutrient solution over a ten-fold concentration range. The results suggest that selectivity for transport of ions to the shoot resides within the stele itself, and not at the cortex-stele interface. A further implication of these results is that vacuolar efflux rates have been over-estimated by measurement of gross efflux, and conclusions regarding transport at the tonoplast may require revision.

Radioactivity

Radioactivity has continued in extensive use in the departments of Biochemistry and Soil Fertility as well as Plant Physiology. A significant improvement has been made in ease, sensitivity and accuracy in counting low energy beta-emitting istopes. A new commercial product (Insta-gel) enables an equal volume of aqueous solution to be held in a stable gel with the organic scintillator liquid, allowing high counting efficiencies to be maintained. Formerly only a small volume of aqueous sample could be made miscible with the scintillator for liquid scintillation counting. This new method has proved useful in several branches of work on plant physiology involving ^{45}Ca and in soil studies with ^{35}S. In collaboration with Soil Fertility, a trial has been made of a method of determining plant available sulphur in soil similar to the 'L' value as determined with ^{32}P. The possible influences on this determination of sulphur additions to the plant from air and water as well as from soil and fertilizer has been investigated. It has also been shown that the counting of ^{32}P and ^{35}S can be separated when both elements are present in the same sample.

A paper on the use of tritium in tracing water[9] has appeared and two papers on the use of ^{14}C labelled material in soil[72, 73] have been accepted. A paper on the cation exchange capacity of plants[23] has appeared and two others[70, 75] are in press.

During his visit, Dr L. P. Raikov of the Nikola Pushkarov Institute of

Soil Science, Bulgaria, examined, in collaboration with Soil Fertility, effects of equilibrium conditions, including ultrasonic dispersion, on the measurement of exchangeable phosphate in soils using ^{32}P, with particular reference to the behaviour of soils with low phosphate contents.

MICROBIOLOGY

The general aims of the department are concentrated on the role of soil micro-organisms in the decomposition of organic matter and their interrelationships with the roots of higher plants, on the interactions between different groups of soil micro-organisms and the effects of clay minerals on microbial activity, and on the microbiology of peat.

Dr H. W. Morgan, an I.C.I. Postdoctoral Fellow, completed his two years in the department at the end of September 1972 and left to take up an appointment as a lecturer in Biological Sciences at the University of Waikato, Hamilton, New Zealand. Mr Masachika Maeda, a graduate student from the Section of Marine Microbiology of the Ocean Research Institute, University of Tokyo, Japan, came for two months to study methods for following the microbial degradation of nucleic acids.

The department was represented on a Visiting Group set up by the Agricultural Research Council to make recommendations for future work on soil microbiology at the Weed Research Organization in Oxford, and on a Working Party on Terrestrial Microbiology set up by the Natural Environment Research Council. During the year members of staff visited organizations with allied interests and also attended the Fifth European Congress on Electron Microscopy at Manchester, a joint meeting of the British and Scandinavian sections of the Society of Protozoology with the British Phycological Society at Cambridge, and a conversazione held by the Society of Applied Bacteriology in London. A paper was read at the Cambridge meeting and an exhibit concerned with microbiological sampling was displayed at the London conversazione.

Interrelationships between Plant Roots and Micro-organisms

Results describing the interaction of micro-organisms with the mucigel layer on the roots of a variety of crop plants grown in nutrient solution, sand, and γ-irradiated soil[76] have been accepted for publication. This work is being continued, with particular emphasis on plants grown in soils, both in the field and under glasshouse conditions. In the glasshouse natural daylight is supplemented by high pressure sodium lamps controlled by a prototype solid-state light-sensitive switch which automatically switches the lamps on and off at predetermined levels of high, medium or low daylight intensities. Improvements have been developed in techniques for growing plants to maturity in soil cultures and nutrient solutions, with the roots maintained in axenic conditions and the shoots exposed to the atmosphere.

Thin-sectioning techniques developed by Soil Survey have been used to investigate the root-soil interface. The results confirm those obtained with the transmission and scanning electron microscopes, showing that surface cells of roots grown in soil are frequently distorted and ruptured and that considerable amounts of soil mineral and organic matter are mixed with the ruptured tissues, which are normally heavily colonized by soil micro-organisms. This casts doubt on the validity of the present concept of the rhizosphere as the region of soil outside a distinct root-soil interface. Some of these findings are incorporated in a review dealing with bacteria and protozoa in the rhizosphere[77] which has been accepted for publication.

Influence of Soil Protozoa on Nitrogen Fixation by Soil Bacteria

Accounts of work on the influence of incubation temperature and agitation on the quantities of nitrogen fixed by the soil bacterium *Azotobacter chroococcum* in the presence and absence of the soil ciliate *Colpoda steini*[24, 25] have now appeared. In view of the known oxygen sensitivity of azotobacter during nitrogen fixation, it was suggested (Annual Report 41, 1970/71) that the ciliates may reduce the dissolved oxygen concentration in the mixed cultures to levels more suitable for nitrogen fixation when the incubation temperature is between 15°C and 25°C. A comparison of the dissolved oxygen contents of two-litre batch cultures of pure azotobacter with those of mixed azotobacter/colpoda cultures grown under controlled pH and temperature for 35 days showed that the mixed cultures respired more rapidly in the first 12 hours of growth after inoculation. Subsequently, when the microbial populations were growing rapidly, the dissolved oxygen in both types of cultures was low. Before the hypothesis that the beneficial effect of ciliates on nitrogen fixation by azotobacter is due to their consumption of some of the dissolved oxygen in the mixed cultures can be confirmed, measurements at lower concentrations are necessary, and this will require either improvement of the electrodes or the development of alternative methods for measuring dissolved oxygen. In addition to providing substantial quantities of bacterial and ciliate cell material for chemical study, these large scale batch culture experiments have also yielded data on the growth rate of colpoda populations with azotobacter as the sole food bacterium which will be useful for comparative purposes when similar studies are made in sterilized soil.

The methods available for the estimation of soil protozoan populations are discussed in a paper[78] which has been submitted for publication.

Lytic Micro-organisms

Work on the incidence of lytic micro-organisms on the roots of winter wheat has continued. Experiments have been carried out principally on the two cultivars Champlein and Joss Cambier, grown under field conditions on a soil of the Tarves Association. The coverage has now been extended to examine the root region of these cultivars growing under controlled conditions on a manganese deficient calcareous soil of the Fraserburgh Association. Preliminary experiments indicate that the root region of the Champlein supports a large population of lytic actinomycetes and addition of manganese, as $MnSO_4 . 4H_2O$, increases the number of micro-organisms. So far no myxobacteria have been observed, but laboratory experiments indicate that *Cytophaga johnsonii* grows normally on this soil both in the presence and absence of added manganese.

Experiments on the growth of other cereal cultivars on these soil types are under way, with the soils maintained at 60 per cent of their moisture-holding capacity, since workers in Canada have shown that cytophagas increase in the root region under these conditions.

Ultrastructure of Fungi

The ultrastructure and chemical composition of hyphal and sclerotial cell walls of various plant pathogens are described in a paper[7] which has now appeared. A joint paper with the Commonwealth Mycological Institute[26] incorporates data on the ultrastructure of spore surface ornamentation of the rust fungus *Aecidium* spp. This study showed the value of transmission and scanning electron microscopy in distinguishing between two fungal species and is being extended to spores of various species of *Haplosporella* and *Botryosphaeria*.

Freeze-etching is also proving a valuable technique for revealing ultra-structural features of cell contents which would not be apparent with thin sections; observations on spores of *Trichoderma viride*[27], which parasitizes sclerotia, and *Mucor plumbeus*[28] have been published. The nuclear membrane of the latter fungus has been shown to be of unusual structure.

Sclerotia of Plant Pathogens

Work has continued on sclerotia of *Sclerotinia sclerotiorum*. Sclerotia of this pathogen have been found in East Scotland each year since 1957 in peas, carrots, potatoes and umbelliferous weeds. The pathogen affects crops in many parts of the world—in Nebraska, U.S.A., for example, it has become endemic in the irrigated field-bean areas—and while no effective method of control is known, rotations of three or more years are of value in that they reduce the number of sclerotia in the soil. In the summer of 1971, with the aid of the Division of Mycology of the School of Agriculture, University of Aberdeen, relatively large numbers of sclerotia were collected after vining from the soil surface in two fields of infected pea crops in Kincardineshire. Observations of the effects of different factors on germination of these sclerotia were made in the laboratory. Parasitic fungi (Annual Report 41, 1970/71) did not prevent germination. Benlate, a systemic fungicide and nitrolim, a nitrogenous fertilizer containing mainly calcium cyanamide, dicyandiamide and benzotriazole completely inhibited germination at 20°C over a period of at least 20 weeks, but parabanic acid had no effect. The initial inhibitory effect of maleic acid hydrazide, a herbicide used in agriculture, was followed by normal germination and resulted in the formation of apothecia. Hydrogen cyanamide was less effective than nitrolim. Both dicyandiamide and hydrogen cyanamide are decomposition products of nitrolim in soil. These results are described in detail in a joint paper with the Division of Mycology of the School of Agriculture, University of Aberdeen[79]. It is hoped that this study may indicate remedial treatments worthy of further examination. Although not altogether surprising, it is interesting to note that when one of the pea fields was cropped with potatoes in 1972 the disease was again quite serious, and collections of sclerotia for further laboratory examination have again been made from the area.

The degradation of sclerotan, a $\beta(1\rightarrow3)$ glucan gel-forming polysaccharide from autoclaved sclerotia of *S. sclerotiorum* or *S. rolfsii*, by enzymes from fungi parasitic on sclerotia was the subject of a display of electron micrographs and charts, prepared with Biochemistry, for a Joint Meeting of the

Scottish Group of the Nutrition Society and Biochemical Society at Aberdeen in June 1972.

Microbial Decomposition of Soil Organic Matter

A study of the effect of clay minerals on the breakdown of soil polysaccharides has commenced in collaboration with Pedology and Biochemistry. Preliminary results show that polysaccharides extracted from soils are quickly broken down when incubated in soils. Micro-organisms capable of effecting this breakdown have been isolated from soil percolated with polysaccharide and are being investigated further. The polysaccharides have been shown to be adsorbed by the clay minerals kaolinite and montmorillonite, especially the latter. Adsorption by montmorillonite is accompanied by a small increase in the lattice spacing. Incubation of the clay-polysaccharide complexes on soils results in a large increase in the numbers of micro-organisms colonizing them and preliminary results suggests that while the polysaccharide adsorbed on kaolinite, or on the external surfaces of montmorillonite, is readily decomposed, that adsorbed in the interlayer space of montmorillonite is more resistant to microbial attack. The degradation of adenine-montmorillonite complexes in soils is discussed in a paper[42] accepted for publication.

Work on the residue remaining after mannan has been attacked by a soil *Arthrobacter* (Annual Report 41, 1970/71) has continued and two organisms have been isolated which were found to be capable of completely degrading the $\alpha(1\rightarrow6)$ linked back bone remaining after mannan had been incubated with the *Arthrobacter* enzyme. The isolates have been tentatively identified as *Bacillus circulans* and a pigmented species of *Cytophaga*. Neither organism is capable of utilizing undegraded mannan. Repeated attempts have been made to purify enzymes from the *Cytophaga* sp. responsible for hydrolysis. They appear to be confined to the cell wall and various methods aimed at releasing them have been unsuccessful. The treatments used included autolysis, extractions with toluene, Tween 80 and 200, sodium lauryl sulphate and concentrated urea solutions, dialysis against EDTA, prolonged ultrasonic treatment, and exposure to proteolytic and lipolytic enzymes.

The *Cytophaga* sp. also produces a $\beta(1\rightarrow6)$ glucanase and several $\beta(1\rightarrow3)$ glucanases, again located in the cell wall, and is able to lyse viable and heat-killed whole yeast cells, and to degrade completely the cell wall material, with release of the mannan. It is also capable of degrading chitin, pectin and starch.

A phosphatase produced by the *Cytophaga* sp. released inorganic phosphate from both mannan and the $\alpha(1\rightarrow6)$ linked mannan back bone.

Microbiology of Peat

Investigation of the bacteriology of a basin peat at the Lyne of Skene, near Aberdeen (Annual Report 41, 1970/71), has continued. Of the techniques examined the use of fluorescin isothiocyanate (FITC) proved the most suitable for direct counts, while the most probable number (MPN) method, using soil extract and mineral salts, was the best for the viable bacterial count. Aerobes were isolated from dilution plates and maintained on a semi-solid agar medium for further study. By staining and microscopic examination it was found that the majority of the isolates were short rods and the rest mainly coccoid forms. No pleomorphic types have so far been encountered. Most of the bacteria were gram negative, a few gram positive, and a very small proportion gram variable. Approximately 50 per cent were motile and between one and 50 per cent were spore-formers, the proportion increasing with depth.

Attempts are being made, using adenosine triphosphate determinations (ATP) and FITC counts, to establish the metabolic state of the microbial cells in freshly sampled peat layers.

The Lyne of Skene profile has been divided into three layers to study, with Pedology, the nitrogen cycle in the peat. Samples of the top layer, a middle (prodominantly Sphagnum) layer, and the humified bottom layer, have been incubated at 15°C. Direct (FITC) counts, together with counts of viable cells, have been carried out at weekly intervals by the MPN technique, using media containing different forms of nitrogen. The results are being correlated with nitrogen determinations carried out by Pedology on the same samples. The work is continuing.

Attempts are also being made to develop a suitable method for the study of anaerobic bacteria in peat.

Other investigations

Production of potassium 2-ketogluconate has continued and the population changes of the bacterium (D11) used for this purpose have been determined with the Helber cell counting chamber and the Coulter Counter. The results obtained from the latter have been processed with the aid of the computer and are giving information on the size distribution of the micro-organism.

SOIL FERTILITY

Research and consultative activities have been continued and extended along the lines summarized below, and the principal aim remains the improvement of manurial practices, soil fertility and crop production.

The research programme is designed to promote better understanding of soil-nutrient-plant relationships, and comprises field, pot and laboratory studies covering the different plant nutrients, the main agricultural crops, and a selection of soil series mapped in the Soil Survey of Scotland. In this approach the contrasting behaviour of the different soils is a key factor in the identification and quantification of the soil properties and processes which regulate nutrient supply and crop growth, and which underlie effects of differences in soil parent material and pedological drainage conditions. The field programme comprises annually some 50 experiments with over 3000 plots, and is carried out at sites on different soil series, with the essential and much appreciated co-operation of farmers. The major part is concerned with the effects of fertilizers, including trace element supplements, on the yields and mineral content of crops in relation to soil nutrient levels and soil productivity. The remainder is devoted to more detailed studies on crop growth and development, with particular reference to influences of environmental factors and husbandry practices. The field programme as a whole provides the basis for evaluation of practical fertilizer recommendations for different soils and crops, including form, rate, time, frequency and method of application. It also provides documented samples representing different soils, crops and fertilizer treatments. These form the main basis for chemical studies on the composition of the crops and on the properties and nutrient relationships of the soils, thereby ensuring that the practical implications of the results can be assessed. In that the emphasis is mostly on intact soil and whole plants these studies are complementary to investigations on soil and plant constituents in the other departments. As well as wider examination of the nutrient status of different soil series, with particular emphasis on laboratory evaluation of available forms, the soil investigations include detailed work on the nature and properties of the organic phosphorus and sulphur fractions, and basic physicochemical studies on soil acidity and anion sorption. Together with the complementary analytical work on plant composition, these studies are essential for fuller understanding of the nutrient supplying power of the different soil series and of the fertilizer requirements of the different crops. In the practical interpretation of the results, plant growth studies under more controlled conditions in pot cultures continue to provide the essential link between the field and the laboratory.

Evaluation of the lime and nutrient status of soil samples submitted by the Advisory Officers of the North of Scotland College of Agriculture continues to provide a valuable reciprocal channel between research and practice. Collaboration has been maintained also with other research organizations and various technical committees, including the Scottish Standing Committee for the Calculation of the Residual Values of Fertilizers and Feeding Stuffs, the Scottish Sub-Committee of the Sugar Beet Research and Education Committee, and the Working Party on the Evaluation of Manurial Residues set up by the Ministry of Agriculture, Fisheries and Food.

The department was represented at the Agricultural Research Council's Crop Science Model-Builders' Working Party, at a Colloquium on Systems Analysis in Agriculture, in the University of Newcastle-upon-Tyne, and at discussions on soil physical problems and methods organized by the Agricultural Research Council and the Agricultural Development and Advisory Service. Members of staff also attended meetings of the British Society of Soil Science, the Agricultural Group of the Society of Chemical Industry, and the Association of Applied Biologists. Dr J. W. S. Reith gave one of the invited lectures at the Seventh Fertilizer World Congress in Austria in May 1972. The department was also represented on the organizing committee of a colloquium on Hill Pasture Improvement and its Economic Utilization, sponsored by the Potassium Institute Limited. An invited paper was contributed to this colloquium which was held in Edinburgh in September 1972.

Fertilizer Requirements of Crops

A joint paper with Pedology and Statistics on the nutrient requirements of herbage growing on deep acid peat[47] has been submitted for publication. The sward was established with adequate Ca, N, P and K, and the subsequent annual treatments consisted of all combinations of 0, 117 and 234 kg N, 0, 29 and 58 kg P and 0, 156 and 312 kg K per ha, arranged in a factorial design. The effects on the botanical composition, yield and mineral content of the herbage, and on the nutrient status of the peat, were measured over a period of five years, three cuts being taken annually and one third of the N dressing being applied for each cut. Tall fescue became the dominant grass species, while cocksfoot persisted much better than either ryegrass or timothy. Applying N markedly suppressed clover, but in the absence of N, K maintained the clover content at about 20 per cent. The yield of dry matter showed large responses to N and K and a marked positive interaction between these two nutrients, 1 kg N per ha, with adequate P and K, usually producing between 15 and 30 kg dry matter. The response to K gradually increased during the five year period, the first increment producing a much larger increase than the second. There was practically no yield response to P until the fifth year when a significant increase was produced.

The mineral composition of the herbage showed a seasonal effect, the percentages of N, Ca, Mg and Na being higher in autumn than in early summer, whereas K decreased from the first to the third cut. The N, P and K treatments had large effects on the percentage of N, P, K, Ca and Mg in the herbage and on total uptakes. In the absence of applied N, but with adequate P and K, the N content depended on the amount of clover in the sward. With 39 kg added N per cut the average N content was 1·7 per cent compared with about 2 per cent from 78 kg. The percentage of P depended on the quantities of N, P and K applied and ranged from 0·14 to 0·54 per cent. The percentage of K varied with the amounts of N and K applied and fell to about 0·5 per cent in the absence of applied K. Apparent recoveries up to 74, 65 and 96 per cent were obtained for N, P and K, respectively.

With continual cutting and removal of the herbage, a mixed sward containing clovers appears to require in the absence of applied N about 120 kg K per ha per annum. In the presence of applied N, the additional requirement appears to be 0·3 to 0·5 kg K per kg N. The P required will depend on the level desired in the herbage and for about 0·3 per cent P in the dry matter the requirement is about 15 kg P per ha per annum plus approximately 0·1 kg P per kg N applied; for a content of 0·4 per cent P the corresponding figures would be about 40 and 0·3 kg P per ha.

Other investigations on the effects of N, P, K and Mg dressings on the yield and composition of crops have been continued, and two review lectures, mentioned earlier, are being prepared for publication in the proceedings of meetings. One, on soil properties limiting the efficiency of fertilizers, was contributed to the Seventh Fertilizer World Congress in Austria, and the other, on soil conditions and nutrient supplies in hill land, to a Colloquium on Hill Pasture and its Economic Utilization, in Edinburgh.

Effects of Nutrient Supply, Environmental Factors and Husbandry Practices on Crop Growth and Development

The series of annual factorial NPK experiments on barley and swedes, mentioned in the last three reports, has been continued. In these experiments the progressive accumulation of dry matter and nutrients is being measured in the crops and their vegetative parts at four contrasting centres, instrumented to record meteorological factors.

In addition to features mentioned in last year's report, the results show indications of substantial differences between sites in wind speed, rainfall, and soil and air temperatures, and have emphasized the importance of seed-bed preparation for cereals. In 1971 seed beds were generally very deep and friable following an abnormally dry winter. Consequently barley tended to be sown deeper than usual. At one site the seed was placed at a depth of about 5-6 cm and all phases of growth were delayed. This delay was accentuated by increased rate of fertilizer N. Although ear number was increased by N there was little yield increase, due to a compensating decrease in grain size. The situation was potentially similar in 1972, but the seed beds were rolled before sowing and growth has been satisfactory. Further work is planned to study the effects of deep planting and varying soil compaction.

Trace Elements

The information available suggests that the boron content of barley crops in north-east Scotland may sometimes be at or near levels which have been considered in other countries to indicate deficiency. Field work has therefore been started to examine the effects of applied B on the yield and B content of grain and straw at representative sites on different soil types.

The final soil and herbage samples have been taken from a series of plots started three years ago to study, in collaboration with Spectrochemistry, the influences of soil parent material and pedological drainage conditions on the relationships between laboratory soil values for trace elements, especially molybdenum, and the contents in the herbage and its constituent species.

Organic Phosphorus

Large amounts of inositol hexaphosphate accumulate in soils, showing that it is very resistant to decomposition in this environment. Similarly, pot cultures show that the availability of inositol hexaphosphate added to soils is low, in marked contrast to its high effectiveness in sand media. In general, therefore, inositol hexaphosphate is strongly retained by soils and makes little direct seasonal contribution to the phosphate nutrition of crops. It may, however, have an indirect beneficial effect on the phosphate status, in so far as it blocks retention sites and agents, especially aluminium and iron, which would otherwise be free to bind inorganic P. In other words, the inositol hexaphosphate in soils may to some extent tend to limit their ability to sorb fertilizer P and to promote a correspondingly higher degree of saturation with inorganic P. This possibility is of particular interest in Scottish soils, in which the degree of saturation is a major factor governing the availability of inorganic P, and which contain large amounts of inositol hexaphosphate. The sorption characteristics and interactions of inositol hexaphosphate and inorganic P have therefore been studied for a selection of acid surface soils, and an account of the results has been prepared for publication.

The maximum amounts of inositol hexaphosphate and inorganic P sorbed are highly correlated with each other and with the same soil properties, especially acid-oxalate soluble aluminium and iron. Treatment of the soils with inositol hexaphosphate markedly decreases their ability to sorb inorganic P and it appears that the same sorption sites and agents are involved, but the sorption patterns and mechanisms are different. High proportions of the inorganic P are sorbed, especially at low levels of addition, but the sorption is never complete. In striking contrast to this, inositol hexaphosphate, up to a certain level of addition which depends on the soil, is completely sorbed. Above this level the amount sorbed decreases, probably due to formation of soluble complexes with aluminium and iron. Since very large amounts of the ester have to be added before any appears in solution, where it can be mineralized by enzymes, the results throw additional light on its stability in these acid soils; they are also compatible with the possibility, noted above, that inositol phosphate may have some beneficial effect on the availability of inorganic P, and further work is planned to clarify this aspect.

Further studies on the nature of the organic phosphates in alkaline extracts have revealed the presence of several esters not previously characterized in soils. One contains *myo*-inositol and was thought at first to be a triphosphate, but some of its chromatographic properties are different. Another is a phosphorylated polyhydroxy carboxylic acid with a C:P ratio of about 7. Purification of these esters is difficult and only very small yields have so far been obtained, but it is possible that the intact soil may contain much larger amounts. A report detailing the methods used to fractionate the esters, and describing their properties, is being prepared for publication.

Inorganic Phosphorus and Sulphur

In addition to the above studies on the sorption interrelationships of inorganic P and inositol hexaphosphate, investigations have been continued on the effectiveness of different forms of added P in pot cultures, and on the significance of soil type and soil properties in relation to the usefulness of different kinds of P values as criteria of phosphate status. To clarify the implications of crop characteristics in the latter respect, a number of concurrent comparative measurements of phosphate status with swedes, potatoes and cereals were carried out in the field and in pots. Collaboration has continued with Plant Physiology in radioisotope measurements of labile P, using ^{32}P in pot cultures, and preliminary work has been done on corresponding use of ^{35}S to assess the sulphur status of soils. The latter development is designed to complement other studies in progress on the composition and behaviour of the organic sulphur fraction in soils.

Nitrogen

Progress has been made in the examination of laboratory methods for evaluating the nitrogen status of soils, and promising results have been obtained with some of the chemical measurements, especially determinations of nitrogen extracted by boiling water and of soluble carbohydrates extracted with barium hydroxide. The main reference criteria are the yield and nitrogen content of oats grown in pot cultures with no added nitrogen, but parallel field data are also being accumulated.

Changes in nitrate and ammonium in field plots receiving contrasting nitrogen treatments have again been monitored. A published method for estimating nitrate, involving reduction with copperized cadmium and formation of an azo dye with *N*-1-naphthylethylenediamine, has been brought into operation on the AutoAnalyser, to replace the standard manual distillation method. This has enabled the estimation of nitrate, as well as ammonium, in potassium chloride extracts of soils to be automated, with consequent marked improvement in the throughput of samples.

Comparisons have been made under different soil and cropping conditions in the field of the effectiveness of different forms of N, including anhydrous ammonia, urea and ammonium nitrate. An account of earlier collaborative work with Statistics[80] on the use of response models in estimating optimum rates of N has been submitted for publication.

The pot experiment programme included further tests on the effects of phenyl phosphonic acid and related compounds on the growth and N content of oats in different media, and an examination of the effectiveness of ammoniated vermiculite of different particle size, prepared by Spectrochemistry, as a source of N.

Soil Acidity and Cation Exchange

To clarify the factors governing crop growth on different types of acid soils, work has continued on the complex interrelationships of pH, aluminium solubility and the exchange equilibria of aluminium with calcium and magnesium.

An account of studies on methods for characterizing soils with respect to soluble and exchangeable aluminium has been prepared for publication. Physicochemical theory requires that the index of cation solubility in soil suspensions should be the ratio of the activities of two ions, rather than the concentration or activity of a single ion, which can vary markedly depending on the amount of soil and the presence of salts. Such ratios are conveniently transformed to logarithmic forms, and in the last report it was suggested that pH-$\frac{1}{3}$pAl might provide an appropriate index of aluminium solubility. Further investigation has shown that this is not so. At a given pH, a higher value of this function certainly indicates a higher solubility of soil aluminium, but it has been found that pH-$\frac{1}{3}$pAl also increases as pH rises, whereas aluminium becomes less soluble. The function $\frac{1}{3}$pAl-$\frac{1}{2}$pCa, expressing the solubility of aluminium in relation to that of calcium, seems more promising, and it can be estimated in a saturation water extract of the soil. A dilute calcium chloride extract (10^{-2}M), such as is used for pH measurements, will also provide a convenient routine index of aluminium solubility. The significance of these indices for plant growth remains to be investigated.

The determination of exchangeable aluminium is confused by the concomitant release of non-exchangeable aluminium. It appears to be impossible to distinguish these in any absolute way, particularly as the removal of non-exchangeable Al on continuous extraction with a concentrated salt solution increases the soil negative charge. However, a single extraction of 5g soil with 100 ml of 1·0 M potassium chloride or ammonium chloride for 30 minutes provides an adequate approximate method.

Two interpretations of the role of aluminium ions in buffering the pH of moderately to strongly acid soils have been tested. One is that the solubility product of aluminium hydroxide (pK = pAl + 3pOH) controls the pH *via* the ion product of water (pK_w = pH + pOH), but experimental results for the relationship between pH and aluminium soluble in 1:1 suspensions of soil in 10^{-2}M calcium chloride solution do not support this mechanism. An alternative view, suggested in last year's report, favours the hydrolysis of aluminium ions ($Al^{3+} + H_2O \rightleftharpoons AlOH^{2+} + H^+$) as the pH-determining reaction. For some soils nearly all the solution hydrogen ions can be accounted for by this second mechanism, but another source is evident in most soils. Because the latter contribution is greater in soils low in clay and high in humus, with peat as the extreme, it is reasonable to assign it to the dissociation of organic proteolytic groups, presumably humic carboxyl groups. The role of the selectivity coefficient (K) for the (Ca + Mg) $\rightleftharpoons$ Al exchange reaction in determining pH, through its effect on the concentration of aluminium in solution, is probably of subsidiary importance because values for contrasting soils appear to vary by less than one pK unit.

Chemical Composition of Plants

Work outlined in last year's report has been continued on the significance, in relation to crop yields, of root cation-exchange capacity and the quantity C—A, the difference between total cations and total inorganic anions in the tops. Differences in C—A can be of genetic origin, as with different crops and different varieties grown under standard conditions, or they may be induced in a single cultivar by varying the fertilizer treatment. Both aspects have been studied, using samples of cereals and root crops from field trials comparing different varieties and fertilizer treatments. In addition, the more controlled conditions in pot cultures have been used to examine the relationships over wider ranges of genetically contrasting oat and barley varieties.

Two reports of collaborative work with Plant Physiology, dealing with other aspects of the cation-exchange properties and chemical composition of plant tissues[70, 75], have been accepted for publication, and an account of parallel studies on pollen[23] has appeared.

Advisory Work

At just over 9000, the number of soil samples examined was about 3000 less than in 1970/71, but as usual they came mostly from agricultural land and were submitted by the Advisory Officers of the North of Scotland College of Agriculture to obtain guidance on lime and fertilizer recommendations. Trace element problems, which frequently concern plant composition and animal health rather than crop growth, continue to be dealt with in collaboration with Spectrochemistry, and assistance has again been given to Pedology in the examination of soil samples from forest nurseries.

The soil results show no evidence of any marked improvement in the lime status and levels of readily-soluble phosphate, potassium and magnesium in agricultural land during the last ten years. There is still a need for remedial lime dressings to correct deficiencies in about 70 per cent of the samples examined. The remaining 30 per cent are at a satisfactory level but require maintenance dressings every six to eight years. About a quarter of the samples still have a low phosphate content and about half are slightly low, leaving only about a quarter in the satisfactory category. There is therefore still a widespread need for quite heavy dressings of phosphate. The position for potassium has always been much better, and currently only about 2 per cent have a low content, while nearly 60 per cent are at a reasonably satisfactory level. The remainder are in the slightly low category and can be expected to give small to moderate responses to potassium dressings, depending on the crop. The magnesium content in practically all the soils is enough to produce full yields, but in many fields the level may not be adequate to provide sufficient magnesium in the crops and herbage to meet animal requirements. On acid soils, the best remedy in such cases is occasional liming with magnesian limestone.

STATISTICS

In the service provided to other departments the main fields covered are the design of experiments, statistical analysis, including analysis of variance of designed experiments and methods of multivariate analysis, data processing and computer operation and programming.

During the year two FAO Fellows have worked in the department. Mr B. Khazai-Nejad from the Soil Science Institute of Iran spent five months studying the design of field experiments and methods of statistical analysis. He also received training in computer programming. For a shorter period Mr A. N. Sadovski from the N. Poushkarov Institute of Soil Science, Bulgaria, studied central composite designs and the use of the computer in multivariate statistical analysis.

Members of staff have attended meetings of the British Computer Society, the Biometric Society and the Royal Statistical Society, symposia on multivariate statistical analysis and on model-building in agriculture, and a Working Party of the Agricultural Research Council on Model-building in Crop and Plant Science.

Computing Service

The appointment of Mr G. J. M. Stephen has allowed more attention to be concentrated on the management of computer use and on programming. The computer system has been extended by the addition of an IBM 1627 model 2 plotter, which has proved of particular value in the graphical presentation of results from Fourier transform spectroscopy and of normalized peak heights from mass spectrographs. A full data preparation service is provided and facilities and equipment are made available to authorized computer users from other departments.

The translation and coding of various suites of programs have formed part of the service, for example in processing results from electron-probe microanalysis and single-crystal structure analysis. A number of the programs written during the year have been for the the production of a three-dimensional plot of the structure of molecules, for the calculation of a discriminator value to distinguish soil humus types using the normalized peak heights from mass spectrographs, for plotting and drawing fitted curves, and for processing microbiological data from a Coulter counter.

Revisions and additions have been made to programs for statistical analysis. For example, the program for the analysis of variance of randomized blocks has been extended to include designs where the control treatment occurs more than once in each block and to produce correlations between sets of residuals. A general subroutine for multiple comparison tests between treatments and a control has been developed. Another subroutine computes coefficients of skewness and kurtosis and their standard errors in testing for non-normality in a set of observations.

Advisory and Collaborative Work

Field experiments designed for Soil Fertility include randomized blocks, lattice squares, central composite designs, and factorial arrangements, some of which have confounding or partial confounding. Two continuing series of experiments of confounded factorial design are concerned with the detailed study of pattern of growth and development of barley and swedes. These provide data for analysis from samples obtained at various times throughout the growing season. Tests of the skewness of the distribution of grain number per ear within plots have also been made, and a computer program has been written to process the data from a sugar-tube method for assessing soil temperature at field sites. Further evaluations of different forms of phosphate fertilizer in terms of crop yield and uptake of phosphate have been made by fitting Mitscherlich response curves. Other Soil Fertility investigations have required the use of programs for correlation and regression analysis, angular transformation of data expressed as percentages, analysis of covariance, and the combination of experimental results over a number of years. Examples of the latter are found in a joint account[47] of the results from a 3^3 NPK factorial experiment on the nutrient requirements of grassland on deep peat and an account[80] of the comparison of four response equations for their ability to predict the optimum economic rate of nitrogen fertilizer.

Collaboration with Pedology has included the writing of several programs to produce variables of interest and perform analyses of variance on derived data for profiles in a randomized block experiment on a peat bog. Analyses of variance have been done on measurements of tree height and height increments for a number of experiments. Data processing and statistical analysis have been carried out on an experiment on the nitrogen nutrition of pines for many variables such as measurements of tree growth, stem taper, weight and chemical composition of needles and litter, and linear regressions have been fitted and compared. A correlation and regression study on poorly drained and freely drained soils involved the prediction of hydroxyl activity from determinations of silica, aluminium and iron. Routine data processing of the results of X-ray silicate analysis continues. The results from the mass spectrometer are processed by three programs; the first produces normalized peak heights, the second plots the normalized spectra, and the third applies a vector of coefficients or weight factors to the normalized peak heights to calculate a discriminator value for pattern recognition.

Further factorial and randomized block experiments in Plant Physiology studies have been designed, and data analysed for the content and ratios of elements in various plant parts. Work has also continued on the analysis of data from various factorial experiments on nutrient relationships in plants.

In collaboration with Microbiology a method of computing the volume of a soil ciliate from measured diameters was devised and tests of skewness of the distribution of the volumes and of differences in mean volume were carried out. In a number of experiments counts of organisms in samples with different treatments have been examined, logarithmic transformations have been used, and tests of significance applied. Published tables for a ten-fold dilution series of any length have been used to estimate the densities of organisms from results obtained by the dilution series method.

Collaboration with Biochemistry has included the fitting of linear regressions and the graphical presentation of the results for experiments on the estimation of sugars as acetylated nitriles.

LIBRARY

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

During the year 174 books were added to stock, 40 being received by donation. Journal intake was again affected by rising subscription costs and only one addition could be made. Shelving problems, which had become acute in recent years, have now been eased by the provision of a stack room.

To meet the requirements of the staff much material has still to be obtained from other libraries and this year 1065 items were borrowed; 311 were lent.

The world-wide interest in the work of the Institute is reflected in the many requests received for papers published by the staff; 5113 reprints were distributed this year. The Institute maintains a mailing list of individual scientists and institutions interested in the various branches of the research work, and lists of staff papers of which reprints are available are sent out periodically. No charge is made for reprints and anyone interested in receiving lists should apply to the librarian.

Volume 9 of Collected Papers, covering the years 1967/69 was issued early in 1972.

PUBLICATIONS

(A) *Published*

1. Randomly orientated powders for quantitative X-ray determination of clay minerals By A. P. Thomson, D. M. L. Duthie and M. J. Wilson. (*Clay Miner.*, **9**, 345-347, 1972.)

   A major difficulty in quantitative mineralogical analysis of clay minerals by X-ray diffraction is the tendency for clay particles in powder mounts to adopt a preferred orientation that cannot be reproduced from sample to sample. A method that overcomes this problem involves the sorption of clay on polyester foam sheeting. This technique has been successfully used for quantitative determination of kaolinite.

2. Clay mineralogy of the Old Red Sandstone (Devonian) of Scotland. By M. J. Wilson. (*J. sediment. Petrol.*, **41**, 995-1007, 1971.)

   As a background to pedological studies on soils the clay mineralogy of the Old Red Sandstone rocks of Scotland has been investigated. In the Lower Old Red Sandstone the major part of the sequence is characterized by a variety of interstratified minerals, including chlorite-vermiculite, dioctahedral smectite-chlorite, and illite-smectite. Kaolinite is rarely present. The clay fractions separated from the Middle Old Red Sandstone rocks of Caithness are mixtures of illite and chlorite. Those from Old Red Sandstone of other areas and all Upper Old Red Sandstone samples are dominated by interstratified illite-smectite, of which there are two distinct types, and kaolinite. These observations may be of use in the classification of soils formed on Old Red Sandstone parent material should the clay minerals inherited by the soils survive in a relatively unaltered form.

3. Clay-mineral studies on some Carboniferous sediments in Scotland. By M. J. Wilson, D. C. Bain, W. J. McHardy and M. L. Berrow. (*Sediment. Geol.*, **8**, 137-150, 1972).

   To provide background information for future investigations on clay fractions of soils developed on tills derived from Scottish Carboniferous sediments the clay minerals present in such rocks have been investigated. Kaolinite and illite are common species, illite being abundant in the Lower Carboniferous and kaolinite in the Upper. The type of kaolinite differs according to the rock type in which it occurs; thus, kaolinite in shales is much more poorly crystalline than kaolinite in sandstones. Such differences could affect soil properties such as cation-exchange capacity.

4. Clay mineral formation in a deeply weathered boulder conglomerate in north-east Scotland. By M. J. Wilson, D. C. Bain and W. J. McHardy. (*Clays Clay Miner.*, **19**, 345-352, 1971.)

   The formation of clay minerals in a deeply weathered boulder conglomerate in Nairnshire has been studied by a variety of physical and chemical techniques. In granite and granulite boulders it was found that, with the exception of microcline, all the felspar minerals weather directly to montmorillonite. Small amounts of kaolinite are also formed from the weathering of muscovite. The environment in which these changes occurred appears to have been alkaline and chemical analyses for related cores and weathered shells of granite and granulite boulders indicate a relatively closed system.

5. Oxidation of chlorites in soil clays and effect on DTA curves. By D. C. Bain. (*Nature phys. Sci.*, **238**, 142-143, 1972.)

   The thermal characteristics of chloritic clay fractions from freely drained and poorly drained soils differ, the characteristics of the fractions from poorly drained soils resembling those for macroscopic chlorite. The reasons for this difference are discussed.

6. Characterization of soils by pyrolysis combined with mass spectrometry. By J. M. Bracewell. (*Geoderma*, **6**, 163-168, 1971.)

   Pyrolysis of soil samples, without prior chemical treatment, followed by identification of the volatile products using low-resolution mass spectrometry, can be used as a rapid technique for identifying the genetic horizons in freely drained soils.

7. Comparison of ultrastructure and chemical components of cell walls of certain plant pathogenic fungi. By D. Jones, V. C. Farmer, J. S. D. Bacon and M. J. Wilson. (*Trans. Br. mycol. Soc.*, **59,** 11-23, 1972.)

   A comparison has been made of the ultrastructure and chemical components of the cell walls of various plant pathogens which, with one exception, form sclerotia that persist as viable resting bodies in the soil. The various analytical methods employed included X-ray diffraction, infrared absorption spectroscopy and paper chromatography. This study is an attempt to relate cell wall composition to fungal classification and to susceptibility of sclerotia to parasitism by certain soil fungi.

8. Nature and extent of Scottish peat resources. By R. A. Robertson. (*Suom. maatal. Seur. Julk.*, **123,** 233-241, 1971.)

   A brief review of the history of peat research and development and of current survey techniques. Maps and diagrams are presented showing the relationship between peat cover, climate and topography. The description of bog and peat types highlights outstanding problems of classification and nomenclature.

9. The effect of ground water level on water movement in peat: a study using tritiated water. By A. H. Knight, R. Boggie and H. Shepherd. (*J. appl. Ecol.* **9,** 633-641, 1972.)

   Tritium was used to trace water movement through peat in five plots in which the water tables were maintained at different depths, ranging from zero to 0·34 m below the surface. Tritiated water was applied to the surface of the peat and at time intervals up to 54 weeks after application the peat below and adjacent to the treated areas was sampled and analysed for radioactivity. Both downward and lateral movement was detected and these were related to the drainage treatments and topography.

10. Evaluation of horticultural peat in Britain. By R. Boggie and R. A. Robertson. (*Proc. IV int. Peat Congr., Otaniemi, Finland, 1972,* **3,** 185-192, 1972.)

    Chemical and physical properties of five horticultural peats and methods of determination are described and discussed. Botanical composition, degree of decomposition, pH, volume-weight and air capacity are the properties which, collectively, appear to form the best basis for practical evaluation.

11. Assessment of climatic conditions in Scotland. 3. The bioclimatic sub-regions. By E. L. Birse. (Map and explanatory pamphlet issued by the Soil Survey of Scotland. Aberdeen: Macaulay Institute for Soil Research. 1972. £0.75.)

    A map of the bioclimatic sub-regions of Scotland, based on thermal zonation, oceanicity and moisture status, has been devised. This third map, used in conjunction with the tables accompanying maps 1 and 2, can provide a reasonably accurate categorization of the climate in relation to the range of climates in the northern hemisphere. The scale is 1:625,000.

12. The soils (of Caithness). By D. W. Futty. (pp. 46-54 of *The Caithness Book.* Edited by D. Omand. Inverness: Highland Printers Ltd. 1972.) *No reprints.*

    Soil formation is discussed in general terms and in particular in relation to soil development in Caithness. The soils are described under parent material headings and a brief outline of soil classification and the characteristic features of the major soils groups and sub-groups are given.

13. The importance of soil investigations prior to drainage improvements. By B. M. Shipley. (In: *J. Ld Drain. Assoc.*, No. 2, 1972.) *No reprints.*

    The article outlines simple but effective methods of examining soil before undertaking a drainage system and explains the meanings of some terms commonly used by soil surveyors. Examples are cited to illustrate the importance of soil examination in assessing the best method of improving drainage.

14. Trace elements in soils. By R. L. Mitchell. (*Tech. Bull. Ministr. Agric. Fish. Fd,* No. **21,** 8-20, 1971.)

    The contents and forms of occurrence of trace elements in soils are discussed in relation to the nature and mineralogical characteristics of the parent material and to the influences of the weathering processes and soil conditions, especially drainage status, which affect their solubility and uptake by plants. Extractants used for assessing the trace element status of Scottish soils are noted, together with limiting values indicating deficiencies and excesses.

15. Trace elements in soils and factors that affect their availability. By R. L. Mitchell. (*Bull. geol. Soc. Am.*, **83**, 1069-1076, 1972; *Spec. Pap. geol. Soc. Am.*, **140**, 9-16, 1972.)

A review, from the point of view of their relationship to the geochemical environment, of the factors that control the uptake by plants of trace elements from a soil, and so affect the health of animals or man dependent on that soil.

16. Trace elements in sewage sludges. By M. L. Berrow and J. Webber (Agricultural Development and Advisory Service, Leeds). (*J. Sci. Fd Agric.*, **23**, 93-100, 1972.)

Analyses of 42 sewage sludges from rural and industrial towns and cities in England and Wales show very large concentrations of certain trace elements. Total contents of 5 per cent Zn, nearly 1 per cent Cr and Cu and 0·5 per cent Ni were found in certain dried sludges. Total Cu, Sn and Zn, and to a lesser extent Ag, Bi and Pb, were much greater than the levels of these elements in soils. Total Cr and also Ni were very high in a small number of samples. Acetic-acid-soluble Zn and Cu levels were generally very much greater than in soils, but overall, Mn, Ni and Zn had considerably higher percentage solubility than Cr, Cu, Mo, Pb, Sn and V. Zn, Cu and Ni appear to be the elements most likely to give rise to toxicity problems in plants due to the use of sewage sludge as a soil additive.

17. Spectrochemical methods for the analysis of soils, plants and other agricultural materials. By R. O. Scott, R. L. Mitchell, D. Purves (East of Scotland College of Agriculture) and R. C. Voss (West of Scotland Agricultural College). (*Bull. consult. Comm. Dev. spectrochem. Wk.*, No. **2**, 1971. 87 pp.)

Detailed descriptions of the techniques employed for the determination of trace elements at the Macaulay Institute for Soil Research, the East of Scotland College of Agriculture and the West of Scotland Agricultural College. Consideration is also given to field sampling, the preparation of samples prior to analysis and the assessment of the analytical findings.

18. Interaction of ammonia with vermiculite. By J. L. Ahlrichs (Purdue University, Lafayette, Indiana, U.S.A.), A. R. Fraser and J. D. Russell. (*Clay Miner.*, **9**, 263-273, 1972.)

As part of a continuing investigation into the possible behaviour of the fertilizer gaseous ammonia when added to soils, a study has been made of its reactions with two vermiculites, one of them from a Scottish soil. It is shown that much ammonia is sorbed by this clay mineral but is not fixed. It is released at rates that are dependent on the exchangeable cations in, and the particle size of the vermiculite, which could thus provide a reservoir of nitrogen in an ammonia-treated soil.

19. Reaction of silica gel with a volatile boron compound released from borosilicate glass. By H. Häni and J. D. Russell. (*Nature phys. Sci.*, **235**, 13-14, 1972.)

The adsorption of butanol and methanol vapour by silica gels is being investigated as part of a study of clay-organic complexes in soils. A silica-boron contaminant was formed when the reaction was carried out in Pyrex glass equipment but not when quartz glass equipment was used, thus demonstrating that the Pyrex glass was the source of the boron.

20. Fundamental aspects of iron nutrition of plants. By P. C. DeKock. (*Tech. Bull. Ministr. Agric. Fish. Fd*, No. **21**, 41-44, 1971.)

A review is presented of the processes whereby iron is absorbed from the soil and translocated to the leaves, with special emphasis on the functions of chelation by organic substances. The synthetic chelating agents such as EDTA and EDDHA have contributed greatly to investigations of chlorosis and have been widely employed to elucidate problems of iron deficiency.

21. The leaf tip of *Ranunculus reptans* L. By P. C. DeKock, Marjorie F. Rutherford and Evelyn M. Birse (Botany Department, University of Aberdeen). (*Ann. Bot.*, **35**, 1191-1195, 1971.)

Ranunculus reptans L. is a comparatively rare boreal species. The form of it growing in Scotland has been found only at the Loch of Strathbeg and Loch

Leven. It is being studied from both taxonomic and ecological standpoints. The knob-like structure at the tip of the winter leaf is shown to have glandular characteristics, probably acting as a hydathode. This may have significance in fitting the plant to its special lake margin niche where fluctuating water-level and wave-action are important factors.

22. Anion absorption by etiolated wheat leaves after vacuum infiltration. By I. R. MacDonald and A. E. S. Macklon. (*Pl. Physiol.*, **49**, 303-306, 1972.)

Leaf cells, in common with all other plant cells, absorb solutes from adjoining cells and vascular tissue. The experimental investigation of the absorptive capability of leaf cells is impeded by the impermeable nature of the leaf surface. To obviate this difficulty leaves of Capelle wheat seedlings were vacuum infiltrated before measurement of chloride and phosphate absorption. The uptake rates observed, and their degree of enhancement by exposure to light, were otherwise attainable only by fragmenting the tissue. No deleterious effects of vacuum infiltration were observable and it is suggested that the technique offers advantages over existing methods in the study of foliar absorption.

23. Chemical composition of pollen, with particular reference to cation-exchange capacity and uronic acid content. By A. K. Knight, W. M. Crooke and H. Shepherd. (*J. Sci. Fd Agric.*, **23**, 263-274, 1972.)

A study was made of the pollen of grasses, herbs, deciduous trees and conifers, and its mineral composition was found to be similar to that of the tissues of other plant parts (leaves, roots and seeds). The contents of the various elements in the latter tissues are generally higher for the dicot species than for the monocots, but except for calcium this not true of the pollen.

24. Nitrogen fixation by *Azotobacter chroococcum* in the presence of *Colpoda steini*. I. The influence of temperature. By J. F. Darbyshire. (*Soil Biol. Biochem.*, **4**, 359-369, 1972.)

Previous reports of increased nitrogen fixation by free-living soil bacteria, *Azotobacter* spp., in the presence of soil protozoa have been confirmed with *Azotobacter chroococcum* and the common soil ciliate *Colpoda steini* when these microbes were incubated at temperatures between 15° and 25°. When mixed and pure cultures of *A. chroococcum*, however, were incubated at 28°, which is approximately the optimum temperature for nitrogen fixation by pure cultures of *A. chroococcum*, the mixed cultures of azotobacter and colpoda fixed less nitrogen that the pure cultures of azotobacter. The actual mechanism whereby ciliates stimulate nitrogen fixation by azotobacter is still unclear. In view of the recently discovered oxygen sensitivity of azotobacter during nitrogen fixation, it is suggested that the protozoa may help to reduce the dissolved oxygen concentrations in mixed cultures to more suitable levels for nitrogen fixation by azotobacter. Future experiments will test the validity of this new hypothesis.

25. Nitrogen fixation by *Azotobacter chroococcum* in the presence of *Colpoda steini*. II. The influence of agitation. By J. F. Darbyshire. (*Soil Biol. Biochem.*, **4**, 371-376, 1972.)

Cultures of the soil protozoan *Colpoda steini* with the soil bacterium *Azotobacter chroococcum* fixed more nitrogen than equivalent pure cultures of azotobacter when the liquid media were gently shaken and incubated at 28°C for two weeks. Equivalent unshaken mixed colpoda-azotobacter cultures fixed slightly less nitrogen than unshaken pure azotobacter cultures in the same period. There was little difference between the amounts of nitrogen fixed by mixed and pure azotobacter cultures in either the shaken or unshaken treatments after four weeks of incubation.

26. *Aecidium* spp. on *Agathis*. By E. Punithalingham (Commonwealth Mycological Institute) and D. Jones. (*Trans. Br. mycol. Soc.*, **57**, 325-331, 1971.)

The taxonomy of two *Aecidium* spp. fungi which attack *Agathis* leaves (Dammar Pine) has been confused in the past. This paper, based on optical and electron microscope observations of spores from 14 collections retained in the Commonwealth Mycological Institute, confirms the existence of two species. These could be distinguished readily on aeciospore surface ornamentation.

27. Frozen-etched spores of *Trichoderma viride*. By D. Jones. (*Trans. Br. mycol. Soc.*, **57**, 348-351, 1971.)

The ultrastructure of spores of the soil fungus *Trichoderma viride*, which parasitizes the plant pathogen *Sclerotinia sclerotorium*, has been examined by the technique of freeze-fracturing and etching. No chemical fixation procedures were required and artifact-free features of the spore morphology are believed to have been obtained. Surface features of the various cell membranes were revealed; this would not have been possible with other techniques.

28. An unusual feature of the nuclear membrane in freeze-etched sporangiospores of *Mucor plumbeus*. By D. Jones. (*Trans. Br. mycol. Soc.*, **59**, 175-178, 1972.)

An unusual ultrastructure feature of the nuclear membrane in spores of a saprophytic soil fungus, *Mucor plumbeus*, as revealed by the technique of freeze-fracturing and etching, is described.

29. Factors affecting the mineral content of herbage. By J. W. S. Reith. (*Norgrass: J. North Scotl. Grassl. Soc.*, No. **12**, 23-28, 1971). *No reprints.*

The main factors, including soil, botanical composition, stage of growth, time of cutting, liming and manuring, influencing mineral composition, are summarized. Since the mineral elements are taken up from the soil, attention is drawn to the importance of soil reserves and of adjusting liming and manuring to correct deficiencies and avoid excesses. Provided there are no serious losses during conservation, hay, silage or dried grass produced with satisfactory liming, manuring and management should normally contain adequate amounts of the mineral elements required by animals.

(B) *Awaiting Publication at 30th September, 1972*

30. The classification of soil silicates and oxides. By R. C. Mackenzie. (To appear in *Inorganic Soil Components*. Edited by J. E. Gieseking. Berlin: Springer.)

31. Heavy minerals. By the late W. A. Mitchell. (To appear in *Inorganic Soil Components*. Edited by J. E. Gieseking. Berlin: Springer.)

32. Oxides and hydrous oxides of silica. By B. D. Mitchell. (To appear in *Inorganic Soil Components*. Edited by J. E. Gieseking. Berlin: Springer.)

33. 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 *Inorganic Soil Components*. Edited by J. E. Gieseking. Berlin: Springer.)

34. Instrumentation for thermogravimetry and differential thermal analysis. By R. C. Mackenzie. (To appear in a monograph on *Thermal Analysis* to be issued by the Society for Analytical Chemistry: Chemical Society, Analytical Division.)

35. Soils. By R. C. Mackenzie and B. D. Mitchell. (To appear as Chap. 36 (pp. 267-297) of *Differential Thermal Analysis*. Vol. 2. Edited by R. C. Mackenzie. London: Academic Press.)

36. General applications (of DTA) in industry, with special reference to dusts. By R. C. Mackenzie and R. Meldau (Güttersloh, Germany). (To appear as Chap. 46 (pp. 535-564) of *Differential Thermal Analysis*. Vol. 2. Edited by R. C. Mackenzie. London: Academic Press.)

37. Peak areas and heats of transition of DTA temperature standards. By R. C. Mackenzie and P. F. S. Ritchie. (*Thermal Analysis: Proc. 3rd ICTA (1971)*, Vol. 1, 441-452, 1972. Basel: Birkhäuser Verlag.)

38. Imogolite, a hydrated aluminium silicate of tubular structure. By P. D. G. Cradwick, V. C. Farmer, J. D. Russell, C. R. Masson (National Research Council of Canada, Halifax), K. Wada (Kyushu University, Japan) and N. Yoshinaga (Ehime University, Japan). (Submitted to *Nature*.)

39. Clay minerals in soils derived from Lower Old Red Sandstone till: effects of inheritance and pedogenesis. By M. J. Wilson. (Submitted to *J. Soil Sci.*)

40. Calculated X-ray diffraction profiles for interstratified kaolinite-montmorillonite. By P. D. G. Cradwick and M. J. Wilson. (Submitted to *Clay Miner.*)

41. Occurrence of interstratified kaolinite-montmorillonite in some Scottish soils. By M. J. Wilson and P. D. G. Cradwick. (Submitted to *Clay Miner.*)

42. Effects of soil micro-organisms on montmorillonite-adenine complexes. By M. P. Greaves and M. J. Wilson (Submitted to *Soil Biol. Biochem.*)

43. Humus type discrimination using pattern recognition of the mass spectra of volatile pyrolysis products. By J. M. Bracewell and G. W. Robertson. (Submitted to *J. Soil Sci.*)

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

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

46. 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. NERC Symp. Peatland Forestry, Edinburgh 1968.*)

47. The nutrient requirements of herbage on deep acid peat. By J. W. S. Reith, R. A. Robertson and R. H. E. Inkson. (Submitted to *J. agric. Sci., Camb.*)

48. Deutsch-englisch-russisches Fachwörterbuch: Moor und Torf. By W. Bick, R. A. Robertson and R. Schneider and S. Schneider (Torfinstitut, Hannover). (Submitted to *Torfnachrichten.*)

49. Vegetation chronology. By S. E. Durno. (To appear in: *Biogeography of Scotland*. Edited by J. Tivy. Edinburgh: Oliver & Boyd.)

50. Kilphedir—hut circle excavation site: the soils of the site. By J. C. C. Romans and S. E. Durno. (To appear as appendix to paper by Fairhurst and Taylor in *Proc. Soc. Antiq. Scotl*).

51. A fossil brown forest soil from Angus. By J. C. C. Romans, S. E. Durno and L. Robertson. (Submitted to *J. Soil Sci.*)

52. Effect of water-table height on root development of *Pinus contorta* on deep peat. By R. Boggie. (*Oikos*, **23**, No. 3, 1-9, 1972.)

53. Nitrogen mineralization and organic matter decomposition in Scots pine humus. By B. L. Williams. (*Forestry*, 45, 177-188, 1972.)

54. Soils in the Cairngorms. By R. E. F. Heslop. (To appear in *The Cairngorms*. Edited by D. Nethersole-Thompson *et al.* London: Collins.)

55. Geomorphology and soils (of Mull). By J. S. Bibby. (To appear in *Flora of Mull*. London: British Museum.)

56. Land use capability. By J. S. Bibby. (To appear in *Biogeography of Scotland*. Edited by J. Tivy. Edinburgh: Oliver & Boyd.)

57. Factors in soil formation. By J. M. Ragg. (To appear in *Biogeography of Scotland*. Edited by J. Tivy. Edinburgh: Oliver & Boyd.)

58. The classification of some British soils according to the comprehensive system of the United States. By J. M. Ragg and B. Clayden (Rothamsted Experimental Station). (To appear as *Tech. Monogr. Soil Surv. Gt. Br.*)

59. The soils of Carrick and the country round Girvan (Sheet 8 and part Sheet 7). By C. J. Bown. (To appear as *Mem. Soil Surv. Gt. Brt.*)

60. Gley soils in the Midland Valley of Scotland. By D. Laing. (Submitted to *Trans. jt. Meet. Comm. V & VI int. Soc. Soil Sci., Stuttgart, 1971.*)

61. The photography of soil and associated landscapes. By J. M. Ragg (To appear in *Soil Survey Handbook.*)

62. Soil bulk density measurement in the field by gamma-ray transmission methods. By J. M. Ragg. (To appear in *Soil Survey Handbook.*)

63. Soil temperature. By J. M. Ragg. (To appear in *Soil Survey Handbook.*)

64. Cobalt in soil and its uptake by plants. By R. L. Mitchell. (Submitted to *Agrochimica*).

65. Lithium, sodium, potassium, rubidium and cesium. By A. M. Ure and R. L. Mitchell. (To appear as Chap. I of *Flame Emission and Atomic Absorption Spectrometry*. Vol. 3. Edited by J. A. Dean and T. C. Rains. New York: Dekker.)

66. Some sources of contamination in trace analysis. By R. O. Scott and A. M. Ure. (*Proc. Soc. anal. Chem.*, **9**, 288-293, 1972.)

67. Effects of structural order and disorder on the infrared spectra of brittle micas. By V. C. Farmer and B. Velde (Laboratoire de Petrographie, Paris, France). (Submitted to *Miner. Mag.*)

68. The effect of 'A' site occupancy upon the hydroxyl stretching frequency in clinoamphiboles. By G. Rowbotham (University of Keele) and V. C. Farmer. (Submitted to *Contrib. Miner. Petrol.*)

69. The characterization of soil minerals by infrared spectroscopy. By V. C. Farmer and E. Palmieri. (To appear in *Inorganic Soil Components.* Edited by J. E. Gieseking. Berlin: Springer.)

70. Cation-exchange capacity, chemical composition and the balance of carboxylic acids in the floral parts of various plant species. By A. H. Knight, W. M. Crooke and J. C. Burridge. (Submitted to *Ann. Bot.*)

71. Electron spin resonance of humic acids from cultivated soils. By M. V. Cheshire and P. A. Cranwell (University of Sheffield). (*J. Soil Sci.*, **23**, 424-430, 1972.)

72. The origin of soil polysaccharide: transformation of sugars during the decomposition in soil of plant material labelled with ^{14}C. By M. V. Cheshire, C. M. Mundie and H. Shepherd. (Submitted to *J. Soil Sci.*)

73. Determination of ^{14}C in soil by a gel suspension method. By M. V. Cheshire, H. Shepherd, A. H. Knight and C. M. Mundie. (*J. Soil Sci.*, **23**, 420-423, 1972.)

74. Effects of amino acid analogues on the growth and protein metabolism of pea root segments. By D. Vaughan and Evelyn Cusens. (Submitted to *J. exp. Bot.*)

75. Cation-exchange capacity and chemical composition of the floral parts of Antirrhinium and Lilium. By A. H. Knight and W. M. Crooke. (Submitted to *Ann. Bot.*)

76. The ultrastructure of the mucilaginous layer on plant roots. By M. P. Greaves and J. F. Darbyshire. (*Soil Biol. Biochem.*, **4**, 443-449, 1972.)

77. Bacteria and protozoa in the rhizosphere. By J. F. Darbyshire and M. P. Greaves. (Submitted to *J. Sci. Fd Agric.*)

78. The estimation of soil protozoan populations. By J. F. Darbyshire. (To appear in *Tech. Ser. Soc. appl. Bact.* No. 7.)

79. Factors affecting germination of sclerotia of *Sclerotinia sclerotiorum* from peas. By D. Jones and Elizabeth G. Grey (School of Agriculture, Aberdeen.) (Submitted to *Trans. Br. mycol. Soc.*)

80. A comparison of response curves for estimating optimum rates of nitrogen. By R. H. E. Inkson and J. W. S. Reith. (Submitted to *J. Sci. Fd Agric.*)

81. Other organic phosphorus compounds. By G. Anderson. (To appear in *Organic Soil Components.* Edited by J. E. Gieseking. Berlin: Springer.)

82. Sulphur in soil organic substances. By G. Anderson. (To appear in *Organic Soil Components.* Edited by J. E. Gieseking. Berlin: Springer.)

(C) *Papers by Members of Staff on Leave of Absence.* (*No reprints.*)

83. 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.*)

(D) *Thesis*

84. The following thesis has been accepted for the degree of Ph.D. by the University of Aberdeen:
Studies of source conditions in applied spectrochemical analysis, with special reference to soils and rocks. By H. K. El-Kholy.

AGRICULTURAL RESEARCH INSTITUTES IN GREAT BRITAIN

The research programmes of the following agricultural research institutes supported by public funds are co-ordinated by the Agricultural Research Council. These institutes generally publish annual or periodical reports summarizing the research work that is in progress. Full details can be obtained from the secretaries of the institutes concerned.

A.R.C. Institutes	
Animal Breeding Research Organisation	King's Buildings, West Mains Road, Edinburgh, EH9 3JQ.
Institute of Animal Physiology	Babraham, Cambridge, CB2 4AT.
Institute for Research on Animal Diseases	Compton, Newbury, Berks.
Food Research Institute	Colney Lane, Norwich, NOR 7OF.
Meat Research Institute	Langford, Bristol, BS18 7DY.
Poultry Research Centre	King's Buildings, West Mains Road, Edinburgh, EH9 3JS.
Letcombe Laboratory	Letcombe Regis, Wantage, Berks.
Weed Research Organization	Begbroke Hill, Sandy Lane, Yarnton, Oxford, OX5 1PF.
State-aided Institutes (Scotland)	
Animal Diseases Research Association	Moredun Institute, 408 Gilmerton Road, Edinburgh, EH17 7JH.
Hannah Dairy Research Institute	Ayr, Scotland.
Hill Farming Research Organisation	29 Lauder Road, Edinburgh, EH9 2JQ.
Macaulay Institute for Soil Research	Craigiebuckler, Aberdeen, AB9 2QJ.
National Institute of Agricultural Engineering (Scottish Station)	Bush Estate, Penicuik, Midlothian.
Rowett Research Institute	Bucksburn, Aberdeen, AB2 9SB.
Scottish Horticultural Research Institute	Invergowrie, Dundee, DD2 5DA.
Scottish Plant Breeding Station	Pentlandfield, Roslin, Midlothian.
State-aided Institutes (England and Wales)	
Animal Virus Research Institute	Pirbright, Woking, Surrey.
East Malling Research Station	East Malling, Maidstone, Kent.
Glasshouse Crops Research Institute	Worthing Road, Rustington, Little-hampton, Sussex.
Grassland Research Institute	Hurley, Maidenhead, Berks, SL6 5LR.
Houghton Poultry Research Station	Houghton, Huntingdon, PE17 2DA.
John Innes Institute	Colney Lane, Norwich, NOR 7OF.
Long Ashton Research Station	Long Ashton, Bristol, BS18 9AF.
National Institute of Agricultural Engineering	Wrest Park, Silsoe, Beds.
National Institute for Research in Dairying	Shinfield, Reading, Berks, RG2 9AT.
National Vegetable Research Station	Wellesbourne, Warwick.
Plant Breeding Institute	Maris Lane, Trumpington, Cambridge, CB2 2LQ.
Rothamsted Experimental Station	Harpenden, Herts.
Welsh Plant Breeding Station	Plas Gogerddan, Aberystwyth, Cardiganshire, SY23 3EB.
Wye College, Department of Hop Research	Ashford, Kent.