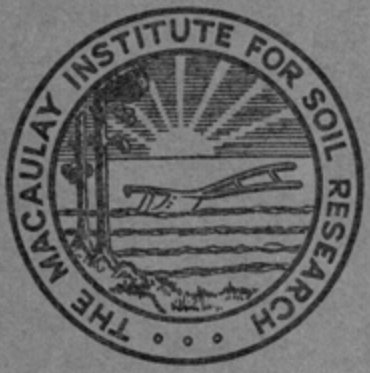
M. S. Davidson

THE MACAULAY INSTITUTE FOR SOIL RESEARCH

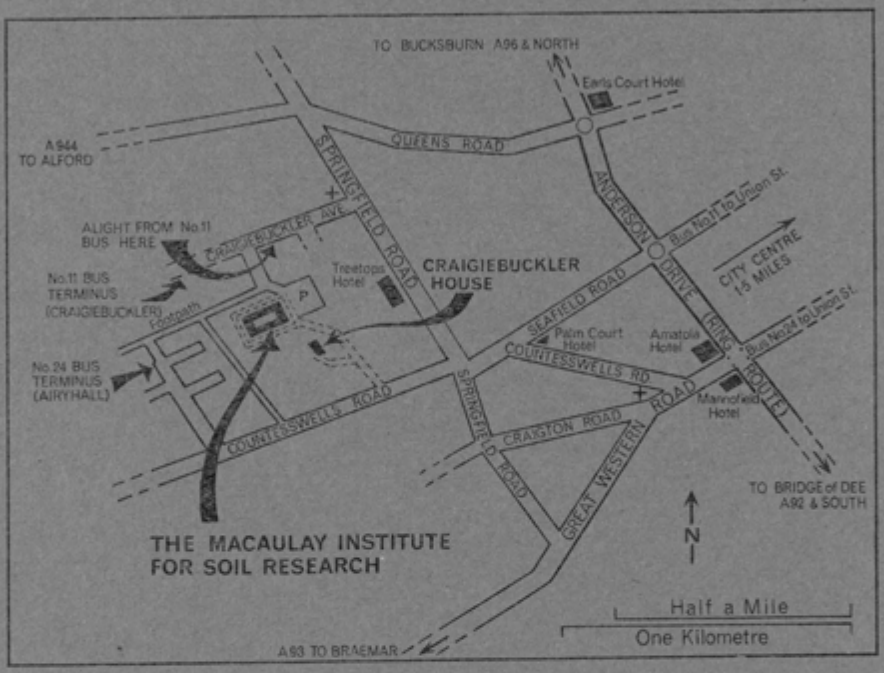


FOUNDED 1930

1972-1973 ANNUAL REPORT

No. 43

The Macaulay Institute for Soil Research, a company limited by guarantee, registered in Edinburgh in 1930, is one of the eight Scottish state-aided agricultural research institutes which are supported by funds from the Department of Agriculture and Fisheries for Scotland and whose research programme is co-ordinated by the Agricultural Research Council.



The Macaulay Institute is situated on the western outskirts of Aberdeen, about three miles from the centre of the city. The main entrance is on Countesswells Road, but visitors using public transport should take either the Corporation Bus Route 11 to the point indicated, from which the Institute is reached in a few minutes by Craigiebuckler Drive, or Route 24 (less convenient) to the Airyhall (not Braeside) terminus.

Telephone—ABERDEEN (0224) 38611

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

(Founded 1930)

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1972-1973

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MISS E. A. PIGGOTT—*appointed* 15/11/72.

STAFF

1972-1973

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F. F. WARDEN.

Peat and Forest Soils

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J. W. Mitchell—appointed 14/5/73.
Miss G. I. M. Keith—appointed 25/6/73.

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G. Bruce.
I. M. Still.

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W. Bick, L.R.I.C., F.I.L.
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A. Hepburn, L.R.I.C.

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Miss K. M. Willox.
Miss L. A. J. Stefani.
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A. Sim.
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H. Shepherd, L.R.I.C.

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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 J. V. Dunbar.

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G. Anderson, B.Sc., Ph.D.
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Miss C. Ireland.
Mrs M. Bjorkvoll—resigned 31/3/73.
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Mrs E. Pirie.
Miss R. Mackenzie—appointed 19/2/73.
Mrs H. M. Duncan—resigned 30/6/73.
Miss E. A. Mackay.
Mrs R. G. McPherson.
Mrs N. I. McFadyen—resigned 22/12/72.
Miss M. E. Leith.
Miss E. A. Cormack—resigned 27/10/72.
Miss S. E. Masson—resigned 16/3/73.
Mrs G. Coutts.
Miss D. B. Thomson.
Miss C. J. Anderson.
Miss E. J. Donald—appointed 18/12/72.
S. D. Porter—appointed 16/7/73.
A. G. Gall.
R. Strachan.
A. R. Douglas.
S. Harris.
J. A. M. Anderson.

STATISTICS

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Miss J. M. Cooper, B.Sc., Dip.Stat., A.I.S.
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G. J. H. Stephen, B.Sc.
Miss K. Gabriel, B.Sc.—appointed 17/9/73.
Miss S. I. D. Walker.
Miss A. McDonald.
Mrs L. M. Wildgoose.
Miss P. L. Parton.

SOIL SURVEY

Head of Department: R. Glentworth, B.S.A.(Manitoba), Ph.D.
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F. T. Dry, B.Sc.
L. Robertson, B.Sc.
J. H. Gauld, B.Sc., Ph.D.
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R. J. F. Morris, B.Sc.
W. B. Kerr, B.Sc.
G. Hudson, B.Sc.

J. MACKAY, B.Sc.
D. W. MERRILEES, B.Sc.
C. G. B. CAMPBELL, B.Sc.—appointed 7/10/73.
W. S. SHIRREFFS.
A. D. MOIR.
R. G. MARSHALL.
MISS M. L. ALLAN—resigned 10/11/72.
MISS S. A. AULD—appointed 1/4/73.
P. G. SUTHERLAND—resigned 28/2/73.
C. M. MIDDLETON—appointed 1/3/73.

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MISS J. M. BROWN, 11/6/73 - 14/9/73.

Information Officer — MISS E. M. WATSON, B.Sc.—appointed 1/2/73.

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M. G. RIDDELL.
G. J. GASKIN.
A. I. A. WILSON.
R. RIDDELL.

Photographer — J. MITCHELL.
D. J. RILEY—appointed 8/1/73.

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ADMINISTRATION

Secretary and Treasurer — MISS E. J. DEY, M.B.E.—retired 30/11/72.
MISS E. A. PIGGOTT—appointed 15/11/72.
MISS E. J. COCKBURN.

Cashier — MISS H. T. G. DONALDSON.
MRS M. MILNE.

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MISS R. A. WILKIE—appointed 4/6/73.
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MISS J. DUGUID—resigned 10/11/72.
MISS K. I. ADAMS.
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Outdoor Staff — H. GORDON.
J. SHAW.
A. MUTCH.
H. SHAW.
J. S. MORRISON.
C. J. BENZIE.

VISITING RESEARCH WORKERS

Mrs Maria Iracemo Barreto (National Agronomical Research Station, Oeiras, Portugal).

*G. F. Brockley (Robert Gordon's Institute of Technology, Aberdeen).

*K. J. P. Campbell (The Polytechnic, Huddersfield).

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

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

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

A. S. de Endredy (FAO, Rome, Italy).

*A. Graham (Napier College of Science and Technology, Edinburgh).

I. F. Kirkman (Department of Soil Science, Massey University, Palmerston North, New Zealand).

G. Lombardi (Institute of Mineralogy and Petrography, University of Rome, Italy).

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

Y. Oztan (Department of Forestry, Karadeniz Technical University, Trabzon, Turkey).

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

*Lorna C. Plimsoll (Trent Polytechnic, Nottingham).

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

R. Soong (Petrology Section, New Zealand Geological Survey, Lower Hutt, New Zealand).

K. R. Tate (Soil Bureau, D.S.I.R., Lower Hutt, New Zealand).

Mrs Neikova Zdravka Varbanova (N. Poushkarov Institute of Soil Science, Sofia, Bulgaria).

Y. H. Yeow (Department of Geology, University of Malaya, Kuala Lumpur, Malaysia).

H. Yoshinaga (Faculty of Agriculture, Ehime University, Matsuyma, Japan).

**Sandwich-Course Student.*

CONTENTS

INTRODUCTION

The past year has seen the initiation of numerous changes in the planning of agricultural research in Britain, following the Government Green and White Papers (Cmd 4814, November 1971 and Cmd 5046, July 1972) entitled 'A Framework for Government Research and Development.' The arrangements made by the Agricultural Research Council, the Ministry of Agriculture, Fisheries and Food and the Department of Agriculture and Fisheries for Scotland to implement the recommendations therein (commonly referred to as the Rothschild proposals) have involved the establishment of a Joint Consultative Organisation to advise on the programmes and priorities required to provide a nationally-integrated agricultural research and development service.

The JCO involves five Research and Development Boards covering Animals, Arable Crops and Forage, Engineering and Buildings, Food Science and Technology, and Horticulture, each with an independent Chairman and about 15 members. Under these Boards, whose duty it is to advise the Agricultural Research Council, the Ministry of Agriculture Fisheries and Food and the Department of Agriculture and Fisheries for Scotland, Committees covering specific project areas are, in December 1973, in process of establishment: these in turn will convene *ad hoc* Working Parties to study and advise on the allocations of resources in particular lines of work.

The introduction of this revised system of organizational oversight of research has led in Scotland to the specification of research packages into which the projects in the programme of work of any Institute could be collected. The Department of Agriculture and Fisheries for Scotland has in 1973/74 agreed to finance work at the Macaulay Institute for Soil Research covering nine research packages, each incorporating a number of projects involving work in various Institute departments. Certain of the projects, particularly these providing a service for the Institute as a whole, contribute to the work of several packages: they have been allotted to the one with which they are most closely related. In the appended list of packages (p. 12), the departmental responsibility for the constituent projects is as follows:

100	Pedology	500	Microbiology
200	Spectrochemistry	600	Soil Fertility
300	Biochemistry	700	Statistics
400	Plant Physiology	800	Soil Survey

In the reports of the work of the individual departments, prepared by the respective Head of Department or senior member of staff (Biochemistry), reference to the projects involved is appended to the appropriate sections or paragraphs: the extent of interdepartmental collaboration will be very apparent.

To meet the recommendations of the ARC Visiting Group who reviewed the work of the Institute in September 1972 and whose report was presented

to the Council of Management in May 1973, it has become necessary to make preparations for some reorganization of the scientific programme, particularly affecting the Departments of Biochemistry and Plant Physiology. As from 1st January 1974 the Department of Biochemistry will be incorporated into a new Department of Soil Organic Chemistry under Dr George Anderson, at present engaged in work on organic forms of nutrients in soils in the Department of Soil Fertility, who has been appointed to the Head of Department vacancy that resulted from Dr J. S. D. Bacon's resignation last year. Later in 1974 further changes, involving members of the staff of Plant Physiology, will be effected.

Following his appointment as Secretary of the Agricultural Research Council, Dr W. M. Henderson visited the Institute in June 1973.

Short term visitors from twenty-seven countries visited the Institute during the year and facilities were made available for longer term research workers from Australia, Bulgaria, Italy, Japan, Kuwait, Malaysia, New Zealand, Papua and New Guinea, Portugal and Turkey. A party of thirty-five members of the West German peat industry, mostly concerned with the production of peat and peat products for horticultural purposes, visited the Institute in June 1973.

Numerous members of staff had the opportunity of visiting conferences or research establishments overseas. The Director presented an invited paper to the IX International Symposium organized by Agrochimica at Punta Ala, Italy, in October 1972. Dr R. C. Mackenzie (Pedology) was invited to lecture at an annual seminar of the Research Branch, Canada Department of Agriculture, in Ottawa in November and under British Council auspices spent two weeks in Egypt discussing soil and clay mineral problems with specialists in Egyptian Universities; he interrupted his return journey to lecture at the University of Pisa.

Dr R. O. Scott (Spectrochemistry) was invited by FAO to spend a week in Bulgaria to advise on the choice of direct reading equipment for the spectrochemical analysis of plants and soils at the N. Poushkarov Institute of Soil Science in Sofia in December 1972. Mr J. C. Burridge (Spectrochemistry) visited Jamaica in November 1972 on the invitation of the Overseas Development Administration to advise the Ministry of Agriculture and Fisheries on the reorganization of their Spectrochemical Unit.

With the aid of funds made available by the Agricultural Research Council and the Department of Agriculture and Fisheries for Scotland several members of staff made profitable study visits to research establishments or participated in scientific conferences abroad. Mr J. C. Burridge (Spectrochemistry) attended the XVII Colloquium Spectroscopicum Internationale in Florence. Dr J. F. Darbyshire (Microbiology) attended the IV International Congress of Protozoology in Clermont-Ferrand. Dr P. C. DeKock (Plant Physiology) visited various research centres in Spain. Dr S. E. Durno (Pedology) visited University Departments in Helsinki and Oulu. Dr R. Glentworth (Soil Survey) attended the final meeting of the FAO Working Party on Soil Classification and Survey in Ghent. Mr R. A. Robertson (Pedology) attended the Third Meeting of an International Working Group on Standards for Peat and Peat Products in Denmark. Dr A. M. Ure

(Spectrochemistry) attended a CEC European Colloquium on Contamination by Mercury and Cadmium in Luxembourg. Dr D. Vaughan (Biochemistry) attended the 9th International Congress of Biochemistry in Stockholm. Dr E. G. Williams (Soil Fertility) visited various agricultural research centres in Denmark, Sweden and Norway.

Approval has been obtained to proceed with the internal renovation of Craigiebuckler House, the original home of the Institute, in order to accommodate Soil Survey and to provide improved conference room, common room and other staff facilities. Work started early in 1973 and it is hoped to commence reoccupation of the premises around April 1974. The transfer of Soil Survey will relieve some of the pressure on space in the main building and in particular provide more suitable accommodation for Statistics and the computing facilities that this department provides.

During the year, members of staff have served on several technical committes 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.

With the retirement on 30 November 1972 of Miss E. J. Dey, who had served the Institute as Secretary since 1941, a long family association with the Institute came to an end. Her father, the late Mr John Dey, was Head Gardener of the Craigiebuckler Estate when Dr T. B. Macaulay provided the funds to establish the Institute in 1930 and he continued to serve his new masters in that capacity until 1955. Past and present Members of Staff and Council were glad to have an opportunity, on the occasion of Miss Dey's retiral, to recognize the efficient and understanding manner in which she had performed her multifarious and onerous duties for so long, and to invite her to accept a suitably inscribed timepiece to mark their appreciation of all she had done on their behalf.

PROGRAMME OF WORK

RESEARCH PACKAGES AND ASSOCIATED PROJECTS

PACKAGE 1: The study of the development and composition of mineral soils and their size fractions.

Objective: To elucidate the factors that control the composition and contribute to the physical and chemical properties of mineral soils. So to provide information that could help to explain differences in soil structure and soil behaviour.

Projects

101 Scottish soil types: chemical and physical characterization in relation to development.

103 Soil mineralogy: relationship with soil type and soil properties.

104 Minerals: alteration during weathering and soil development.

107 Mineral and organic soils: development and application of chemical and instrumental methods for their examination.

108 Mineral and organic soils: characterization by products of thermal decomposition.

109 Mineral and biological materials: characterization, structure and elemental composition as revealed by electronoptical techniques and electron probe microanalysis.

201 Distribution and location of trace elements in soil profiles: effect of soil parent material and drainage conditions.

204 Geochemical distribution and pedological behaviour of trace elements.

205 Spectrochemical and other techniques for the determination of trace elements: direct reading methods and the application of computer processing.

206 Flame emission and atomic absorption spectroscopy: instrumentation and techniques for the determination of trace and major elements.

703 Computer techniques for data storage and retrieval, for data processing, and for mathematical and statistical analysis.

PACKAGE 2: The study of the nature and surface properties of soil clay minerals and mineral-organic matter complexes.

Objective: To investigate the factors involved in the surface and colloidal reactions of soil minerals, particularly of the clay minerals and complexes that participate in the mobilization or binding of plant nutrients in the soil.

Projects

105 Soil colloids: nature, origin and behaviour of inorganic, organic and organomineral complexes.

106 Surface characteristics of soil particles.

207 Characterization of soil minerals and study of their surface properties and weathering by infrared spectroscopy.

304 Chemistry of soil-organic-matter: mineral complexes.

PACKAGE 3: The survey and classification of the mineral soils of Scotland.

Objective: To map and classify soils systematically according to their parent materials, pedological drainage and other field characteristics: to produce land use capability maps. The systematic survey identifies soil types and enables other departments to investigate the cause of differences in their fertility and other soil properties.

Projects

801 The systematic survey of Scottish soils.

804 Studies of soil structure and genesis.

PACKAGE 4: The study of the nature and properties of soil organic matter.

Objective: To determine the nature of the organic material in soils at different stages of decomposition under different pedological conditions and to ascertain its contribution to the physical structure and chemical behaviour of soils and its effect on the growing plant.

Projects

208 Characterization of soil organic matter by infrared and ultraviolet methods.

303 Nitrogenous constituents of soils, peat and leaf litter: relationships with co-occurring macromolecules.

305 The synthesis of soil polysaccharides.

307 Effects of cultivation on the electron spin resonance spectra of soil humic acids.

309 Effects of plant hormones and related substances on plant cell and organ cultures.

311 Effects of organic soil constituents on enzymes in plant storage tissue.

312 Effects of hydroxyproline on extension growth of plant cells.

313 Provision of analytical facilities employing special equipment.

315 Degradation of soil organic matter constituents in soil.

316 The characterization of soil organic matter fractions that influence the growth of plants.

406 Salt absorption: effect of organic soil constituents.

PACKAGE 5: The investigation of the role of soil microorganisms in soils and in soil-plant relationships.

Objective: To assess the effects of soil microorganisms in the breakdown of organic material in soil and to study the interactions between soil microorganisms and plants in order to ascertain the nature of their contribution to crop growth yield.

Projects

301 Degradation of fungal cell walls by microbial enzymes.

308 Growth of plants in closed systems under controlled conditions.

501 Incidence and characteristics of lytic microorganisms in the root region of cereals.

502 Production of cell material and by-products of soil microorganisms.

503 Microorganisms involved in the decomposition of peat and its components.

504 Interrelationships of soil protozoa and bacteria inoculated on axenic (microorganism free) plant roots.

505 Interrelationships of soil protozoa with other soil microorganisms.

506 Microbial degradation of soil organic matter as influenced by clay minerals.

507 Ultrastructure and chemical composition of soil fungi, including plant pathogens.

508 Soil-borne fungal parasites.

509 Soil protozoa in the metabolism of soil organic matter.

510 Investigation of soil protozoan populations.

511 Physiology of actinomycetes in soils.

PACKAGE 6: The study of the nature and distribution of organic soils and peat in Scotland.

Objective: To survey and classify the peat deposits and organic soils in Scotland and to study their utilization and potential fertility for agricultural, horticultural and forestry purposes.

Projects

110 Organic soils: moisture retention and root development.

111 Organic soils: site capability and amelioration.

112 Scottish peat deposits: survey, classification and characterization.

113 Pollen and plant-fossil analyses: post-glacial vegetational and climatic changes.

114 The use of peat and peat products in agriculture and horticulture.

116 Nitrogen mineralization: factors controlling release of nitrogen immobilized in peat and humus.

404 Water movement in peat: its observation by means of tritium.

PACKAGE 7: Investigations on the fertility of soils and the yield of agricultural crops.

Objective: To investigate factors controlling, and to study means of improving, the fertility of agricultural soils by related field, pot and laboratory studies on soil nutrient status, fertilizer usage and crop yield.

Projects

203 Forms of occurrence of trace elements in soils and the mechanism of their movement towards the plant root.

314 Supervision and maintenance of general glasshouse facilities.

601 Inorganic soil phosphorus and sulphur: evaluation of available forms and effects of fertilizers.

602 Organic phosphorus and sulphur and organo-mineral complexes in soils, in relation to soil type and nutrient supply.

603 Available nitrogen in soils.

604 Soil acidity: aluminium solubility and cation exchange equilibria in different soil types.

605 Anion sorption: kinetics and equilibria of phosphate reactions in relation to soil composition.

607 Growth, development, nutrient accumulation and yield of field crops: effects of environment and management.

608 Field responses to nutrients: soil type effects and prediction of fertilizer requirements.

609 Trace element status of soils and crops: effects of soil type: diagnosis of deficiencies and excesses.

610 Assessment of lime and nutrient status of soils.

611 Soil potassium and magnesium: distribution, solubility and availability in different soil series.

612 Soil physical conditions and crop growth.

701 Design and analysis of experiments including crop response functions and the fitting of response surfaces.

702 Relationship of crop yield and composition to soil properties, and the numerical classification of soils.

PACKAGE 8: The study of factors affecting crop composition.

Objective: To investigate the effects of soil conditions on crop composition and to study plant-physiological aspects of soil-plant relationships. The content of the plant and its individual parts may have particular reference to soil-plant-animal problems related to both major and trace nutrients.

Projects

202 Trace element uptake by plants: distribution in different species and plant parts.

401 Iron and copper metabolism of plants.

402 Uptake and physiological effects of chelated trace elements on plants.

403 Cation-anion balance of plants.

405 Salt absorption: metabolic aspects.

407 Salt absorption: ion fluxes and physical transport gradients.

408 Nitrate reductase and molybdenum-copper interactions in plants.

409 Provision of radioactive facilities.

606 Plant composition: nutrient forms and patterns, cation:anion balance and organic constituents, in relation to age, growth conditions and yield.

PACKAGE 9: The study of the fertility of forest soils and other non-agricultural soils and their natural vegetation.

Objective: To study the nutrition of conifers and other non-agricultural crops on forest soils, peats and other soils of limited capability. To study the natural vegetation in relation to soil type and to consider means of improving the utilization of marginal land.

Projects

115 Conifer nutrition: nutrient cycling, tree growth and influence of fertilizers.

117 Nutrient deficiencies in conifers: diagnosis and amelioration.

802 Plant communities and their relation to genetic soil types.

A research grant from the Forestry Commission contributes towards the cost of the forest soil projects.

1. PEDOLOGY

The function of the work of the department may be classified under four headings—(a) to help elucidate the factors that control development, composition, constitution and physical and chemical characteristics of mineral soils; (b) to examine and assess factors determining the surface and colloidal properties of soil components, especially those minerals and complexes that retain and supply plant nutrients; (c) to survey, characterize and classify the peatlands of Scotland with particular reference to their use in agriculture, horticulture and forestry; (d) to study the nutrition of conifers growing on peatland and other nutrient-deficient sites with special reference to nutrient cycling in the plant-soil system. In pursuance of these aims, work is in progress on 16 separate projects, eight in Chemistry and Mineralogy and eight in Peat and Forest Soils.

As analytical methods become increasingly refined it is frequently possible to associate particular chemical attributes with specific morphological or other, sometimes complex, features of the soil—as is well illustrated by information obtained by the scanning electron microscope and electron microprobe system, by selective chemical techniques and other modern methods. Moreover, because techniques themselves are becoming more sophisticated, it is now possible to perform on total soil samples determinations that were previously possible only on separated, and often purified, fractions. Consequently soils can now be investigated almost in the field condition and results are less likely to be affected by artefacts.

In addition to the collaborative studies mentioned below, samples have been examined on specialized equipment for other departments of the Institute and some relevant samples have been tested for outside bodies. Close connections have been maintained with the Department of Agriculture and Fisheries for Scotland, the Forestry Commission, the Highlands and Islands Development Board, the North of Scotland Hydro-Electric Board, the Scottish Development Department and other bodies on aspects of the survey and utilization of peat. Information and advice on peat have also been given to many organizations and individuals as part of the Institute responsibility for the collection and dissemination of relevant material.

Mr Y. H. Yeow, Geology Department, University of Malaya, Mr P. L. Searle, Soil Bureau, Lower Hutt, New Zealand, Dr J. H. Kirkman, Soil Science Department, Massey University, New Zealand, Prof. N. Yoshinaga, Faculty of Agriculture, Ehime University, Japan, and Prof. G. Lombardi, Istituto di Mineralogia e Petrografia, University of Rome, Italy, have all spent periods in the department during the year and have been involved mainly in studying the poorly ordered inorganic components of soils. Dr A. S. de Endredy, FAO, Rome, and two sandwich-course students —Mr A. Graham from Napier College of Science and Technology, Edinburgh, and Mr G. F. Brockley from Robert Gordon's Institute of Technology, Aberdeen—have also assisted in the work of the department.

Members of staff have attended various scientific and technical meetings, including the Sixth International Mass Spectrometry Conference in Edinburgh, an ARC course on environmental instruments, an International

Symposium on the Classification of Peat and Peatlands in Glasgow (organized by Mr R. A. Robertson under the auspices of the International Peat Society) and meetings of, *inter alia*, the British Society of Soil Science and the European Quaternary Botanists.

Dr R. C. Mackenzie, at the invitation of the Canada Department of Agriculture, Ottawa, gave a Research Branch Seminar on the role and origin of clay minerals in soils and a lecture to staff of their Soil Research Institute on inorganic gels in soils; he also took the opportunity of visiting the Ontario Research Foundation, Sheridan Park, Mississauga, Ontario. At the request of the British Council, Dr Mackenzie spent a fortnight in Egypt to consult with soil scientists in various universities and institutes. During his return journey he delivered, by invitation, a lecture on the non-crystalline inorganic constituents of soils at the Laboratorio per la Chimica del Terreno, Pisa, Italy. Mr R. A. Robertson participated in a meeting of the International Working Group on Peat Standards at Ebeltoft, Denmark, and Dr S. E. Durno visited the University of Oulu, Finland, to study the pollen analytical and Quaternary research in progress there.

CHEMISTRY AND MINERALOGY

Analytical and Morphological Studies

Chemical. Such modifications to analytical methods as the incorporation of automatic sampling and print-out facilities into spectrophotometric techniques have enabled completion of the systematic chemical and physical examination of almost 2500 samples collected by Soil Survey during 1971. The results have now been fully collated and work on samples collected during the 1972 field season is progressing satisfactorily. Chemical methods for determining and characterizing non-crystalline inorganic gels in soils are also being further developed and more rapid and complete destruction of organic matter in extracts is now possible[45]. 101, 105, 801

X-ray fluorescence spectroscopy has been used to determine the chemical composition of a wide range of inorganic materials, including fresh and weathered serpentinites. Its suitability for plant materials, being assessed in collaboration with Plant Physiology, has now been proved for bromine, which can be rapidly and conveniently determined. Most of the 500 plant materials so far examined have contained up to 60 ppm bromine, but marine algae give values in the range of 200-500 ppm. 104, 107, 403

Gas Chromatographic. A laboratory-constructed gas chromatograph has been used to analyse gas samples related to aeration studies on organic soils and a new gas sampling technique has been devised, thoroughly tested, and found satisfactory. Preliminary results for experimental plots at Lon Mor, Inverness-shire, designed to test the effect of water-table level on moisture-aeration relationships and plant growth, indicate that considerable variations occur in the composition of the soil atmosphere within short distances and that large numbers of probes would be necessary for a comprehensive study. Sufficient information has now been accumulated, however, to reveal the inverse relationship between oxygen and carbon dioxide concentrations and the effects of depth, water-table level and active tree roots on atmospheric composition. These determinations have been greatly

speeded up by a commercially available gas chromatograph which has also considerably extended the range of gaseous components that can be analysed. 107, 108, 110

Thermoanalytical. A general assessment has been made of the value of thermoanalytical techniques[1] and of their use in mineralogy[46] and in quantitative studies[2]. It has been demonstrated that, with the increased sensitivity of commercial equipment, differential thermal analysis can now be performed on total soils (i.e. air-dried, <2 mm) with a clay content of above 15 per cent, thus avoiding the danger of alteration and of production of artefacts during separation procedures[3]. A general review of the use of the technique in technology and industry[4] has been published. While thermogravimetry can yield valuable quantitative information[47], the most comprehensive picture is obtained when results are integrated with those from complementary techniques[48, 49]. The differential thermal analysis equipment in use at the Institute has been shown to yield reasonable calorimetric information[5]. 103, 107, 801

Electronoptical. A scanning electron microscope enables features in soils to be examined in a detail impossible under an optical microscope; moreover, when combined with electron probe microanalysis the presence or absence of elements at particular locations is immediately visible. An examination of the ochreous and grey mottles that occur largely on the outer surface of peds in poorly drained soils has revealed that both ochreous and grey-mottled surfaces are smoother than unmottled material and that the grey mottles are somewhat aluminous. Pseudoconcretions of manganese oxides, which occur in the B horizons of imperfectly drained profiles, are also being studied. 109, 801

The best methods of sample preparation for various soil mineralogical studies by the scanning electron microscope and microprobe system are continually being assessed. Because of difficulties with available equipment, a robust gas-flow proportional counter that is sensitive for sodium determinations has been developed. 107, 801

Soil Mineralogy

The minerals in the soil not only influence the soil fabric but also form its nutrient capital and influence its inherent fertility; consequently, minerals likely to occur in soils deserve detailed investigation. Since such studies usually necessitate the use of all relevant techniques at the command of the investigator, the adequacy of methods has to be continuously assessed and possible improvements devised. 107

In collaboration with the ARC Unit of Nitrogen Fixation, a single-crystal structure determination has been commenced on a molecular nitrogen complex containing rhenium, molybdenum, chlorine and phosphorus in addition to nitrogen; since such compounds are of interest from the viewpoint of nitrogen fixation, the strength of the nitrogen bond in the complex is of particular importance. 105

Sand Fractions. The fine sand separate, which gives information on the parent rock of the soil, on the glacial till on which the soil is developed and

on the relative stability of primary minerals in the soil, is usually examined under the petrological microscope after separation into light and heavy mineral fractions. In profile samples from the principal soil series of the Peebles and Edinburgh and Latheron and Wick areas (Sheets 24/32, 110/116), the light fraction always contains quartz and felspars as dominant minerals whereas the minerals in the heavy fraction, which rarely comprises more than 1 per cent of the sand, vary markedly with the soil association. Thus, the soils of the Thurso and Canisbay Associations contain more apatite, epidote, garnet, hornblende and sphene than do those of the Braemore and Berriedale Associations. An apparatus for density gradient separation has been useful in these studies, particularly in separating felspars. 104, 801

Usually the sand fractions of soils are considered to be relatively inactive chemically, but the following three examples of the converse have been found during the year. 103, 104

In soils of the Sourhope Association, which are developed on till derived from Old Red Sandstone (Devonian) lavas and the clay mineralogy of which has already been examined[6], a major part of the cation-exchange capacity and most of the exchangeable calcium and magnesium reside in the sand fraction: the exchangeable potassium, on the other hand, is mainly associated with the clay. The high cation-exchange capacity of the coarse fraction arises from aggregates of saponite and the exchangeable calcium and magnesium from weathering of plagioclase felspar and saponite, respectively; increase in magnesium saturation down the profile reflects the more rapid weathering of saponite. Scanning electron microscopy has revealed that saponite aggregates are so flaked and fractured that they enter readily into exchange reactions and that the plagioclase felspar grains show extensive evidence of corrosion. Various interstratified minerals also occur in these soils; theoretical study of the effect of various types of interlayering on the X-ray powder pattern[7, 53] has, however, enabled better characterization of the kaolinite-montmorillonite interstratifications[8]. 101, 103, 104, 105, 801

A collaborative investigation with Spectrochemistry has been instituted to determine the source of the nickel in soils developed on till derived from serpentinite (Leslie Association), which are known to be rich in exchangeable and acetic-acid-extractable nickel. It has now been established that considerable amounts of total and acid-extractable nickel occur in the sand fractions, being closely associated with serpentine minerals and weathered biotite flakes. 103, 104, 201

Even the coarse fractions of some granite soils are not, because of the presence of vermiculitized biotite, as inert as might be anticipated. A platy halloysite has been identified in the clay fractions of some of these soils and tubular halloysite has been detected in a hydrothermally altered hornblende schist, where it has formed from laumontite[54]. 103, 104

Clay Fractions. The clay fraction is the most highly surface-active soil separate and therefore determines many soil properties. Its mineralogy not only enables its surface properties to be deduced but, if properly interpreted

in relation to that of the parent rock, reveals much about the mode of soil formation. X-ray diffraction, thermoanalytical, electronoptical and selective chemical methods have all been used in the systematic study of clay fractions from the principal soil series in the Kirkmaiden, Whitburn, Stranraer and Wigtown and the Nairn areas (Sheets 1/2/3/4, 84); the latter area provides the most diverse set of soils developed on recent alluvium yet encountered. Many soils contain, in addition to crystalline clay minerals, considerable amounts of non-crystalline material the behaviour of which can only be understood if it is compared and contrasted with that of related materials from soils elsewhere, such as allophanic materials from soils in Japan and New Zealand. The structure of the poorly crystalline fibrous mineral imogolite has been further refined, largely by electronoptical methods[9], and its existence has been established in New Zealand soils[55] as well as in Scottish soils in no way connected with volcanic ash. To establish a proper perspective, soil clays from Angola, Australia, Egypt, Italy, Malaysia and New Guinea have also been subjected to mineralogical examination. 103, 105, 109, 801

From further studies on soil development on till derived from chloritic rocks it has been established that clay-size chlorite is normally fairly stable. However, in one podzol with thin humus iron pan the chlorite decreases progressively in amount towards the surface, being completely absent in the A_2 horizon where the clay fraction is dominated by a dioctahedral mica-montmorillonite interstratification. This particular chlorite is iron-rich and appears to have been dissolved out by the percolating soil solution, leaving goethite as a decomposition product. 104, 801

Determinative techniques in clay mineralogy have been further investigated. From a detailed thermoanalytical study on natural and synthetic aluminous-interlayered clay minerals it would appear that the DTA curve after glycerol saturation may be diagnostic for dioctahedral montmorillonite with interlayer alumina. The possibility of accurate quantitative determination by X-ray diffraction has been examined by studies on montmorillonite, mica, gibbsite, quartz and felspars. The value of Mössbauer spectroscopy in examining ferriferrous minerals has been well exemplified in a collaborative study with Spectrochemistry on the oxidative weathering of biotite[56]. 107, 207

Clay:Organic Matter Complexes

Since the clay fractions of soils usually contain large amounts of clay-organic complexes, they are as important as the mineral part of the clay in determining soil properties. Studies on the chelation of iron in relation to the oxidation-reduction cycle in gley soils have shown that iron can undergo valency changes during the formation and decomposition of iron chelates without the introduction of extraneous oxidizing or reducing agents[57]. Examination of the role of plant alkaloids in mobilizing and translocating silica in soils has been undertaken as an extension of this work. A description has now been published, in collaboration with Microbiology, of the resistance of montmorillonite–adenine complexes to microbial attack[10]. 105, 506

Surface Properties of Soils and Clays

Discrepancies observed in results obtained by different methods of determining specific surface areas of inorganic gels have been traced to differences in pore-size distribution. Micro-pore analyses of imogolite are in agreement with present concepts of the structure of this mineral. Orientation of sorbed stearic acid molecules on clay-mineral surfaces has been shown by flow microcalorimetry to depend on the polarity of the substrate; in consequence, the polarity of soil-clay surfaces is currently being assessed. 106

The effectiveness of a series of cations and anions in dispersing Scottish and Japanese soils containing large amounts of poorly ordered inorganic materials is in the reverse order to that observed for some clay minerals and montmorillonitic soil clays. Treatment of the soils with weak sodium carbonate solution reverses the order, indicating that the effect of the clay minerals is shrouded by that of the poorly ordered material. The dispersion order for cations can be interpreted in terms of increasing negative sorption, with resultant expansion of the diffuse double layer, and the order for anions in terms of a lyotropic series. 105

To determine and characterize their non-crystalline components, soils of the principal series of the Peebles and Edinburgh and Wick and Latheron areas (Sheets 24/32, 110/116) have been treated with sodium fluoride solution and extracted with sodium carbonate and sodium dithionite solutions. For freely drained soils significant multiple correlations are obtained between fluoride reactivity and amounts of silica, alumina and ferric oxide extracted, but for poorly drained soils there is a high correlation only between fluoride reactivity and extracted alumina; the relationship deteriorates for silica and is low for ferric oxide. These results emphasize the importance of aluminous surfaces in gley soils. 101, 105, 801

In an extension of the study of clay movement in gley soils, particle-size distribution and specific surface-area measurements have been found to yield no conclusive evidence for translocation of clay particles from the surface to the Bg horizon. 101, 106, 801

Organic and Biological Materials

Results of an examination of raw humus profiles from Culbin sands (Laigh of Moray Forest), Morayshire, by differential thermal analysis in oxygen and by vacuum pyrolysis coupled to mass spectrometry have indicated that the processes operative during initial humification of vegetation are oxidative degradation, which is enhanced by liming, and selective degradation of organic compounds with high thermal dissociation energies. The deepest humus horizon yields pyrolysis products characteristic of the translocated humus in freely drained soils[58]. 108, 801

In collaboration with Microbiology, samples from a peat profile at Lyne of Skene, Aberdeenshire, have also been examined by vacuum pyrolysis coupled to mass spectrometry. The spectra obtained resemble those of raw humus but indicate a decrease in combined oxygen content to a depth of 1·5 m, below which it remains constant. A change in pattern at 6 m corresponds to change in botanical origin. Since the amounts of minor volatile

products are low compared with those from mineral soils, the method is being modified to include gas-liquid chromatography; this should improve reproducibility and increase the range of products that can be measured. 107, 108, 503

The growth inhibitor maleic acid hydrazide is being examined by single-crystal X-ray diffraction techniques to assess whether its structure can be used to elucidate its mode of action. 105

PEAT AND FOREST SOILS

Peat Survey and Evaluation

Survey, classification and evaluation of Scottish peat resources continue to provide information of practical as well as scientific importance. Results are incorporated in appropriate Soil Survey memoirs and in detailed maps and reports covering areas scheduled for development or with development potential. 112, 113, 801

Survey techniques and expertise are also widely employed to support field and laboratory investigations concerned with drainage, cultivation[11] and afforestation[59] of peatlands and with the winning and utilization of peat for horticulture[60] and other purposes. 110, 111, 114, 802

Survey and characterization of selected deposits in the Peebles and Edinburgh areas (Sheet 24/32) and of Din Moss in Fife (Sheet 40) have been completed. Close-grid and multiple-line surveys have been employed to study the topographical and stratigraphical features of 760 ha (1900 acres) of peatland complexes on the Island of Mull (Sheet 43/44/51/52) and over 400 ha (1000 acres) of deep peat in the Nairn area (Sheet 84). In collaboration with Soil Survey, an acceptable classification of peatland types in the Nairn area has been attained. 112, 801

Special surveys have been carried out at Drumbreck, Arden and Drumbow Mosses in Lanarkshire to determine the reserves of horticultural peat and the extent to which further extraction is possible. At the request of the Department of Agriculture and Fisheries for Scotland, advice has been given on the disposal of peat, and its use in rehabilitating overburden from open-cast coal workings in Fife, and an area of peat near Mallaig, Inverness-shire, has been surveyed to determine the feasibility of draining and cultivating for grass production. Detailed surveys are currently being undertaken on behalf of the Scottish Development Department to establish the nature, extent and topographical relationships of areas of deep peat straddling proposed routes for the realignment of the A9 trunk road between Carrbridge and Inverness. 112, 114

Possible correlations between vegetation types and physical and chemical characteristics of surface horizons of peat are being examined in an attempt to devise a system of peatland classification that is meaningful in terms of site capability[61] and to establish mapping units that are reflected by simple patterns on aerial photographs. 111, 802

As in previous years, cartographic work, documentation and laboratory analyses have progressed satisfactorily. The close liaison maintained with

national and international agencies concerned with peat research and technology has proved invaluable in fulfilling responsibilities for recording, exchanging and providing information on peatlands and their development[12, 13]. 112

Pollen Analysis and Quaternary Research

Pollen analyses have in the past given valuable information on palaeoclimatic changes and on stratigraphical correlations. In consequence, in collaboration with Statistics, pollen analytical results from some 70 important sites investigated over the past two decades are being transferred to punched cards and standardized pollen diagrams are being produced by the computer. This has the advantage of facilitating accessibility and enabling easier comparison of a very wide range of accumulated information[14]. The possibilities of the scanning electron microscope in relation to pollen analysis are also being thoroughly examined. The information is in a way complementary to that obtained under the optical microscope, since only external features of the grains are visible. 107, 113

A fossil brown forest soil from near Edzell, Angus, examined in collaboration with Soil Survey and dated to the beginning of the Sub-Boreal period, contained few pollen grains[15]. Some alder and birch pollen as well as fern spores were detected but no oak pollen was found despite an abundance of oak charcoal: this would seem to confirm that oak pollen production is low at the northern end of its climatic range. Pollen analyses of silty clay with organic matter from Stenness, Orkney, currently being examined in collaboration with Soil Survey, and of samples from sites on the Island of Lewis may be more informative on environmental conditions dating back to the Late Glacial period. 113, 804

Root and Moisture Studies in Peat

In order to assess factors of the soil environment that affect root development and distribution and to isolate and quantify those that influence plant growth, investigations have been continued on the effect of five water-table levels on growth of lodgepole pine and Sitka spruce at Lon Mor, Inverness-shire[16]. Ten years after planting, the average height of lodgepole pine in the plot where the water table is deepest (35 cm from the surface) is 2·7 m, whereas in the wettest plot, where the water table is at the surface, the trees are on average only 0·7 m high. Sitka spruce, which was planted on the same plots in 1971, was severely affected by early frost in 1972 and is not showing significant height differences between plots. The current survival rates for plots in which the water tables are 35, 24, 18, 9 and 0 cm below the surface are 99, 98, 78, 68 and 16 per cent, respectively. 110

The aeration of peat profiles in relation to depth of water table has now been studied over a complete growing season using an oxygen meter to measure the oxygen content of the water in the peat and mass spectrometry and gas chromatography to analyse the soil atmosphere above the water table. In contrast to concentration of dissolved oxygen, which varies between horizons but is fairly uniform within horizons, gas composition, as mentioned on p. 18, shows considerable variability within horizons. A

laboratory experiment to assess the effects of various oxygen concentrations in the rooting medium on the growth of lodgepole pine and Sitka spruce seedlings has shown that lodgepole pine can sustain some root growth in the virtual absence of oxygen, whereas Sitka spruce roots cease to grow when the oxygen concentration in the medium falls below 5 per cent. 108, 110

The technique of using tritiated water to trace movement of ground water in the soil has been applied, at the request of the Forestry Commission, to check the effect of depth and spacing of ditches at Achray Forest near Stirling (deep peat) and Kershope Forest in the Scottish Borders (peaty gley). Two samplings have been carried out since the tritium was placed in early summer 1973 and, although analyses and computations are not yet complete, patterns of water movement related to drainage, topography and time are apparent at both sites. 110, 404

Peat Standards

Further progress has been made in establishing criteria and methods for characterization and evaluation of horticultural peat and peat products in a study that is being coordinated by an International Working Group on Peat Standards. Although broad agreement has been reached on product declaration, some difficulties remain in preparing a draft standard for analytical techniques, particularly for the determination of volume weight, pore volume and water and air capacities. The value of particle size determination is being questioned, largely because results of collaborative tests have been highly variable and seem to depend on moisture content, time of sieving and amplitude of the shaker. 114

Glasshouse experiments, set up in collaboration with Plant Physiology to evaluate a range of peat types as mono-ingredient substrates for plant growth, indicate that structural properties are not adversely affected by intensive cropping with tomatoes for two years. 114

Nutrient Uptake from Forest Soils

Investigations of the relationship between tree growth and nutrient uptake in pole-stage Sitka spruce have commenced with the establishment of two of a series of six experiments. These sites, located in collaboration with the Forestry Commission at Fetteresso (Mearns Forest) near Stonehaven and at Leanachan Forest near Fort William, were intensively sampled during March and April, fifteen whole trees and numerous samples of the forest floor being taken from each. Both were fertilized in the first weeks of May and since then litter and rainwater samples have been collected at fortnightly intervals. The second two experiments in the series are at present being laid out at Strathyre and Elibank Forests, near Lochearnhead and Peebles, respectively, and search for the final two sites has narrowed down to mid-Argyll and the Scottish Borders. 115

To cope with the large number of samples that will be produced, both by these new experiments and by the investigation into nitrogen mineralization in peat and humus, considerable attention has been given to means of improving the rate of sample through-put in the laboratories. Simplified

procedures of sample preparation have been introduced and wherever possible chemical analyses have been automated, the output from the instruments being processed directly by computer. 107

Detailed examination continues on the relationship between pattern of growth and nutrient uptake under different nitrogen regimes in pole-stage Corsican pine on the Culbin sands (Laigh of Moray Forest), Morayshire. Large growth responses have been obtained but these have not been accompanied by any marked change in the distribution of stem growth, either between trees or at different points up the stem[63]. Both stem growth and the percentage of nitrogen in autumn needle-litter can, however, be related to the previous autumnal values for nitrogen levels in top-whorl foliage and it has proved possible to derive models predicting growth from the levels of nitrogen in litter of the same year; these are analogous to growth-predicting models based on the previous year's foliar nitrogen levels. 117

In this same crop it is estimated that litter accounts for about 98 per cent of the phosphorus reaching the soil but for only 33, 29 and 69 per cent of the potassium, magnesium and calcium, respectively. For potassium another 12 per cent is derived from input in rainfall, 29 per cent from aerosols trapped by the tree crowns and 26 per cent from release, by crown leaching, of nutrients previously taken up by the trees. The same factors account for 24, 19 and 28 per cent, respectively, of the magnesium reaching the soil and 11, 14 and 6 per cent of the calcium. Aerosol input is clearly of importance and effort is being expended to improve the methods of separating true release by crown leaching, which is merely a turn-over of nutrients already in the ecosystem, from net input in gross rainfall and aerosols. 107, 115

The study of rainwater at Culbin sands has included a period when considerable quantities of sea-derived salt spray were carried inland by gales blowing across the neighbouring Moray Firth. Although this input was not associated with any visible salt scorch, detailed assessments suggest that insidious damage had occurred, with a reduction in yield. In coastal regions such sub-clinical damage is likely to be recurrent and could well result in appreciable reduction of growth. 117

Nitrogen Mineralization in Peat and Mor Humus

In an attempt to assess the ease with which nitrogen in organic matter can be mineralized and rendered available to the plant, rates of nitrogen mineralization continue to be measured in samples of peat incubated under controlled conditions. Earlier studies on the response to additions of phosphorus and potassium have been extended to peats of different nitrogen content, as it has been observed that, even under optimum conditions, peats with less than 1·0 per cent nitrogen release only small quantities of ammonium. To complement this, peats are being separated into fractions by washing the fresh material through a series of sieves of mesh size ranging from 5 mm to 50μm. Treated in this way *Sphagnum-Eriophorum* peat produced a coarse fraction (>5 mm), of fibrous plant remains containing only 0·5 per cent nitrogen and a finely dispersed material (<50 μm) containing more than 1·6 per cent nitrogen, the respective C:N ratios being 120 and

30. The rate of mineralization of nitrogen in these fractions is now receiving attention. 116

The effect of water-table level on nitrogen mineralization in peat, carried out with samples cut from the 0-10 cm horizon at the experimental drainage site at Lon Mor, Inverness-shire, has shown that lowering the water-table to 18 cm significantly decreases the amount of nitrogen mineralized on incubation under anaerobic conditions. On further lowering of the water-table, the position is reversed, mineral nitrogen production in the surface horizon increasing significantly to at least a water-table depth of 35 cm. Incubation under aerobic conditions is more complex and results have to be assessed in relation to the degree of aeration of the peat. 110, 116

Samples of humus taken each year from an experiment testing forms of fertilizer nitrogen, in combination with phosphorus and lime, on pole-stage Scots pine at Culbin (Laigh of Moray Forest) are examined chemically and by the incubation technique. Lime applied in 1968 continues to show a marked effect on the acidity and calcium content of the humus but the increased evolution of carbon dioxide during incubation detected in the early years after application is now absent. Initially, nitrogen fertilizers stimulated production of mineral nitrogen on incubation but by 1973 this effect appears to be confined to humus from those plots that also received lime. 116, 117

Experience gained from the nitrogen mineralization studies on Scots pine humus is now being applied to spruce-derived humus as part of the investigation into nutrient cycling in pole-stage Sitka spruce. 115, 116

2. SPECTROCHEMISTRY

The scope of the work of the department includes the investigation of the distribution of trace elements in soils, soil profiles and clay minerals and of the forms in which they occur, together with examination of their distribution in plant materials of agricultural interest. Apart from establishing general soil-plant relationships, an important aim is the elucidation of deficiency or toxicity problems affecting both the growth of plants and their value as a source of animal food. The determination of biologically important elements at the levels normally encountered involves the use of sophisticated spectroscopic techniques, including flame emission, atomic absorption, and arc emission spectrochemical methods of analysis, and development of these is continuing with a view to increasing the speed of analysis and lowering the limits of determination. The molecular and structural characterization of soil constituents is carried out largely by infrared spectroscopic methods; a Harwell Mössbauer Spectrometer installed this year will provide information to supplement that obtained by other techniques.

During the year several visiting research workers have used the spectroscopic facilities available. Dr R. L. Parfitt, Department of Chemistry, University of Papua and New Guinea, and Mr R. Soong, New Zealand Geological Survey, Lower Hutt, New Zealand, pursued infrared studies of soil minerals, while Dr B. G. Davey, Department of Soil Science, University of Sydney, New South Wales, Australia, carried out investigations into the constituents of zinc deficient soils. Dr H. K. El-Kholy, Teachers' Training College, Audillia Kharbia, Kuwait, who was in 1972 awarded the degree of Doctor of Philosophy by the University of Aberdeen for his work at the Institute, spent a further two months in the department.

Two overseas consultative visits were made. Under the auspices of FAO, Dr R. O. Scott visited the N. Poushkarov Institute of Soil Science in Bulgaria to advise on the suitability of emission and X-ray spectroscopic methods for soil and plant analyses. He also gave three lectures on the application of spectrochemical methods to the analyses of agricultural materials. Mr J. C. Burridge, on behalf of the Overseas Development Administration of the Foreign and Commonwealth Office, advised the Ministry of Agriculture of Jamaica on the rehabilitation of their spectrographic laboratory. Dr A. M. Ure went to Luxembourg to attend a European Colloquium on Problems of the Contamination of Man and his Environment by Mercury and Cadmium, while Mr J. C. Burridge presented a paper[21] at the Seventeenth International Spectroscopic Colloquium in Florence. Two papers were given at an Institute of Physics conference on Spectroscopy in Environmental Studies held in Aberdeen. Members of staff were also largely responsible for the local organization of the conference.

Trace Elements in Soils, Plants and Biological Materials

Investigations into the distribution of total and extractable trace elements in soils and soil profiles and their relationships to plant uptake are con-

tinuing. An account of the chemical composition of the floral parts of various plant species[18] and a review of the factors affecting the availability of cobalt in the soil and its uptake by plants[19] have now been published.

Soils and Soil Parent Materials. Investigation of the content and distribution of trace elements in soil profiles with iron or manganese pans has continued. Thin iron pans developed in podzols have been compared with groundwater iron pans formed in soils derived from the same parent material at various locations on the Corby and Boyndie Associations. In the thin iron pans acetic acid extractable aluminium and iron are much higher and extractable cobalt and manganese much lower than in the corresponding ground water iron pans. As anticipated, all iron pans contained higher levels of acetic acid extractable iron than the ochreous horizon of the soils in which they formed. However, the levels of extractable cobalt, nickel, copper and manganese were similar. A study of the chemical form of iron in nine selected iron pans using Mössbauer spectroscopy, other physical methods of analysis and various chemical extraction techniques has been carried out. 201, 203

In collaboration with Pedology, the distribution of trace elements in some soils of the Leslie, Greenhill and Charleston series of the Leslie Association developed on serpentine till in the Strathdon area has been studied. The total and acetic acid extractable trace element contents in the various horizons, and in the coarse sands, fine sands, silts and clays separated from these, have been determined; the clay fractions were found to contain an average of 26, 19, 16 and 5 per cent of the total nickel, iron, cobalt and chromium in the whole soil, respectively. The relationship between these findings and those from a detailed mineralogical analysis of the particle-size separates, including specific minerals from the coarse sands, is being examined. In a sample of serpentine rock from Leslie, Aberdeenshire, more than 80 per cent of the total nickel of the crushed rock (< 2 mm) was dissolved by a single extraction with 2·5 per cent acetic acid. From X-ray diffraction data, the high solubility of the nickel would appear to be due to the fact that it is present in the form of a nickel-iron-hydroxy-carbonate. 104, 201

Determinations of trace elements in selected soil profiles sampled by Soil Survey have continued. Work on soils from parts of Sheet 83, 84, 93 and 94, covering the Black Isle, Cromarty and Invergordon, and of Sheets 110/116 (Latheron/Wick) is continuing. Analyses for the total and acetic acid extractable trace elements in these profiles have now been completed: the contents extracted by EDTA have still to be determined. 101, 201

In a collaborative study with Pedology on trace elements in peat, the determination of the total contents of copper, manganese, iron, barium and strontium in profiles from basin and blanket bogs has been completed and the determination of other elements is in progress. 112, 201

Soil Status and Plant Uptake. The number of samples analysed on behalf of Soil Fertility from areas with suspected nutritional deficiencies of plants or animals has decreased somewhat, but with the determination of a greater

number of elements per sample there has been little change in the number of individual determinations carried out. 205, 206, 610

Analyses of soils from the long-term Soil Fertility field experiments laid down to examine the effects of pedological drainage conditions are being continued, top soils sampled in the second and third years of the experiment, together with soil profiles from some of the plots, having been examined for trace elements extractable by acetic acid and EDTA. The analyses of the mixed herbage samples from these plots have been completed, and work has started on the analysis of individual herbage constituents. A computer-controlled graph plotter will be used to display the soil-plant relationships, using the extensive data obtained from analysing the very large number of related soil and plant samples for a wide range of elements. 201, 202, 609, 801

In collaboration with the Agricultural Development and Advisory Service of the Ministry of Agriculture, Fisheries and Food, the effects of additions to soil of sewage sludges high in zinc, nickel, copper and chromium on trace element uptake by plants have been further investigated. Soils treated with various applications of sewage sludge over a period of five years have now been examined for acetic acid extractable trace elements. Five years after one 125 t/ha application of sludge to a soil more than 100 ppm of copper, nickel and zinc remained extractable by acetic acid, compared with less than 10 ppm in the untreated soil. All plant samples taken during the 5-year period of the experiment have been analysed for copper, iron, manganese, barium and strontium. The chromium, nickel, zinc and lithium contents of the samples are also being assessed from the Polychromator output employed for the determination of the above elements. Sludges from four different sewage treatment works sampled over a 5-year period contained consistently high contents of zinc, nickel, copper and chromium. 201, 202, 205

In collaboration with the Animal Diseases Research Association and with the assistance of Soil Fertility, an investigation into the possible relationship between trace elements and grass sickness in horses has begun. Analyses in hand relate to soil and herbage plant samples from 17 sites on farms on which the disease has recently occurred. 201, 202, 609

Miscellaneous samples dealt with have included soil and plant materials from pot experiments for Microbiology, Biochemistry, Plant Physiology and Soil Fertility. Trace element determinations have been carried out on Sitka spruce shoots (from the Forestry Commission Northern Research Station), conifer samples (from Pedology), ryegrass (from the Scottish Horticultural Research Institute), feeding stuffs (from the Rowett Research Institute), cotton leaves (from Ahmadu Bello University, Northern Nigeria), soils and fly ashes (from the National Vegetable Research Station), and soils (from the Central Services Laboratory, British Railways Board, Derby). 117, 201, 202, 205, 206, 307, 402, 501, 603

Glasshouse pot-experiments on the uptake by cocksfoot, ryegrass and clover of mercury and other trace elements from soils mixed with an industrial chlor-alkali waste are continuing. 201, 202, 314

In the course of the development of atomic absorption methods for the determination of mercury and cadmium described below, the contents of these elements in many soils and plant materials have been assessed. In a range of air-dry arable Scottish top soils the total mercury contents and the cadmium extracted by acetic acid both lay between 0·05 and 0·3 ppm. Herbage samples generally had less than 0·03 ppm mercury and less than 0·1 ppm cadmium in the dry matter. 201, 202, 206

Spectrochemical Methods of Analysis

In investigations into the trace element content of agricultural materials, contamination of the samples prior to and during analysis is always a problem. An account of some of the sources of contamination[20] has now been published. The accuracy, as distinct from the reproducibility, of the analytical results obtained by the cathode layer arc spectrographic technique for the total trace element contents of rocks and soils has been confirmed by the analysis of the analysed standard rocks supplied by the United States Geological Survey, the Canadian Standard Reference Materials Project, the Geological Survey of Japan and the Centre de Recherches Pétrographiques et Géochimiques, France. The contents found for the individual elements generally lie near the mean or within the ranges reported for these standard samples. Other standard samples available but not yet analysed include rocks from the Central Geological Institute, East Berlin, and the South African Bureau of Standards, Pretoria, and orchard leaves from the United States National Bureau of Standards. 205

No analysed standard samples are available for confirming the analytical techniques used for extractable trace elements in soils. For this reason the accuracy of determinations of elements is checked within the department by employing two independent analytical techniques, if suitable methods are available. In recent investigations into the amounts of copper extracted by 0·5 N acetic acid (usually about one-tenth that extracted by EDTA), the determinations were carried out by both porous-cup solution-spark and atomic absorption techniques. Good agreement, for manganese as well as for copper, was obtained for a range of soils, provided the organic matter in the extract was destroyed prior to determination. 205, 206

Arc Emission. An arc stand incorporating adequate rigidity, current-carrying capacity and high voltage insulation to carry the twin gas jet source described in last year's report has been designed and constructed. A stabilized high-current source unit capable of supplying up to 40 amperes, required for this anode excitation method, is approaching completion. The Hilger E492 Large Quartz Spectrograph which will be employed for the initial testing of the method has been modified to reduce stray light caused by the collimator lens surfaces. Reflections from the plane surface have been deflected away from the focal plane by the simple method, used by Mannkopff, of tilting the lens. Reflections from the convex surface produce an intense reduced image of the slit at a point about a third of the way between the collimator and the focal plane. A small mask, approximately 5 mm square, placed at the position of this image, greatly reduces the stray

light reaching the photographic plate. By these means both line shape and the line-to-background intensity ratio have been improved. 205

Direct Photometry. The 49-channel Hilger E789 3-metre Polychromator which has been in operation for five years has developed few electronic faults; any that have arisen have been traced and rectified by the staff of the department. The corrections required for the transfer of the determination of the total contents of trace elements in rocks and soils from photographic to direct reading have now been almost completely evaluated. A method for background correction using multiple regression was mentioned in last year's report. It has now been found that in the cathode layer arc an adequate matrix correction to the signal of an analysis line can be expressed in the form:

$$\text{Matrix correction} = \text{constant} \times (\text{In})^a \times (\text{Pd})^b$$

where a and b are coefficients established experimentally from matrices of variable composition and (In) and (Pd) are the signals for the lines of these internal standard elements. 205

The technique for the determination of boron and other elements in plant ash by the rotating pressed-disk technique, using the Hilger medium direct reader and a triggered alternating-arc, has been improved by using a constant weight of ash in the disk, with a form of background correction and computer evaluation. A report of the method[21] has been published. A transistorized electronic console to replace the obsolete 16-year old valve console is being fitted to this direct reader and should enable more efficient use to be made of this instrument. 205

Flame Emission. The demand by the various departments of the Institute for potassium and calcium determinations has declined by about 25 per cent to the analyses of 18,000 samples, reflecting a decrease in advisory requirements. The increase in the number of sodium determinations reported last year has been maintained. 206

Determinations of aluminium in EDTA and acetic acid extracts of soils using the Techtron AA4 instrument with a nitrous-oxide:acetylene flame are now being carried out as a routine service. This instrument is finding increasing application for the determination by emission and atomic absorption of low calcium contents, using a nitrous-oxide:butane flame, while a nitrous-oxide:acetylene flame is used for the determination of barium and for the indirect determination of sulphate. 201, 202, 206, 308, 604

Atomic Absorption: Flame Techniques. The Techtron AA4 atomic absorption instrument is being fully utilized. Besides being used for the emission analyses described above, the instrument is employed for the atomic absorption determination of magnesium in plant materials and soil extracts and for copper, zinc and manganese in EDTA and acetic acid extracts of soils. Over 20,000 element determinations have been performed with this instrument during the year on behalf of Pedology, Biochemistry, Plant Physiology and Soil Fertility. 206

To accommodate the new Mössbauer Spectrometer the two laboratory-built atomic absorption instruments used for the determination of cobalt

and mercury are being transferred : the instrument for the determination of cobalt is again operational. The number of cobalt determinations in acetic-acid soil extracts has dropped from an average of about 700 over the past few years to about 400, part of this decrease being caused by the transfer of the instrument. The laboratory-built 4-channel flame emission/atomic absorption instrument is now fully operational, although its introduction to routine use has been delayed because of the reorganization mentioned above. 206, 610

Cadmium is being determined in plant materials and acetic acid extracts of soil by flame atomic absorption, using the cadmium line 2288Å and an air : acetylene flame, with a lower limit of determination of 0·01 ppm in the solution. To obtain accurate results a correction is made for non-atomic absorption and light scattering effects. With plant samples matrix effects are so severe that standard solutions must incorporate the matrix elements. The lower limit of determination in acetic acid extracts of soils is about 0·005 ppm and in plant materials 0·2 ppm cadmium. An account of the determination of the alkali metals by flame photometric and atomic absorption methods[65] is awaiting publication. 201, 202, 206

Atomic Absorption: Non-flame Techniques. The problems involved in the analytical method described in last year's report for the determination of the total mercury content of agricultural materials by the cold-vapour atomic absorption technique have now been resolved, but studies have been and are continuing to be made on the problems of obtaining a representative sample prior to analysis. Losses of mercury can occur during the drying of both soils and plant materials, while mercury in the laboratory atmosphere can be sufficient to contaminate soils and the reagents employed in sample pre-treatment. 206

An electrically-heated carbon or graphite filament type atomizer has been built and is being used along with one channel of a multi-element spectrometer at present under construction. This channel, for the atomic absorption determination of cadmium, has been completed and three other channels using a solar-blind photomultiplier detector for atomic fluorescence are being assembled. With the carbon filament method for the determination of cadmium, poor reproducibility and matrix effects in aqueous solutions of soil extracts and plant materials were so pronounced that the determination of cadmium was impracticable. Both disadvantages have been overcome by extracting the sample solution with an equal volume of 0·05 per cent dithizone in chloroform, separating the organic phase by filtration through Whatman PSI phase sensitive paper, and employing a 5 μl aliquot of the organic phase for the determination. The present limit of determination is about 0·01 ppm of cadmium in solution (0·005 ppm in the soil; 0·1 ppm in the oven-dry plant material) but this limit can almost certainly be improved. 206

Molecular Spectrometry of Soil Constituents

Optical Absorption Spectroscopy. Infrared spectroscopy continues to play an essential role in characterizing both inorganic and organic soil con-

stituents and in exploring their reactivity and mutual interactions. This wide applicability is reflected in its contributions to several Institute projects. In the field of inorganic components, infrared spectroscopy has contributed to the identification and characterization of a wide range of soil minerals, including goethite in yellow podzolic soils and (most unexpectedly) dickite in a red podzolic soil. A study of the fate of zinc added to alkaline zinc deficient soils has shown that the basic carbonate mineral hydrozincite can form under the conditions of pH and CO_2 concentration characteristic of such soils. 103, 201, 207

Conclusions such as these are, of course, usually reinforced and confirmed by X-ray diffraction, electron-probe analysis, and scanning electron microscopy, but infrared spectroscopy is invaluable for its ability to reveal the unexpected and for the rapidity with which a large number of specimens can be surveyed for selection of representative or distinctive samples for more time-consuming investigations. In spite of these advantages, the regular use of infrared spectroscopy in the study of natural and synthetic inorganic materials is still restricted to relatively few laboratories, largely because the basic information necessary for such applications is not readily available. This deficiency will be remedied by a monograph placing emphasis on practical applications which will include contributions arising from the wide experience gained in the course of work at this Institute[66, 67, 68, 69, 70, 71]. Practical applications of infrared spectroscopy in mineralogy depend on the careful study of families of well-characterized minerals, and fundamental studies of this type mentioned in previous reports have now been published[22, 23]. The substance of a lecture surveying the field of mineral spectroscopy[72] is to appear in a book on physical methods of characterizing minerals. An English translation of a Russian work on mineral spectra has been edited for publication[24]. 207

Infrared spectroscopy also continues to assist studies on organic soil components in Biochemistry and Microbiology. In characterizing these essentially non-crystalline components, infrared absorption spectra play a unique role in surveying the progress of fractionation procedures. The ability to recognize the unexpected is exemplified in the recognition of aphid wax as a resistant component persisting in deep peats. 208, 303, 304, 503

Interactions between organic and inorganic components under both natural and idealized laboratory conditions are also receiving attention. Examination of natural soil-organic complexes shows that the concentration of peptide material in clay fractions is higher than that in the total soil organic matter. This peptide material undergoes thermal decomposition at surprisingly low temperatures, significantly even at 100°C, leading to liberation of ammonia, which is trapped by the usually acidic clay component in the form of ammonium ion. This finding may be related to the increased availability of soil nitrogen following burning of vegetation[73]. Other work concerned with the reactivity of soil minerals includes the characterization of ammoniated vermiculite, which is being tested in pot experiments where it behaves as a slow-release nitrogen source. Studies continue on the reactivity of aluminium and iron hydroxides and of the very high-surface-

area aluminosilicate imogolite, which is much more widely distributed than was previously thought[55]. A structure proposed for this tubular mineral[9] suggests that the outer surface resembles aluminium hydroxide, while the inner surface resembles silica gel. 207, 208, 603

Studies of the effect of reducing conditions on soil minerals are being pursued by combining infrared with Mössbauer spectroscopy, applications of which are surveyed below. 203, 207

Mössbauer Studies. In addition to its application in the work on iron pans mentioned above, Mössbauer spectroscopy has been used in the study of a number of mineralogical problems. The work on the aging of iron-catechol chelates to various iron oxides[57] has now been completed. 105, 201, 203

An investigation of site populations of ferric iron in a series of nontronites has produced no evidence for the expected tetrahedrally co-ordinated iron. Mössbauer spectroscopy has also been used for the assessment of ferrous: ferric ratios of chemically reduced smectites. 203, 207

In the natural weathering of biotite in a sedentary soil profile developed on appinite (Insch series, Insch Association) ferrous ions were shown to be readily oxidized and the site populations of both ferrous and ferric iron have been established at stages in the alteration of the biotite to a vermiculitic end-product[56]. A similar study on hornblende from the same soil profile has shown that the ferrous ions resist oxidation and that mineral breakdown produces a concentration of ferrous ions in one particularly favoured site. 104, 203

Electron Paramagnetic Resonance Studies. With the aid of facilities provided by the Department of Chemistry of the University of Aberdeen, an electron paramagnetic resonance (EPR) investigation was made of some peats and peat humic acids to which copper had been added. The copper complexes resistant to treatment with HCl were identified as copper-porphyrin complexes[25]. Similar copper complexes were identified in humic acids from a range of arable soils which had been boiled with hydrochloric acid. The possibility of using the EPR technique for the quantitative determination of copper-porphyrin complexes is being assessed. The nature of some vanadyl and manganous complexes occurring naturally in fulvic acid fractions of soil organic matter are being investigated by EPR, as are the organic radicals formed in alkaline solutions of humic acids. 203, 307

3. BIOCHEMISTRY

During the year, pending the appointment of a new Head of Department, work has continued on most of the projects previously in progress. These may be divided into studies on the nature and origin of soil organic matter and on the effects of the organic matter on the growth and metabolism of plant tissues.

Dr Kevin Tate of the Soil Bureau, DSIR, Lower Hutt, New Zealand, arrived in April to work for one year in the department.

Dr D. Vaughan attended the Ninth International Congress of Biochemistry in July 1973 in Stockholm, Sweden.

Nature and Origin of Soil Organic Matter

Soil Polysaccharide. In collaboration with Microbiology, studies on the origin of soil polysaccharide have continued along two lines—the effect of temperature on the transformation of ^{14}C-labelled glucose during incubation with soil, and the decomposition of extracted soil polysaccharide. In incubation experiments at laboratory temperature (19-24°C) reported previously (Annual Report 39, 1968/69), a large part of the glucose was consistently transformed to hexoses and methyl pentoses, with very little conversion to the pentoses xylose and arabinose. In preliminary experiments at outdoor winter temperatures (–4 - 15°C), however, glucose was transformed to xylose as well as to the usual sugars.

Polysaccharide extracted from soils of the Countesswells series (Countesswells Association) and Insch series (Insch Association) by adsorption on charcoal contained all the kinds of sugar present in the whole soil, although the proportion of glucose was smaller, being similar to that of other hexoses. The polysaccharide, which was strongly acidic, also contained glucosamine, galactosamine and amino acids, which appeared to be in chemical combination with the carbohydrate. When the polysaccharide complex was incubated with moist soil, the rate at which it was decomposed was dependent on the amount added. Thus, with the addition of 1 per cent polysaccharide the substrate was completely decomposed within four weeks, but with 3 per cent polysaccharide 30-50 per cent still remained after 16 weeks. Neutralization of the polysaccharide by calcium hydroxide prior to incubation increased the rate of breakdown in a soil of the Countesswells series but had little effect on a soil of the Insch series. Over the same period, in strong contrast to these rates of breakdown, little or no change in polysaccharide content was observed in incubated soil not amended with polysaccharide. It is concluded that the stability of this alkali soluble fraction of the polysaccharide in soil is related to physical inaccessibility or chemical complexing and not to any unique biologically stable molecular structure.

305, 315, 506

A paper on the decomposition of ^{14}C rye straw in soil[27] has been published, and one on the decomposition of ^{14}C rye straw hemicellulose[75] has been submitted for publication.

Humic Acid. Studies on humic acid using electron paramagnetic resonance spectroscopy have continued[28]. Humic acid obtained from the H horizon of a local soil of the Charr series of the Countesswells Association has been examined in alkaline solution. The spectrum, showing hyperfine splitting, was found to vary with the concentration of the alkali, indicating the presence of two different, but related, free radical species. 203, 307

Humic acids derived from podzolized soils have been shown to form aromatic anhydride structures on heating to 150°C, whereas those derived from soils showing no signs of podzolization do not. In addition, humic acids generate aromatic ring structures on heating. After humic acids have been boiled with water and acid the insoluble product, the acid boiled humic acid, does not show the aromatization reaction, but the fraction soluble in hot water does. The most likely source of the aromatic substance is thought to be polysaccharide. 208, 303

Soil Organic Nitrogen. Gel permeation and adsorption chromatography have been used on a preparative scale to separate alkali-soluble humus on the basis of molecular weight into three major fractions, shown by chemical degradation and infrared spectroscopy to contain different proportions of protein, lignin and non-lignin aromatic residues, and aliphatic carbon chains. The molecular weight distribution of the humic acid has been found to vary with the concentration of the sodium hydroxide extractant. Increasing the concentration produced only marginal differences in the protein content of the humic acid but a considerable decrease in the amino-sugar component caused, it has been established, by deamination. 208, 303

In experiments carried out in collaboration with Microbiology, a purple crystalline material produced by an unnamed bacterium proved identical to iodinin (1,6-dihydroxyphenazine-5,10-dioxide) isolated from a type culture of *Pseudomonas iodinum.* 208, 303, 503

The effect of micro-organisms on the exudate of pea roots is another subject of collaboration. Membrane ultrafiltration of exudates has shown that the organic nitrogen is concentrated in a fraction of molecular weight between 1000 and 10,000.

Interaction of Soil Organic Matter with Copper. Electron paramagnetic resonance spectroscopy has also been used to characterize the bond between copper and humic acid in the most stable complexes formed. The complexes were prepared by saturating colloidal humic acid with copper ions and repeatedly washing with HCl, and results showed that the copper still retained by the humic acid was bonded to the nitrogen atoms of porphyrin structures[25]. Such complexes have also been observed in acid-washed humic acids and peat, and this substantiates the long-held view that the unavailability of copper frequently found in soils with a high organic matter content is caused by the fixation of the copper in strong complexes with the organic matter. 203, 307

Podzol Development. Soil profiles provided by Soil Survey have been studied in an attempt to elucidate a chronosequence of podzol development.

The most characteristic feature of the organic matter of the mature podzols examined has been the large proportion of acid-extractable fulvic polymers in the illuvial horizon. Similar polymers have been extracted from acid brown earths, but in lower yields.

The relationship between these organic compounds and mineral soil components has been examined, using an assay system based on the acid-extractable humus, the acid-soluble phosphate, and the pH of an ammonium fluoride extract of the soil sample. It appears that the retention and accumulation of humus in the B horizon of a podzol is dependent on the development previously of a lower layer rich in acid-soluble phosphate. This increase in phosphate is accompanied by an increase in other soluble inorganic components. The assay system has been the means of demonstrating major differences between the organic matter of acid brown earths and podzols, and has been valuable in classifying intergrade profiles.

Results suggest that the conditions required for either podzol or acid brown earth development are created before vegetation becomes well established, and the extent to which they subsequently influence the type of vegetation which develops is being studied.

Profiles in Darnaway and Cawdor forests with upper horizons radically altered by agriculture are being studied to establish the contribution to the S horizon from the pre-agricultural humus. The assay system has indicated the distinctly podzolic nature of these soils. 304, 801

Effect of Organic Matter on Plant Growth

Humic Acid and Cell Elongation in Pea Roots. Work on the role of hydroxyproline in cell elongation has continued. It has been found that the four-fold increase in the wall-bound *trans*-hydroxyproline content of pea root segments when cell elongation is ceasing is paralleled by even greater increases in this component in 2 mm sections cut serially from the root tip, representing a natural time course in the intact roots[29, 76, 77]. It seems probable that wall-bound hydroxyproline is present in a distinct group of non-labile proteins, which are metabolically stable because the imino acid is linked to arabinose[77]. The increase in wall-bound hydroxyproline appears to be related to continuous protein synthesis because both processes are inhibited by cyclohexamide, chloramphenicol and azetidine-2-carboxylic acid. The hydroxylation of protein-bound proline to hydroxyproline was prevented by 2,2′-bipyridyl, but not by 4,4′-bipyridyl, indicating that iron is involved[76, 78]. At concentrations inhibiting the formation of hydroxyproline, 2,2′-bipyridyl also enhanced cell elongation in the roots of winter wheat grown under gnotobiotic conditions using a Trexler thin film isolator.

Low concentrations (up to 25 mg/litre) of humic acid had no effect on protein synthesis measured in terms of the incorporation of ^{14}C-leucine or ^{14}C-proline. Humic acid also inhibited the increase in wall-bound hydroxyproline, an inhibition which could be prevented by the presence of ferrous, but not ferric, iron. The similarity of the effects of humic acid and 2,2′-bipyridyl on the extension growth of pea root segments suggests that humic acid acts by complexing the iron required for hydroxylation of proline to hydroxyproline in the tissue, a biochemical step essential for the cessation

of cell-wall extension. Alternatively, an effect of humic acid on respiration cannot be ruled out at this stage. 308, 312

Effects on the Metabolism of Beetroot Disks. Humic acid and the residues after water and acid extraction have been found to stimulate the development of invertase and peroxidase activities in beet disks during aging. The fractions which had most effect on invertase development also caused the greatest sporangia formation in several species of the *Actinoplanaceae*[80]. Gel filtration studies have revealed that the component of the humic acid active in stimulating invertase development in beet disks is a low molecular weight fraction (Ca 2000), but that not all low weight fractions of soil organic matter have this ability. The use of ^{14}C-labelled soil organic matter fractions has shown that the failure of some of these low molecular weight components to stimulate enzyme development cannot be attributed to exclusion from intact cells on their sub-cellular components[79]. The nature of the link between chemical structure and biological activity is unknown, but all fractions which are biologically active contain aromatic core material[80]. 311, 409

Collaboration with Plant Physiology has continued in studies on the effect of humic acid on the cation uptake of beet disks during aging. Particular emphasis has been given to cation uptake, since the soil organic matter acts as a reservoir for cations. It has been shown that the humic acid stimulates the uptake of sodium and barium but has no effect on the uptake of potassium and calcium. 311, 406

Effect on Cultured Tomato Roots. Previous studies showed that various soil organic matter fractions enhance the growth rate of sterile cultured tomato roots and considerably depress their iron content (Annual Report 42, 1971/72). Investigations of the relationship between the iron nutrition and the growth of the roots have indicated that the depression of iron uptake is not in itself responsible for the enhanced growth rate. 309

An investigation to find out whether soil organic matter depresses iron uptake by forming soluble complexes from which the iron is unavailable or by affecting the physiology of the roots has been initiated. Preliminary studies using ^{59}Fe-labelled ferric citrate, in collaboration with Plant Physiology, suggested that over a range of pH values and salt concentrations there is an inverse relationship between the uptake of iron by tomato roots, or the adsorption of iron on to disks of cellulose filter paper, and the extent of polymerization of the ferric citrate to soluble high molecular-weight compounds. Uptake of iron appears to be more affected by such changes in pH and salt concentration than uptake of other cations. Even the uptake of iron from solutions of ferric EDTA and ferric nitrilotriacetate by roots or cellulose is altered by the presence of salts such as KCl.

Adsorption of iron from ferric citrate solutions on to disks of various cellulose derivative papers, having either positively or negatively charged groups in their structure, has revealed that the proportion of positively charged iron species in the solution decreases with increasing pH, so that

at pH 7·0 only a small proportion remains, while the proportion of negatively charged species shows a concomitant increase.

No conclusion can be drawn from these findings as to whether the capacity of roots to take up iron is influenced by soil organic matter or whether the changes in iron uptake result merely from the complexing of iron in solution. They do, however, indicate the need for caution in proposing a physiological mechanism to explain effects of organic matter on iron uptake, and possibly also indicate that experiments on the uptake of iron carried out in the absence of other salts may bear little relation to conditions existing in the soil solution. 309, 406

4. PLANT PHYSIOLOGY

The work of the department has dealt mainly with ion relationships in the plant, using soil, sand and water culture methods. Investigations have centred on the effect of calcium in relation to various disorders. It would appear that calcium nutrition is intimately connected with polyphenol metabolism and results so far obtained indicate that this finding may prove a means of diagnosing calcium deficiency.

During the year Dr P. C. DeKock visited research centres in Spain, including those in Murcia and Granada where research on many aspects of agriculture is carried out.

Ion Relationship Studies

Iron Nutrition. A study of the effect of various chelating agents on growth showed that salicyclic acid had a growth effect on Lemna only when the nutrient medium contained the ammonium ion; with the nitrate ion as sole nitrogen source, the growth effect was not observed. The effect was also apparent only if the medium contained iron, so that it is the iron chelate which exerts a physiological effect, the ligand alone being inactive. 401, 402

Nitrate Reductase. An account of this work was presented at the meeting of the Society of Experimental Biology at Reading in July. 407

Calcium Deficiency. A recent hypothesis that calcium could be specifically bound to polysaccharides through the hydroxyquinone of caffeic acid prompted a study of chlorogenic acid, the depside of caffeic and quinic acids, in relation to calcium deficiency. In experiments on potato sprouts, conducted in collaboration with Soil Fertility, it was found that growth stopped unless calcium was supplied to the sprout tip. Chlorogenic acid was always higher in sprouts affected by calcium deficiency and decreased when calcium was supplied. Other changes associated with the application of calcium included a decrease in the contents of potassium and citric acid and an increase in calcium and malic acid, together with a reduction in total phosphate and phytatephosphorus. Earlier work on the relation between EDTA and calcium has been published[30]. 402, 607

Studies on Peat. In the present series of experiments four varieties of tomato—Ohio Hybrid, Eurocross, Money Maker and Gardeners' Delight—were studied in relation to blossom end rot; incidence was very high in Ohio Hybrid, while in Gardeners' Delight the disorder did not occur. In view of the relationship established between chlorogenic acid and calcium deficiency in potato sprouts, chlorogenic acid was studied in the tomato and was found to be high in tissues of tomatoes suffering from blossom end rot. Studies are continuing on other tissues, such as tissues of carrots and parsnips affected by cavity spot. As this finding has implications for cell wall synthesis, studies on pea root segments have been conducted in collaboration with Biochemistry[29]. 114, 312, 401, 402

Calcium and Root Growth. Calcium is essential for good root growth, yet the biochemical basis for this is still not adequately understood. Precise

definition of its biochemical activity is made difficult by the fact that other elements such as strontium or magnesium can often substitute for it. The function of calcium in stimulating root growth is usually explained theoretically in terms of maintaining membrane integrity and intracellular structure or of promoting cell division and differentiation. In practice experiments confined to one or other of these possibilities are difficult to devise. It is well known that with most plants the root growth is totally inhibited in aqueous salt solutions lacking calcium. Pretreatment of the roots with calcium to build up the cellular concentration is ineffective and calcium cannot be supplied to affected roots using split root techniques. Growth of roots in aqueous salt solutions can be maintained only when calcium is present externally. To study this effect perspex chambers have been devised in which the apical meristems of wheat roots can be exposed to one solution and the remainder of the root to a different solution. From results obtained it appears that only the root tip is very sensitive to the absence of calcium. When roots are exposed to single salt solution, for example 20 mM NaCl, growth is irreversibly inhibited, but with 0·1 mM Ca present growth is normal. Using the compartmented perspex chamber it has been shown that if the root tip is supplied with calcium the remainder of the root can be exposed to 20 mM NaCl (a toxic level in the absence of Ca) without deleterious effect. On the other hand, if the apical meristem is exposed to a salt solution lacking calcium further growth is totally inhibited even when the remainder of the root system is immersed in Ca. It follows that calcium performs a vital role in promoting growth by protecting the meristematic tissue from the deleterious effect of univalent salt solutions.

^{45}Ca-labelled seeds were used to study the distribution of calcium in wheat roots and its exchangeability with sodium in the external solution. The seeds were labelled by imbibition with $^{45}CaCl_2$, a method which provides a ready supply of labelled seedlings. Wheat has also been grown to maturity with ^{45}Ca in the external solution and it is hoped to show from this radioactive grain that the distribution of calcium in seedlings labelled by imbibition is typical of that in the seed *ab initio*. 406, 409

Soil Organic Compounds and Ion Uptake. Work on the effect of soil organic compounds on ion uptake is proceeding in collaboration with Biochemistry. The emphasis in the current year has been on the uptake of ^{59}Fe by tomato roots. 309, 406

Metabolic Control of Ion Uptake Mechanisms in Wheat Laminae. Leaf cells, no less than root cells, are dependent on ion uptake mechanisms in the cell membranes and organelles to supply them with essential nutrients from the xylem stream. One major difference between root and leaf cells is that the latter are able to utilize photochemical energy directly, with a consequent increased uptake in the light. Earlier studies with etiolated wheat laminae indicated that the use of vacuum infiltration to overcome the problem of cuticular resistance to ion penetration was not injurious to the leaf metabolism and was a more convenient method of studying ion uptake mechanisms than the alternative method of chopping the tissue into narrow slices. However, application of the technique to green wheat laminae has

revealed that qualitative changes are induced. Work is continuing with a view to establishing the nature of this difference. 405

Ion Flux Studies

Isotope uptake and elution studies using onion root segments have continued. In experiments designed to distinguish between efflux from the cortical cells and leakage from the cut ends of the segments, a significantly greater proportion of the total isotope content of the root sample was washed out than was usual from the bulk samples previously used. This was apparently because water loss, occurring in the 7 to 10 minutes required to seal the segments into the experimental vessel, increased the leakiness of the root cells until water content was restored during the wash-out procedure. This difficulty was overcome by omitting to blot dry the surface of the segments on removal from the isotope loading solution. The additional activity, contained in the adhering solution, was removed in the first few minutes of washing and thereafter, for all ions investigated, the efflux pattern closely resembled that obtained from bulk samples run in parallel. SO_4^{--} fluxes are now being examined in addition to those of K^+, Na^+, Ca^{++} and Cl^-. Use of the Institute computer has saved much time in analysing these results. 407, 701, 703

As part of a study of the use of a sprouting inhibitor (chlorpropham) and cool conditions for improving keeping qualities, carried out in collaboration with the School of Agriculture, Aberdeen, some aspects of the post-harvest physiology of yam tubers have been investigated. Exposure of yam tissue to temperatures below about 10 °C leads to chilling injury, an early indication of which is a marked increase in the permeability of the cell membranes. The effects of this change on ion absorption, and on the retention of nutrients already present, has been examined. The results are contained in a report[82] accepted for presentation to an international symposium. 407

Radioactivity

Water Movement. At the request of the Northern Research Station of the Forestry Commission a method developed during work at Inchnacardoch Forest has been applied to two drainage experiments at Achray Forest (Flanders Moss) and Kershope Forest. The earlier work, on deep peat and on a part of the experimental area unplanted with trees, showed that water movement could be followed in peat maintained at different ground water levels by applying tritiated water to a surface area of about one square metre. The peat was sampled at different depths in the plot and at various distances from the plot during the course of a year. The water was extracted from the sample and the concentration of tritium (^3H) counted.

The two Forestry Commission areas presented certain complications. Flanders Moss is a flat region of deep peat and Kershope Forest a thin peat overlying a clay loam on a sloping site, and in both areas there are trees, of heights of approximately 2 m and 6 m respectively. In the application of the tritium method such factors present difficulties in setting up the experiment, in sampling, in extraction of water and interpretation of the results. Nevertheless the experiments were carried out as information on relative

rates of water movement in these areas, with drains at different depths and spacings, was necessary as a guide to future drainage policy. At Kershope Forest, with that height of tree and the shallow rooting, on which drainage treatment might have a bearing, windblow was liable to occur.

Placements of tritiated water at Flanders Moss were made by watering the surface of the plots, which were 7·5 m apart and drained by ditches 60 cm and 120 cm deep. A plot 30 m wide with a ditch 60 cm deep was also used. Placements were made in the plots at Kershope Forest at 10, 20 and 40 m spacing with ditches of 90, 60 and 60 cm depth respectively. Tritiated water was applied on the surface and also directly on the mineral layer after removal of the peat, which was then replaced. Sampling was by core augur. Water was extracted from the Flanders Moss samples by pressing and from the Kershope samples by addition of inactive water, mixing and then centrifuging to obtain a sample of the diluted labelled water.

Results form a consistent pattern and show that the tritium method is applicable to these experimental areas. Water tracing in the field by the tritium method involves the use of several Curies of activity, in contrast to tracer experiments in the laboratory which are mostly at the tens of microcurie level. Several thousand samples of tritium, a low energy isotope, require to be counted and this can be effectively accomplished with an automatic sample change liquid scintillation spectrometer. 110, 404

Soil and Plant Studies. The radioactive tracer technique has been used in adsorption studies by Spectrochemistry, in pot experiments by Soil Fertility and in plant physiological experiments. The liquid scintillation spectrometer has also been used in a non-radioactive method to measure adenosine triphosphate; an account of this work[31], in collaboration with Microbiology, has appeared. Studies on the distribution in plants of bromine, chlorine and iodine have required the use of an X-ray fluorescence method of analysis. 107, 207, 308, 403, 405, 406, 407, 409, 505, 601

A further report has been made, with Biochemistry, on the decomposition of ^{14}C-labelled plant material in soil[75], and accounts of previous studies on ^{14}C-labelled carbohydrate transformations in soil[26, 27] have been published. Soil organic matter labelled with ^{14}C has been used in physiological experiments[79] and seeds labelled with ^{45}Ca at high specific activity have been produced for the work involving root growth. Work on cation-anion balance in plants[18, 32] has been published. 305, 311, 403, 406, 409

5. MICROBIOLOGY

The work of the department is concerned with the relationship of certain major groups of soil micro-organisms, bacteria, fungi, actinomycetes and protozoa, to the healthly development of crops and with the role of these organisms in the breakdown of organic matter in soil. The main projects currently being pursued include studies on the interrelationships of soil micro-organisms and the roots of higher plants, on the interactions between groups of soil micro-organisms and on the breakdown of organic matter in soil. Studies on sclerotia of plant pathogens and on the ultrastructure of fungi are continuing and work is also in progress on the microbiology of peat. Collaboration with various departments of the Institute and with organizations with allied interests has been maintained.

The department continues to be represented on a Working Party on Terrestrial Microbiology set up by the Natural Environment Research Council. During the year members of staff also visited various organizations and attended meetings of the Fourth International Congress of Protozoology at Clermont Ferrand, France, the Society for General Microbiology in London, an International Symposium on Freeze-etching, held in the University of Kent, Canterbury, a Symposium on U.K. Terrestrial Ecosystem Studies in the International Biology Programme, held in Liverpool University, and in London the Ninth Coulter Counter Users' Conference, to which a paper was contributed. An invited paper[33] was presented at a Symposium on The Rhizosphere organized by the Society of Chemical Industry in London.

Interrelationships between Plant Roots and Micro-organisms

A review of bacteria and protozoa in the rhizosphere[33] and an account of work dealing with the interactions of micro-organisms and the mucigel layer on several crop plants[34] have now been published. This work has continued and a study of the exudates produced by pea roots grown in nutrient solution has commenced in collaboration with Biochemistry. Preliminary results indicate that there are some minor differences between the exudates from 62 day-old axenic roots and from those inoculated with a soil bacterium, *Pseudomonas* sp., or with the bacterium plus a soil amoeba, *Acanthamoeba palestinensis*. These differences are being investigated further to determine their significance and the possibility of any relationship to the type of micro-organism present on the roots. 303, 504

Examination of the effect on the bacteriophagus amoeba *Acanthamoeba palestinensis* on the numbers of the *Pseudomonas* sp. colonizing pea root surfaces has shown that *A. palestinensis* does have an effect on the bacterial numbers in its immediate vicinity. Around each trophic amoeba is a zone (about 30 to 40 μm diameter) in which no bacteria could be seen on the root surface. It is assumed that this zone represents the feeding area of the amoeba.

The microdiluter method mentioned below has made it possible to count bacteria on large numbers of root samples, and the colonization of different

regions of pea roots by *Pseudomonas* sp. has been followed. It has been established that the greatest numbers of bacteria are found on the root surface in the lateral root region and the least on the surface of the elongation zone, and this was borne out by the examination of the numbers of this bacterium able to penetrate and colonize the root cortical tissues; relatively few bacteria were found in the younger regions of the root but high numbers in the older regions, especially where lateral roots were present. In the old root regions the numbers of bacteria in the cortical tissue frequently exceeded those colonizing the surface. 504, 701

Preliminary experiments on winter wheat cultivar Champlein grown in the glasshouse on a soil of the Fraserburgh Association which had been stored for one year indicated the absence of the lytic non-fruiting myxobacterium (Annual Report 42, 1971/72). The reason for the apparent absence of this micro-organism has been further investigated. The experiment was repeated with fresh samples of the same soil but had to be discontinued because of infection with powdery mildew—*Erysiphe graminis hordei*. In an attempt to control this infection the seed was dressed with a fungicide. The microflora of the washed roots was apparently unaffected by the fungicide and the lytic non-fruiting myxobacterium was present, particularly during the early stages of plant growth. Further experiments with stored soil will be set up. 501

A study of the incidence of lytic micro-organisms on the washed roots of spring barley, cultivar Ymer, is being made on material from Soil Fertility field experiments on the above soil and from parallel experiments in the departmental glasshouse. 501, 609

Soil Protozoa

Interrelationships with Other Soil Micro-organisms. A mathematical model describing the growth of a soil ciliate, *Colpoda steini*, preying on a soil bacterium, *Azotobacter chroococcum*, in a 2-litre-batch culture of liquid media has been developed in collaboration with Statistics. The population dynamics of this model system were investigated by digital computer simulation. Results of edibility trials in which *C. steini* was fed either *Azotobacter* rods or *Azotobacter* cysts have confirmed earlier microscopial observations that rods are more readily eaten than cysts, indicating that some relationship exists between edibility and age of individual *Azotobacter* cells. Examination of the ciliate food vacuoles by transmission electron micoscopy following further trials with *Colpoda* similarly fed has also confirmed this hypothesis. 502, 505, 703

A complementary series of experiments with the same ciliate and bacterium grown in soil previously sterilized by γ-irradiation has provided some information on the more complex predator : prey relationships in soils. In these experiments the soil was held at constant suction or pF by the use of tensiometers. Results suggest that the ciliate cannot multiply in soils in which all the constrictions or so-called necks in the soil pores of larger dimensions than itself are filled with air. Such conditions would so severely restrict the movement and feeding of the ciliate that most of the bacterial

population would be unavailable to it as food. This work is continuing in the hope of developing a satisfactory mathematical model to describe ciliate growth in previously sterilized soils. 505, 703

Soil Protozoan Populations. A review of the usual methods of estimating soil protozoan populations[35], including an account of the microdiluter method used at the Macaulay Institute has been published. This microdiluter method has also proved satisfactory for counting bacteria from both peat and soil and represents a great economy of materials and incubator space; consequently it is hoped to increase the frequency of microbial population estimates in soil or peat. An account of this method for counting bacteria and protozoa in soil or peat is being prepared for publication. 503, 510, 701

The morphology of an unusual phagotrophic flagellate isolated in small numbers from three soils in North East Scotland has been described in a joint paper[53] with the Zoology Department of the University of Glasgow and the British Museum (Natural History). The only previous report of this flagellate, made in 1924, was based on observations from a few living specimens in a week-old infusion of horse dung collected in Finland. An amoeba isolated from local soils and sent for further identification to the Curator of the Natural Environment Research Council Culture Collection of Algae and Protozoa in Cambridge has proved to be a new species of the genus *Vahlkampfia*. It would appear likely that a further examination by this method of samples from agricultural soils in Scotland, collected in conjunction with Soil Survey, will reveal other rare or undescribed species of protozoa. Eventually it should also be possible to establish whether or not there is any correlation between protozoan distribution and the physical or chemical composition of the soil samples. 101, 201, 510, 801

Soil Fungi

Ultrastructure. The combined use of the scanning and transmitting electron microscopes, together with the employment of a wide range of preparative techniques, has revealed the ultrastructural features of the fruiting structure of *Sclerotina sclerotiorum* (Lib.) de Bary, an ubiquitous soil-borne plant pathogen, in unusual detail. A unique three-dimensional picture of the gross external features of the apothecium was obtained with the scanning electron microscope, while a similar picture of the internal structure was obtained by examining replicas of freeze-fractured cells in the transmitting electron microscope; the results of these observations supplemented those obtained from ultra-thin sections. It is hoped that this information, combined with that from infrared spectroscopic analysis of the cell wall of the stipe and apothecium, will further our understanding of the biology of this very successful plant pathogen. A lecture on the contribution of ultrastructural studies to fungal taxonomy was given at a Symposium on Newer Approaches to Microbial Taxonomy and Identification organized by the Aberdeen Biochemical Society. 208, 507

A joint study on a saprophytic fungus, *Graphium putredinis*, has been made with the School of Pharmacy, Robert Gordon's Institute of Techno-

logy, Aberdeen. The synnemata and mycelial condiophores have been examined by both scanning electron microscopy and light microscopy. The results have once again indicated the value of the scanning electron microscope in revealing the detailed surface fine structure of a sporulating fungus. An exhibit entitled *Graphium putredinis:* Scanning Electron Microscopy of Synnemata, was presented at a Conversazione and Exhibition of British Fungi, organized by the British Mycological Society, in London in September. 507

Sclerotia of Plant Pathogens. A study has been made with Biochemistry on the co-operative action by endo- and exo-β-(1→3) glucanases from parasitic fungi in the degradation of cell wall glucans from *Sclerotinia sclerotiorum* The enzymes were obtained from culture filtrates of two soil fungi, *Coniothyrium minitans* Campbell and *Trichoderma viride* Pers. ex Fr., grown on autoclaved crushed sclerotia of *S. sclerotiorum* which they parasitize. The results obtained were viewed in relation to the structure of the sclerotial cell walls and their glucan constituents. 301, 508

Plant material (largely from peas) infected with *S. sclerotiorum* was again found in arable fields in Kincardineshire and a report covering this work[36] has appeared. Infected potato plants from Shetland were also examined, and inoculum from pure cultures derived from this material was used to infect potato plants artificially in the glasshouse. Successful infection was obtained only when the plants were enclosed in a moist environment at a temperature of approximately 20°C. Tests with various systematic fungicides in the glasshouse are in progress. Dazomet, a chemical fumigant which in contact with moist soil releases methyl isothiocyanate, proved lethal over a range of temperatures to sclerotia of *S. sclerotiorum* collected from soil and agricultural crops in North East Scotland; in comparison, calcium cyanamide and dicyandiamide proved to be fungistatic but not completely fungicidal. A lecture on biological control with special reference to *Sclerotinia sclerotiorum* was given at a Seminar for students of the Division of Mycology of the North of Scotland College of Agriculture. This was illustrated with a colour cine film of the life history of *S. sclerotiorum* taken in the field and in the laboratory at the Macaulay Institute. 508

Soil Organic Matter

Microbial Decomposition. The study of the breakdown of soil polysaccharide extracted from soils of the Countesswells series (Countesswells Association) and Insch series (Insch Association) by Biochemistry has continued. The results indicate that the microflora involved in the degradation of polysaccharide added to the above soils consist of a wide range of bacterial types. Most frequently encountered were *Arthrobacter* spp. and short, Gram-negative rods with characteristics similar to those of *Pseudomonas* spp. It was found that most of these organisms were sessile and thus did not appear in solutions containing the soil polysaccharide which had been perfused through soil columns. Studies of the effects of substrate adsorption on the decomposition of polysaccharide in soils, using perfusion techniques and soil incubations, have shown that as much as 20 per cent of the added substrate may be adsorbed by the soils. This material resists

decomposition for a short period (up to about seven days) but is thereafter attacked by micro-organisms, suggesting that adsorption alone is not responsible for the stability of the polysaccharide fraction in soils. 315, 506

An account of the effects of adsorption of adenine by montmorillonite on microbial degradation[10] has now appeared. 105, 506

Microbiology of Peat. The work on the relationship between microbial populations and adenosine triphosphate in peat[31] has now been published. The adenosine triphosphate content of most of the bacteria, calculated from counts by direct microscopy using the fluorescein isothiocynate method, was at a level similar to that of cells grown for long periods in nutrient deficient media. 409, 503

Work has continued on the aerobic bacterial populations of the basin peat at the Lyne of Skene. The relationships between population numbers and physical and chemical parameters have been evaluated by Statistics. 116, 503, 701, 703

During the study of isolates from aerobic dilution plates of peat it was noted that a few isolates grown on agar media produced magenta coloured crystals on the surface of their colonies and within the agar. The crystals have been identified by Biochemistry as iodinin; the organism was compared with a type culture of *Pseudomonas iodinum* (N.C.I.B. 8179) but was found to differ in a number of characteristics. 208, 303, 503

A satisfactory anaerobic growth cabinet has now been developed and the choice of a suitable medium for the growth of peat micro-organisms is under investigation. A study of the anaerobic bacterial population of the basin peat at the Lyne of Skene is to be undertaken.

During the microbial investigations of peat samples small white aggregates, about 3 mm in diameter, were frequently observed. The origin of these aggregates has been studied and it has been established that they are wax fibres secreted by the aphid *Colopha compressa* (Koch) which colonizes the roots of *Eriophorum* spp. growing on peat. This is the first report of the occurrence of this aphid in Scotland. 208, 503

Production of Cell Material and Microbial By-products

Work has continued on the growth of *Azotobacter chroococcum* at different temperatures and pH values. A mixed culture, using *A. chroococcum* and the ciliate *Colpoda steini* was also investigated under these conditions to study predator: prey relationships. The Coulter Counter Model B has been extensively used for these experiments not only for enumerating the cells during growth but also for measuring the various sizes and volumes of the cells present in the mixed culture. The results obtained have been processed by Statistics. 502, 505, 703

6. SOIL FERTILITY

Complementary field, pot and laboratory studies have been continued on the nutrient relationships, properties and productivity of contrasting soil series mapped by the Soil Survey of Scotland, on the effects of fertilizers, soil conditions and environmental factors on the yield and chemical composition of crops, and on the development and calibration of laboratory methods for evaluating nutrient status of soils, as a guide to practical fertilizer recommendations. The main topics are reviewed below, together with related consultative activities. The latter continue to provide essential reciprocal channels between research and practice, and as well as advisory soil testing in collaboration with the North of Scotland College of Agriculture they include representation on various technical bodies. Under the latter head come the Agricultural Research Council Working Group on Soil Physical Conditions, the Scottish Standing Committee for the Calculation of the Residual Values of Fertilizers and Feeding Stuffs, the Scientific Working Party on the Evaluation of Manurial Residues, set up by the Ministry of Agriculture, Fisheries and Food, and a Soils Working Group formed by the Scottish Agricultural Development Council. Normal contacts and collaboration have also been maintained with other research organizations, especially the Rowett Research Institute, the Scottish Horticultural Research Institute and the Animal Diseases Research Association, Moredun Institute.

During a study tour in Scandinavia, Dr E. G. Williams visited the principal agricultural research centres in Denmark, Sweden and Norway. Another visit abroad was made by Dr J. W. S. Reith who gave one of the invited papers at a meeting of the International Superphosphate and Compound Manufacturers' Association in Paris. Two other papers were also contributed to scientific gatherings, one to a symposium on Soil Phosphorus and Crop Growth, organized by the Agricultural Group of the Society of Chemical Industry in London, and the other to a meeting of the Society for Experimental Biology, at Reading. These papers are summarized in the relevant sections below. The department was also represented at meetings of the British Society of Soil Science, at a conference on The Fertility of our Soil, organized by the Royal Society of Arts in London, at the North Eastern European Symposium on Intensive Agriculture and the Environment, organized by the International Centre for Co-operation in Agricultural Research at Newcastle-upon-Tyne, and at an International Meeting in Edinburgh on Nitrogen Fixation and the Biosphere.

Facilities were provided for two visiting workers. During a stay of six months at the Institute Mr P. L. Searle, Soil Bureau, Department of Scientific and Industrial Research, New Zealand, spent the major part of his time studying analytical methods, especially automated procedures, used in soil fertility studies and advisory work. Mrs N. Z. Varbanova, N. Poushkarov Institute of Soil Science, Bulgaria, came for three months, with the aid of an FAO fellowship, to gain experience in studies on cation exchange in soils.

A selective review of recent advances in soil chemistry[37], with the emphasis on physiochemical and inorganic topics relating to soil fertility, has been published, covering surface charge, cation exchange, soil potassium, anion adsorption, soil acidity and liming, fertilizer reactions with soils, and ion transport in soils.

Fertilizer Requirements of Crops

Field experimentation, with complementary analytical work on soil and crop samples, on the effects of nitrogen, phosphate, potassium and magnesium dressings on the yield and nutrient content of crops and herbage on different soil types has been continued. In two new experiments on herbage, one on a mineral soil and the other on deep peat, particular attention is being given to the amounts of phosphate and potassium required at high levels of applied nitrogen. 206, 608, 701

An account of earlier joint work with Pedology and Statistics on the nutrient requirements of herbage on deep acid peat[11] has now appeared. The main conclusions were summarized in last year's report. 112, 206, 608, 701

The implications of nutrient supply and soil conditions in hill land were reviewed in an invited paper[38] presented to a Colloquium on Hill Pasture Improvement and its Economic Utilization in Edinburgh in September 1972, and the text has now been published. This summarizes the main factors, including adverse environmental conditions, which limit the generally low fertility of hill soils and which restrict the potential economic returns from relatively expensive improvements involving cultivations, liming, manuring and reseeding. In selecting areas for improvement priority should of course be given to the best land and microclimate. To maintain productivity on reseeded or surface seeded land controlled grazing is essential, and in addition to periodic liming, to replenish losses of calcium by leaching as well as to correct acidity, regular dressings of phosphatic fertilizers are also likely to be required to maintain the supply of available phosphate. Unlike agricultural land, unimproved hill soils do not contain fertilizer residues, and the nutrient reserves, though large, are present in relatively insoluble and difficultly available forms. In so far as native species are better adapted to the hill conditions than most agricultural grasses and clovers and are better able to utilize the nutrient reserves, consideration should be given to possibilities of improving the growth and palatability of the natural herbage. For example, controlled grazing together with the application of some calcium and phosphate, without any seeding, may be a relatively inexpensive way of gradually improving areas where better types of grasses such as *Agrostis* and *Festuca* predominate. There are, however, large areas dominated by poorer species, such as *Molinia, Nardus* and *Calluna*, where such treatment would have little effect. On such land reseeding is often not justifiable and the development of some other simple and cheap method of improvement would be valuable. 608

The main principles and factors which govern efficient use of fertilizers have been reviewed in two invited lectures contributed to international meetings, and the texts have been submitted for publication. One, on soil

properties limiting fertilizer efficiency[84], was contributed to the Seventh Fertilizer World Congress in Austria in 1972, and the other, on the effectiveness of different methods and times of application[85], was presented at the meeting mentioned earlier, held in Paris in February 1973. In both cases the salient factors are summarized on the basis of the dominant characteristics of the individual major nutrients considered in relation to the quantity and intensity aspects of nutrient supply, and to the influences of the relevant soil processes, properties and constituents which regulate solubility and availability. References are also made to harmful effects of high salt concentrations, to restrictions imposed by trace element deficiencies and excesses, and to influences of soil physical factors, crop characteristics and agricultural practices. In the second paper[85] more detailed attention is given to the importance of positional availability and the benefits from suitable placement of fertilizers, especially in the early stages of growth, in relation to methods and times of application and to effects of cultivations. In both papers illustrative results are quoted from the literature and from investigations under Scottish conditions. 608

Crop Growth and Development

With some modifications, the series of annual NPK factorial experiments on barley and swedes, mentioned in recent reports, have been continued at four contrasting centres equipped to measure soil and air temperatures, rainfall, humidity, wind speed and soil moisture. These experiments are designed to assess the implications of site, environment and season as well as soil conditions and husbandry practices. At one centre potatoes are now being studied instead of swedes, and in one of the barley experiments seed rates ranging from 100 to 400 kg per ha (90-360 lb per acre) were compared. Since the responses of barley to phosphate and potassium have not been significant, these nutrients will in future be applied as basal dressings to allow other factors to be introduced without increasing the size of the experiments. Further comparisons of seed rates are envisaged, and it is also intended to examine various methods of seed bed preparation in relation to depth of sowing, since there have been indications of the marked importance of this factor. With optimum fertilizer dressings the crop yields have so far been generally very satisfactory. Despite the relatively short growing season dry matter yields of 5·7 and 10·0 t per ha (2·3 and 4·0 tons per acre) have been attained for barley grain and swede bulbs respectively. In keeping with the long daylight during most of the season, growth is relatively rapid, and for barley rates of 220 to 250 kg per ha per day for total dry weight in June and about 190 kg for ear growth in July have commonly been obtained. Comparable values for swedes are about 160 kg for total dry weight during August and about 130 kg for bulb dry weight in early September. Barley yields have tended to increase during the experimental span of four years, and among contributory factors may be improved mildew control and beneficial effects arising from the sequence of mild dry winters, including possible improvements in the supply of soil nitrogen. The responses of swedes to nitrogen have generally been relatively small and one major factor affecting yield differences between sites and

seasons appears to be variation in planting dates. If yields of 10 t per ha of bulb dry matter are to be obtained it seems essential that rapid growth should start before the end of July. Another objective of these experiments is to study the progressive accumulation of nutrients in the different parts of the crops throughout the season. In the case of swede bulbs attention has been given to the distribution of dry matter and nutrients between outer and inner tissues in relation to the normal method of sampling by taking diagonal cores. 206, 607, 801

Effects of Calcium on Sprout Growth of Potatoes

In field studies on the growth and development of potatoes account has to be taken of possible marked effects arising from differences in the treatment of tubers prior to planting. A study has therefore been made, in collaboration with the Department of Biology of the University of York, of the tendency for some potato cultivars when sprouted in the dark to develop necrotic lesions 3 to 5 mm below the sprout apex. An account of this work was given to a meeting of the Society for Experimental Biology at Reading in July 1973, and a report is being prepared for publication. The name *sub-apical necrosis* is proposed to describe the initial symptoms and the cause appears to be inadequate supply of calcium to the sprout apex. Application of small amounts of calcium in solution to the sprout tip completely prevented the necrosis. Application of calcium to the tubers increased the growth rate of the sprouts but did not improve the supply to the tips sufficiently to prevent the necrosis. The development of roots by the sprouts, however, not only increased their growth but at temperatures up to about 20°C induced enough translocation of calcium from the tuber to prevent the necrosis, and when calcium was supplied directly to the roots sprout growth was maintained at still higher temperatures. With some cultivars, sprouting in the dark did not produce the visible necrotic symptoms, but deficiency of calcium was still shown by the fact that unless it was applied sprout extension stopped, apical dominance was lost, and lateral branches were produced. In the case of Pentland Dell, the lateral branches were almost entirely diageotropic and produced tubers. Since the progression of these phases can be arrested by supplying calcium, and they are all accepted indices of increasing physiological age in potatoes, it would appear that this process is a function of the calcium metabolism of the sprouting tubers. Sprouts and tubers from this investigation were supplied to Plant Physiology for further examination. 206, 402, 607

Trace Elements

Progress has been made in an investigation on the boron status and requirements of barley in north-east Scotland, with particular reference to the occurrence of crop boron levels which have been considered in other countries to indicate deficiency. 609

Two experiments have been laid down, one on a mineral soil and the other on deep peat, to study, in collaboration with Spectrochemistry, the effects of high rates of nitrogen, up to 570 kg per ha, on the contents of the biologically important trace elements in herbage cut three times per year,

and to determine requirements for trace element supplements. Assistance has been given in the selection of sites to provide crop and soil samples for collaborative work by Spectrochemistry and the Animal Diseases Research Association on the incidence of grass sickness in horses. 205, 206, 609, 701

Inorganic Phosphorus

References have been made in recent reports to investigations on the effectiveness of very finely ground rock phosphates as sources of phosphate for crops. An account of the results was contributed to a Symposium on Soil Phosphorus and Crop Growth held by the Agriculture Group of the Society of Chemical Industry in London in February 1973. It is of course well known that, subject to overriding influences of rock type, crop characteristics and soil conditions, the effectiveness of rock phosphate generally increases with decreasing particle size. The practical benefits of grinding have therefore been extensively studied over the years and the capabilities of products with particle size down to about 20 to 30 μm are well understood. Though very small, this size is still much above the colloidal limit, and to examine the effects of lowering the particle dimensions to this range rock phosphates of contrasting inherent effectiveness were ground down to 10 μm and to less than 1 μm for comparison with the same materials at the normal 50 to 150 μm size. Since mixing with sulphur is another possible way of enhancing the effectiveness, corresponding products were also prepared into which elemental sulphur of the same particle size was incorporated, either by co-grinding or by subsequent mixing. The various materials were tested on oats in Mitscherlich pot cultures and on potatoes and swedes in the field. Even under the very favourable conditions provided by low rate of application to mixtures of acid soils and sand in pot cultures, the effects of both fine grinding and sulphur were markedly dependent on the inherent effectiveness of the rock. Where this was poor there was little benefit, but where it was relatively good the performance was much improved. The 1 μm products were generally somewhat better than the 10 μm materials. Even so, with no sulphur added, the best 1 μm product was still clearly inferior to soluble phosphate. Sulphur produced some distinct improvements and in the case of the best rock tested the dry matter yield and phosphate uptake from the 1 μm product containing 10 per cent of sulphur were fully as good as from soluble phosphate. But irrespective of rock type, particle size and addition of sulphur, the slower action of the rock products was always evident in the early stages of growth, and the effectiveness still decreased markedly with increasing soil pH. Under the less sensitive conditions in field trials, the effects of both fine grinding and sulphur were generally smaller, and often inconclusive. On potatoes there were clear improvements, but even the best 1 μm product was still much inferior to soluble phosphate. The pattern for swedes was more variable. The better 1 μm products were occasionally comparable with soluble phosphate, but only where effectiveness of the normal material was also high. The benefits from grinding were also clearer on the basis of phosphate uptake than dry matter yield. Like the poor performance on potatoes and the shortcomings under pot conditions, this shows that the rate of solution

of the fine products was still not sufficiently high to enable them to match soluble phosphate in raising the intensity of the phosphate supply, especially in the early stages of growth. As shown also by the continuing overriding effects of soil pH and rock type, the main conclusion is that despite some striking improvements the inherent limitations of rock phosphates were still evident, even in the best of the materials co-ground with sulphur to less than 1 μm. 601, 701

Integrated field, pot and laboratory investigations have been continued on the significance of different types of soil phosphorus measurements and on the influences of soil properties and crop characteristics on their usefulness as indices of phosphate status. As well as assessing possibilities for practical improvements in advisory soil testing, a major objective in these studies is to clarify the implications of the quantity, intensity and buffer components of the phosphate supply. To these ends assistance continues to be obtained from Plant Physiology in measurements involving the use of radioactive phosphorus, and concurrent field and pot evaluations of phosphate status are being made with different crops, especially swedes, potatoes and oats. 409, 601, 701

Organic Phosphorus and Sulphur

Further progress has been made in the characterization of a number of novel phosphate esters which, as mentioned in last year's report, have been isolated from sodium hydroxide extracts of soils. Glycerol, *myo*inositol and *chiro*inositol have been identified among the hydrolysis products of two of these esters, which are thought to be derivatives of the class of lipids known as phosphoinositides, although *chiro*inositol has not been previously recorded in such compounds. Of the other esters, four contain carboxyl groups and have a C:P ratio of 7 or 8 to 1, while two react quickly with periodate, showing the presence of at least two hydroxyl groups. The esters present in greatest amounts in the extracts, however, were inositol phosphates, the ratio of the hexa-: penta-: tetra-: tri-phosphate being 100:15:4:1. An account of these studies[86] has been submitted for publication. Progress has also been made in related investigations on organic sulphur compounds in soils, especially the organic sulphate fraction, which accounts for the major part of the total organic sulphur. The properties of this fraction are being studied, particularly the rate of mineralization by acid treatments. Attention is also being given to the use of partial hydrolysis to obtain moieties of lower molecular weight, more amenable than the parent macromolecules to chromatographic separation and purification. 602

The results of an investigation on the sorption characteristics of inositol hexaphosphate in acid soils, with particular reference to interactions with inorganic orthophosphate, were summarized in last year's report and an account of this work[87] has been accepted for publication. 601, 602

Nitrogen

The main effort has centred on the monitoring of changes in nitrate and ammonium nitrogen in field plots under contrasting cropping and nitrogen treatments. In four experiments on barley a band of nitrochalk was drilled

in at 5 cm from each seed row. Soil samples were then taken at monthly intervals throughout the growth period from treated and untreated plots at positions 2·5 cm on either side of the seed rows, corresponding to distances of 2·5 and 7·5 cm from the initial fertilizer bands. In two other experiments on barley, comparing various forms of nitrogen, anhydrous ammonia was injected at a depth of 15 cm in rows 30 cm apart. Soil samples were taken at monthly intervals from cropped and fallow plots at positions corresponding to the initial injection rows and to the midpoints between them. In three experiments on swedes nitrochalk was broadcast on the cultivated surface before ridging, while in an experiment on potatoes it was applied over the open ridges before planting. In both instances regular soil sampling was carried out at the apices of the final ridges and between them at the bottom of the furrows. In the laboratory, inorganic nitrate and ammonium nitrogen extracted with molar potassium chloride were estimated directly by automated methods. Measurements on this scale have now been carried out in three successive seasons. Detailed conclusions must await completion of the sampling and analyses, but a striking feature of the barley experiments has been that by mid June to early July the initially high nitrogen levels in plots receiving about 100 kg N per ha have fallen to the values for the plots receiving no nitrogen. Further work has also been done to examine the usefulness of various laboratory methods for evaluating the nitrogen status of soils. 603, 607, 608

In collaboration with Spectrochemistry, pot studies have been continued to characterize the behaviour of ammoniated vermiculite as a source of nitrogen in sand and soil media to oats and to successive cuts of ryegrass. The growth patterns confirmed that the effectiveness is markedly dependent on particle size, and the coarser products appear to have potentialities as slow-release nitrogen sources. 207, 603

Earlier studies, extending over several seasons, established that under appropriate conditions in pot cultures phenyl phosphonic acid has characteristic effects on the development of oats, especially initial retardation of growth and subsequent delayed senescence, and can markedly increase the yield and nitrogen content of the grain. To examine further the factors involved, the effects of inhibiting nitrification with N-Serve and of varying the basal dressings of other nutrients have been investigated. The analytical coverage has also been broadened by examining the levels of soluble nitrogen fractions in the plants at intervals during the season. Attention has also been given to the effects in calcareous compared with acid soil media. In the latter media the standard effects of phenyl phosphonic acid on oats continue to be reproduced irrespective of soil type, variety, seed rate, amount and form of added nitrogen, and levels of basal nutrients. 603, 606

Soil Acidity and Cation Exchange

The studies mentioned in recent reports on relationships between the exchangeable cations and the pH and aluminium concentration in dilute calcium chloride suspensions of acid soils have been concluded. The importance of the selectivity coefficient for the exchange reaction between calcium

plus magnesium and aluminium in determining these relationships is greater than has hitherto been thought. Variations in this coefficient can account for differences of up to 0·7 of a pH unit between contrasting soils with similar proportions of exchangeable cations. Three groups of soils that have shown considerable differences in this respect are sandy topsoils, loamy topsoils and loamy subsoils. The strength of aluminium bonding relative to calcium and magnesium increases in this sequence, with corresponding decreases in the amounts of hydrogen ions arising from aluminium hydrolysis. These effects, together with differing dissociation of hydrogen ions from humic acids, enable considerable differences between the soils in the relationships between pH and soluble aluminium to be explained. An account of these studies[88] has been submitted for publication and their implications in relation to plant growth are being examined. 604

During her stay in the department, Mrs N. Z. Varbanova of the N. Poushkarov Institute of Soil Science, Sofia, Bulgaria, collaborated in studies on the potassium relationships of soils. The effect of soil pH on potassium adsorption and fixation was examined on a soil of the Countesswells series (Countesswells Association), formed on till derived from granite and granitic gneiss, using samples from long-term field plots maintained at different pH values by the North of Scotland College of Agriculture. For samples with pH in the range 4·0 to 6·7 there was little difference between potassium adsorption isotherms determined over 10 days compared with half an hour, but more potassium was adsorbed during the longer period by a sample with pH 7·5. For this sample the adsorption and desorption isotherms diverged, showing that some fixation may have occurred in the potassium enriched soil, but for the others they followed essentially the same path. This apparent lack of fixation in all but the sample with the highest pH, despite the micaceous nature of the clay, is compatible with the relatively low clay content (13 per cent) and substantial organic matter content (8 per cent) of the soil. 206, 604, 611

Chemical Composition of Plants

The significance of the quantity C – A, the difference between total cations and total inorganic anions, in the tops of plants has been further investigated in relation to crop yields. For swedes, ranges of yield and C – A were obtained by taking samples of fully expanded leaves, about eight to ten weeks after sowing, from an NPK field experiment incorporating combinations of five levels of each nutrient and a comparison of potassium chloride with potassium sulphate. For ryegrass, different yields and C – A values were obtained by taking three successive cuts from pot cultures receiving different rates and forms (nitrate, ammonium + N-Serve, nitrate + ammonium) of nitrogen at three levels of potassium. Changes in the simpler nitrogenous constituents (nitrate, ammonium, amide and free amino acid nitrogen) of the ryegrass leaves are also being examined, to broaden the basis for interpreting the variations in yield and C – A and to standardize procedures for more extensive investigations on field crops. To the latter end, also, standard methods for estimating total chloride and sulphate in plants have been brought into operation on the AutoAnalyzer. 206, 606

Two reports of collaborative work with Plant Physiology and Spectrochemistry on the chemical composition and cation-exchange properties of the floral parts of different plant species[18, 32] have now appeared. 202, 403, 606

Advisory Work

Concurrently with the general application of charges for advisory analyses, the number of soil samples submitted by the Advisory Officers of the North of Scotland College of Agriculture fell markedly to just under 5000, compared with over 9000 in 1971/72. The main requirements, however, continued to be the evaluation of lime recommendations and assessment of the phosphate and potassium status. A substantial proportion also required estimation of the magnesium status, and in collaboration with Spectrochemistry about 6 per cent were examined for trace elements, in relation to problems of animal health as well as crop growth. 205, 206, 610

With the assistance of the Colleges of Agriculture, a review of lime requirement and usage in Scotland has been carried out for the Department of Agriculture and Fisheries for Scotland. Based on advisory soil data for 1970 to 1972, which are considered to be reasonably representative of the arable land and permanent grass, the total amount of lime required to correct outstanding deficiencies, excluding rough grazings, is estimated to be about 5,700,000 tons $CaCO_3$, which is practically the same as the corresponding estimate made in 1967. Advisory results indicate that out of a total of a little over 4,000,000 acres of arable land and permanent grass only about one-third is adequately supplied with lime. Based on experimental results and on the quantity of lime applied during the ten years 1963 to 1972, it appears that about 750,000 tons $CaCO_3$ would be required annually to maintain the present position, assuming that the quantities of basic slag and fertilizer nitrogen applied remain similar to those used during 1967 to 1970. If the lime status of all the arable land and permanent grassland were raised to satisfactory levels corresponding to pH 6·2 and 6·0 respectively, the estimated annual maintenance requirement would be 940,000 tons $CaCO_3$. 608

7. STATISTICS

The work of the department is of a consultative and advisory nature, concerned with maintaining a service in experimental design, statistical analysis, computer programming and data processing.

During the past year, Mrs M. I. Barreto from the Estacao Agronomia Nacional at Oeiras in Portugal spent three months in the department studying sampling techniques, problems of reproducibility and accuracy of results, and the use of multivariate methods of analysis. She also received some training in computer programming and studied a number of statistical programs which had been developed in the department. Members of staff have attended meetings of the Biometric Society, the Royal Statistical Society and the Agricultural Research Council Crop Science Model-Builders' Group, a course on systems analysis in biology and agriculture, and a conference on computational problems in statistics.

Computing Service

The data preparation and computer facilities are available to authorized users from other departments who process results from various spectrochemical procedures and from crystallographic and botanical studies. The department is responsible for the programming, data preparation and computer operation for all other work, including the maintenance and development of statistical programs. New analysis of variance program packages have been written to extend facilities for split-plot and partially confounded designs. In the course of this program development a number of existing subroutines have been modified and improved. 701, 703

Pedology. The processing of results from pyrolysis: mass spectrometry continues with a pattern recognition vector trained to calculate a discriminator value to classify the soil types. An investigation has also been made of the use of a complex-valued non-linear discriminant function in the classification of soils. The computer program written for the purpose makes use of a generalized Walsh transformation of the intensities of the spectrum at each mass number. The discriminant function is a complex number and is non-linear with respect to the components of the mass spectrum. The classification is based on the sign of the real part of the complex discriminant function. 108, 703

The program written for processing the results from electron-probe microanalysis applies corrections for interelement effects based on generation, absorption and characteristic fluorescence factors, so providing quantitative determination of major elements. 109, 703

A numerical surface technique program system has been used to produce contour maps of surveyed areas. For example, in a peat bog survey the x and y co-ordinates of points and the depth of peat at each point are input to the computer and converted to a square grid of data values to represent the conformation of the surface, using program NUPRX. Program CONTR is then used to produce on the graph plotter a contour map of the surveyed area with symbols and depth of peat printed at the locations of the data points. 112, 703

A program has been developed to produce pollen diagrams on the plotter. The systematically classified pollen counts for a profile are converted to percentages of a specified total at each depth. The percentages are then tabulated on the line printer and plotted in profile for each species. Considerable progress has been made in the production of such diagrams from accumulated results. 113, 703

Microbiology. For dilution series in microbiological studies a computer program has been written for the solution of equations to determine the most probable number (MPN) of organisms in a sample and the probability of occurrence of the numbers of fertile tubes in the series. The program can also be used to produce the MPN tabulation for all possible results for a particular dilution factor and a given number of tubes at each dilution. 503, 504, 703

The processing and plotting of Coulter Counter results continues and the dual threshold case has predominated. Plots of the corrected counts against mean diameter provide information on the size distribution of micro-organisms. 502, 505, 703

The continuous system modelling program (CSMP) for the IBM 1130 computer has been used extensively to investigate the batch culture of a bacterium and a protozoan assuming a straight food chain—soluble substrate → bacterium → protozoan. The model has also been expanded to include the conversion of bacteria into and out of an edible state. Results were tabulated on the line printer and growth curves produced on the plotter. 505, 703

Advisory and Collaborative Work

Pedology. In two forestry experiments of central composite design, random arrangements have been made for measuring equipment to be placed within the forest plots. Data processing and statistical analyses have continued on an experiment on the nitrogen nutrition of Corsican pine[63], on an experiment to compare methods of estimating mineral nitrogen at different water levels, and on a glasshouse experiment with tomatoes grown on peat. Prediction of tree weights and weights of nutrients in the trees have been made on an area using regression relationships and the stem distribution by basal area classes. A number of computer programs have been written for sorting and selecting data from records of rainfall, throughfall and stemflow. Numerous linear regression equations were compared to select the best variable for predicting throughfall and stemflow from measurements of rainfall in the open. Regression comparisons were also made for different gauges and different size classes of trees. Modifications to a regression program were made to deal with this work. 110, 114, 115, 116, 117, 701, 703

Further work for Pedology, using correlation and multiple regression analysis, has been done on the prediction of hydroxyl activity from determinations of silica, aluminium and iron. The processing of data to obtain corrected percentages of oxides in X-ray silicate analysis has continued and linear regression equations have been used in the production of sodium calibration lines and in bromine analysis. Probit analysis, linear

regression and tests of skewness and kurtosis in distributions of radioactivity counts have been applied in aluminium identification. 105, 107, 701, 703

Spectrochemistry. Collaboration has included the use of analysis of variance and correlation programs in comparisons of methods of analysis, and multiple regression in fitting and testing equations with nine predictors to provide suitable background corrections for certain biologically important elements. 201, 205, 206, 7

Biochemistry. Collaboration has involved the use of polynominal regression and analysis of variance in experiments on the spectific activity of different sugars with different methods of analysis. 305, 701

Plant Physiology. A computer program has been developed to analyse isotope elution data obtained from a series of experiments on onion root segments. The data from each experiment are used to construct an efflux curve which is resolved into a series of straight lines. A least squares method is used, starting with the last three points and adding successive points as long as the residual mean square does not increase. When a point causes this to happen it is used as the start of the next line in the series. The points and the lines are presented graphically on the plotter. The slope of each line is characteristic of a particular compartment in the root cells and yields values for the rate constant and the half-time of efflux from vacuoles, cytoplasm and free space in the root cortex. 407, 703

Continuing work has involved correlation, regression and analysis of variance for a number of randomized block and factorial experiments and sampling investigations dealing with nutrient contents and relationships in plant parts for various plants and crops. A joint account of a series of experiments on the growth and other properties of lemna[30] has been published. 401, 402, 408, 701, 703

Microbiology. The relationship between bacterial counts at various depths in peat and the chemical properties of the peat has been examined. The estimation of bacterial counts from the results of a five-fold dilution series with eight tubes at each dilution has been based on a method which computes the maximum likelihood estimate in terms of the logarithm of the density of the bacterial suspension instead of the density itself. The method uses the loglog transformation, weighting coefficients and maximum and minimum working deviates to provide an estimate of the logarithms of the density and fiducial limits for it. 503, 504, 701, 703

In a study of a soil ciliate, the volume of ciliates was estimated from measured diameters and tests of the value of a square root transformation and of the skewness of the distribution of volumes were made. 505, 703

Soil Fertility. Experimental designs currently in use in field experiments include randomized blocks, Latin squares, lattice squares, central composite designs and factorial arrangements, some of which have confounding or partial confounding and fractional replication. 601, 603, 607, 608, 609, 701

In an investigation of liming policy, exponential-type regressions of lime content of soil and lime loss on the pH value of the soil were fitted. The

regressions of yield and yield percentage on the pH value of the soil were linear or quadratic for barley, grain, grass and swede crops. These equations were then used to predict, for certain given annual lime applications, the annual values of the soil pH and the yield percentage of the three crops over a period of 20 years. Mitscherlich and quadratic response curves have also been used in a comparison of broadcast and drilled applications of phosphate fertilizer for four soil types. In two series of factorial experiments on barley and swedes a multiple regression program has been used to fit and test 460 polynomial regression equations to relate the yield response of various plant parts to the nitrogen, phosphorus and potassium applied in fertilizers. 607, 608, 701, 702, 703

An example of the combination of experimental results over a period of years is contained in a joint account of the results from a 3^3 factorial experiment on the nutrient requirements of herbage on deep peat[11]. Analysis of variance, correlation and regression programs have been used to examine the relationships between chemical composition and the size and variety of swedes. 114, 607, 608, 701, 703

Other investigations have made use of correlation, regression, analysis of variance, transformation, the solution of a cubic equation for 152 sets of coefficients generated from combinations of a number of parameters, and a number of individually tailored computer programs.
601, 603, 604, 606, 607, 608, 609, 701, 703

8. SOIL SURVEY

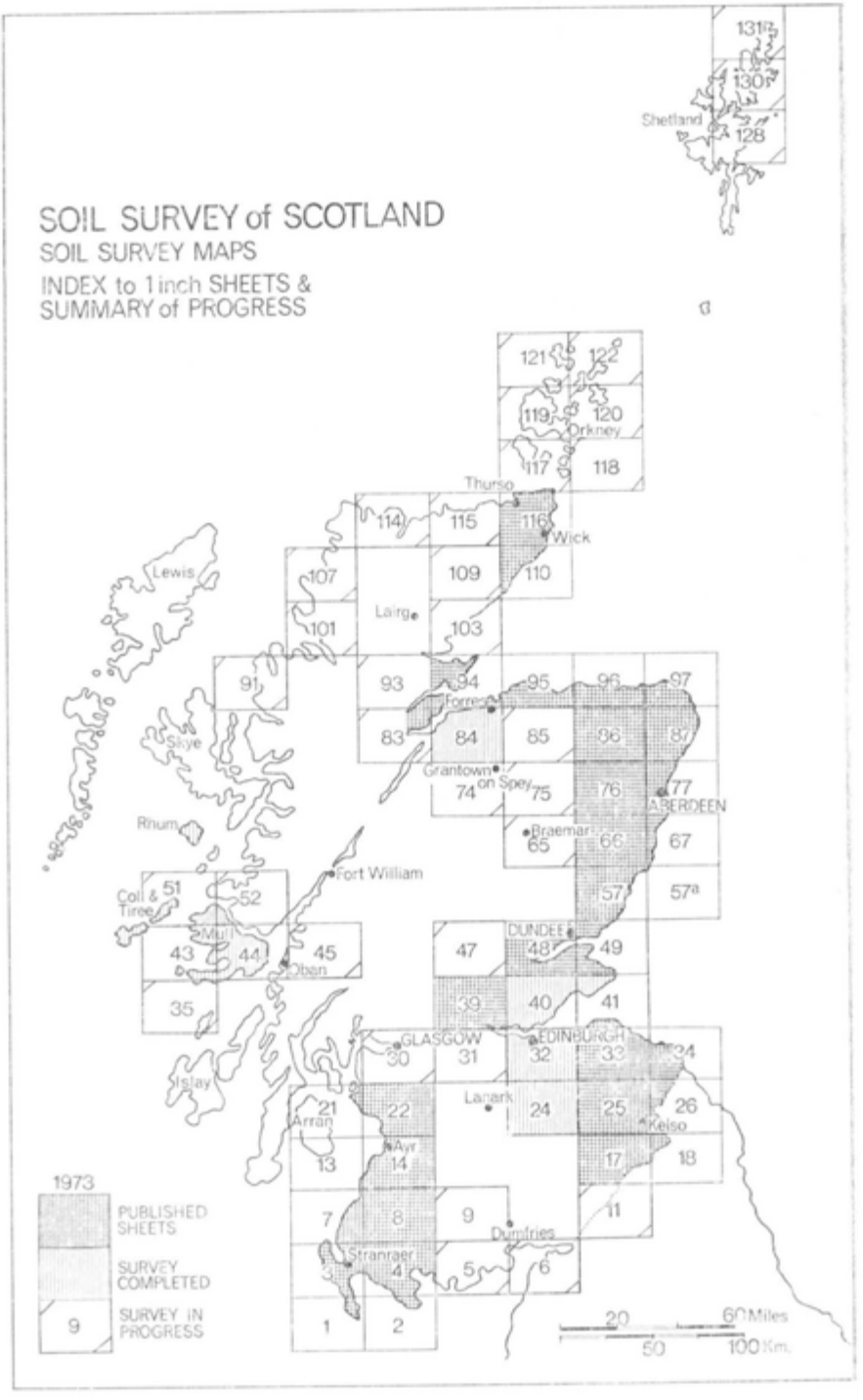
The main task of the Soil Survey of Scotland is to describe, classify and map the soils of the country. The classification is based on the characteristics of the soil profile and the nature of the parent material on which the soil is developed. Landscape features and the current land use are also recorded and, at the same time, a land use capability assessment is made, based on the limitations for use imposed by the soil, the site and the prevailing climate. Representative soil profiles are sampled for collaborative laboratory studies by other departments. The natural vegetation is also studied and the species composing the plant communities related to specific soils are recorded.

Mapping on a scale of 1:25,000 has now been completed over most of the eastern side of Scotland from John o' Groats to the Borders with the exception of a small area around Golspie in Sutherland. In the south-west, an area from Largs round to Dumfries has been completed. The comparatively smooth slopes with gentle to rolling relief which occur in these areas and through the Midland Valley are the result of glaciation followed by the overlay of till and associated fluvio-glacial deposits. Throughout this terrain it has been possible to map soil series and to group the series into soil associations on the basis of the common geological origin and composition of the parent material. To date 505 soil series in 120 soil associations have been mapped in an area of approximately 12,000 square miles.

North of the Clyde, on the western side of Scotland, the Highlands and Islands have a more rugged relief, ranging from sharply undulating to mountainous. In this region intense glacial scouring has taken place and glacial deposits are patchily distributed and often thin or absent. In such terrain soil series mappable on a scale of 1:25,000 are of only limited extent and the greater part can be sub-divided only as complexes of soils within a particular association. For instance, in the soil map of Mull, described later in the report, only 15 per cent of the area could be mapped as soil series; because of the extremely irregular pattern of relief 85 per cent is occupied by soil complexes. Each complex receives a name within a particular soil association, the dominant soil series which form it are named and a description of the relief is given. The percentage cover of the component soils in a particular complex may be obtained by superimposing a grid pattern, describing the soil at the intersects and analysing the result statistically. Thus a complex may be found to contain 45 per cent peat, 30 per cent peaty podzol, 15 per cent peaty gley, 5 per cent rock and 5 per cent water.

Systematic soil surveying has continued in ten areas and steady progress in soil and land use capability mapping has been maintained. There has been a marked increase in the demand for soil survey and land use capability information for specific areas, mainly from County Planning Authorities and consultant engineers; it has often been possible to meet such requests by rearrangement of the Survey programme.

During the six months from April to September 1973 approximately 620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1973
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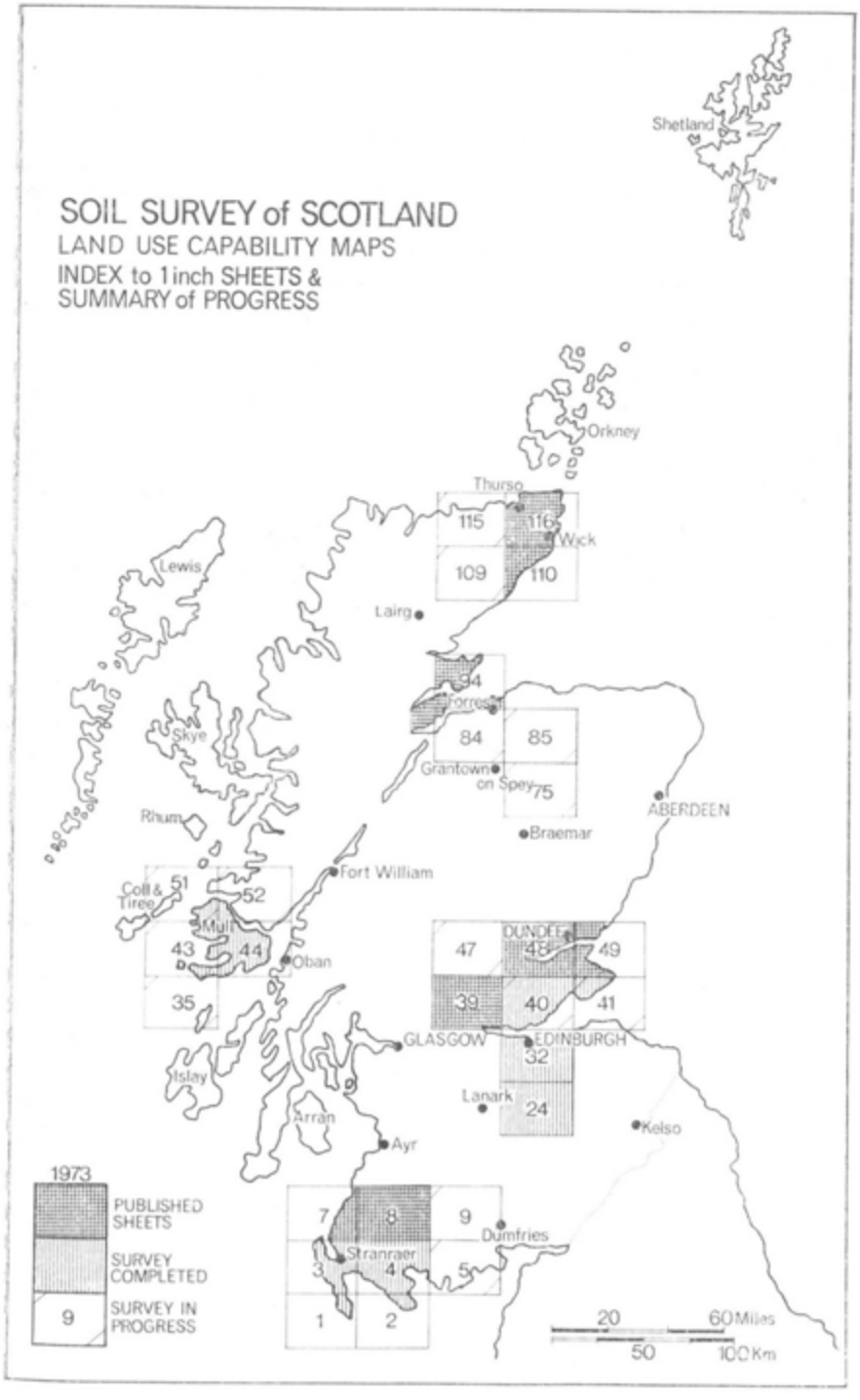
SOIL SURVEY of SCOTLAND
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1973
PUBLISHED SHEETS
SURVEY COMPLETED
9
SURVEY IN PROGRESS
20
60 Miles
50
100 Km

square miles (1600 km²) have been surveyed, 62 on Sheets 118, 119, 120 121, 122, and part 117 (Orkney), 60 on Sheets 109 (Auchentoul) and 115 (Reay), 33 on Sheet 85 (Rothes), 50 on Sheet 75 (Tomintoul), 40 on Sheet 74 (Grantown), 150 on Sheets 51 (Coll), 52 (Tobermory) and 53 (Ben Nevis), 35 on Sheet 47 (Crieff), 92 on Sheets 23 (Lanark) and 31 (Airdrie) and 100 on Sheets 5 (Kirkcudbright) and 9 (Maxwelltown). Three hundred and sixty-five profiles taken with the aid of the Smalley excavator have been described and sampled for analysis. 801

During the year Dr Yilmaz Oztan, Faculty of Forestry, Kardeniz Technical University, Trabzon, Turkey, and Dr Sadao Fukushi, National Institute of Agricultural Sciences, Nishigahara, Kita-Ku, Tokyo, spent some time with the Survey.

Members of staff attended meetings of the Ordnance Survey Advisory Committee, a conference of the Agricultural Development Advisory Service Lands Arm Research Group at Harrogate, a meeting of the British Society of Soil Science at Wye College and field excursions of the International Society for Plant Geography and Ecology in southern England. Mr J. C. C. Romans attended privately the Fourth International Meeting on Soil Micromorphology held at Kingston, Ontario, Canada. Dr R. Glentworth attended the FAO Expert Consultation on Land Evaluation for Rural Purposes at Wageningen, Holland, and the Ninth Session of the FAO European Commission on Agricultural Working Party on Soil Classification and Survey in Europe at Ghent, Belgium.

The department was represented on the Working Group on Drainage Investigations of the Department of Agriculture and Fisheries for Scotland and on the Soils Working Group of the Crops Committee of the Scottish Agricultural Development Council.

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

Approximately 62 square miles (160 km²) have been surveyed in the parishes of Firth, Evie and Rendall, and Birsay and Harray in the West Mainland and on the islands of Westray, Papa Westray, Graemsay and Stroma. Forty-three profiles have been described and sampled.

The most commonly occurring mineral soils mapped on the Mainland of Orkney were those of the Thurso Association, Bilbster, Olrig, Thurso and Camster series being identified; small areas of Tresdale series (Canisbay Association) were also found. Extensive areas of peat have been delineated and it has been found necessary to recognize a thin peat–Olrig series complex and, in hillside depression sites, a flush complex of peat, peaty gleys and colluvial soils.

The mapping of the soils of Westray and Papa Westray was completed. The southern limb of Westray (the districts of Skelwick and Rapness) is largely till-covered and two red or reddish brown tills were encountered—a sandy loam to sandy clay loam till that can be equated with the parent material of the Canisbay Association and a loamy sand till containing many red sandstones of the Eday Beds. Peaty gleys and cultivated peaty gleys were the most frequently occurring soils, with allied non-calcareous gleys. Drift cover in the west and north of the island is generally thin and the red

tills are absent. Soils of the Bilbster series are common and soils of the Thurso series, often developed on weathered rock, were found along the western seaboard in an area much exposed to the influences of gusting and consequent erosion. A complex of soils was mapped on the strikingly stepped slopes of Fitty Hill, with the Thurso series, or sometimes the Olrig series, developed on the treads and Bilbster or Camster series with ranker soils and rock outcrops on the steps. Around the base of Fitty Hill, in the area of Kirbist, a Canisbay variant was found with the Tresdale series on the treads. Soils of the Fraserburgh Association were mapped round many bays, with more extensive areas of blown shelly sand around Pierwall and the Loch of Tuquoy. Soils similar to those of Westray were met on Papa Westray, although the drift cover tends to be much thinner and freely drained soils developed on a red loamy sand drift over rock were found.

The principal soils of Graemsay are peaty gleys of the Canisbay Association and, around the farm of Fillets, the Countesswells series of the Countesswells Association. Small areas of the Bilbster and the Fraserburgh series were mapped and areas of poorly drained soils on weathered rock and on a loamy sand drift with sandstones of the Upper Old Red Sandstone were also found.

On the island of Stroma, just over one square mile (3 km²) in area, the soils are principally peaty gleys of the Canisbay Association (Canisbay series) which, on the eastern side of the island, have been cultivated and in some cases have plaggen horizons up to 60 centimetres thick. 801

Sheets 109 (Achentoul) and 115 (Reay)

Surveying has continued in three main areas, amounting to about 60 square miles (156 km²). The area around the headwater of the River Thurso in the western part of Caithness accounts for just over half. Shallow and deep blanket peat, together with peaty podzols of the Berriedale Association (Berriedale series), the Strichen Association (Gaerlie series) and the Countesswells Association (Charr series) are the predominant soils. A soil complex of peaty podzols and shallow peat, occurring on gently undulating or stepped topography, is a common mapping unit in all three associations.

Mapping in the Strath Naver district has been completed. The soils mostly belong to the Strichen Association and consist mainly of peaty podzols (Gaerlie series) and peaty gleys (Hythie series) which are commonly mapped in complexes with peat and rock, although brown forest soils (Fungarth series) have been delineated on some steeper slopes. Blanket peat is also a frequent mapping unit. Humus-iron podzols of the Corby Association (Corby series) and freely drained soils developed on sandy alluvium (Culnacoyle series) have been mapped along the River Naver.

Mapping has begun in the Achentoul district of Sutherland. The soils encountered so far are peaty podzols of the Countesswells Association and the Strichen Association, together with shallow and deep blanket peat.

In all three districts most of the land is uncultivated and has been placed in land use capability class 6. Such cultivated land as there is has generally been formed from reclamation of peaty podzols and is rated class 4. 801

Sheet 85 (Rothes)

Approximately 33 square miles (86 km²) have been surveyed and 33 soil profiles collected. The mapping of this sheet is now largely completed though some local revision and correlation, particularly in areas where the soils are developed on parent materials derived from Old Red Sandstone, have yet to be done.

Survey has been concentrated in two contrasting areas of the sheet. The first is an irregular area of arable land with scattered woodlands straddling the River Spey between Ballindalloch and Craigellachie. It lies for the most part between 550 feet (150 m) and 750 feet (225 m), but ranges from 250 feet (75 m) on the alluvial terraces of the Spey near Craigellachie to about 1000 feet (300 m) at Tamfarclas on Ballindalloch estate. The soil parent materials include till derived from acid schists and from granite and schist, together with compact glacial silt, fluvioglacial gravels and alluvium. There is an extensive peat moss just south of Archiestown. With the exception of the soils on glacial silt, which may have to be accommodated in a new association, the soils have been included in the Strichen, Aberlour and Corby Associations. On the arable lands the soils include cultivated podzols, non-calcareous gleys and peaty gleys.

The second area extends north-eastwards from the southern edge of the sheet up Glen Rinnes to Dufftown and beyond Dufftown to Tips of Cluny-more and Carran Hill. It is fairly evenly divided into upland moor and arable land, with some substantial blocks of planted forest. The moorland rises to 1250 feet (380 m) to 1350 feet (410 m) on the hills north-east of Dufftown, to over 1500 feet (450 m) on Jack's Hill, and to 1700 feet (520 m) on Hill of Achmore. The arable land ranges from 500 feet (150 m) to 1300 feet (400 m), with occasional patches of reseeded grazing to 1400 feet (430 m). The soil parent materials include tills derived from black schist and slate (Foudland Association), with some limestone present locally, acid schists (Strichen Association) and quartzite (Durnhill Association). There are patches of coarse sandy moraine in the valley bottom between Succoth farm and Dufftown. So far it has not proved practicable to distinguish on an Association basis areas where limestone is present. The tills are strongly leached and the soil response to normal agricultural liming does not differ from surrounding areas. Small sink holes occurring locally on the moor-land grazings have occasionally proved a hazard to sheep. On the arable land the soils are generally cultivated podzols, non-calcareous gleys and peaty gleys. On the moorland the upper fringe of the podzol zone is some-times present, with extensive areas of peaty podzols and associated peaty gleys and, on the highest ground, a limited development of subalpine podzol. 801

Sheet 75 (Tomintoul)

About 50 square miles (130 km²) have been surveyed and 20 profiles described and sampled. Most of the mapping was done in moorland country drained by the upper reaches of the Rivers Don and Avon. Much of the land cannot be rated better than class 6 of the land use capability classification, its use being limited to rough grazing.

Most of the soils are formed from granite, quartzite, acid schists and slaty rocks which, with their derived drifts, give rise to soils of the Countesswells, Durnhill, Strichen and Foudland Associations respectively. A mixed drift derived from granite and acid schists, the soil parent material of the Aberlour Association, also occurs but is inextensive. Limestone soils, provisionally grouped within Deecastle Association, are found in a few places.

Below about 2500 feet (760 m) peat and peaty podzols are dominant. The B_2 horizon of the peaty podzol can be compact rather than friable, and is sometimes replaced by an indurated B_3 layer, the upper part of which is iron-enriched. On limestone, the B horizons of the peaty podzols are very weakly developed. Above about 2250 feet (680 m) peat becomes less common and podzols give way to montane humus soils with black humose horizons below a thin surface organic layer.

Four complexes have been distinguished for granitic soils. The first occupies rugged relief and is a complex of montane humus and skeletal soils, while the second occurs on receiving sites and comprises wet mineral and peaty soils. The third complex has been distinguished on very steep slopes where the soils are immature and formed on stabilized and bare scree and on rock outcrops, and the fourth is found on the morainic topography of valley floors, the soils being mostly podzols and peat. Where the moraine grades downhill into fluvioglacial gravel a complex of the Corby Association has been separated. On the Strichen and Durnhill Associations two complexes have been distinguished, the one comprising montane humus soils and shallow peat and the other, occurring on steep slopes, including podzols and skeletal soils. 801

Sheet 74 (Grantown-on-Spey)

Systematic survey in this area at 2·5 inches to 1 mile occupied the first part of the field season when 20 square miles (52 km²) were mapped in the north-central and north-western sectors, an area lying between 1000 feet (300 m) and 2000 feet (600 m) and mainly dedicated to deer forests and grouse moors. Extensive hill peat occurs above 1700 feet (520 m), usually overlying a peaty podzol mineral profile with a well developed iron pan. Associated with the hill peat are the distinctive erosional patterns previously reported. These are particularly dominant in the catchment basin between Carn Dearg and Carn Moraig where the peat mantle is between 8 and 14 feet thick.

Mineral soils are mainly in the Aberlour, Corby, Countesswells, Dulsie and Strichen Associations, already described for this area. The triple division of the parent material of certain associations, as determined for Sheet 84 (Nairn), into till, shallow drift or shattered rock and deeply weathered rock continues to provide meaningful mapping units. Humus-iron podzols, peaty podzols and, to a lesser extent, peaty fragogleys are the characteristic major soil subgroups. 801

Sheets 66 and 67 (Banchory and Stonehaven)

In the land use capability assessment, based on the soil map and on field observations, about two-thirds of the area have been covered. 801

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

The second stage in the mapping of the soils of the parishes of Ardnamurchan, Morvern and Sunart has now been completed. Approximately 150 square miles (388 km²) have been mapped. Soil complexes were defined using soil type, soil pattern and relief (both altitude and average slope) and recorded by aerial photo-interpretations with ground control.

Seven soil complexes were required to represent soils of the Insch Association mapped within the gabbroic rocks north of Kilchoan, 13 to represent the soils of the granitic area (Countesswells Association) extending southwards from Strontian to Loch Linnhe in the east of Sheet 53, and 12 to represent the soils of the Moine schists, which have been placed within the Strichen Association. Pending correlation, none of these complexes has been named. Soil complexes described for the Isle of Mull have been used to map the basalt area of Morvern and the Mesozoic sandstones and shales of Ardnamurchan and Morvern. In addition to the complexes, soils of the Corby Association have been mapped on outwash gravel derived from schist and granite and soils of the Gruline Association on raised beaches bordering the Sound of Mull. The latter contain more basalt than in the type area in Mull, but schist and granite are still present. 801

Sheet 47 (Crieff)

Approximately 35 square miles (90 km²) of new mapping has been completed in the western part of Sheet 47 between Loch Earn and Loch Tay. This area includes a large portion of dissected moorland and upland rising to over 2000 feet (600 m). The soils encountered are all developed on drift derived from Highland Schists and most have been included in the Strichen Association. Limited deposits of fluvioglacial sand and gravel occur along the northern shore of Loch Earn and soils developed on these have been included in the Corby Association.

In the uplands north of Loch Earn the drift contains a high proportion of felsitic rock, giving a parent material which may be similar to that of the Aberlour Association of the Rothes and Grantown areas of the Northern Grampians. If they are considered sufficiently extensive and important to justify it, soils developed on this 'contaminated' drift will be separated from the Strichen Association.

In the north central part of Sheet 47 approximately 25 square miles (65 km²) of new mapping has been completed in the area centred on Glen Quaich between Kenmore and Amulree. This is another upland area, rising from 900 feet (275 m) on the glen floor to over 2000 feet (600 m) and including some very dissected terrain. The soils here are also developed on drifts derived from Highland Schist rock and have been included in the Strichen Association. 801

Sheet 40 and part 41 (Kinross and Elie)

The survey and revision of this district has now been completed, and in addition a survey was made of the Isle of May some six miles east of Anstruther. Thirteen soil profiles, including three from the island, have been described and sampled. Draft land use capability field maps have also

been prepared for the district. These have been examined and discussed with advisory officers from the East of Scotland College of Agriculture and a land use capability map will be published on the 1:63,360 (1 inch to 1 mile) scale. 801

Sheets 23 (Hamilton) and 31 (Airdrie)

The soil survey of National Grid squares NS 74 and 75, amounting to 77 square miles (200 km²), has been completed. This is an area in the neighbourhood of Hamilton, Motherwell and Larkhall and encompasses the designated area of the new town of Stonehouse. Most of the soils encountered have been assigned provisionally to the Bargour, Rowanhill and Sorn Associations and all are developed on till derived from various mixtures of Carboniferous sediments. The essentially similar nature of some soils of these Associations makes distinction very difficult when they occur in such close proximity. The soils are mostly imperfectly drained, with the Caprington and Glenpark series dominant. Alluvial soils and Bargour, Darvel and Darleith series are of secondary importance.

Soils on steeply sloping (15-25°) land bordering the Clyde and its tributaries have given rise to a new mapping unit. On these slopes the soil pattern is complex, consisting of modified phases of known series, flushed soils, colluvium and sedentary soils. Unlike the mapping unit 'mixed bottom land' these areas are usually utilized for grazing and have at one time been cultivated; the classification of their soils is still under consideration.

Approximately 15 square miles (35 km²) of new mapping and some revision have been carried out on the part of Sheet 31 extending north of the Forth and Clyde canal. This completes the mapping of this part of Stirlingshire. All the soils encountered have been described previously. The soils occurring south of Fintry have been included in the Darleith Association and those between Kilsyth and Denny in the Darleith, Darvel, Giffnock and Sorn Associations. 801

Sheets 5 (Kirkcudbright) and 9 (Maxwelltown)

Approximately 100 square miles (260 km²) have been surveyed and 57 profiles described and sampled. Mapping has been concentrated in the west of the area—in the Water of Ken Valley and the country west of the River Dee. This completes the survey of the areas bordering the published Sheets 7 and 8 (Girvan and Carrick) and 1/2/3/4 (Kirkmaiden/Whithorn/Stranraer/Wigtown). The soils belong mainly to the Ettrick, Dalbeattie, Yarrow and the provisionally established Castle Douglas Associations. The Ettrick Association soils are most widespread, with the Brochloch, Stroanpatrick and Achie complexes the most commonly occurring mapping units. Of the soils in this Association the peaty gley Dochroyle series and the peaty podzol Dod series are the most widespread in the northern part of the area and brown forest soils in the area to the south. Soils of the Dalbeattie Association have been mapped on the eastern part of the outcrop of the Cairnsmore of Fleet granite intrusion, but areas of soil sufficiently uniform to be mapped as soil series are rare and the Garrary

and Loch Fleet complexes are the most commonly encountered mapping units. Soils of the Yarrow Association are mainly brown forest soils of the Yarrow and Cairnside series. Soils assigned to the Castle Douglas Association are mainly imperfectly drained brown forest soils occurring on drumlinoid reddish till deposits derived from greywacke and shale in the area between Tongland and Dornell. Areas of both deep and shallow blanket peat occur commonly in upland areas. 801

Special Surveys

Sullom Voe, Shetland: A soil and land use capability survey of an area of approximately 15 square miles (40 km²) lying to the east of Sullom Voe in Shetland was made at the request of the North of Scotland College of Agriculture. The geology consists of metamorphic rocks, chiefly schists and quartzites in the south and a granite injection complex in the north. Much of the area is covered by peat, but peaty podzols and peaty gleys of the Countesswells and Strichen Associations and soils developed on loamy alluvium (Waterton and Lochside series) were also mapped. Class 4 land occurs on the arable and former crofting areas, class 5 land on the gently sloping areas of peat and peaty soils at altitudes below 300 feet (100 m) and class 6 land on eroded peat and all land above 300 feet (100 m). Maps on the scale of 6 inches to 1 mile and a brief report have been prepared 801

Baltasound, Unst, Shetland: Soil and land use capability maps on a scale of 6 inches to 1 mile of about 4·5 square miles (14 km²) of the Baltasound area of Unst were prepared at the request of the North of Scotland College of Agriculture and a report has been written. Soils of the Leslie and Corriebreck Associations were mapped. 801

A9 Trunk Road: Soil conditions between Avielochan and Bogbain, Inverness-shire, along the alternative routes for the proposed new A9 trunk road have been investigated at the request of the Scottish Development Department. Some 20 square miles (52 km²) have been mapped on a scale of 6 inches to 1 mile. The examination of peat deposits along specific alignments, for instance at Badengorm and Slochd Mor, has been the responsibility of Peat Survey. 112, 801

Stonehouse New Town: The soils of 1:25,000 Sheet NS 74 have been surveyed at the request of the East Kilbride Development Corporation and a report on the soils and land use capability, with maps, has been provided. 801

Low Todhill Farm, Ayrshire: A survey on the 1:25,000 scale of the soils of Low Todhill Farm, covering 94 acres (38ha), has been made at the request of the West of Scotland Agricultural College. 801

Vegetation Surveys

The description of the plant communities for a bulletin on the vegetation of the Lowlands and Southern Uplands of Scotland has been completed. Only the chapter linking the plant communities with the genetic soil groups remains to be written. The vegetation of the above-mentioned Sullom Voe and Baltasound areas of Shetland was sampled and recorded in conjunction

with soil surveys of these areas and reports on the plant communities have been prepared. During May and July the vegetation of Sheet 85 (Rothes) was sampled and recorded by plant sociological methods. These records will provide the basis for an account of the vegetation to be included in the soil memoir of the area.

In collaboration with Peat and Forest Soils, a visit was paid to the Drynachan area in Nairnshire to locate sites for sampling peat and relating its physical and chemical characteristics to the plant communities growing on it, and re-mapping of the permanent quadrats at Scare Hill, Monymusk, Aberdeenshire, has been carried out.

The field excursion of the International Society for Plant Geography and Ecology in July gave opportunities for comparison of the plant communities of southern England with the vegetation of Scotland, and also provided useful contact with visiting continental plant sociologists. 802

Soil Micromorphology

Soil thin sections relating to over 20 Soil Survey profiles have been prepared and examined and a limited amount of sampling and thin section preparation has been carried out for Microbiology, Pedology and Biochemistry. The method of impregnation of soil samples has been modified and the acquisition of a large, steel, heated vacuum impregnation vessel has made it possible for 30 soil samples ($7{\cdot}5 \times 5{\cdot}5 \times 5$ cm) to be impregnated simultaneously under controlled conditions. Much of the soil material collected during the latter half of the year has had to be frozen and stored pending the delivery of a freeze-drying unit. Ten soil monoliths have been prepared and included in the Soil Monolith Library. A set of profiles from south-east Scotland have been sampled in detail for micromorphological investigations and comparison, to help differentiate the characteristics of brown forest soils.

An account of the genesis of alpine and upland soils in Britain[95] was presented to the Fourth International Working Meeting on Soil Micromorphology at Kingston, Ontario, Canada.

Soil samples from recently deglaciated material collected on Elephant Island (Antarctica) in the course of geomorphological investigations made by the 1970/71 Joint Services Expedition have been examined. They have provided useful information concerning the earliest stages of development of Scottish soils. 804

Other Survey Work

Collaboration with the Department of Agriculture and Fisheries for Scotland and with the three Scottish Colleges of Agriculture has continued on such matters as drainage and reclamation problems, the selection of sites for future drainage development work and the monitoring of existing experiments, and the selection of sites for crop trials. An extensive range of soils of differing parent materials and pedological drainage conditions has been sampled for an investigation designed to compare laboratory soil levels of trace elements, including molybdenum, with herbage contents. 205, 609, 801

Liaison has also been maintained with the Forestry Commission, the

Nature Conservancy, the Hill Farming Research Organization, the Animal Diseases Research Association, the Highlands and Islands Development Board and the Scottish Development Department and with other departments of the Institute.

Excavations at archaeological sites at Skara Brae, Quanterness and Maeshowe in Orkney and at Raigmore, Inverness-shire, have been examined and discussed and various soils from the sites sampled for analysis and micromorphological investigation. Many requests for information on soils in particular localities have been dealt with, from individuals, planning consultants, forestry interests, County and Regional Planning Authorities and other public bodies. Talks have been given on the work of the Survey and soils demonstrated in the field to students from various departments of the Universities of Aberdeen, Edinburgh, Glasgow, Bangor and East Anglia. 801

Maps, Memoirs and Cartography

A systematic soil survey on the scale of 1 inch to 1 mile covering Sheet 94 (Cromarty and Invergordon) has been published. The colour proofs for the soil map of part Sheets 35/36/43/44/51/52 (Island of Mull) and for the land use capability map of Sheets 1/2/3/4 (Kirkmaiden/Whithorn/Stranraer/Wigtown) have been corrected and returned to the Ordnance Survey for final printing. The colour proof of the soil map for combined Sheet 24/32 (Peebles/Edinburgh) has also been received. A scribed negative and colour model for the land use capability map of this area has also been submitted to Ordnance Survey for colour proofing. A 1 inch to 1 mile map entitled Moray Firth: Land Use Capability, printed locally in two colours, was prepared for inclusion in Special Report No. 9 of the Highlands and Islands Development Board[41].

Twenty-six sheets have been added to the uncoloured 2·5 inches to 1 mile soil survey field sheets for restricted circulation, bringing the total to 102. The recent additions are seven sheets from Easter Ross, 14 from North East Scotland, three from South East Scotland and two from West Scotland. 801

The Nairn/Cawdor vegetation map on the 2·5 inches to 1 mile scale is nearing colour proof stage. Fifteen negative colour masks have so far been prepared and it is anticipated that at least seven separate colours will have to be employed in the final printing. 804

The memoir that accompanies Sheet 7/8, The Soils of Carrick and the Country round Girvan[39], has been published. The drafts of the memoirs for Sheet 48/49 (Perth/Arbroath) and Sheet 110/116 (Wick/Latheron) have been completed and others are in preparation. 801

SOILS OF THE ISLAND OF MULL

As the soil map of part Sheets 35/36/43/44/51/52 (Island of Mull) has been prepared, a summary of the principal findings can now be presented. 801

The Island of Mull lies close to the western seaboard of the Scottish

mainland and has an area of some 346 square miles (896 km²). The southern and eastern parts are mountainous, with an average summit height of some 2300 feet (700 m); the highest point, Ben More, is 3169 feet (966 m). The northern and western areas are less mountainous, summits reaching only 1200-1300 feet (370-400 m). Almost 50 per cent of the land area lies below 500 feet (150 m), 33 per cent between 500 and 1000 feet (150-330 m) and 18 per cent over 1000 feet (300 m). The coastline is deeply indented by many sea lochs, and there are two major freshwater lochs, Loch Ba and Loch Frisa.

The island is now sparsely inhabited, supporting a population of approximately 2000, as compared to over 10,000 in 1821. The Highland Clearances and continuing trends of rural depopulation account for the fall in numbers. The main sources of employment are agriculture, forestry, tourism and fishing, the last relatively unimportant.

Mull owes its shape and relief to the type and structure of the rocks of which it is composed and to their reaction to the influences of changing climate through time. Although rocks of Precambrian and Mesozoic ages are found, the bulk of the rocks in the island were formed during a period of vulcanicity in the early Tertiary and the evolution of the island must date from this time. Considerable speculation exists among geomorphologists over the sequence of events during the Tertiary period after the eruptions had ceased. There appears to be little doubt, however, that the major valley system of the island was established by subaerial erosion along lines of structural weakness at this time, when climatic conditions were deteriorating from warm and fairly moist to cold, culminating in the onset of the Pleistocene glaciation. The abrupt rise of the island from the continental shelf has been quoted as evidence that Mull was an island long before glacial times. Whether Mull itself was separated from the mainland before the glacial overdeepening of the Sound of Mull is a moot point. There is, however, evidence from several localities on the west coast of the existence of a pre-glacial wave-cut platform between 100 and 160 feet (30-48 m). It has been suggested that some raised beaches below 100 feet (30 m) may be the remains of pre-glacial beach levels. The available evidence suggests that there was considerable marine erosion prior to the major glaciation of the West Highlands and the isles to the west of Mull (Iona, Staffa, Treshnish group) almost certainly became detached from Mull sometime during the Pliocene period, even though Mull itself was still attached to the mainland. The sea-bed to the west of Ardmeanach peninsula was undoubtedly overdeepened as a result of the confluence of ice from the Mull ice-cap and the mainland, and both Mull and the smaller western islands certainly existed as separate entities at the end of the major glacial period.

During the major glaciation, Mull was completely inundated by ice. The higher parts of the island supported their own ice cap which, judged by the distribution of erratics of mainland origin, resisted and diverted the flow of mainland ice to north and south. Glaciation removed the weathered mantle which would presumably have developed prior to glaciation, emphasizing the differential erosion of the hard and soft rocks and the lines of weakness

along which erosion had already commenced, and depositing a thin drift in the few parts of the landscape that were protected from the full force of the ice stream. At this time a series of elongated drumlins was formed in the vicinity of Bunessan, indicating that ice which had skirted the south flank of the Mull ice-cap had taken up a north-westerly direction of flow. The retreat of the major ice field was followed by a resurgence of valley glaciation, confined to the central higher hills; surrounding areas were subject to a periglacial climate. Snowfield nivation, frost shatter of exposed rocks, landslips, mudflows and the sorting of the deposits by frost action were dominant throughout most of northern and western Mull. Around the mouths of the glaciers outwash fans were formed of material brought down as moraine, and parts of these outwash fans were re-sorted by changes in sea level to form raised beaches. It was in this period that the parent materials of present-day soils were largely formed.

From the outset of soil survey operations it was obvious that the major mapping unit would have to be the soil complex. This raised difficulties, a soil complex being very unspecific as a unit for the transfer of information, and, commensurate with the time available for survey, a system was devised to minimize the difficulties of both definition and interpretation. In the event, 85 per cent of the island was mapped in complex units, 10 per cent as peat and only 5 per cent as soil series.

Soil complexes were defined using the following characteristics: genesis of the parent material (rock type and formative process); soil genesis (including climatic effects); landscape pattern; soil pattern; vegetation pattern. In practice these characteristics interact and the resultant complexes prove to be landscape types, though with a fairly high degree of internal variation. The stages in the survey consisted of the recognition of the various soil complexes through their expression as 'landscape,' both on aerial photographs and on the ground; field checking for correctness of aerial-photo interpretation and concurrent soil description; and, finally, detailed inspection of those complexes which were most extensive and about which the most detailed information was likely to be required. Statistics co-operated in the selection of sampling areas, which was based on a major grid system with randomized nest sampling for checking and for added detail.

For each of the soil complexes the following information can be provided: location of complex; extent of complex; variation in taxonomic units within the complex; amount of each taxonomic unit within the complex, within known confidence limits; morphological descriptions of each unit; indications of the variation in each recorded morphological character within and between complexes; a detailed description of the relationships between the various units of the complex; standard chemical and mineralogical data on most soils.

Sixteen soil series have been recognized and mapped; a further 33 taxonomic units have been recognized and grouped into 23 soil complexes. The mapping units, series and complexes, have been grouped together on the basis of differences in parent material into 12 soil associations.

Association	*Parent Material*
Boyndie	Raised beach sand derived from acid rocks.
Corby	Raised beach gravel and sandy gravel derived from granite and schist.
Countesswells	Colluvium derived from granite.
Darleith	Colluvium, moraines and residuum from olivine basalt.
Fraserburgh	Raised beach and wind blown shell sands.
Gruline	Raised beach and outwash gravels derived from mixed acid and basic rocks.
Inchkenneth	Colluvium and till derived from Mesozoic rocks.
Lussa	Strongly indurated valley moraine derived from mixed acid and basic igneous rocks.
Sourhope	Stony colluvium derived from andesite.
Strichen	Shallow drift and colluvium derived from mica schist.
Tarves	Till derived from schist, granite and basalt.
Torosay	Stony colluvium derived from mixed acid and basic igneous rocks.

In addition, the following miscellaneous soils have been mapped: dune sand; alluvium; peat; peat alluvium; and saltings.

A general description of the physiography and the geomorphic evolution of the landscape types associated with each of these soil associations is given below, with comments on the soil complexes differentiated and the major soils recognized.

Boyndie Association

Soils of this Association are of very limited extent (less than 1 per cent) and occur principally in the Ross of Mull, Iona, Inchkenneth and Gribun. The parent material is a raised beach sand, derived from granite and schist on the Ross of Mull and Iona and from Mesozoic sandstones on Inchkenneth and at Gribun. The Mesozoic sandstones were themselves derived from the Highland Schists. Two soils series have been recognized, the freely drained iron podzol Boyndie, which is largely croft land and cultivated, and the peaty gley Ballindarg, which is usually under permanent grass.

Corby Association

Corby Association is more extensive than Boyndie, although still forming less than 1 per cent of the soils of the island. The parent material, raised beach gravel and sandy gravel, is derived from the Ross of Mull granite and the schists of the same district. The soils have been mapped as Corby, Tarbothill, Mulloch and Mundurno series, all of which have previously been found in north-east Scotland. The podzolic soils, Corby and Tarbothill series, form the arable croft ground, the gleyed and peaty gleyed soils, Mulloch and Mundurno series respectively, are either enclosed grazings or unimproved pasture.

Countesswells Association

Soils of the Countesswells Association (3 per cent of the island) are confined to the area of outcrop of the Ross of Mull granite. Although other granitic rocks occur on Mull they are usually so veined by basic cone sheets that the derived soil parent material is an intimate admixture of the two rock types. Two soil complexes, Erraid and Ghlinne Mhoir, were mapped. Both are easily recognizable topographically, the Erraid complex being dominantly hilly and the Ghlinne Mhoir complex dominantly flat with small rocky knolls. The Erraid complex is composed of peat (40 per cent) in gullies and small hollows in the rock surface, rock (20 per cent) and the peaty lithosol Spinneag series (25 per cent), a thin peaty layer over rock. Other soils encountered are the peaty gley Drumlassie series and the peaty podzol Charr series. The Ghlinne Mhoir complex comprises over 70 per cent peat, with the remaining 30 per cent small rocky knolls sometimes with soils similar to those within the Erraid complex. As might be expected, both the Erraid and the Ghlinne Mhoir complexes are rough grazing.

Darleith Association

Soils of the Darleith Association occupy 45 per cent of the island. The basalts are a sequence of flow lavas, often individually thin but cumulatively of great thickness. Due to gaseous escape by release of pressure, each flow as it erupted developed a slaggy top which, on cooling, formed a vesicular basalt with porous, friable texture. The interior and base of the flow cooled and solidified relatively slowly to form a more massive and less porous basalt. This initial differentiation in texture is of great importance in the subsequent weathering of the rock, for the vesicular basalts weather readily while the more massive types are resistant. The type of landscape to which this gives rise is often referred to as trap featuring. The trap feature is the basic unit of the landscape pattern but the soils and vegetation found vary according to the climatic influences at work. These variations are most noticeable with increasing altitude and the soil complexes were defined accordingly.

Knockan Complex. The dominant soil is Darleith series, a brown forest soil of low base status. It is freely drained and sometimes has compacted lower horizons. The typical profile consists of an A_1 horizon of dark brown silty loam with a very fine subangular blocky structure overlying a marginally redder silty loam B_2 horizon. The C horizon, where present, consists of dark brown loam with coarse platy structure and a moderate degree of induration. It has been encountered at depths ranging from 7 to 26 inches (18-22 cm). The Darleith series accounts for 65 per cent of the complex. Fifteen per cent is accounted for by the Glenaros series, which has surface horizons identical to those of the Darleith series. There are no B or C horizons, however, as rock lies directly beneath the A_1. Other soils found are the Treshnish series, a brown forest soil with imperfect drainage, and the poorly drained gley Drinnan series, where the impedance is usually caused by rock or induration at shallow depth. The gley soils are not similar to those of their Ayrshire counterpart, the Amlaird series, being both stonier and lighter in texture. Rock outcrops frequently and peat and

peaty gleys sometimes occur where hard rock is close to the surface. The brown forest soils support an *Agrostis-Festuca* grassland with *Pteridium*, while the shallow lithosols are frequently dominated by *Calluna* and *Erica cinerea* and the peaty gleys and peats by *Molinia*, *Scirpus caespitosus* and *Eriophorum* spp. The landscape pattern of the Knockan complex consists of strong step featuring, with the deeper soils developed at the inner angle of the tread, adjacent to the next riser; the tread itself and the outer angle are associated with shallow soils.

Mishnish Complex. Above 500 feet (150 m) brown forest soils rapidly die out and the major soil subgroups most frequently encountered are iron podzols, intergrading to brown forest soils as their surface horizon becomes less organic and to peaty podzols with thin iron pan with increase in surface humus. Despite the usually steep slopes, organic topsoils are common because of the higher rainfall and cooler conditions obtaining at higher altitudes. There is reason to believe that were it not for the high basicity of the parent material podzolic soil types would be encountered at much lower altitudes.

The Arle series is the major soil unit, occupying approximately 30 per cent of the complex. A surface humus horizon 4 to 12 inches (10-30 cm) thick is underlain by a dark reddish brown loam B_2 horizon. The B_3 and C horizons, where present, are of a loam and sandy loam texture, the C horizon often showing coarse platy structure. On drying the profile sometimes reveals a very weak A_2 horizon separating the surface organic horizon from the underlying B_2. The Arle series has been classified as a humus-iron podzol. Intergrades to the peaty podzol Baidland series occupy 15 per cent of the complex. Other soils found in the complex are the peaty gley Airigh series (12 per cent), the Darleith series (8 per cent), a peaty lithosol, Coarach series (7 per cent), and several other soils of very minor extent.

The iron podzols are characterized by dry heath with *Calluna* and *Erica cinerea*, while the peaty podzols support a slightly more moist vegetation with *Calluna* dominant and *Molinia* present. On some rocky ledges where shallow peat is developed *Molinia* and *Scirpus caespitosus* become dominant.

Cruachan Complex. The Cruachan complex exhibits the step topography characteristics of all the areas mapped as Darleith Association on Mull, but here the regional slope is much less. As a consequence the dominant soils are peats (40 per cent) and the peaty gley Airigh series (20 per cent). Although podzols are found within the complex, they are as a rule confined to the steeper scarp slopes and are never extensive.

The Airigh series is a stony loamy soil, shallow (bedrock was within 30 inches (75 cm) in 80 per cent of the soils examined) and with a high humus content reflected by very low chroma in all horizons. A surface humus horizon, on average 9 to 13 inches (20-33 cm) thick, is succeeded by an A-B horizon of dark reddish brown stony loam. Many stones within the horizon are weathered and the horizon is gleyed, though all colours are muted due to extensive humus staining. In some soils more distinct horizon formation may be encountered, but the general characteristics described

above still apply. Airigh series contrasts sharply with the peaty gley Myres series of the Kilmarnock district in texture, structure, stoniness and depth.

Surface conditions within the complex are generally wet and, except where locally enriched by flushes, the peat has a low pH. The vegetation is dominated by *Molinia, Scirpus caespitosus, Erica tetralix* and *Calluna*. Rock outcrop is frequent.

Drise Complex. The Drise complex occupies mountain summit sites above approximely 1200 feet (365 m), although in exposed conditions it is found at lower altitudes. The soil types are very immature podzols and peaty gleys, with many lithosolic soils. The zone as a whole is characterized by the active frost heaving of the soils during the winter months, forming stone stripes and patterned ground and rupturing turf by creep and hydrostatic pressure. Loam and sandy loam textures are frequent, as are very coarse platy subsoil structures. Occasionally, however, the calcium-bearing secondary mineral in the vesicles has enhanced the calcium content of the basalt and slightly richer patches of soil occur. It is probably these that provide conditions suitable for *Koenigia islandica* on part of Ardmeanach peninsula. The major vegetation type of this facet is montane heath, with *Rhacomitrium lanuginosum, Dicranum* spp., etc.

Gribun Complex. Along much of the coastline high sea cliffs with grassy stabilized screes have been developed. These very conspicuous landscape units have been distinguished from the somewhat similar Knockan complex, on the basis of both land form and soils, and mapped as the Gribun complex. The soils are often disturbed by movement and exhibit complex profiles. Most sites are occupied by *Agrostis-Festuca* grassland, heavily grazed in the more accessible parts. In the less accessible areas goats have been introduced in an effort to discourage sheep foraging and consequent loss of stock.

Fraserburgh Association

Confined to the western coasts of Mull and Iona, soils of the Fraserburgh Association occupy less than 0·5 per cent of the island. Despite this their occurrence is well known locally, for they have long been a source of shell sand for land improvement purposes. They occur as raised beaches and wind blown sand, the machair of the Western Isles, now subject to much ecological pressure through increasing tourism. The excessive use of such areas for recreational purposes is destroying the turf cover and accelerating erosion.

Gruline Association

Although occupying only 1·5 per cent of the surface of the island, soils of the Gruline Association are amongst the most important agriculturally. They occur on level and gently sloping raised beach and glacial outwash deposits. The parent rocks of the essentially gravelly deposits are a range of acid intermediate and basic igneous rocks from granophyre to gabbro. The raised beaches and outwash fans were produced by the valley glaciers of the Highland Re-advance that occupied central Mull. Material brought down by the glaciers as moraine was re-sorted by both marine and fresh-

water action to form two distinct terraces, the lower (Gruline series) not indurated and the upper (Torranlochan series) almost always indurated, sometimes very strongly. During and shortly after periods of heavy rain, the upper terrace is frequently completely saturated and surface run-off occurs. In the profile, however, the soil shows little sign of these periodic saturations. In receiving sites a peaty surface horizon has developed, producing on non-indurated parent material the peaty gley Scallacastle series and on indurated parent material the peaty gley Cruinn series. A peaty podzol, Drumlang series, is also developed above an indurated layer.

Round the southern and eastern coasts of Mull a narrow rock platform is frequently found at approximately 25 feet (7 m) O.D. Beach deposits have accumulated in cracks and crevices in the platform, but it is essentially covered by peat. The pattern formed by peat and rock together with occasional occurrences of Scallacastle series is intricate, and the entire area has been mapped as Kilpatrick complex.

Inchkenneth Association

The Tertiary basalts of the Isle of Mull erupted on to a land surface composed partially of metamorphic rocks and partially of a condensed sequence of Triassic, Jurassic and Cretaceous rocks. Where the Mesozoic rocks now reach the surface, soils of the Inchkenneth Association are found. The parent material varies widely from sandstone and sandy limestones to silicified chalk, but it has not been found possible to map the soils derived from these various rock types separately. The Association is therefore one of more than usual variation. Two soil complexes have been mapped, the Balmeanach, composed principally of brown forest soils both freely and imperfectly drained, and the Ohirnie, composed of peaty gleys and peaty podzols, both usually shallow.

The Inchkenneth series is a brown forest soil with free or only slightly impeded drainage varying considerably in depth from a few inches to over 6 feet (2 m). It is most fully developed on Inchkenneth Island and at Balmeanach Farm in the west of Mull. In the east of the island the series is considerably more stony and liable to contamination by basalt colluvium. This series is the only soil of the Association suitable for cultivation, the others being used for grazing.

Lussa Association

In central Mull the ice has left classic evidence of its presence in the shape of hummocky moraine deposits in well developed U-shaped valleys. Terminal and lateral moraines (Loch Don and Glen Forsa), medial moraines (Upper Glen Forsa), push moraines (Kinlochspelve) and general ground moraines can be clearly distinguished. Some areas of fluvioglacial materials, too small in extent to justify a separate grouping, have been included within this association.

Although the parent rocks are similar to those that contribute to the Torosay Association (granites, gabbros, basic cone sheets, pneumatolysed basalts, schists, etc.) the morainic material can be separated very easily both on topographic and on soil profile evidence. Soils in the Lussa Association

all possess a strong, olive-coloured indurated horizon, usually within 30 inches (75 cm) of the surface of the mineral soil. Three soil series account for 90 per cent of the association—the peaty gley Lussa, the peaty podzol Garmony and the brown forest soil Killean. The Lussa series consists of 3 to 15 inches (7-38 cm) of peat overlying either a gleyed A-B horizon, heavily peat stained, or a very dark grey brown gleyed B_2 horizon. The loam texture of these horizons contrasts sharply with the indurated olive grey sandy or fine sandy loam of the underlying C horizon. A coarse platy structure is usually associated with the induration which is encountered at an average depth of 20 inches (50 cm) from the surface. The Garmony series has depths of humus similar to the Lussa, but the peat is succeeded by a dark brown to greyish brown loamy A_2, a strong thin iron pan and a brown to yellowish brown B_2 horizon of freely drained loam. The indurated olive or olive-grey C horizon varies in texture from fine sandy loam to fine sandy gravel. The basal part of the B_2 may be heavily stained by percolating humose water that is impeded by the underlying induration. After rainfall, water may run freely from this horizon even though the A_2 and upper part of the B_2 are relatively dry. The Killean series, found usually only below 250 feet (75 m) has an A_1 horizon of very dark brown loam, sometimes cultivated, overlying a dark reddish brown B_2 horizon, also loamy. The C horizon comprises the typical olive grey indurated sandy loam or stony fine sandy loam. In the gley and podzolic soils it is not unusual to find an iron pan sealing the indurated layer.

Of the three soil complexes distinguished, Gorten is of very limited extent, being confined to the Loch Don and Loch Spelve sand and gravel moraines; Knockantivore is most extensive, occupying approximately 30 square miles (77 km^2), while Talaidh is confined to very steep slopes. The typical pattern within the Knockantivore complex is of hummocks of indurated moraine, consisting of peaty or iron podzols (Garmony and Clachach series) or peaty gleys (Lussa series), separated by areas of deep peat. The Talaidh complex is found on the steep flanks of the U-shaped valleys. Induration is here very close to the surface and shallow phases of the Garmony, Clachach and Lussa series are found.

Sourhope Association

Andesites, giving rise to soils of the Sourhope Association, are found only on the flanks of the Loch Don anticline. Two complexes have been distinguished, the Stotfold, consisting of brown forest soils, brown lithosols, flush gleys and rock, and the Clenamacrie, consisting of peaty gleys, peaty podzols and rock. Slopes carrying Stotfold complex are usually steep and given over to scrub woodland and rough grazing. The Clenamacrie complex is utilized only as rough grazing.

Strichen Association

Despite the frequent presence of areas of schist and gneiss within the volcanic complex, no soils attributable to the Strichen Association have been found in central Mull. The effect of the schist and gneiss is small compared with that of the large igneous masses that penetrate them. On

the Ross of Mull and on Iona the outcrops of the Moine schists form low hilly tracts of land. Only one soil complex, the Assapol, has been distinguished. Shallow and deep peat and rock, together with a stony phase of the Hythie series (peaty gley) are the important components, but a peaty lithosol, the Saorphin series, also occurs widely. Some podzols are found, often on steeper sites where a colluvial accumulation has taken place.

The ground is chiefly used for rough grazing and forestry. Parts of the complex might be suitable for regeneration of grassland by surface seeding techniques.

Tarves Association

During the major glaciation of Mull, ice of mainland origin was diverted round the central part of the island by a strong minor centre of ice accumulation there. One of these diverted ice streams swept round the south of the island and assumed a north-westerly course, passing over the western part of the Ross of Mull. It was responsible for the formation of a number of drumlins which are now separated by peat. The drumlins consist of a till, a mixture of basalt, schist and granite, with clay loam texture. Below the topsoil, an indurated layer about 15 inches (40 cm) thick is frequently found overlying softer till with strong ochreous mottling. The soils have been correlated with the Tarves, Thistlyhill, Pitmedden and Pettymuck series, previously mapped in eastern Scotland.

A soil complex, the Poittie complex, was mapped where till had lodged in hollows in the granites and schists. Such areas were at one time the sites of small crofting townships or of summer grazings. The major drumlin areas are utilized as arable ground, but the areas of Poittie complex are now only rough graing.

Torosay Association

This association, which occupies 24 per cent of the island, is found in the central south and south-east. The rock types included within the central igneous mass of Mull vary widely from acid granophyres through intermediate and basic cone sheets to basic gabbros. The main characteristic of all the rocks, however, is that they are very hard. Even the gabbros have extremely coarse structure and have not weathered extensively to provide the fertile residuum which characterizes their occurrence in some other parts of Scotland. The resistance to erosion has ensured that central Mull remains a mountainous area. Colluvial creep of weathering products down the steep slopes has resulted in mixing of material derived from both acid and basic sources, although one or the other type may assume slight dominance locally.

The central mountain area with its higher precipitation provided a gathering ground for snow and for a time at the end of the Ice Age supported a valley glaciation. The interfluves between glaciers suffered from intense frost action during the glaciation; crest sites suffered denudation, while scree deposits formed against the edges of the ice and on lower slopes, where these were not glaciated. Seasonal torrents from melting snow and ice built up alluvial cones on footslopes and in hill country. Given such

varied parent rocks and conditions of accumulation, it is hardly surprising that it is difficult to generalize about the regolith upon which the soils have been developed; even in a small area it is usually found that several processes have been at work simultaneously. The following notes on the various complexes may nevertheless give some indication of the pattern of soil formation.

Buie Complex. The Buie complex has been mapped on the hills on ridge crests, plateaux remnants and other flatter sites where deep peat has developed. Widespread erosion of the peat has caused hagging, while on mounds protruding through it are found a wide range of peaty gley soils, podzols and, frequently, oroarctic peaty gleys and peaty podzols. The pattern of land of this type, as seen both from aerial photographs and on the ground, is very characteristic. A generally elevated position renders it of very little use other than for extensive grazing. *Molinia* and *Trichophorum* grassland with *Calluna* is the dominant vegetative type.

Chioch Complex. The hardness of the rock and its resistance to erosion has caused numerous crags and screes. Crag and active scree have been grouped into the Chioch complex.

Cameron Complex. The Cameron complex occupies a footslope position in the landscape and is generally wooded with scrub oak, birch and rowan. The ground is steeply sloping, extremely bouldery and flushed by peaty water draining from higher ground. Although a brown forest soil is frequently developed, it is generally so broken by rock outcrop and large boulders as to be virtually useless. The brown forest soil, Sroine series, is similar to the Darleith series in general morphology but is usually shallower and considerably stonier. The textural range is considerable, varying from loamy gravel to silty loam. Unlike the Knockan complex, its counterpart in the Darleith Association, which is always present below 500 feet (150 m), the Cameron complex is developed only intermittently at corresponding elevations in the area occupied by the Torosay Association.

Odhar Complex. Shallow soils over rock and excessively stony scree deposits are characteristic of the Odhar complex. The ground is almost always steeply sloping but, despite this, where rock intervenes at shallow depth the soil surface is usually peaty and poorly drained. Where deeper coarse subsoils are present, as on the scree, and peat has failed to develop despite the extremely high rainfall, stony brown forest soils (Sroine series) are found. These carry *Agrostis-Festuca* grassland which in spring and autumn contrasts sharply with the *Molinia* and *Nardus* grassland of the peaty soils which frequently lie both above and below them. Rock outcrops and surface boulders are characteristic features and flushing is common.

Soil textures are gravelly loams and angular gravels, the humus content of the surface horizon is frequently high even when the horizon its not peaty, and the soil structure is moderately to strongly developed subangular blocky. The stronger structures are the result of grassland vegetation remaining undisturbed for a considerable time.

Tiompan Complex. The Tiompan complex is the mapping unit used to accommodate a variety of soils whose common characteristic is their occurrence on mountain summits and ridge crests above 1500 feet (460 m). The complex accounts for 13 per cent of the Torosay Association. The chief component, the Torosay series, is an immature oroarctic soil, usually showing signs of very weak podzolization, occasionally with gley features. An O horizon or highly humose A_1 horizon is usually underlain by an A_2 horizon, also black but with bleached sand grains, followed by a greyish brown or brown very stony B horizon overlying shattered rock. Very weak thin iron pans sometimes occur above the B horizon or at the rock surface. The Torosay series has been found at 50 per cent of the sites examined in the Tiompan complex, the other major components being rock (20 per cent), Ghraid series, a peaty lithosol (10 per cent), and peat (7 per cent). Wind erosion and active frost heave during the winter months are features of the soils within the complex. Vegetation is often stunted due to exposure.

Scarisdale Complex. The Scarisdale complex, the largest (45 per cent) of the Torosay Association, occupies large tracts of land on the periphery of the glaciated areas and ranges in altitude from sea-level to approximately 1500 feet (450 m). Its dominant parent rocks are flow basalts of a type similar to those included in the Darleith Association. Late stage metasomatic influences caused a secondary hardening of the upper scoriaceous layers of the flows, and in consequence these scoriaceous layers no longer weather readily. The soft brown loams characteristic of the Darleith Association are absent from the Scarisdale complex and drifts are thin and overlie hard impermeable rock. The dominant soils within the complex are the Dishig series (40 per cent), the Ghraig series (20 per cent) and peat (20 per cent).

The Dishig series is a peaty gley soil with poor or very poor drainage. The surface organic horizon is followed by a gleyed A_1 or A_2 loamy horizon over very dark greyish brown stony loam. A dark greyish brown C horizon is sometimes present. At about half the sites examined a black highly humose A-B horizon lay beneath the O horizon. Stones within the A-B were strongly gleyed and mottled, but the humus within the horizon appeared to be both intimately mixed with the mineral portion of the soil and coating structure faces. Rock was encountered at the base of 75 per cent of the profiles observed.

The Ghraig series is a peaty lithosol where any mineral horizon that occurs between the organic surface and the rock is less than 2 inches (5 cm) thick. Several other soils of minor extent occur in the complex. Terracing is again a feature, similar to that of the Cruachan complex but more weakly expressed. Between Loch Scridain and Loch na Keal a transition from the one complex to the other is observed as the degree of pneumatolysis of the basalt changes, and the boundaries there are necessarily arbitrary.

The vegetation pattern varies according to depth of solum available for drainage, degree of run-off, and flushing, but *Molinia* grassland is widely developed with *Calluna* becoming more noticeable on scarp slopes where the drainage status is better.

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.

Rising costs continue to affect intake of stock; 142 books were purchased during the year and one additional journal subscription taken out. Much of the literature required by members of staff had to be obtained from other libraries and this year 1325 items were borrowed; 292 items were lent.

In response to the steady demand from all parts of the world for papers published by members of staff, 5544 reprints were distributed. 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 10 of Collected Papers, covering the years 1970/72, has been prepared for binding.

PUBLICATIONS

(A) *Published*

1. Thermal analysis in perspective. By R. C. Mackenzie. (*Proc. Soc. analyt. Chem.*, **9**, 243-245, 1972.) *No reprints.*

   A brief review of the techniques included under the name 'thermal analysis' with some comments on their usefulness in various types of investigation.

2. Thermoanalytical techniques: their use in quantitative studies. By R. C. Mackenzie. (pp. 8-23 of *Nordforsk: Symposium i Termoanalys, Hagaland, Finland, 1972.* Stockholm: Nordforsk. 1973.) *No reprints.*

   Thermal analysis includes thermogravimetry, derivative thermogravimetry, differential thermal analysis, differential scanning calorimetry, dilatometry and evolved gas analysis, together with some less widely used techniques. All are quantitative for some property or parameter, but care must be exercised in choosing the correct technique; several applied simultaneously reveal more information than any one alone.

3. Soils. By R. C. Mackenzie and B. D. Mitchell. (pp. 267-297) of *Differential Thermal Analysis.* Vol. 2. Edited by R. C. Mackenzie. London: Academic Press. 1972.) *No reprints.*

   Differential thermal analysis (DTA) finds wide application in studies on total soils as well as on various particle size fractions, non-crystalline inorganic components, organomineral complexes and soil organic matter. Techniques for sample preparation and factors involved in choice of suitable DTA apparatus and experimental technique are described. The type of information that can be obtained by DTA alone and by DTA in conjunction with other techniques is illustrated with particular reference to soil mineralogy. The applicability of DTA to other soil problems is also discussed.

4. General applications [of DTA] in industry, with special reference to dusts. By R. C. Mackenzie and R. Meldau (Gütersloh, Germany). (pp. 555-564 of *Differential Thermal Analysis.* Vol. 2. Edited by R. C. Mackenzie. London: Academic Press. 1972.) *No reprints.*

   A concluding chapter. The features of DTA that render it particularly useful in industry and technology are reviewed, using illustrations from earlier chapters in the book, and a brief account is given of some studies on dusts where the technique has been of value.

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

   In studies on soils and clays it is frequently necessary to make quantitative determinations by differential thermal analysis (DTA). Such quantitative determinations are most accurately made by measurement of the energy absorbed or evolved during a reaction. Standard materials have recently been recommended by the Standardization Committee of the International Confederation for Thermal Analysis as suitable for temperature calibration of DTA equipment. Since these materials are well characterized they have been checked on the Institute apparatus with the view of assessing their usefulness for energy calibration. Despite the simple technique used encouraging results were obtained with most of the samples.

6. Clay minerals in soils derived from Lower Old Red Sandstone till: effects of inheritance and pedogenesis. By M. J. Wilson. (*J. Soil Sci.*, **24**, 26-41, 1973.)

   The clay minerals in 32 profiles located mainly in the Vale of Strathmore and developed on glacial till derived from Lower Old Red Sandstone sediments and

lavas have been investigated by X-ray diffraction. The influence of parent rock is very strong and the clay minerals inherited by the soil often include expansible magnesium-rich types with a high cation-exchange capacity which are unstable in freely drained acid soils. Their decomposition frequently leads to relatively high values for exchangeable magnesium in the basal horizons.

7. Calculated X-ray diffraction profiles for interstratified kaolinite-montmorillonite. By P. D. G. Cradwick and M. J. Wilson. (*Clay Miner.*, **9**, 395-405, 1972.)

   Interstratified minerals are of common occurrence in soils, but it is usually difficult to interpret X-ray diffraction patterns in terms of composition. To assist in determination of the relative proportions of component minerals present, diffraction profiles have been calculated for interstratifications of kaolinite and montmorillonite.

8. Occurrence of interstratified kaolinite-montmorillonite in some Scottish soils. By M. J. Wilson and P. D. G. Cradwick. (*Clay Miner.*, **9**, 435-437, 1972.)

   A clay mineral composed primarily of interstratified kaolinite and montmorillonite has been found in soils derived mainly from Old Red Sandstone lavas and located in the counties of Angus, Fife and Perth around the Tay estuary.

9. 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). (*Nature phys. Sci.*, **240**, 187-189, 1972.)

   Imogolite occurs in volcanic ash soils and is chemically similar to the amorphous aluminosilicates that are more common components of soils. It is here shown to contain orthosilicate anions, and a structure is proposed which accounts for its tubular morphology, its infrared spectrum, its porosity, and the principal features in its electron diffraction pattern.

10. Effects of soil micro-organisms on montmorillonite–adenine complexes. By M. P. Greaves and M. J. Wilson. (*Soil Biol. Biochem.*, **5**, 275-276, 1973.)

    Adenine, a product of the microbial degradation of nucleic acids, is strongly adsorbed in the interlayer region of clay minerals such as montmorillonite. Examination of montmorillonite-adenine complexes during incubation on soils, by X-ray diffraction techniques, indicates that the adsorbed adenine is resistant to attack by enzymes produced by soil micro-organisms. It is suggested that the spacing of the clay interlayer region is too small to allow penetration of these enzymes.

11. The nutrient requirements of herbage on deep acid peat. By J. W. S. Reith, R. A. Robertson and R. H. E. Inkson. (*J. agric. Sci., Camb.*, **80**, 425-434, 1973.)

    An experiment was carried out on grassland, established with adequate Ca, N, P and K on deep acid peat, to determine the amounts of nutrients required to produce herbage for regular cutting for conservation. The effects of a range of N, P and K treatments on the botanical composition, yield and mineral content of the herbage, and on the levels of readily soluble nutrients in the peat were measured over a period of five years. The N and K treatments had large effects, especially on yield and mineral content, and there was a marked positive interaction between these two nutrients. The yield of dry matter did not show any response to P until the fifth year, but the percentage of P in the herbage was always increased by the P treatments. Rates of N, P and K are suggested for producing grass on this type of peat which can yield over 8 metric tons per ha of dried grass per annum.

12. Peatlands. By P. C. Jowsey. (pp. 109-121 of *The Organic Resources of Scotland*. Edited by J. Tivy. Edinburgh: Oliver & Boyd.) *No reprints.*

    A general account of the peatlands of Scotland covering aspects of their distribution, mode of formation, vegetation, exploitation, and value as a natural resource.

13. Deutsch-englisch-russisches Fachwörterbuch: Moor und Torf. By W. Bick, R. A. Robertson, and R. Schneider and S. Schneider (Torfinstitut, Hannover). (Bad Zwischenahm: Torfforschung GmbH. 1973.)

14. Vegetation chronology. By S. E. Durno. (pp. 24-37 of *The Organic Resources of Scotland*. Edited by J. Tivy. Edinburgh: Oliver & Boyd. 1973.) *No reprints.*
An outline is given of the contribution made by the study of vegetational history in tracing environmental change in Scotland from the Ice Age to the emergence of man as an important ecological factor. The valuable role of pollen analysis in such studies is illustrated by results for selected sites in different parts of the country.

15. A fossil brown forest soil from Angus. By J. C. C. Romans, S. E. Durno and L. Robertson. (*J. Soil Sci.*, **24**, 125-128, 1973.)
A soil profile preserved below a barrow of Neolithic age appears to have been a brown forest soil developed under deciduous woodland in which oak was an important component. There is evidence of Neolithic forest clearance.

16. Effect of water-table height on root development of *Pinus contorta* on deep peat in Scotland. By R. Boggie. (*Oikos*, **23**, 304-312, 1972.)
Lodgepole pine was grown on deep peat in plots in which the water tables were maintained artificially at five levels ranging from zero to 35 cm below the ground surface. Root growth was severely restricted under conditions of water-logging, but a progressive improvement was seen as the level of the water table was lowered. Root form varied according to water treatment but in all profiles root development was largely confined to the upper, aerobic horizons as defined by sulphide staining on silver rods and redox potential measurements. There was a higher air/moisture volume ratio in the upper horizons of the peat in those parts of the plots planted with trees than in those under the natural vegetation.

17. Nitrogen mineralization and organic matter decomposition in Scots pine humus. By B. L. Williams. (*Forestry*, **45**, 177-188, 1972.)
Practical ways of stimulating nitrogen release from the organic layers of the forest floor by applications of nitrogen, phosphorus and lime are being studied in a 40-year old crop of nitrogen-deficient Scots pine (*Pinus sylvestris* L) at Culbin Forest, Morayshire. Significant treatment effects, detectable two years after final fertilizer application, include an effect of lime on pH and organic matter breakdown and an effect of ammonium sulphate, urea and ammonium nitrate fertilizers on the net production of mineral nitrogen.

18. 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. (*Ann. Bot.*, **37**, 159-166, 1973.)
Separation of flowers of antirrhinum, fuchsia, daffodil and maize into their component parts has shown that cation-exchange capacity, calcium and the calcium/potassium ratio increase progressively from the tip of the style and are highest in the ovary. Anthers and ovaries contain higher concentrations of trace elements than the neighbouring filaments and styles. For daffodil, in keeping with results for leaf tissue, a close relationship exists between the potassium/calcium and the citric acid/malic acid ratios in the floral parts with the exception of anther and ovary.

19. Cobalt in soil and its uptake by plants. By R. L. Mitchell. (pp. 521-532 of *IX Simp. int, Agrochim., La Fitonutrizione Oligominerale, Punta Ala, Italy, 1972.*)
A review of the factors affecting the availability of cobalt in the soil and its uptake by plants.

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

In all work concerned with the determination of trace elements, contamination can produce spurious results. Some of the sources from which contamination can arise during the sampling, packaging and analytical procedures are given with indications of the total and extractable contents of some of the materials commonly used in laboratory apparatus.

21. A rotating briquetted-disk method for boron and other elements in plant material. By J. C. Burridge and R. O. Scott. (*Acta XVII Colloq. spectros. int., Florence, 1973*, **1**, 235-240, 1973.)

Boron and eight other elements are determined in plant material by excitation by means of a condensed a.c. discharge of plant ash incorporated into a graphite-based rotating briquetted-disk. The intensities of the spectral lines are measured using a Hilger and Watts Medium Quartz Direct Reading Spectrometer

22. The effect of 'A' site occupancy upon the hydroxyl stretching frequency in clinc-amphiboles. By G. Rowbotham (University of Keele) and V. C. Farmer (*Contrib. Miner. Petrol.*, **38**, 147-149, 1973.)

The amphiboles, which are important constituents of many basic igneous and metamorphic rocks, have a wide range of compositions. One aspect of this variability is the occasional entry of alkali metal cations into a site which is more usually vacant. The probability of recognizing occupancy of this site by means of infrared spectroscopy has been explored.

23. 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). (*Mineralog. Mag.*, **39**, 282-288, 1973.)

To gain a better understanding of factors which affect the infrared spectra of layer silicates, which are common components of soil clays, the spectra of brittle micas have been examined. The vibrations of the structural hydroxyl groups and the silicate network have been found to reflect the composition of these minerals and the regularity of their structures.

24. Vibrational spectra and structure of silicates. By A. N. Lazarev (Institut Khimii Silikatov im I. V. Grebenshchikov, Leningrad). Translation by G. D. Archard, edited by V. C. Farmer. 308 pp. (New York: Consultants Bureau. 1972.)

25. Electron paramagnetic resonance evidence that copper is complexed in humic acid by the nitrogen of porphyrin groups. By B. A. Goodman and M. V. Cheshire. (*Nature new Biol.*, **244**, 158-159, 1973.)

EPR studies have shown that copper strongly bound to peat humic acids is complexed by the nitrogen of porphyrin derivatives.

26. 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.)

A simple procedure for the direct determination of ^{14}C in soil by scintillation counting involves suspension of the finely ground sample in a thixotropic gel.

27. The origin of soil polysaccharide: transformation of sugars during the decomposition in soil and plant of material labelled with ^{14}C. By M. V. Cheshire, C. M. Mundie and H. Shepherd. (*J. Soil Sci.*, **24**, 54-68, 1973.)

Studies on the decomposition of whole plant material labelled with ^{14}C in soil over a period of 14 months have shown that about half of the carbon is oxidized to CO_2 and about one-third of the two main sugars of the material, glucose and xylose, persist in the soil. It was concluded that much of the xylose present in soil could be in plant residues.

28. 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.)

Humic acids formed under acidic conditions give a characteristic electron spin resonance signal. Humic acid of this type has been found in Aberdeenshire soils that have been cultivated for over 150 years and are now much less acid than the natural soils from which they were derived. A humic acid of the same type has appeared in a Rothamsted soil on land which was allowed to revert to wilderness 80 years ago and which has since become acidic. These observations show that humic acids of this type may persist in soils through relatively long periods of cultivation, but may be formed again quickly when the soil becomes acidic.

29. Effects of hydroxyproline on the growth of excised root segments of *Pisum sativum* under aseptic conditions. By D. Vaughan and Evelyn Cusens. (*Planta, Berl.*, **112**, 243-252, 1973.)

Although most naturally occurring amino acids do not affect the growth of excised pea root segments cultured under aseptic conditions, hydroxyproline is an exception. While stimulating extension growth, this amino acid inhibited some aspects of protein metabolism. The effects of externally supplied hyroxyproline, which is formed in plant tissues from proline, were compared with those of added azetidine-2-carboxylic acid, which replaces proline in newly formed proteins. It is suggested that hydroxyproline stimulates extension growth by interfering with protein synthesis in the cell walls.

30. The effect of oxalate and ethylenediaminetetraacetic acid on the absorption of calcium into Lemna. By P. C. DeKock, Y. Ohta, R. H. E. Inkson and A. H. Knight. (*Physiol. Plant.*, **28**, 379-382, 1973.)

Both oxalate and EDTA were shown to affect the uptake of calcium into *Lemna*, oxalate stimulating the uptake and EDTA at concentrations equivalent to the calcium concentration in the growth medium retarding the uptake.

31. Relationship between microbial populations and adenosine triphosphate in a basin peat. By M. P. Greaves, R. E. Wheatley, H. Shepherd and A. H. Knight. (*Soil Biol. Biochem.*, **5**, 685-687, 1973.)

Adenosine triphosphate (ATP) content has been used as a measure of the number or biomass of the micro-organisms in some environments, since it is present in all living micro-organisms as an energy source for cell metabolism. An evaluation of this method shows that although unsuitable for determining microbial numbers or biomass in peat, ATP measurement may be useful as an indicator of the metabolic state of a population of one type of organism, or more especiallv of a pure culture of a micro-organism.

32. Cation-exchange capacity and chemical composition of the floral parts of *Antirrhinum* and *Lilium*. By A. H. Knight and W. M. Crooke. (*Ann. Bot.*, **37**, 155-157, 1973.)

A study was made of the cation exchange capacity (CEC) and mineral content of the component parts of the flowers of two ornamental species; different patterns were found. In the dicot plant, antirrhinum, the K content fell and the CEC and Ca content increased in the order stigma - style - ovary, but these effects were not found for the monocot, tiger-lily.

33. Bacteria and protozoa in the rhizosphere. By J. F. Darbyshire and M. P. Greaves. (*Pestic. Sci.*, **4**, 349-360, 1973.)

The zone of soil close to plant roots, the rhizosphere, is discussed with special reference to soil bacteria and protozoa. The physical, chemical and biological factors which are known to influence the rhizosphere populations of these microbes are listed and briefly considered. Root exudates and electron micrographs of roots are discussed in relation to microbial ecology.

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

Although the root-soil interface is an important micro-environment in plant nutrition and root pathology, little is known about the relationships between the mulcilaginous outer layer on plant roots and soil micro-organisms. An electron microscope study of this layer on the roots of 16 species of agricultural crops grown under different conditions showed that the mucigel on axenic roots appears as an unevenly distributed layer of granular and fibrillar material covering the root surface. When colonized by micro-organisms it became thicker, lost much of its granular and fibrillar appearance and frequently developed a distinct outer boundary.

35. The estimation of soil protozoan populations. By J. F. Darbyshire. (*Tech. Ser. Soc. appl. Bact.*, **No. 7,** 175-188, 1973.)

The common dilution method employed for estimating the numbers of protozoa in soil is described together with the modification developed at the Institute. Future possible improvements are briefly discussed.

36. Factors affecting germination of sclerotia of *Sclerotina sclerotiorum* from peas. By D. Jones and Elizabeth Grey (North of Scotland College of Agriculture, Aberdeen). (*Trans. Br. mycol. Soc.*, **60,** 495-500, 1973.)

The fungus *Sclerotinia sclerotiorum*, a parasite of many agricultural crops, forms sclerotia or resting bodies which germinate in early summer and infect susceptible plants. This paper describes laboratory studies on the effects of various chemicals and different temperatures on the germination of sclerotia collected from soil in fields of infected pea crops in Kincardineshire in the summer of 1971. Nitrolim, which contains calcium cyanamide as the main constituent, benzotriazole and benomyl, completely inhibited germination, whereas parabanic acid had no effect. No sclerotia germinated at 10°C on untreated soil whereas most germinated at 20°C.

37. Soil chemistry. By B. W. Bache. (*Rep. Progr. appl. Chem. 1972,* **57,** 371-381, 1972.)

Recent developments in the following fields are briefly reviewed, with the emphasis on the physicochemical aspects: surface charge of soil colloids, cation exchange, soil potassium, anion adsorption, soil phosphate, soil acidity and liming, reactions of fertilizers with soils, and ion transport in soils.

38. Soil conditions and nutrient supplies in hill land. By J. W. S. Reith. (*Proc. Potassium Inst. Colloq.*, **No. 3,** 5-12, 1973.)

The main conditions, especially acidity and low nutrient supplies, that limit productivity on hill land are briefly reviewed. Experimental work has established the general lime and fertilizer requirements for direct reseeding or surface seeding, and shown that cobalt or copper deficiencies may occur in some areas. Attention is drawn to the need for producing herbage with adequate contents of the minerals needed by animals. In addition to good grazing management after establishment, dressings of lime and nutrients are likely to be required to maintain not only the yield but also the mineral content of herbage. Since direct reseeding or surface seeding is expensive, there is a need for some cheaper method of improving hill land.

39. The soils of Carrick and the country round Girvan. (Sheets 7 and 8.) By C. J. Bown. (*Mem. Soil Surv. Gt Br.: Scotl.* 1973. 378 pp. With soil maps. H.M.S.O., £9.)

The soils of the area (545 square miles) are described and classified. Chemical data are quoted for 68 soil profiles and further chemical, spectrochemical and mineralogical analyses are given for selected soils. Ancillary chapters give information on the physiography, geology, climate, agriculture and forestry, and

plant communities from woodland to moorland are described. An assessment is made of the land use capability of the area, taking into account the limitations imposed by soils and the natural factors of site and climate. The memoir includes coloured soil and land use capability maps on the scale of 1 inch to 1 mile.

40. 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). (*Tech. Monogr. Soil Surv. Gt. Br.* **No. 3.** 1973. 228 pp. Aberdeen: Macaulay Institute for Soil Research. £1.20.)

    After a review of the literature, the important features of the American diagnostic horizons, epipedons and other criteria relevant to the British soils are set out. Descriptions of one or more profiles, amounting to 78 in all, illustrate the 37 great groups believed to be important in Britain. Each profile is classified to subgroup level and is accompanied by analytical and micromorphological data pertinent to its placement in the new taxonomy. The classification of the profiles is discussed and comments on both the limitations and usefulness for soil survey in Britain are given.

41. Preliminary report on the soils of Mull. By J. S. Bibby. (*Spec. Rep. Highl. Isl. Dev. Brd,* **No. 10,** 85-102, 1973.)

    An account is given of the physiography of the island in terms of land systems which tie in closely with geology and glacial and post-glacial history. The soils are described and classified and their distribution in relation to their environment and parent material is discussed. They have been mapped in 17 soil associations, represented by 32 soil complexes in which 74 soil series have been identified. A land use capability assessment is derived by consideration of the soil types and their interrelation with climate and landform.

42. Gley soils in the Midland Valley of Scotland. By D. Laing. (*Trans. Commn. V. & VI int. Soc. Soil Sci., 1971,* 229-236, 1973.)

    The principal gley soils occurring in lowland regions of the Midland Valley of Scotland are described and their generalized distribution is shown on a map. The terms used in Scotland to classify the soils are compared with those used by Mückenhausen and with the FAO/UNESCO nomenclature prepared for the Soil Map of Europe. Evidence is presented showing that parent material and climate play important parts in determining the distribution of major soil groups which, in turn, strongly influence the pattern of land use capability.

43. Factors in soil formation. By J. M. Ragg. (pp. 38-50 of *The Organic Resources of Scotland.* Edited by J. Tivy. Edinburgh: Oliver & Boyd. 1973.) *No reprints.*

    Following a presentation of the post-glacial stages of soil formation in Scotland, the inter-relationships of climate, organisms, topography and parent material are discussed. Under climate, the distribution of Scottish soils is related to potential water deficit and temperature. After a résumé of the provenance and genesis of drift deposits the influence of parent material and topography on soil-forming processes and distribution is described. A review of the functions of soil macro- and micro-organisms is followed by a discussion of the part that man has played over the past 3000 years in changing the vegetation and altering the physical and chemical properties of the soils by various farming practices.

44. Land use capability. By J. S. Bibby. (pp. 51-65 of *The Organic Resources of Scotland.* Edited by J. Tivy. Edinburgh: Oliver & Boyd. 1973.) *No reprints.*

    The major physical features affecting land use are described and stress is laid on interactions between them. A broad description of the major agricultural regions in terms of their physical characteristics follows and some attempt is made to indicate the range of land use capability classes existing within each. A brief description is given of methods of land assessment currently in use in Scotland.

(B) *Awaiting Publication at 30th September, 1973*

45. The removal of organic matter from soil extracts by bromine oxidation. By B. D. Mitchell and B. F. L. Smith. (Submitted to *J. Soil Sci.*)

46. Thermal analysis. By R. C. Mackenzie. (To appear in *Physiochemical Methods of Mineral Analysis.* Edited by A. W. Nicol. London: Plenum Press.)

47. Instrumentation for thermogravimetry and differential thermal analysis. By R. C. Mackenzie. (To appear in *Thermal Analysis.* Edited by J. P. Redfern. London: Society for Analytical Chemistry: Chemical Society, Analytical Division.)

48. 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.)

49. Complementary techniques. By R. C. Mackenzie. (To appear in *Thermogravimetry.* Edited by J. P. Redfern and C. J. Keattch. London: Butterworths.)

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

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

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

53. On the calculation of one-dimensional X-ray scattering from interstratified material. By P. D. G. Cradwick. (Submitted to *Clay Miner.*)

54. Hydrothermal formation and alteration of laumontite in hornblende schist near Huntly, Aberdeenshire. By M. J. Wilson. (Submitted to *Mineralog. Mag.*)

55. Occurrence of imogolite in some volcanic ash soils of New Zealand. By N. Yoshinaga, J. M. Tait and R. Soong. (Submitted to *Clay Miner.*)

56. A study of the weathering of a biotite using the Mössbauer effect. By B. A. Goodman and M. J. Wilson. (*Mineralog. Mag.*, **39**, 448-454, 1973.)

57. Formation of iron oxides by decomposition of iron-phenolic chelates. By W. J. McHardy, A. P. Thomson and B. A. Goodman. (Submitted to *J. Soil Sci.*)

58. Humus type discrimination using pattern recognition of the mass spectra of volatile pyrolysis products. By J. M. Bracewell and G. W. Robertson. (*J. Soil Sci.*, **24**, 421-428, 1973.)

59. 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.*)

60. Peat for the garden. By R. A. Robertson. (Submitted to *Scott. Garden.*)

61. 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.*)

62. 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.*)

63. Changes in amount and distribution of stem growth in pole-stage Corsican pine following application of nitrogen fertilizers. By H. G. Miller and J. M. Cooper. (Submitted to *Forestry.*)

64. 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.*)

65. Lithium, sodium, potassium, rubidium and cesium. By A. M. Ure and R. L. Mitchell. (To appear as Chap. 1 of *Flame Emission and Atomic Absorption Spectrometry.* Vol 3. Edited by J. A. Dean and T. C. Rains. New York: Dekker.)

66. Vibrational spectroscopy in mineral chemistry. By V. C. Farmer. (To appear in *Infrared Spectra of Minerals;* monograph of the Mineralogical Society.)

67. The anhydrous oxide minerals. By V. C. Farmer. (To appear in *Infrared Spectra of Minerals;* monograph of the Mineralogical Society.)

68. Orthosilicates, pyrosilicates, and other finite-chain silicates. By V. C. Farmer. (To appear in *Infrared Spectra of Minerals;* monograph of the Mineralogical Society.)

69. The layer silicates. By V. C. Farmer. (To appear in *Infrared Spectra of Minerals;* monograph of the Mineralogical Society.)

70. Symmetry and crystal vibrations. By V. C. Farmer and A. N. Lazarev (Institut Khimii Silikatov im I. V. Grebenshchikov, Leningrad). (To appear in *Infrared Spectra of Minerals*; monograph of the Mineralogical Society.)

71. Instrumentation and techniques. By J. D. Russell. (To appear in *Infrared Spectra of Minerals;* monograph of the Mineralogical Society.)

72. Infrared spectroscopy in mineral chemistry. By V. C. Farmer. (To appear in *The Analysis of Minerals by Physical Methods.* Edited by A. Nichol. London: Plenum Press.)

73. Thermal decomposition of protein in soil organic matter. By J. D. Russell, A. R. Fraser and J. R. Watson (University of Western Australia, Nedlands) and J. W. Parsons (University of Aberdeen). (Submitted to Geoderma.)

74. 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.)

75. Transformation of sugars when rye hemicellulose labelled with ^{14}C decomposes in soil. By M. V. Cheshire, C. M. Mundie and H. Shepherd. (Submitted to *J. Soil Sci.*)

76. Effects of hydroxyproline on the growth and cell-wall protein metabolism of excised root segments of *Pisum sativum.* By D. Vaughan. (*Planta, Berl.*, **115,** 135-145, 1973.)

77. Protein-bound hydroxyproline and root growth. By D. Vaughan and Evelyn Cusens. (Submitted to *Trans. Biochem. Soc.*)

78. Effects of hydroxyproline and other amino acid analogues on the growth of pea root segments. By D. Vaughan, P. C. Dekock and Evelyn Cusens. (Submitted to *Physiol. Plant.*)

79. Uptake by beetroot tissue and biological activity of ^{14}C-labelled soil organic matter fractions. By D. Vaughan, M. V. Cheshire and C. M. Mundie. (Submitted to *Trans. Biochem. Soc.*)

80. Some effects of humic acid on two different biological systems. By D. Vaughan and C. D. Baker and L. G. Willoughby (Freshwater Biological Association, Windermere Laboratory.) (Submitted to *Pl. Soil.*)

81. A study of iron chlorosis in pear leaves. By P. C. DeKock, A. Hall, R. H. E. Inkson and R. C. Little and R. R. Charlesworth (ADAS, Wolverhampton). (Submitted to *An. Edafol. Agrobiol.*)

82. Some physiological investigations of chilling injury in the yam, *Discorea alata* L. By A. O. Olorunda (School of Agriculture, University of Aberdeen) and A. E. S. Macklon. (Submitted to *Proc. III int. Symp. Tropical Root Crops.*)

83. *Apusomonas proboscidea* Alexieff: an unusual phagotrophic flagellate from soils in north-east Scotland. K. Vickerman (University of Glasgow), J. F. Darbyshire and C. G. Ogden (British Museum). (Submitted to *Arch. Protistenk.*)

84. Soil properties limiting the efficiency of fertilizers. By J. W. S. Reith. (Submitted to *Proc. VII Fertilizer World Congress, Baden, Austria, 1972.*)

85. The effectiveness of different methods and times of applying fertilizers. By J. W. S. Reith. (Submitted to *Phosphorus in Agriculture.*)

86. The nature of alkali-soluble soil organic phosphates. By G. Anderson and R. E. Malcolm. (Submitted to *J. Soil Sci.*)

87. A comparison of the sorption of inorganic orthophosphate and inositol hexaphosphate by six acid soils. By G. Anderson, E. G. Williams and Jacqueline O. Moir. (Submitted to *J. Soil Sci.*)

88. Soluble aluminium and calcium-aluminium exchange in relation to the pH of dilute calcium chloride suspensions of acid soils. By B. W. Bache. (Submitted to *J. Soil Sci.*)

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

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

91. 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.*)

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

93. Petrofabric analysis. By J. S. Bibby. (To appear as an appendix to a paper by E. W. Mackie in *Phil. Trans. R. Soc.*)

94. Some genetic characteristics of the freely drained soils of the Ettrick Association in East Scotland. By J. C. C. Romans and L. Robertson. (Submitted to *J. Soil Sci.*)

95. Some aspects of the genesis of alpine and upland soils in the British Isles. By J. C. C. Romans and L. Robertson. (Submitted to *Proc. IV Working Meeting on Soil Micromorphology, Kingston, Ontaria, Canada, 1973.*)

96. The soils of the country round Perth, Arbroath and Dundee. By D. Laing. (Sheets 48 and 49.) (To appear as *Mem. Soil Surv. Gt. Br.*)

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

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

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

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

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

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

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 Organization	King's Buildings, West Main Road, Edinburgh, EH9 3JQ.
Institute of Animal Physiology	Babraham, Cambridge, CB2 4AT.
Institute for Research on Animal Diseases	Compton, Newbury, Berks, RG16 0NN.
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, OX12 9JT.
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 Research Institute	Ayr, KH6 5HL.
Hill Farming Research Organisation	Bush Estate, Penicuik, Midlothian, EH26 0PH.
Macaulay Institute for Soil Research	Craigiebuckler, Aberdeen, AB9 2QJ.
National Institute for Agricultural Engineering (Scottish Station)	Bush Estate, Penicuik, Midlothian, EH26 0PH.
Rowett Research Institute	Bucksburn, Aberdeen, AB2 9SB.
Scottish Horticultural Research Institute	Invergowrie, Dundee, DD2 5DA.
Scottish Plant Breeding Station	Pentlandfield, Roslin, Midlothian, EH25 9RF.

State-aided Institutes (England and Wales)

Animal Virus Research Institute	Pirbright, Woking, Surrey, GU24 0NF.
East Malling Research Station	East Malling, Maidstone, Kent, ME19 6BJ
Glasshouse Crops Research Institute	Worthing Road, Rustington, Littlehampton, Sussex, BN16 3PU.
Grassland Research Institute	Hurley, Maidenhead, Berks, SL6 5LR.
Houghton Poultry Research Station	Houghton, Huntingdon, PE17 2DA.
John Innes Institute	Colney Lane, Norwick, NOR 7OF.
Long Ashton Research Station	Long Ashton, Bristol, BS18 9AF.
National Institute of Agricultural Engineering	Wrest Park, Silsoe, Beds, MK45 4HS.
National Institute for Research in Dairying	Shinfield, Reading, Berks, RG2 9AT.
National Vegetable Research Station	Wellesbourne, Warwick, CV35 9EQ.
Plant Breeding Institute	Maris Lane, Trumpington, Cambridge, CB2 2LQ.
Rothamsted Experimental Station	Harpenden, Herts, AL5 2QJ.
Welsh Plant Breeding Station	Plas Gogerddan, Aberystwyth Cardiganshire, SY23 3EB.
Wye College, Department of Hop Research	Ashford, Kent, TN25 5AH.