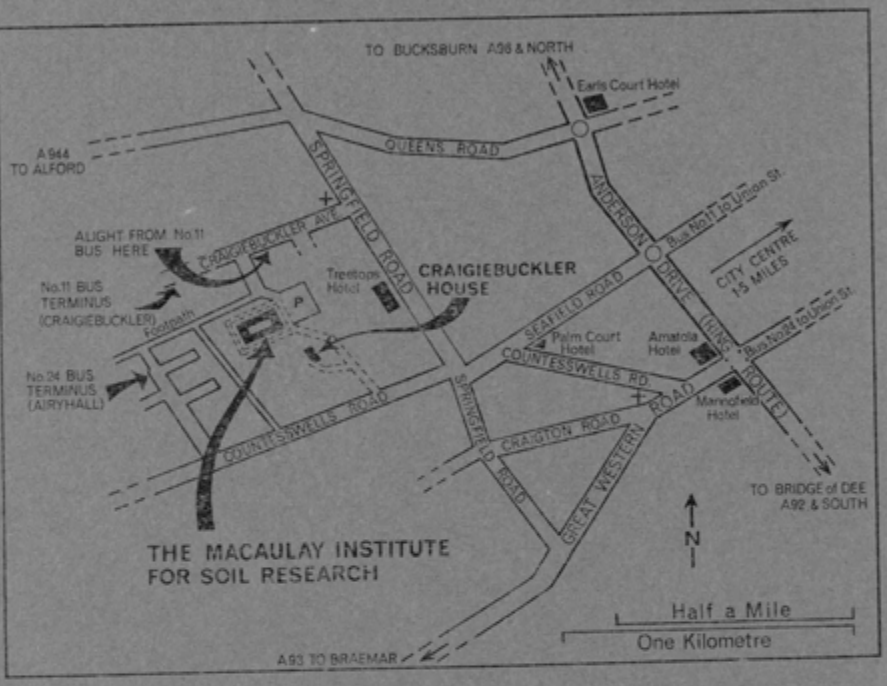
THE MACAULAY INSTITUTE FOR SOIL RESEARCH

FOUNDED 1930

1973-1974 ANNUAL REPORT

No. 44

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.



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Telephone—ABERDEEN (0224) 38611

This report covers the period from 1st October, 1973 to 30th September, 1974 and was published in March, 1975.

Prior to the 12th report (1941-42), the Annual Reports were prepared for restricted circulation only.

Printed by SCOTTISH & UNIVERSAL NEWSPAPERS LTD., Galashiels

THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

(Founded 1930)

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1973-1974

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MISS A. POLSON.
MRS M. SHEPHERD.
MISS E. M. HAY.
MISS J. A. MCWILLIAM—resigned 31/7/74.
MISS R. CORMACK—resigned 12/7/74.
MISS L. R. GREIG—resigned 12/9/74.
G. A. REID—appointed 10/12/73.
MISS Y. RYLES—10/12/73 - 26/4/74.
MISS J. L. BUNCH—appointed 1/6/74.
A. J. WILLIAMS—appointed 26/8/74.
MISS A. S. BURNETT—appointed 9/9/74.
G. F. BROCKLEY—appointed 1/10/74.
F. F. WARDEN.

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Miss A. McDonald—resigned 17/5/74.
J. W. Mitchell.
Miss G. I. M. Keith—resigned 17/5/74.
Miss Y. E. M. Gray—appointed 1/6/74.
Miss A. M. Smith—appointed 1/9/74.

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G. Bruce.
I. M. Still.

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Head of Department: G. Anderson, B.Sc., Ph.D.—appointed 1/1/74.
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D. Vaughan, B.Sc., Ph.D.

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MISS R. M. PATERSON—appointed 1/4/74.

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B. G. ORD.
MRS F. DUTHIE.
R. J. CUMMING—resigned 16/8/74.
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Radioactivity A. H. KNIGHT, B.Sc.—transferred 1/4/74.
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MRS A. E. REID—appointed 7/1/74.
MRS J. V. DUNBAR—resigned 4/1/74.
MRS M. J. MACCALLUM—4/2/74 - 22/2/74.
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P. W. DYSON, B.Sc., Ph.D.
W. E. SIMPSON, B.Sc.
K. S. CALDWELL, S.D.A., S.D.D.H.
R. E. MALCOLM—transferred 1/4/74.
H. SHEPHERD, L.R.I.C.—appointed 1/4/74.
J. A. M. ROSS, N.D.A.
G. S. SHARP, L.R.I.C.
MISS S. M. LAW.
A. H. SINCLAIR, B.Sc.—appointed 1/10/74.
J. MUNRO.
MRS I. BLACK.
MISS C. IRELAND.
A. J. MILTON, B.Sc.—appointed 8/10/73.
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MRS C. CRAIGMYLE—appointed 1/12/73.
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R. STRACHAN—retired 31/5/74.
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J. S. MORRISON—appointed 2/9/74.
S. HARRIS—resigned 11/4/74.
J. A. M. ANDERSON.
W. J. DUNCAN—appointed 6/5/74.

STATISTICS

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MISS A. MCDONALD.
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MRS P. L. ROSS—resigned 12/4/74.
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MISS L. STEVENSON—appointed 1/9/74.

SOIL SURVEY

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F. T. DRY, B.Sc.
L. ROBERTSON, B.Sc.
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W. B. KERR, B.Sc.—resigned 18/10/74.
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R. J. F. MORRIS, B.Sc.—resigned 31/1/74.
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J. MACKAY, B.Sc.
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D. J. HENDERSON, B.Sc.—appointed 1/11/73.
G. G. WRIGHT—appointed 1/10/74.
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A. D. MOIR.
R. G. MARSHALL—resigned 30/11/73.
MISS S. SHERRIFFS—appointed 7/1/74.
MISS S. A. AULD—resigned 28/12/73.
MISS P. R. CARNEGIE—appointed 27/5/74.
C. M. MIDDLETON.

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J. H. NORMINGTON.
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G. J. GASKIN.
A. I. A. WILSON.
J. A. MACDONALD—appointed 1/6/74.
R. A. BURNS—appointed 1/9/74.
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	MISS R. A. WILKIE.
	MRS R. C. M. GORDON—resigned 6/3/74.
	MISS H. M. SAVILLE—resigned 25/1/74.
	MISS K. I. ADAMS—resigned 1/3/74.
	MISS M. H. BETT—resigned 15/2/74.
	MRS A. C. MCDONALD—appointed 5/3/74.
	MISS M. H. DARGIE—appointed 7/3/74.
	MRS I. M. SHAND—appointed 1/4/74.
	MRS C. T. GARDEN—appointed 6/5/74.
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	A. MUTCH.
	J. SHAW—retired 29/3/74.
	H. SHAW.
	J. S. MORRISON—transferred 2/9/74.
	C. J. BENZIE.
	D. R. MACLEAN—appointed 22/7/74.

VISITING RESEARCH WORKERS

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

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

A. S. DE ENDREDY (FAO, Rome, Italy).

* I. M. HALL (North-East London Polytechnic).

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

N. MORANDI (Institute of Mineralogy and Petrography, University of Bologna, Italy).

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

K. W. PERROTT (Department of Agriculture, Ruakura Soil Research Station, Hamilton, New Zealand).

J. A. ROBERTSON (Department of Soil Science, The Alberta Institute of Pedology, University of Alberta, Edmonton, Canada).

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).

N. YOSHINAGA (Faculty of Agriculture, Ehime University, Matsuyama, Japan).

**Sandwich-Course Student.*

CONTENTS

INTRODUCTION

In the course of the year some reorganization to implement the recommendations of the 1972 ARC Visiting Group has been effected. As from 1st January 1974, the Department of Biochemistry was incorporated into a new Department of Soil Organic Chemistry, under Dr G. Anderson from the Department of Soil Fertility, as foreshadowed in last year's report. On 1st April, Dr I. R. MacDonald and his supporting SO and ASO posts were transferred from Plant Physiology to Soil Organic Chemistry to concentrate work on the influence of soil organic constituents on root growth in the latter department. At the same time the work on Radioactivity under Mr A. H. Knight and Mr H. Shepherd was transferred to Soil Fertility from Plant Physiology. The resulting changes in the programme of work are incorporated in the list of projects which follows. These changes would appear to have rationalized some aspects of the work of the Institute and to be operating satisfactorily.

Work on the renovation of Craigiebuckler House is essentially complete and it is anticipated that Soil Survey will occupy their new premises before the end of 1974.

Among major new pieces of equipment installed during the year, mention must be made of an AEI MS702R spark source mass spectrograph.

Short-term visitors from twenty-two different countries visited the Institute during the year and facilities were provided for longer-term workers from Canada, Italy, Japan, New Zealand and Turkey.

It is with regret that the deaths of Mr William Hunter, OBE, and Mr W. H. Guillebaud are recorded. Mr Hunter served as a Member of Council from 1954 until 1966 and Mr Guillebaud from 1934 until 1948.

It is also with regret that the sudden deaths of Mr A. P. Thomson (Pedology) on 1st April and Mr H. Gordon (Head Gardener) on 9th June are recorded. Mr Thomson had been a member of staff of the Institute since 1946, and his contribution to the work of the Institute is recorded below. Mr Gordon joined the staff only in 1970, but had already effected considerable improvements in the grounds. Both will be difficult to replace.

Mr John Shaw, the last remaining member of the original staff of the Institute, who has been on the Outdoor Staff since December 1930, retired in March 1974. Mr A. M. Fraser (Technical Services) retired in April 1974 after 24 years' service, during which he built up the most efficient instrument workshop facilities that do much to reinforce the scientific programme.

Dr H. G. Miller (Pedology) and Miss J. M. Cooper (Statistics) have jointly been awarded the 1974 Silvicultural Prize of the Institute of Foresters of Great Britain for an article entitled Changes in Amount and Distribution of Stem Growth in Pole-stage Corsican Pine following Application of Nitrogen Fertilizer[1]. The award was made at the Annual General Meeting of the Institute in September at the University College of North Wales.

The Director accepted an invitation to present a paper on Soil Analysis at the meeting of INTERAN, an International Conference on Analytical

Chemistry, in Prague in September. Immediately preceding this visit he attended the Seventh International Colloquium on Plant Analysis and Fertilizer Problems in Hanover, Germany. Dr R. C. Mackenzie (Pedology) accepted an invitation from the Association Francaise de Calorimétrie et d'Analyse Thermique and the Groupe de Thermodynamique Expérimentale of the Société Chimique de France to present a paper at their joint meeting in the University of Rennes on 9th and 10th May 1974. His expenses were met by the Société Chimique de France. Dr G. Anderson (Soil Organic Chemistry) accepted an invitation from the Danish Natural Science Research Council to visit Copenhagen for one week in February 1974 to advise regarding an extension of their programme in Soil Biochemistry. He also lectured to the Danish Society for Soil Science. The expenses of this visit were met by the Danish Research Council.

Several members of staff made very profitable visits to research establishments and attended scientific conferences abroad with the aid of funds made available by the Agricultural Research Council. Seven members of staff, Dr E. G. Williams (Deputy Director), Dr M. L. Berrow (Spectrochemistry), Dr G. Anderson (Soil Organic Chemistry), Dr D. Jones (Microbiology), Dr B. W. Bache (Soil Fertility), Mr R. H. E. Inkson (Statistics) and Dr R. Glentworth (Soil Survey), attended the Tenth International Congress of Soil Science in Moscow in August 1974. Dr M. J. Wilson (Pedology) attended the Joint Meeting of Western European Clay Societies in Strasbourg in March. Mr A. H. Knight (Soil Fertility) attended a meeting on Water in Agriculture at the Tenth International Agrochimica Symposium in Bari, Italy, in May. Dr M. V. Cheshire (Soil Organic Chemistry) and Mr M. P. Greaves (Microbiology) attended the First International Symposium on Biodegradation and Humification in Nancy, France, in September.

In the programme of work which follows, a number of changes compared with 1972/73 are attributable to the above-mentioned reorganization affecting Biochemistry, now Soil Organic Chemistry, Plant Physiology and Soil Fertility consequent on the recommendation of the 1972 Visiting Group. The departmental responsibility for individual research projects is as follows:

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

In addition to the research projects, a number of service projects are also listed. When these are non-departmental, provided by Technical Services or Administration, they bear a 900 series identification, while for inter-departmental services for which one department is responsible, the appropriate series number of that department is prefixed by 5. A list of service projects follows that of the research projects.

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 of chemical and instrumental methods of examination.

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

109 Mineral and biological materials: structure and composition by electronoptical and electron probe methods.

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

204 Geochemical distribution and pedological behaviour of trace elements.

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

206 Development of flame emission and atomic absorption methods: instrumentation and techniques for trace and major elements.

703 Development of computer techniques and programs.

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 methods.

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 materials 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 and degradation of polysaccharides and related constituents of soil organic matter.

307 Characterization of soil humic substances by means of their paramagnetic properties.

309 The effect of organic constituents of soil on the growth and nutrition of plants, with particular reference to processes involving the root.

311 The effects of organic constituents of soil on biochemical processes in plants.

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 Chemical and biochemical investigations of organic material of microbial origin.

501 Incidence and characterictics 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.

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.

317 The nature and properties of organically bound phosphate in soils.

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

602 Organic phosphorus and sulphur 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.

407 Salt absorption: physical and metabolic aspects.

408 Nitrate reductase and molybdenum-copper interactions in plants.

606 Inorganic and organic constituents in crops: forms, patterns and balance in relation to age and yield.

613 Development of radioactive techniques.

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.

SERVICE PROJECTS

Non-Departmental

Projects

901 Provision of Instrument Workshop facilities.

902 Provision of Photographic facilities.

903 Provision of specialized materials and equipment.

Departmental

Projects

5107 Mineral and organic soils: application of chemical and instrumental methods of examination.

5205 Application of techniques for the determination of trace elements: direct reading methods and computer processing.

5206 Application of flame emission and atomic absorption methods for trace and major elements.

5313 Provision of analytical facilities employing special equipment.

5314 Supervision and maintenance of general glasshouse facilities.

5613 Provision of radioactive facilities.

5701 Production of designs for experiments and statistical analysis of data.

5703 Data preparation and computer processing.

1. PEDOLOGY

In pursuit of its general aim, to obtain a better understanding of the origin and properties of the complex soil system using the methods of pure science, the work of the department has continued along the lines detailed in last year's report.

Over the past decade there has been a notable change of emphasis in the mineralogical work of the department, a preoccupation with crystalline components of soil clays giving place to a wider outlook engendered by the appreciation that, as noted in the last few reports, disordered and non-crystalline inorganic materials can have a disproportionate effect on soil properties. Since these materials are probably the major inorganic part of the organomineral complexes in the soil, the trend towards study of these complexes and compounds, with special reference to their nature and properties, is likely to intensify as methods capable of dealing with such materials are developed. A recently acquired gas chromatograph and mass spectrometer system, in conjunction with a Curie-point pyrolyser, is likely to be one of the tools used in the forefront of this attack.

It is pleasing to record the award of the Sylvicultural Prize of the Institute of Foresters of Great Britain to Dr H. G. Miller and Miss J. M. Cooper (Statistics) for a joint paper[1] on nitrogen nutritional studies on Corsican pine at Culbin Sands.

The sudden death of Mr A. P. Thomson has robbed the department of a valued senior scientific officer. Appointed as scientific assistant in 1946, he originally assisted the late Dr G. F. Walker in classical studies on vermiculite in Scottish soils and subsequently collaborated with the late Mr W. A. Mitchell and with Dr M. J. Wilson in their X-ray diffraction investigations on soil clays and related materials. With an electronics qualification, he was invaluable for maintenance of scientific equipment, and his thorough knowledge of clay mineralogy, acquired over the years, was instrumental in establishing some promising lines of research. At the time of his death he was responsible for day-to-day supervision of X-ray diffraction studies and for collation and correlation of mineralogical information on Soil Survey samples; he was also involved in investigating the crystallization of inorganic gels in the presence of organic materials. He trained many visiting research workers in the intricacies of operation of various pieces of X-ray equipment and in the interpretation of the patterns obtained. He made valuable contributions to several scientific papers, including one on iron oxide formation from chelates[39] now awaiting publication.

Specialized techniques have been used to examine samples from other departments and specimens relevant to current research projects received from outside bodies; other collaborative studies are mentioned below. Close connections have been maintained with relevant sections of 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 various other bodies, particularly on aspects related to survey and utilization of peat. The

Institute is responsible for the collection and dissemination of information and advice on peat resources and their development, and many requests from individuals and organizations are dealt with.

Professor N. Yoshinaga, Faculty of Agriculture, Ehime University, Japan, and Dr K. W. Perrott, Ruakura Soil Research Station, Hamilton, New Zealand, have spent periods in the department studying poorly ordered components of soils, while Dr N. Morandi, Istituto di Mineralogia e Petrografia, Università di Bologna, Italy, has carried out a study of some serpentine minerals. Dr A. S. de Endredy, FAO, Rome, and Mr G. F. Brockley, a sandwich-course student from Robert Gordon's Institute of Technology, Aberdeen, have also assisted in the work of the department.

Members of staff have attended an ARC Conference on Electron Microscopy and meetings of, *inter alia*, the British Society of Soil Science, the Clay Minerals Group of the Mineralogical Society, the Electron Microscopy and Analysis Group of the Institute of Physics, the Meres and Mires Research Group and the Institute of Foresters of Great Britain. At the invitation of the Preager Society, a lecture on the weathering of minerals was delivered to the Society at the New University of Ulster and, also by invitation, a key-note address on thermal analysis[40] was presented to the Centenary Celebrations of the Society for Analytical Chemistry in London.

Dr M. J. Wilson presented a paper on cristobalite[2] at a joint meeting of European Clay Groups at Strasbourg, France, and Mr R. A. Robertson attended a meeting of the Council of the International Peat Society in Jyvaskyla, Finland, thereafter participating in a symposium on peatland drainage.

CHEMISTRY AND MINERALOGY

Analytical and Morphological Studies

Chemical. Despite limitations imposed by soil handling facilities and availability of storage space, some 2000 soil samples collected by Soil Survey in 1972 have now all been prepared for analysis and systematic physical and chemical investigations are well advanced. About 1600 samples collected in 1973 are currently being prepared for study. 101, 801

Previous investigations on seasonal variation in the composition of the soil atmosphere (Annual Report No. 42, 1971/72) have been supplemented by examination of seasonal variation in major-element content of the soil solution in two gley profiles (from the Terryvale and Drumlasie series) of the Countesswells Association. In spring the silicon and aluminium contents are only about one quarter and one half, respectively, of those in the autumn whereas the ferric iron content has increased about three times; no clear seasonal variation has yet been established for calcium, manganese or titanium. 101, 801

With the development of a method for determining manganese to a lower limit of about 0·02 per cent MnO, X-ray fluorescence can now be used for determination of all major elements normally included in the chemical analysis of silicate minerals and rocks. In collaboration with Plant

Physiology, this technique has also been employed to determine the chlorine, as well as the bromine, contents of plants: in most plants examined the chlorine : bromine ratio is about 300 : 1. 104, 107, 403

Soil extracts are often difficult to analyse chemically because of interference from compounds left in solution on destruction of organic matter; in such instances bromine has proved to be a very suitable oxidant[41] and is now widely used. 105, 107

Thermoanalytical. Differential thermal analysis is particularly useful in the initial examination of soil clays separated from profile samples, X-ray diffraction examination being reserved for about two samples from each profile unless marked changes are observed on the differential thermal curves[42]. Thermogravimetry generally provides more accurate quantitative information, although differential thermal equipment specifically designed for quantitative studies is now readily available[43, 44, 45]. The micro-thermobalance currently in use has been modified to record weight losses directly in per cent and is being used along with quantitative differential thermal analysis to investigate the effect of exchangeable cations on the combustion characteristics, in an oxygen atmosphere, of humic acids separated from *Calluna* peats. 103, 107, 801

Electronoptical. A scanning electron microscope and microprobe system continues to give valuable information on soil structure, mineral weathering and compositional changes at surfaces. It has been shown, for example, that in the gleyed surfaces of structural units of a soil developed on lacustrine clay (Tipperty Association) individual clay particles cannot be resolved, whereas in the red-brown interior of the units clay particles are clearly visible. The grey gleyed material, in fact, consists essentially of a skin of clay particles with a slightly lower silica : alumina ratio than the red-brown material. Manganese staining in this and some other soils has been observed to have a leaf-like form. Ochreous mottles from soils with impeded drainage have a blocky structure, the surfaces of the blocks being covered with botryoidal iron oxides. Various morphological features that have been observed in thin sections of soils show up in greater detail under the scanning electron microscope and the electron microprobe attachment enables chemical changes across such sections to be observed readily: there is clearly, therefore, much scope for use of these techniques in conjunction with optical microscopy. Striking dissolution features have been observed on the surfaces of weathered mineral grains in soils, commencing presumably at lattice dislocations, and it has also been shown that weathering products depend on the environment: for example, biotite can yield vermiculite, chlorite, smectite, kaolinite or gibbsite. Such observations are of great value in assessing the weathering mechanisms operative in soil formation. 104, 109, 801

To pursue these studies it is necessary to keep experimental and determinative methods under continuous review so that the maximum amount of information can be extracted from the results obtained. To this end, an improved gas flow proportional counter for determination of sodium has been developed[3]. 107, 801

Soil Mineralogy

One of the major criteria for classifying Scottish soils is the nature of the parent material, the minerals in which determine, to a considerable extent, both the morphological characteristics and the nutrient capital of the soil. Although interpretation of results is facilitated by separation into various fractions, some of which are discussed individually below, it must be remembered that the properties of these have to be integrated to arrive at the properties of the soil and that one separate can sometimes have a disproportionate influence. The ultimate aim is, of course, to examine the total soil as nearly in the field condition as possible. 103

A thesis on the weathering of chlorite in Scottish soils, submitted to the University of Aberdeen by Mr D. C. Bain for the degree of Ph.D., has been sustained. 104

Sand Fractions. As reported last year, evidence is accumulating that the sand fraction is not the inert skeletal material that is sometimes supposed. Thus, the sand-size fraction from a serpentinite, the parent rock of the Leslie Association, contains a nickeliferous mineral of the pyroaurite-sjögrenite group which is unstable in weakly acid conditions and if inherited by the soil would be expected to release nickel. Soils of the Benan Association, on parent material derived from the Benan conglomerate which contains a high proportion of basic igneous material, are found in south-west Scotland and contain saponite in all size fractions of the C horizon. This saponite, however, weathers out towards the surface even in poorly drained soils, its decomposition leading to a high content of exchangeable magnesium. 101, 103, 104, 207, 801

The leucophosphite mineral in some Antarctic soil samples, which is intermediate between the potassium-iron and ammonium-aluminium isomorphs, may have formed through the reaction of micaceous and chloritic soil minerals with guano. In collaboration with Spectrochemistry, the structure of so-called disordered α-cristobalite, a mineral that occurs widely in sediments, has been shown to be more closely related to that of tridymite than to that of cristobalite[2]. 103, 207

In a single-crystal structural examination of aluminium iodate nitrate, a compound that is of interest because it forms only in conditions reminiscent of those necessary for aluminosilicate formation, the aluminium ions have been found to exist as $Al(H_2O)_6^{3+}$. 105

Clay Fractions. The clay fraction, which contains the smallest particles in the soil, has an extremely large area of very reactive surface. Its mineralogy, as revealed by X-ray diffraction, thermoanalytical, electronoptical and selective chemical methods, not only enables some assessment to be made of surface properties but also indicates the mechanism of soil formation. In the Kinross and Elie areas (Sheets 40, 41) the soils of the Rowanhill, Hindsward and Giffnock Associations, developed on tills derived from predominantly sandstone sediments of Carboniferous age, are high in kaolinite, which is in all probability inherited from the parent rock, since it is known that the argillaceous material in many sandstones is kaolinitic.

In contrast, the soils of the Darleith Association, developed on till derived from basic and intermediate lavas, contain an abundance of smectites formed by weathering of primary minerals. Interstratified minerals that occur frequently in this area are often difficult to identify accurately, but theoretical studies on the type of X-ray powder patterns likely to be produced by different types of interstratification are improving diagnosis[49]. In addition to crystalline clay minerals, non-crystalline inorganic material has been identified in most of the samples examined and quantitative determinations show that it predominates in some horizons. The poorly crystalline aluminosilicate imogolite has also been identified in the B_2 horizons of eleven out of twenty-five Scottish soils as well as in soils from New Zealand[4] and New Guinea[50]; although this mineral is generally considered to be associated with volcanic ash deposits, there is no indication of ash in any of the Scottish soils examined. To provide background information for interpretation of results on Scottish soils, some soils from Antarctica, from New South Wales, Australia[51], and from Egypt, as well as alunite–kaolinite and serpentine clays from Italy, have been examined. 103, 105, 107, 109, 207, 801

Tubular crystals of halloysite have earlier been recorded in a hydrothermally altered hornblende schist[5] and attention is now being paid to a platy metahalloysite which has been detected along with trioctahedral vermiculite and kaolinite in soils developed on granitic till (Countesswells Association) in north-east Scotland. Since the kaolinite minerals occur in all series of the Association they are believed to have been inherited from material weathered in pre-glacial, probably Tertiary, times.
101, 104, 109, 801

The value of Mössbauer spectroscopy in examination of ferriferous minerals has been demonstrated by a collaborative study with Spectrochemistry on the fate of iron during oxidation of biotite[6]. 104, 107, 203

Clay: Organic Matter Complexes

In order to obtain information on the role of organomineral complexes and inorganic gels on aggregate formation in soils, the stability of aggregates in different horizons of a freely drained cultivated soil developed on granitic till (Countesswells series, Countesswells Association) has been studied using particle size distribution and specific area measurements. When dry aggregates are suddenly wetted, considerable disruption occurs in aggregates of 2–0·425 mm size because of the sudden expulsion of air. Within this size range the magnitude of aggregate disruption increases with depth. 106

Surface Properties of Soils and Clays

Calorimetric measurements of the heats of sorption of fatty acids on natural and synthetic inorganic gel systems and crystalline clay minerals can be interpreted in terms of the configuration adopted by the fatty acid molecule on the various surfaces and thus reveal information on the polarity of the surface. Preliminary investigations on the sorption of carbon dioxide on goethite and phosphated goethite, carried out in collaboration with Spectrochemistry, indicate that similar lattice sites are involved in the sorption of carbon dioxide and phosphates. 106, 207

The degree of polymerization of silica tetrahedra in crystalline and non-crystalline silicates can be determined from the porportions, as determined by gas-liquid chromatography, of monomeric and the various polymeric silica derivatives in the volatile materials resulting from treatment of the samples with trimethylchlorosilane. The semi-quantitative results so far obtained for soils indicate that the ratio of monomeric to dimeric silica is higher in podzolic than in brown forest soils and decreases down the mineral horizons of the profile in both: only monomeric silica is observed in H horizons. 105

The release of hydroxyl ions on the addition of sodium fluoride to soils has been used to indicate the presence of non-crystalline inorganic material. An investigation into the mechanism of this process is in progress. Rate of release of hydroxyl ions from silica and iron oxide gels is negligible above pH 7·6 and pH 8·57 respectively, but hydroxyl ions are still released from alumina gels at pH 10, although the rate of release decreases as the degree of crystallinity increases. The Al:Si ratio appears to determine the ratio of the amounts of hydroxyl released at pH 8 and pH 6·8. 105

Results for soils representing the principal series mapped by Soil Survey, obtained by the various selective chemical techniques currently employed for assessment of the presence of non-crystalline inorganic material (extractions with sodium carbonate, sodium dithionite and potassium pyrophosphate and hydroxyl release on treatment with sodium fluoride), are being analysed statistically to determine the degree of correlation and to assess whether variations down profiles are significant. Some highly significant correlations have been obtained and the investigation continues. 101, 105, 5703, 801

Organic and Biological Materials

The possibility of distinguishing between several humus types from the results of mass spectrometric examination of volatile materials obtained on rapid pyrolysis *in vacuo*[7] has been confirmed using a simplified statistical treatment that does not entail any prior assumptions[52]. The thermal decomposition characteristics of humus horizons from a profile on afforested blown sand at Culbin have been described[53]. Gas chromatography of the volatile materials produced has shown that one particular group of relatively polar compounds varies in abundance with humus type; these originate mainly from little humified plant material (mor humus) and decrease in abundance towards mull humus and down the profile. To enable a better assessment of such trends a low-resolution fast-scan mass spectrometer (VG Micromass 12 B) has been installed for use with a gas chromatograph as an interface with the pyrolysis unit. 101, 108, 5703, 801

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 of scientific importance. Close grid topographical, stratigraphical and botanical surveys, multiple line traverse and photogrammetric techniques are widely used and adapted,

depending on individual circumstances and requirements. Results are incorporated in Soil Survey memoirs and in more detailed maps and reports for areas scheduled for development or with development potential.
112, 113, 801

Survey techniques and expertise are also employed to support projects concerned with site capability[54], peatland drainage[55], cultivation and afforestation[56] and with the production and utilization of peat for horticulture and other purposes. 110, 111, 114, 802

In order to devise a more comprehensive and meaningful system of peatland classification, sites representative of a wide range of types have been selected for study in the vicinity of Banchory and Stonehaven (Sheet 66/67), in the Latheron and Wick areas (Sheet 110/116) and in the region around Stranraer (Sheet 1/2/3/4). Phytosociological, morphological, hydrological and stratigraphical characteristics are being used in assessment, a primary objective being the establishment of the relative importance of these factors as classification criteria. The peatlands so far examined are very diverse, but geographical gradients have been identified from vegetation and morphological features. Peat cores have been taken from selected sites for plant fossil analysis. 111, 112

Further surveys to establish the nature, extent and topographical relationships of deposits of deep peat straddling proposed routes for the realignment between Carrbridge and Inverness of the A9 trunk road have been carried out at the request of the Scottish Development Department. A total of 14 deposits, including Baddengorm (162 ha, 350 acres) and Slochd (48 ha, 105 acres), have been examined and appropriate maps and sections prepared. At certain localities the depth, which can be as great at 8·0 m, and the high incidence of tree remains in some horizons present problems in relation to extraction and disposal. On Islay, a small area of blanket bog has been evaluated to provide information on the quantity and quality of peat available for a local distillery, and in the Scottish Borders over 325 ha (700 acres) of deep peat have been surveyed to determine the reserves suitable for horticultural purposes and to assist the preparation of a long-term plan for drainage and extraction. In collaboration with Soil Survey, a reconnaissance to establish the nature and extent of peatland areas in Ardnamurchan has been completed. 112, 114, 801

Cartographic work and laboratory analyses have progressed satisfactorily and the close liaison maintained with national and international agencies concerned with peat science and technology has greatly assisted in the recording and provision of information on many aspects of peat research and development. 112

Pollen Analysis and Quaternary Research

In collaboration with Statistics, further progress has been made on the application of computer techniques to the organization and evaluation of results, accumulated over the years, of pollen analysis, and to the standardization of relative abundance diagrams. The computation of frequencies of the most important species in the form of histograms is facilitat-

ing comparative studies and is providing a new insight into the vegetational history and palaeoclimate of Scotland on a regional basis. 113, 703

Joint investigations involving soil survey, archaeology and pollen analysis have continued to provide valuable information on pedological processes, primitive agriculture and environmental history in general[8]. 113, 804

Stratigraphical and chronological investigations in Inverness-shire have been greatly assisted by road construction operations on the A9 trunk road which have exposed deep sections of peat containing a vertical sequence of Scots pine remains: profile samples have been taken at several localities for laboratory examination. In collaboration with Soil Survey, a chapter on vegetational history is being prepared for a publication on the plant communities of lowland Scotland. 113, 802

Root and Moisture Studies in Peat

These studies are designed to isolate and quantify factors of the soil environment that influence root development and plant growth on peat and related organic soils[9]. 110

The experiment at Lon Mor, Inverness-shire, continues to provide information on the effect of water table depth on the performance and growth of coniferous trees planted on deep acid peat. The lay-out incorporates five plots surrounded by perimeter ditches in which water levels are maintained at 0, 10, 20, 30, and 50 cm from the surface, respectively, and carrying stands of lodgepole pine, planted in 1963, and Sitka spruce, planted in 1972. In summer 1974 whole trees of lodgepole pine were sampled for detailed biomass analysis; results are currently being computed. The spruce trees are still recovering from frost damage sustained during their first season and, despite a second dressing of fertilizer equivalent to 130 kg N, 41 kg P and 72 kg K per ha, are still under severe competition from vigorous heather, especially on the drier plots. 110

Investigations on the aeration status of peat profiles, using equipment similar to that described previously (Annual Report No. 42, 1971/72), have been extended to a raised bog at Skene, Aberdeenshire, where studies on the aerobic bacterial population of the upper peat horizons are in progress. Average values for the oxygen content of the soil atmosphere in June were 16 per cent at 5 cm below the surface but less than 1 per cent at 15 cm, approximately 6 cm above the water table. 110, 503

Peat Standards and Glasshouse Investigations

Studies on the characterization and evaluation of horticultural peats and peat products[57] have continued in collaboration with national and international standards organizations. Consideration is currently being given to the refinement of analytical techniques, particularly those concerned with determination of the physical properties of peat substrates. 114

Successive cropping with tomatoes of six mono-ingredient peat substrates has shown no detectable reduction in plant growth or in fruit yield over three years. In contrast, during 1974, the fourth year, there has been a considerable loss of plant vigour and, although the last of the crop has not been harvested, fruit yields appear well below those obtained on the same sub-

strates in the earlier years. The effect of long term cropping on the structures of peat substrates is being investigated. 114

Experiments in collaboration with Plant Physiology have illustrated the high incidence of blossom-end-rot on tomatoes grown on peat substrates. Since one factor is reputed to be luxury uptake of potassium, possibly caused by differences in solubility of applied nutrient salts, an attempt is being made to correlate incidence of the disease with soil moisture status. 114, 402

Nutrient Uptake from Forest Soils

Studies of the nutrition of pole-stage Sitka spruce have continued at Mearns Forest (Fetteresso) and Leanachan Forest (near Fort William) and the third and fourth experiments in the series of six envisaged in last year's report have been established at Strathyre and Elibank Forests, near Lochearnhead and Peebles, respectively. The four experiments are located in different climatic sub-regions and at each site nutrient movement is being examined, in both unaltered and fertilized plots, by first determining the distribution of nutrients within the crop and subsequently monitoring movement in litter fall and rainwater. The four crops exhibit very different growth rates, although the accumulated dry weights within each ecosystem are very similar (about 150 tonnes per ha). The experiments at Mearns and Leanachan Forests are proceeding satisfactorily, but some problems with insect contamination of rain gauges and with excessive volumes of stemflow, which is averaging 10-20 per cent of gross rainfall as against the 3-5 per cent anticipated, have necessitated design changes in the new experiments. At neither of the first two sites has there been detectable fertilizer contamination of the outflow water from the experimental area. 115

The techniques of whole-tree sampling in spruce developed for this investigation have been applied to a stand in Mearns Forest in which the University of Aberdeen is conducting an intensive study on canopy processes. The crop here is of the same age as the four mentioned above and carries about the same weight of foliage. In collaboration with Statistics, it has been shown that the vertical distribution of number of needles through the canopies of four of these stands follows a normal curve, but only at two is the distribution still normal when weight of foliage is used. 115

Detailed examination continues on the relationship between pattern of growth and nutrient uptake under different nitrogen regimes in pole-stage Corsican pine on the sand dunes of Culbin (Laigh of Moray Forest), Morayshire. It has proved possible to relate tree growth in this crop to the levels of nitrogen in freshly fallen needle litter[58]. Rainwater is responsible for transferring to the forest floor almost half the potassium and magnesium and about 90 per cent of the sodium released by these trees[59]. Most of the transfer of nitrogen and phosphorus occurs in litter fall, although nitrogen is released into rainwater at certain times of the year—a feature that may reflect seasonal variations in the levels of soluble nitrogen in foliage. Recent work has concentrated on reconstructing the pattern of dry weight increment, in particular the build-up of foliage mass, across the fertility gradient provided by the fertilizer treatments. This approach is yielding particularly useful information on the mechanism of fertilizer response in coniferous trees. 115, 117, 701, 703

Results from nitrogen fertilizer experiments that have run for ten and twelve years in old Scots pine have emphasized that, whereas it is possible to provide a reasonable forecast of the absolute growth of fertilized trees, vagaries in the year-to-year growth of unfertilized control trees, presumably associated with variations in rate of nitrogen mineralization in the humus layer, make it very difficult to forecast the relative response, and hence the economic return. 117

In the glasshouse the efficiency of different phosphate fertilizers supplied by the Forestry Commission are being examined in a series of pot experiments. Analytical determinations have been completed on peat samples taken from Flanders Moss, Stirlingshire, before the intensive peat drainage experiment was established there by the Forestry Commission and the results will serve as a basis for assessing the long-term effect of drainage. In addition, information on various matters relating to the forest-soil ecosystem have been supplied to a number of outside bodies. 111, 115, 117

Nitrogen Mineralization in Peat and Mor Humus

The effects of different factors on the rate of mineralization of nitrogen continue to be assessed in samples of peat incubated under controlled conditions. The influence of incubation temperature and of prior freezing and thawing has been studied at temperatures up to 30°C on samples of three peats having total nitrogen contents in the range 1·0–2·0 per cent oven-dry matter. Freezing and thawing fresh samples of peat has a marked effect on the subsequent rates of mineral nitrogen production, the rates in frozen-then-thawed samples incubated at 10°C increasing by a factor of two to three compared with those in unfrozen samples incubated under the same conditions and being comparable with rates of production in unfrozen samples incubated at 30°C. 116

The rates of production of mineral nitrogen on incubation of peat samples supplied by the Forestry Commission Research Branch from Naver Forest (Sutherland) and Penninghame Forest (Wigtownshire) are being studied; these cover a range of types selected on the basis of surface vegetation and topographical features. After incubation at 30°C flushed peats yield a considerable amount of nitrate whereas unflushed peats yield mainly ammonium. 111, 116

Incubation under anaerobic conditions of samples taken from the peat drainage experiment at Lon Mor, Inverness-shire, has shown that lowering the water table to 18 cm significantly decreases the amount of nitrogen mineralized in the top 10 cm of the profile but further lowering results in a significant increase[60]. 110, 116

Mor humus samples from an experiment comparing forms of fertilizer nitrogen, applied alone or in combination with phosphorus and lime on pole-stage Scots pine at Culbin (Laigh of Moray Forest), have again been examined. The residual effect of lime, applied in 1968, on the acidity and calcium content of the humus is still apparent and, as in 1973, the stimulatory effect of nitrogen applied in 1968 and 1969 on mineral nitrogen production is confined to humus from those plots that also received lime. 116, 117

2. SPECTROCHEMISTRY

The work carried out in the department can be divided into three interrelated categories: the investigation of the distribution and mode of occurrence of trace elements in soils, soil profiles, clay minerals and plant materials; the examination of the composition, reactivity and structure of inorganic and organic components of soils; and the provision of an analytical service for the determination of elements in samples from other departments. The installation during the year of an AEI MS702R spark-source mass-spectrometer will permit the determination of a wider range of elements in soils and plants and lower the limits of detection of many elements.

Several visiting research workers have used the spectroscopic facilities available. Mrs J. Bollingberg of the Mineralogisk-Geologiske Instituter, Mineralogisk Museum, Copenhagen, studied spectrographic methods employed for the determination of trace elements in rocks and minerals. Computer corrections employed for line interference and for variations in background and matrix composition required with direct-reading emission methods have been discussed with other visitors. Infrared studies on soil clays were carried out by Professor N. Yoshinaga, Faculty of Agriculture, Ehime University, Matsuyama, Japan, while Mr R. Soong, New Zealand Geological Survey, Lower Hutt, New Zealand, examined chlorites and sulphide minerals.

During a visit to Yugoslavia at the invitation of the Faculty of Agriculture of the University of Sarajevo, Dr A. M. Ure gave lectures at the Institute Jozef Stefan, Ljubljana, and the Institute of Chemistry and Physics, Sarajevo. Dr M. L. Berrow attended the Tenth International Congress of Soil Science in Moscow. Contributions were made by members of staff to a seminar on Computers in Spectroscopy, held at Leicester, a conference on Contamination, held at Salford, and a meeting of the Mössbauer Discussion Group of the Chemical Society at Leeds; meetings of the Chemical Society, the Scottish Direct Reading Spectroscopy Group and the Inter-Services/D.T.I. Panel on Spectroscopy were attended. Lectures were given to post-graduate students in the Soil Science Department of the University of Reading.

Trace Elements in Soils, Plants and Biological Materials

Assessment of soil status using the extractants 0·5 N acetic acid, neutral N ammonium acetate and 0·05 M EDTA continues. About 600 samples from soil profiles per annum have been analysed for total trace element content during the period 1971 to 1974, compared with about 200 in previous years, the increase being partly due to the employment of the E789 Hilger and Watts Polychromator for the trace element determinations. The results of the analyses for the total and extractable contents of selected soil profiles from west Fife and mid-Stirlingshire were reported in the Programme and Guide to Excursions for the Autumn Conference of the British Society of Soil Science. The trace element problems on Scottish soils have been reviewed[61].

Soils and Soil Parent Materials. Investigations on the association of trace elements with secondary oxides of iron and manganese in pan horizons of

soil profiles have continued. The form in which the iron is present has been studied in ten well developed iron pans from podzols derived from a range of parent materials, using different extracting agents such as acetic acid (pH 2·5), ammonium oxalate (pH 3·3), sodium dithionite (pH 3·8), EDTA (pH 7·0) and potassium pyrophosphate (pH 10·0). Results indicate that most of the iron in the pans (mean 82 per cent of the total iron content) is present as a mixture of crystalline and non-crystalline oxides and hydrous oxides, that a considerable proportion (mean 16 per cent) is present as primary mineral forms, and that iron complexed by organic matter constitutes only a small proportion (mean 2 per cent). The presence of these forms of iron is being confirmed by Mössbauer spectroscopy and other physical methods. 201, 203

Very high amounts of acetic acid and EDTA extractable copper (67 ppm and 96 ppm respectively) have been found in a gleyed subsoil horizon from a poorly drained profile developed on Middle Old Red Sandstone till of the Thurso Association (Olrig series); the lead and zinc extracted by these two reagents and by ammonium acetate are also very high. High extractable contents of all three elements have also been found in comparable horizons from other profiles developed on Middle Old Red Sandstone parent material in Orkney and Caithness. 101, 201

Determination of trace elements in selected soil profiles sampled by Soil Survey has continued. Work on the soils from the area covered by Sheets 1, 2, 3, 4 and part of 7 (Kirkmaiden, Whithorn, Stranraer and Wigtown) is in progress, while examination of soils from the Black Isle, Cromarty and Invergordon (parts of Sheets 83, 84, 93 and 94) and from the Latheron and Wick areas (Sheet 110/116) has been completed. 101, 201

The trace elements in humic and fulvic acid fractions of a soil from the Insch Association (Insch series), prepared by Soil Organic Chemistry, have been determined. The humic acid fraction was much richer than the fulvic acid fraction in iron, titanium and copper, but lower in aluminium, while the contents of manganese and vanadium were similar in both. 201, 307

Collaborative studies with Pedology on the trace elements in peat profiles have continued and profiles from the Isle of Mull and Wigtownshire are being investigated. The determinations of the total contents of copper, manganese, iron, barium and strontium in Isle of Mull samples have been completed and those on Wigtownshire samples are in progress. Thirty-four profiles representing high and low level blanket peat and basin peat from different areas of Scotland, varying in depth from 0·5 to 11·5 metres, have been examined. They differ widely in copper and manganese content, but in almost every profile the copper content is high at the surface, thereafter decreasing with depth until a sharp increase close to the mineral parent material is observed. In contrast, the manganese content increases down the profiles. 112, 201

Soil Status and Plant Uptake. The number of element determinations carried out has risen by about 30 per cent this year. Cobalt, copper and molybdenum determinations for Soil Fertility, relating to suspected nutritional disorders of plants or animals, have remained about the same as last year. 5205, 5206, 610

Soils from Soil Fertility experimental plots are being analysed for their total and extractable trace element contents, to examine the effects of pedological status on mobilization. Determinations of total, acetic acid, ammonium acetate and EDTA extractable contents have now been made on soil profiles from five areas in Caithness where soils with high molybdenum contents have been previous recorded. The analyses of the individual plant species from these sites have still to be completed. 201, 202, 609

In collaboration with the Agricultural Development and Advisory Service of the Ministry of Agriculture, Fisheries and Food, investigations have continued on the effects of additions to soil of sewage sludges high in zinc, nickel, copper and chromium and on trace element uptake by plants grown on sludge-treated soils. Soils taken from control plots and from those treated with sewage sludge over a period of five years have now been largely examined for EDTA extractable trace elements. The determination of the total mercury content of over 50 sludges, including 42 sampled for the initial trace element survey, is nearing completion. Sludges from four sewage treatment works, which over a five-year period produced material with consistently high zinc, nickel, copper and chromium contents, have again been sampled by ADAS and analyses are in progress. The analyses of plants from the sludge-treated plot experiments are continuing. The determination of chromium, nickel and zinc directly in plant ash by means of the Polychromator is not yet possible because of uncorrected matrix and background effects, and about 200 of the 1000 plant samples have now been analysed using the more time-consuming chemical concentration technique. In these determinations the highest levels encountered have been approximately 400 ppm zinc, 35 ppm nickel, 40 ppm copper and 10 ppm chromium.
201, 202, 205

An investigation into the possible relationship between trace elements and grass sickness in horses, carried out in collaboration with the Animal Diseases Research Association and with the assistance of Soil Fertility, is proceeding. Samples of soils and plants from plot and field sites in areas where the disease has recently occurred have now been analysed. No obvious relationship has been found between the disease and the trace element content of either the surface soils or the plants. It also appears unlikely that there is a toxicity problem caused by such elements as lead, cadmium, mercury or selenium, but on about half the sites the mixed herbage would be considered cobalt-deficient for ruminants. A detailed assessment of the results is being made. 201, 202, 609

The glasshouse pot experiments mentioned in last year's report on the uptake of mercury and other trace elements from soil mixed with an industrial chlor-alkali waste are continuing. 201, 202, 5314

Thirteen coal samples from various areas of New Zealand, on which infrared studies were carried out by a visiting research worker, have been analysed. The high boron content, 10 to 625 ppm (mean 220 ppm), in many of the samples confirms the abnormally high boron content of New Zealand coals already reported by other workers. 201

Miscellaneous samples analysed have included soils and mineral separates (from Pedology), rocks (from Dr El Kholy, University of Sanaa, Yemen) and fly ashes (from the National Vegetable Research Station). Plant samples examined have included ryegrass (from the Botany Department, University of Sheffield), ryegrass and Sitka spruce samples (from the Soil Science Department, University of Aberdeen), conifer samples (from the Forestry Commission Northern Research Station) and mixed herbage samples (from Imperial College, London). Other materials of biological interest include sheep diets (from the Rowett Research Institute and from the Animal Diseases Research Association) and marine organisms (from the Institute of Marine Biochemistry, Aberdeen). 104, 5205, 5206

Spectrochemical Methods of Analysis

The difficulty of achieving accuracy in the determination of trace elements is now more widely recognized and is reflected in the increasing number of standard rocks issued by the various organizations mentioned in last year's report. Few standard samples have been available for plant analyses, but a wheat flour and a corn flour have now been obtained from the International Atomic Energy Agency in Vienna. Rocks from the Central Geological Institute, East Berlin, have now been analysed, and the trace element contents found are close to the reported values. The mercury content of the standard reference orchard leaf sample (United States National Bureau of Standards) has been confirmed, using an oxygen flask combustion method followed by a cold vapour atomic absorption measurement. 205, 206

Arc Emission. The only change in the cathode-layer arc technique has been the use of Grade SG-305E (6 inch long by 5·5 mm diameter) Morganite carbon rods in place of Grade SG-305H. The new grade has lower contents of copper, lanthanum, molybdenum, titanium and vanadium. Samples arced in electrodes prepared from the two grades of carbon show no noticeable difference in the line intensity ratios normally measured in spectrographic methods. Electronic measurements from the E789 Polychromator, however, have shown a significant difference in the intensity ratio of the lines of the two internal standards indium and palladium when a narrow-bore electrode is employed. The computer programs used to evaluate the Polychromator data have been modified to take account of the changes in the grades of carbon. 205

A stabilized high-current source has been constructed and tested up to 20 A using a triple gas jet source and new arc stand. The arc current can be run-up automatically by motor drive from the lowest stand-by value of about 2·5 A to any of seven pre-selected stabilized currents in about 12 seconds. Alternatively it can be stepped up or down between any of the values (3, 5, 7, 9, 12, 15 and 20 A) by manual push-button operation. A description of the triple gas jet[62] is awaiting publication. 205

Direct Photometry. The 49-channel Hilger E789 3-meter Polychromator has been in use for nine months for the analysis of chemical concentrates and consequently the time required for the determination is now considerably less than when microphotometry of spectrographic plates was employed.

A recent re-calibration using plant ash standards has shown that this instrument has maintained its stability to within ±5 per cent over a three-year period. Over a one-year period a similar stability of trace element to internal standard line intensity ratio has been found with rocks for a range of 1 to 3000 ppm of many elements in synthetic standard samples. The internal standard line intensity ratio of In:Pd, in addition to being used to monitor the arc stability (Annual Report, No. 42, 1971/72) and to correct for matrix variation (Annual Report, No. 43, 1972/73), is now also used to make the corrections necessitated by the alteration in excitation conditions caused by the change of electrode carbon from SG-305H to SG-305E, so that the same working curves can be used with samples arced in electrodes prepared from either grade of carbon. 205, 5205

A transistorized electronic console has replaced the 17-year old valve console of the Hilger Medium Direct Reader, and the instrument is again operational. 205

Flame Emission. The number of samples analysed by the three-channel laboratory-built flame photometer has remained at about the same level as last year, with calcium and potassium determinations each about 20,000 and sodium about 13,000. 5206

A Techtron AA4 spectrometer used in the emission mode with a high-temperature nitrous-oxide:acetylene flame has been employed for about 300 determinations of aluminium as well as for determinations of calcium in samples of rocks and fly ashes, in which high aluminium can cause interference at lower temperature. 201, 5206

Atomic Absorption: Flame Techniques. Few changes have been made in the techniques employed; the scope for development is now limited by the full utilization of the Techtron AA4 spectrophotometer for established analytical methods. During the year this instrument has been used for determinations of magnesium in soil and plant extracts and cadmium in soil extracts, using an air:acetylene flame; for determinations of copper, manganese and zinc, using a separated air:acetylene flame; and for determinations of calcium, using a nitrous-oxide:butane flame. The advantages of the last, a relatively high-temperature flame, for calcium are the low limits of determination and the negligible interference from variation in the phosphorus content of samples. Determination of cobalt in acetic acid extracts of soils has continued at the same level as last year. An account of the determination of the alkali metals by flame photometric and atomic absorption methods[63] is still awaiting publication. 206, 5206

Atomic Absorption: Non-flame Techniques. A description of the cold vapour atomic absorption technique for the determination of mercury in soils and other materials of agricultural interest[10] has been published, and a report on the mercury content of some top-soils and soil profiles is in preparation. As mentioned in last year's report, the main problem in mercury determination is to obtain a representative example. 201, 206

Cadmium can be determined satisfactorily in soil extracts by a flame method, but with solutions of plant materials the background correction

required is so large that both the precision and the limit of determination are poor. For plant ash solutions, therefore, the dithizone-extraction carbon-filament method described in last year's report has been developed to give a precision of three per cent at 0·1 ppm Cd content, with a limit of determination of 0·005 ppm in solution (0·05 ppm in the oven-dry plant material). The accuracy of the method has been checked by determining the cadmium content of soil extracts by both flame and carbon-filament atomization. Cadmium contents have been found to be generally less than 0·1 ppm in herbage samples, over 1 ppm in potato shaws, and several ppm in plants grown on soils treated with sewage sludge. 201, 202, 206

Spark-Source Mass-Spectrometery. An AEI MS702R spark-source mass-spectrometer with photographic detection has been installed. The lines of elements with mass numbers from No. 7 (lithium) to No. 238 (uranium) can be recorded on one photographic plate, and detection down to at least 0·01 ppm is possible for many elements. Two alternative photoelectric detection systems will shortly be installed. In one, elements in the mass range given above are electronically scanned and recorded; in the other, integrated signals for up to 20 pre-selected elements are sequentially displayed on a digital voltmeter. The information so obtained will supplement that from optical emission methods, especially for such elements as arsenic, bromine, fluorine, selenium and the rare earths, which are not readily determined by emission spectroscopy. 205

The work to date has been concerned with optimizing the electrode geometry to provide continuous and uniform ion transmission. Pelleted rod electrodes with wedge-shaped tips are proving the most satisfactory; they consist of one part of the sample powder (rock or soil) mixed with either three parts graphite or one part aluminimum powder. To facilitate the positioning of electrodes both initially and during an exposure a twin projection lamp adjustment system has been devised. This produces on the primary-slit face two adjacent sets of images of the electrodes, by means of which alignment of the electrode positions can be made with the aid of a low-power telescopic sight. A Leeds-Northrup 6700 P-1-S microphotometer proved to have insufficient resolution for mass-spectrographic plates and a laboratory-built microphotometer (Annual Report No. 36, 1965/66) in the recording mode is being used. A plate-holder attachment with adjustments that provide accurate focus over the whole ten-inch plate length has been added; this enables the complete spectrogram to be recorded in a continuous scan, facilitating the allocation of line peaks to mass numbers. 205

Preliminary semi-quantitative estimations of the elements in the United States Geological Survey rocks BCR-1 and G-2 have been made and reasonable agreement with the values reported in the literature has been found for antimony, barium, calcium, cerium, chromium, cobalt, copper, europium, fluorine, iron, lanthanum, lead, lithium, nickel, niobium, phosphorus, rubidium, strontium, sulphur, tantalum, terbium, titanium, vanadium, yttrium, zinc and zirconium. Elements observed for which comparison values are not available include arsenic, boron, bromine and caesium. 201, 205

Molecular Spectrometry of Soil Constituents

Optical Absorption Spectrometry. Hydrous oxides of aluminium and iron can appear as discrete minerals in soils, but more commonly occur as ubiquitous coatings on the surface of other minerals. Accordingly, they play an important role in determining the physical and chemical properties of soils, especially as they strongly absorb anions such as phosphate and humate. The reactive sites on the surface of these oxides have been presumed to be partially exposed cations, oxide ions, or hydroxyl groups, but until now they have not been accessible to direct study. It has, however, been established here that it is possible to prepare specimens of gibbsite, an aluminimum hydroxide, and goethite, an iron oxyhydroxide, of sufficiently small crystal size and sufficiently large surface area to allow direct observation of the vibrations of surface hydroxyl groups in infrared spectra. This advance has opened the way to the study of the involvement of these hydroxyl groups in absorption reactions, and it has already been shown that phosphate reacts with one of the two types of hydroxyl detected on goethite surfaces[11]. These infrared studies have also shown that atmospheric carbon dioxide reacts with wet or dry goethite surfaces to form carbonate ion, the presence of which has hitherto been unsuspected. This new field of investigation is being actively explored in collaboration with Pedology, which has equipment for quantitative gas adsorption studies. 106, 207

Infrared spectroscopy also contributes to the identification and structural characterization of soil minerals, mostly in collaborative studies with Pedology. A new assessment of the structure of a platy form of silica[2] usually described as a disordered cristobalite suggests that this material is more closely related to tridymite. It appears to be frequently associated with montmorillonite, and its presence accounts for some previously unexplained variability in montmorillonite spectra. A study of the clay mineralogy of red and yellow podzolic soils[51], mentioned in last year's report, has been submitted for publication, and work continues on the oxidation and reduction of iron in clay minerals. The first comprehensive treatise on the infrared spectra of minerals[12] has been edited and published during the current year; chapters have been contributed on instrumentation and techniques[13], symmetry and crystal vibrations[14, 15], oxides[16], island silicates[17], layer silicates[18], and a survey of applications[19]. Two chapters[64, 65] to be incorporated in other compendia, one of some eight years standing, are in proof. 103, 207

Infrared spectroscopy continues to contribute to investigations of the fractionation and characterization of soil organic matter, but considerable difficulties remain in separating the organic components of fulvic acids from the inorganic. Failure to recognize the presence of silica gel, sulphate and bicarbonate salts in chromatographic fractions has led other workers into serious misinterpretations of the infrared spectra of fulvic acids[66]. The previously reported study on the thermal decomposition of soil organic matter[20] has now been published, and that on aphid wax in peat[67] submitted for publication. 208, 304, 503

Mössbauer Studies. Mössbauer spectrometry is proving useful for mineralogical investigations of relevance to Scottish soils. The work on the weathering of biotite[6] reported last year has now been published and that on hornblende has been extended. In the studies with hornblende, results indicate that the occupancy of the octahedral sites in the structure by ferrous iron is more complex than has generally been assumed, and a new scheme for the assignment of sites in amphiboles is in preparation. Following the investigations on nontronites reported last year, evidence has now been obtained of the presence of tetrahedrally-coordinated ferric iron in many of the samples investigated; Mössbauer parameters for ferric iron in the two types of octahedral site as well as in the tetrahedral site have now been established. The Mössbauer spectra of a muscovite in which iron was present almost entirely in the ferric form have been used as the basis for a reassignment of the octahedral sites in dioctahedral micas. 104, 203, 207

An account of a study on the formation of iron oxides by decomposition of iron-phenolic chelates[39] is awaiting publication. 105, 203

Electron Paramagnetic Resonance Studies. With the aid of the electron paramagnetic resonance (EPR) facilities provided by the Department of Chemistry of the University of Aberdeen investigation of the nature of trace metal complexes formed with soil organic materials has continued. The presence of copper porphyrin complexes in humic acids extracted from representative soils from north-east Scotland has been established. The formation of complexes between soil organic matter and vanadium has been investigated, and EPR spectra have shown that added vanadate is at least partially reduced to vanadyl by humic acids, resulting in complexes in which oxygen-containing groups are probably involved. No evidence has as yet been obtained for the presence of such complexes in naturally occurring humic acids, although they have been found in some soil fulvic acids. Molybdenum behaves in a similar manner to vanadium, the addition of molybdate to humic acids resulting in the formation of molybdenyl complexes. Extraction of molybdenum-treated humic acids with hydrochloric acid has indicated the presence of at least two different molybdenum-humic acid complexes. 203, 307

3 SOIL ORGANIC CHEMISTRY

The aims of the department are to characterize the organic constituents in soil, to establish their effects, direct or indirect, on plant growth and to clarify the factors affecting their degradation or accumulation in the soil. The investigations in progress are described below. Close co-operation has been maintained with other departments of the Institute and with various outside organizations.

During the year Dr K. R. Tate, on leave from the Soil Bureau, Lower Hutt, New Zealand, completed a study on the acid hydrolysis of soil humic acids. Three overseas visits were made. Dr G. Anderson was invited to the Royal Veterinary and Agricultural University in Copenhagen to advise on a research programme on soil phosphorus biochemistry and while there he gave a lecture to the Danish Society of Soil Science and visited the Agricultural Research Department of the Danish Atomic Energy Commission at Risö. He also attended the Tenth International Congress of Soil Science in Moscow. Dr M. V. Cheshire gave a paper at the First International Colloquium on Biodegradation and Humification held in Nancy. Members of staff attended the Fiftieth Anniversary Meeting of the Society of Experimental Biology at Cambridge, and a Symposium on Soil Pollution held at Manchester.

Nature and Transformation of Soil Organic Matter

Humic Acid. Acid hydrolysis of humic acids releases ether-soluble low molecular weight compounds, including phenolic acids. Work is in progress on the identification of unknown compounds in the hydrolysates, involving the use of gas chromatography, either alone or in conjunction with mass spectrometry, and infrared spectrometry. The major product in all hydrolysates is laevulinic acid, accompanied by lower yields of succinic acid and the lignin-derived 4-hydroxy-, 3-methoxy-4-hydroxy-, and 3,4-dihydroxybenzoic acids. Polysaccharide destruction by 6M hydrochloric acid presumably accounts for the laevulinic acid, but the source of the succinic acid is not immediately apparent. The ratio of 4-hydroxybenzoic acid to 3-methoxy-4-hydroxybenzoic acid (vanillic acid) reflects the nature of the plant lignin incorporated in the humus. The 3,4-dihydroxybenzoic acid can arise either via demethylation of vanillyl residues or from the well known 4-hydroxyphenyl→catechyl metabolic pathway, which leads eventually to succinic acid. It has been suggested that the hydroxylation of the 4-hydroxyphenyl ring is probably dependent upon the incorporation of gaseous oxygen into the enzyme responsible; in the hydrolysates of samples derived from plant communities with a high oxygen demand, such as sedge or phragmites peats, the 4-hydroxybenzoic acid:3,4-dihydroxybenzoic acid ratio is considerably higher than that found in the case of peats or soils derived from typical ericaceous vegetation. In all these peats the contribution from vanillyl residues is negligible and it may thus be postulated that, in the case of the sedge and phragmites peat, the oxygenase reaction is limited by the higher oxygen demand of the plant community. In none of the above hydro-

lysates has 3,5-dihydroxybenzoic acid or other meta-dihydric phenols been detected, these products being expected from typical flavonoid plant products degraded in soil. 208, 303

In a continuing study, the fractionation of humus by gel permeation and adsorption chromatography shows several features of interest. As noted by others, solute-gel interactions, desirable in terms of fractionation, become suppressed by solute-solute interactions as the sample:gel ratio is increased. In view of the known surfactant nature of the humus polymers, this is not remarkable, but the fraction most affected by the electrolyte concentration of the sample contains only low amounts of species such as lignin, polysaccharide and protein, easily characterized by infrared spectroscopy or chemicals means, so that a promising fractionation is being achieved.
208, 303, 304

Soil Polysaccharide. Further co-operative studies on the stability of soil polysaccharide have been carried out with Microbiology.

It has been shown that a large proportion of a radioactively labelled soil polysaccharide is quickly decomposed during incubation in soil, confirming previous findings with non-radioactive polysaccharide (Annual Report No. 43, 1972/73). The remainder could be undecomposed substrate or polysaccharide newly synthesized by micro-organisms.

It has also been shown that the transformation of glucose to xylose in soil at natural winter temperatures, or at a constant 5°C, is almost certainly caused by yeasts. Populations of bacteria at 5°C are only one-tenth of those at 20°C whereas those of yeasts are unaffected by this difference in temperature. Analysis of microbial isolates has shown that 85 per cent of the yeasts from the soil contain xylose, compared with only 3 per cent of the bacteria. Xylose was not detected in fungi or actinomycetes. 305, 506

Joint papers on the decomposition of ^{14}C rye straw hemicellulose[21] and on the degradation of fungal cell-wall glucans[22] have been published, and an account of an investigation on the decomposition of soil polysaccharide[68], mentioned in last year's report, has been accepted for publication.
301, 305, 506, 508, 5613

An account of the part played by β-glucanases in the lysis of fungal cell walls[23] has been published. Polysaccharides composed of glucose are major components of the cell walls of all fungi so far examined. This paper reviews existing knowledge of the enzymes that attack these glucans and concludes that their action is the key to the degradation of the fungal cell wall. They are thus of importance for the destruction of pathogenic fungi in the soil, and for the sequence of microbial degradation of organic matter there. Closer investigation has shown that many different β-glucanases exist, and some are much more effective than others in attacking particular fungi. Reference is made to recent research at the Institute on the role of β-glucanases in the parasitism of sclerotia-forming plant pathogens by other soil fungi. 301

Another review paper, dealing with recent developments in research on soil polysaccharides and carbohydrate phosphates[69], discusses the origin,

structure and stability of these compounds, and includes work carried out at the Institute. 305, 317

Soil Organic Phosphorus. A considerable proportion of the uncharacterized organic phosphate in soil is associated with the humic acid fraction of the organic matter. There is growing evidence that some of this phosphate is present in acidic polysaccharide material which on hydrolysis releases a number of phosphorylated carboxylic acids. Investigations into the nature and properties of this material have continued and possible microbial sources are being examined. 317, 502

Soil-Organic-Matter : Metal Complexes. In a co-operative study with Spectrochemistry, electron paramagnetic resonance spectroscopy has been used to measure the amounts of copper porphyrin complexes, and the amounts of porphyrin available for complexing copper, in soils from north-east Scotland. In many cases a considerable proportion of the soil copper appears to be in the form of copper porphyrin, while the greatest number of free porphyrin sites was found in the two peat samples examined. A study is being made of the distribution of iron, manganese, copper and vanadium between various humic acid and fulvic acid fractions of soil organic matter, and of the forms in which they occur. 201, 203, 307

Podzol Development. Attempts to establish the chronosequence of podzol development have continued. Aluminium appears to be the major metal ion associated with the translocated humus, whereas iron is present in much smaller amount. High aluminium concentrations also appear in the horizons rich in acid-soluble phosphate which, as noted in last year's report, lie below the B horizon humus. 304, 801

The characterization of that fraction of humus extractable by dilute mineral acid is now in progress. Unlike most other soil organic polymers, this material is readily soluble in polar organic solvents and can thus be studied by more conventional techniques. 208, 303, 304, 801

Soil Organic Matter and Plant Growth

Effects on Root Growth and Nutrition in Wheat Seedlings. The beneficial effect of humic constituents on plant growth is well known, but the physiological effects are as yet poorly understood. Several humic acid preparations have been examined for their ability to stimulate root growth. Wheat seedlings grown in water culture are being used as one test system and preliminary experiments indicate that the addition of humic acid at a concentration of 50 mg/litre can increase the rate of growth of roots by as much as 50 per cent above that of roots growing in dilute calcium chloride solution which is normally optimal for seminal root growth. A stimulation can also be obtained from humic acid when a full nutrient solution containing chelated iron is used as the growth medium. The preliminary evidence suggests that in the test system used the promotion of root growth by humic acid is not attributable to a nutritional effect. Root growth, however, can be very sensitive to small changes in the ionic environment and since it is no easy matter to remove all the contaminating cations from the humic acid preparations the stimulation observed cannot yet be categorically associated

with an organic component of the organic matter. Experiments concerned with the effect of humic acid in the nutrient medium on the uptake of major elements by wheat seedlings have not shown any significant effect on absorption or distribution over a three-week growth period. An investigation on the ability of humic acid to counteract harmful effects of the ionic environment on root growth is also in progress. 309

Effects on Cell Elongation in Pea Root Segments. Reports of work on the metabolism of cell-wall protein in relation to cell elongation[24, 25, 26, 27] have been published, and further studies have been carried out.

One mechanism by which humic acid may enhance cell elongation in excised pea root segments is by sequestering ferrous iron within the cell (Annual Report No. 43, 1972/73), thus removing it from a key biochemical step essential for the cessation of cell-wall extension. But humic acid is a heterogeneous material the composition of which is still obscure and it may influence other aspects of protein metabolism associated with cell-wall rigidity and hence with cell growth.

Disulphide bridges between cysteine residues are thought to provide linkages between wall proteins and thus contribute to the rigidity of the cell walls. An investigation using analogues of naturally occurring pyrimidine bases and amino acids has now provided evidence that changes in these disulphide bridges may be important in controlling the cessation of cell growth. It appears that when there is an increase in the disulphide linkages between proteins the cell-wall becomes more rigid and cell elongation ceases. When 2-thiouracil, 2-thio-6-azauracil or thioproline is included in the culture medium the increase in disulphide linkages is prevented, and both the growth rate and duration of growth of the cells are enhanced, even although these analogues have no general effect on the changes in protein synthesis which occur during growth. The investigation should provide further valuable data for interpreting the effects of humic acids since some of these contain up to 1 per cent sulphur. 311

A joint paper with the Freshwater Biological Association describing some effects of humic acid on two different biological systems[28] has been published. 311

Effects on Cation Uptake by Cultured Tomato Roots. It is important in investigations of the effects of soil organic matter on plant growth to distinguish between changes in growth caused by chelation of nutrient cations by the organic matter and changes resulting from other influences of organic matter.

Uptake of iron, zinc and manganese by excised roots has been shown to be largely a non-metabolic process. As a consequence it seems likely that purely chemical interactions between the cations, organic matter and root will control the uptake of the ion. The presence of humate in solution at pH 5·5 produces a considerable depression in the uptake of iron from solutions of ferric citrate, ferric nitrilotriacetate, ferric EDTA or ferric EDDHA (ethylenediamine di-*ortho*hydroxyphenylacetate), even in the presence of a

thousand-fold excess of KCl which is included to prevent simple electrostatic binding. Thus at this pH humate appears to compete successfully for iron with strong chelating agents such as EDTA and EDDHA. Although humate depresses iron uptake from ferric citrate at pH 5·5, it has very little effect on the much lower uptake which occurs at pH 7·0. This may be because at neutral pH ferric citrate hydrolyses to form a stable high molecular weight negatively charged species in which the iron is not accessible to humate. That humate is capable of cation binding at neutral pH is apparent from the results obtained with zinc where binding by humate, resulting in depressed uptake by roots, is similar at both pH 5·5 and pH 7·0. Both zinc and manganese behave as positively charged species at all pH values, in contrast to iron where the proportion of positively charged species decreases with increased pH. Despite the positive charge, the expected binding of manganese does not occur at any pH, and furthermore there is no evidence that the uptake is influenced by humate. Thus binding of iron and zinc by humate appears to result from specific complexing rather than from simple cation exchange and such complexing is of importance in influencing the uptake of these trace elements. 309

Effects on the Metabolism of Beetroot Disks. Work has continued on the differential effects of humic acid on plant metabolism. Of several enzymes investigated, the development of only three, peroxidase, phenolase and invertase, is stimulated when beetroot disks are aged in solutions of humic acid. Protein synthesis generally, measured in terms of the incorporation of ^{14}C-leucine and ^{14}C-proline, is unaffected. The paper describing the biological activity of ^{14}C-labelled organic matter fractions[29], mentioned in last year's report, has now been published. 305, 311

By using radioactive isotopes it has been shown that humic acid stimulates the uptake of sodium and barium, but inhibits the uptake of zinc. There is no evidence that it affects the distribution of any cation tested beween the various sub-cellular particles. As with tomato roots, the inhibition of zinc uptake is due to the complexing of zinc by humic acid and in this case can be prevented in the presence of copper. As yet there is no explanation for the effect of humic acid on the other cations investigated. Reports on these studies are in preparation and further work is in progress. 311, 5613

4. PLANT PHYSIOLOGY

The mineral nutrition of plants, and especially calcium nutrition, has again been the major concern. During the year members of staff gave a series of lectures to students of the Department of Agricultural Chemistry of Leeds University, and attended the Fiftieth Anniversary Meeting of the Society of Experimental Biology held in Cambridge in July.

Calcium Deficiency

Work started last year on sub-apical necrosis of potato sprouts has continued and a paper is being prepared for publication. Results confirm the previous finding that chlorogenic acid always increases under conditions of calcium deficiency, and the amount of this substance can therefore be used as a criterion for calcium deficiency even when the calcium analyses show no apparent differences.

Further work has been done on blossom-end-rot in tomatoes, bitter pit in apples and cavity spot in carrots, with results similar to those found for sub-apical necrosis of potato sprouts. Usually all these disorders are associated with an increase in phosphorus and potassium in the affected tissues, changes accompanied by increased amounts of citric acid and, usually, depressed amounts of malic acid which result in higher ratios of potassium to calcium and citric acid to malic acid. 402

Iron Nutrition

Earlier work on lime-induced chlorosis in pear leaves[30] has now been published. As aluminium implication in this form of chlorosis has been suggested from leaf analysis, aluminium analyses were carried out on the leaves. The content of this element was higher in the chlorotic leaves and while application of an iron chelate to the roots of the trees caused a decrease, there was no decrease when the leaves were sprayed with an iron chelate; apparently, therefore, the enhanced uptake of aluminium is associated with iron deficiency in the roots. Such iron deficient roots contain increased amounts of polyphenols. 401

In acid soils aluminium is often a toxic factor. Study of chlorosis in lucerne on such soils has continued and poor growth has been shown to relate to aluminium content. The chlorotic plants contain lower amounts of phosphorus and potassium, and consequently lower ratios of phosphorus to iron and also of potassium to calcium. These two ratios show a very high correlation. 401

An account of the effect of iron salicylate on the growth of Lemna[70] is now in the press.

Iron and Cell Extension

Collaboration with Soil Organic Chemistry on work involving changes in cell wall metabolism during cell elongation in segments of pea roots[27] is continuing, involving the effect of phenolic substances on extension growth,

with particular reference to those phenols which can be derived by the oxidation of humic acid. The elucidation of the mechanism(s) by which such phenols as protocatechuic and cinnamic acids stimulate cell elongation may lead to a greater understanding of the process of plant growth.
311, 402

Ion Flux Studies

Earlier reports have explained how membrane potential measurements and ion flux data, particularly from isotope elution studies, are used to identify ion pumps at the cellular level and their location within the cell. The importance of several sources of error and the effects of experimental procedures have also been assessed in previous reports, and it is now well established that the onion root segments used provide a satisfactory system for ion flux studies. The findings are described in two papers submitted for publication. The first[71] reports the results for K^+, Na^+ and Cl^-, all of which it now appears are actively accumulated into the cytoplasm of root cortex cells, at least from the balanced nutrient solution used as the external medium. The results for Ca^{++} are reported in the second paper[72]. It appears that Ca^{++} enters root cells passively down a diffusion gradient, and that entry is limited by an efflux pump at both the plasmalemma and tonoplast membranes. The major difficulties in this study lay in assessing the partitioning of the calcium content of the tissue between cell compartments and in estimating the proportion of calcium which was chemically active, particularly in the vacuole. Upper and lower limits for vacuolar Ca^{++} could be set, however, and it was shown that even at the upper limit less calcium accumulated in the vacuole than would have been expected as a result of passive diffusion.
407

During loading with radioisotope, tissues used in isotope elution studies are exposed to radiation doses considerably higher than normally required in tracer uptake studies, to ensure that activity appearing in the washing solutions is sufficient to allow a satisfactory radioassay. To assess whether this treatment results in damage to the cell membranes, with consequent change in influx or efflux of ions, experiments have been conducted in which onion root segments were exposed to radiation doses (by immersion in solutions containing ^{24}Na) ranging from 0·1 to 100 times that normally used. The results show that Cl^- and Na^+ fluxes are both unaffected. 407, 5613

Accounts of work on some aspects of the post-harvest physiology of yams[73, 74], undertaken in collaboration with the School of Agriculture, Aberdeen, have now been accepted for publication. The particular interest of this study to the Institute programme of work lies in the effects of chilling temperatures, in the range of 10 to 12°C, on membrane permeability in the tuber tissues, and their implications for membrane structure and function.
407

5. MICROBIOLOGY

The work of the department continues to be concerned with the relationships of certain major groups of soil micro-organisms to the healthy development of crops and with the role played by these organisms in the breakdown of organic matter in soil. Progress in the projects underway is detailed below. During the energy crisis some slowing down in certain investigations, particularly in those being carried out in the glasshouse, was unavoidable.

Mr M. P. Greaves, who had been a member of the staff for twelve years, left the department in September to take up an appointment as Head of the Microbiology Group of the ARC Weed Research Organization. The department continues to be represented on the Natural Environment Research Council Working Party on Terrestial Microbiology. Dr D. Jones attended the Tenth International Congress of Soil Science held in Moscow in August, and in September Mr M. P. Greaves attended the First International Colloquium on Biodegradation and Humification in Nancy, France, at which two papers were presented, one in collaboration with Soil Organic Chemistry. Four papers were presented by members of the department at the Summer Conference of the Society of Applied Bacteriology which was held in Aberdeen in July, the theme being Microbiological Trends in Agriculture, Fisheries and Food. During the year visits were paid to various organizations with allied interests. Mr I. M. Hall, a sandwich course student from the North-East London Polytechnic, spent six months assisting in the work of the department.

Interrelationships of Plant Roots and Micro-organisms

Investigations of the bacterial and protozoan populations on the roots of spring barley plants grown in fields which have borne several consecutive barley crops have been started, in collaboration with the Division of Plant Pathology of the North of Scotland College of Agriculture. It is known that the incidence of take-all disease of cereals frequently reaches a maximum after two or three consecutive crops and decreases in subsequent crops. It has been suggested that the decline might be caused by the bacterial antagonists of *Gaeumannomyces graminis*, the fungus responsible for the disease, and consequently current investigations have been concerned with a search for possible bacterial and protozoan antagonists. With the collaboration of Soil Fertility and Spectrochemistry, attempts are also being made to study the associated chemical changes in the rhizosphere soil from the barley fields during the growing season. Other workers have already suggested that take-all disease is most severe in consecutive cereal crops when the ratio of ammonium to nitrate nitrogen in the rhizosphere soil is greatest. The present investigation could reveal other significant chemical changes in the rhizosphere soil with increasing incidence of the disease.

206, 504, 603

Analyses by Soil Organic Chemistry have shown large differences in the quantities of organic matter present in the nutrient rooting medium of pea plants grown for 62 days either without any microbes or in the presence of

the soil bacterium *Pseudomonas* sp., with or without the soil amoeba *Acanthamoeba palestinensis*. Although insufficient replicates of the rooting media were available for statistical analyses, the ratio of amino acid nitrogen present in the hydrolysates was 6:3:1 for roots inoculated with bacteria and amoebae, roots inoculated with bacteria, and uninoculated roots respectively. In addition, some amino acids were present only in the hydrolysate of the rooting medium of inoculated plants. More extensive experiments with improved analytical techniques developed during these preliminary assays should verify or disprove these chemical differences in the rooting media. 303, 504

Experiments have shown the inadequacy of expressing microbial colonization of roots solely in terms of total numbers of microbes present. More detailed studies of amoebal predation would seem to require measurements of the local patterns of microbial colonization of roots. Although with increasing plant age there was some indication of increase in numbers of both bacteria and amoebae, expressed as total numbers per gram of root, there was no consistent inverse correlation between bacterial numbers and the presence of large populations of trophic amoebae, despite the presence of bacteria-free zones around many trophic amoebae on the root surface. Drawing or photographing all the bacteria around each amoeba is impractical and is not a substitute for quantitative analysis. The use of instruments which rapidly scan microscopical fields holds most promise of future progress, but some advance could be achieved by the adaptation of existing plant ecological methods. Possible methods of analysing the patterns of microbial colonization of plant roots were suggested in a paper delivered at the Summer Conference of the Society of Applied Bacteriology at Aberdeen in July. 504

Since 1972 patches of badly stunted plants have been reported in barley crops grown on the light sandy soils in the Elgin area of Morayshire. In an investigation of the microbiological aspects of this so-called 'barley stunt disorder' results so far obtained show clearly that the roots of affected plants carry much larger bacterial populations than the roots of unaffected plants. The roots of affected plants were found to be galled, stunted and distorted just two weeks after sowing. Subsequently these symptoms became more severe and were accompanied by rotting of the root cortex, which was often stripped away leaving large sections of vascular tissue exposed. It is still not clear whether the high incidence of micro-organisms on the affected roots is the actual cause of the disorder or whether their presence is a secondary effect of some as yet undetected factor. 501, 504

Results from a preliminary experiment on the winter wheat cultivar Champlein on a Fraserburgh Association soil (Annual Report No. 43, 1972/73) indicated that storage of the soil might be responsible for the absence of the lytic non-fruiting myxobacterium, but further studies have established that this micro-organism is not adversely affected by storage. 501

As part of the programme of work on the examination of the root region of cereal cultivars grown on different soil types, a study has been made on

the incidence of lytic micro-organisms on the washed roots of the spring barley cultivar Ymer on a Fraserburgh Association soil in the field and in parallel pot cultures in the glasshouse. 501, 609

Soil Protozoa

Estimation of Soil Protozoan Populations. The microdiluter method[75] has been extensively tested for protozoan populations in rhizosphere soil samples collected throughout the growing season from two field crops of barley. Twelve replicates are now used and all the results are computer-processed by Statistics. A future improvement to the microdiluter method is the use of immunofluorescence microscopy for rapid identification of protozoan species. Specific antiserum has been prepared for the flagellate *Heteromita* sp. with the collaboration of the Department of Bacteriology, Aberdeen University Medical School, and it has been used successfully to stain this common soil protozoan with the fluorochrome fluoroscein isothiocyanate. 504, 510, 5701

Survey of Protozoa in Scottish Soils. Examination of further samples from agricultural soils collected in conjunction with Soil Survey has revealed the presence of a new family of soil amoebae, the Echinamoebidae, in a soil from Dullommuir Farm near Kelty, Fife. This amoeba has been sent to the N.E.R.C. Culture Collection of Algae and Protozoa in Cambridge and the type specimens to the British Museum (Natural History). The unusual flagellate *Apusomonas proboscidea*[31] has now been isolated from Orkney soil samples collected at Swanbister as well as in samples from the Scottish mainland. 101, 201, 510, 801

The Growth of Protozoan Populations in Liquid Media and Soil. The results of studies of the growth of soil ciliates in liquid nutrient media or in γ-irradiated soil are being prepared for publication and aspects of the soil microenvironment important for protozoan growth have recently been reviewed[76]. More detailed studies of protozoan digestion of bacteria in food vacuoles using transmission electron microscopy have been initiated and should provide information about the relative digestibility of different bacterial species and different bacterial subcellular fractions. 502, 505, 5703

Ultrastructure. A description of the ultrastructural features of the spore-producing disk (apothecium) of *Sclerotinia sclerotiorum* (Lib) de Bary, a soil-borne plant pathogen[77], has been accepted for publication. A proposal to replace the generic name *Sclerotinia* by *Whetzelinia* has recently been made by other workers. On this basis *S. sclerotiorum* will become *Whetzelinia sclerotiorum* (Lib.) Kork & Dumont.

A set of electron micrographs illustrating a freeze-etched apothecium of *S. sclerotiorum* was shown at an ARC Conference on Electron Microscopy at the National Vegetable Research Institute at Wellesbourne in April, and also at a British Mycological Society Exhibition, Fungi '73, at Chelsea College, University of London, in December.

Highly magnified electron micrographs of freeze-fractured spores and of spore surfaces were exhibited at the Seventh Annual Conference of the

Institute of Medical and Biological Illustration held in Aberdeen in September. Autotone pre-coloured photographic paper was used for visual effects. 507

Sclerotia of Plant Pathogens. The biochemical aspects of the parasitism of sclerotia of *S. sclerotiorum* by two soil fungi, *Trichoderma viride* Pers. ex Fr and *Coniothyrium minitans* Campbell[22], are described in a recent publication. In this study the mechanism by which sclerotia are disintegrated was determined. Chromatographic fractionation of enzymes in the culture filtrates of the parasitic fungi revealed several laminarinases, the most active being an exo-β-(1→3)-glucanase which, when combined with an endo-β-(1→3)-glucanase, led to almost complete breakdown of the sclerotial cell walls. 301, 508

Sclerotia on infected plants in the field and on agar plates exude colourless droplets of a rather viscous liquid. There is evidence that enzymes detected in this exudate, such as phenolase and peroxidase, are important in the formation of the black protective rind encapsulating the sclerotium. A study of the kinetics of these enzymes has been initiated with Soil Organic Chemistry. 301, 508

In co-operation with the Plant Pathology Division of the North of Scotland College of Agriculture work has continued on *Sclerotinia sclerotiorum* in an area of Kincardineshire where it has recently become established following an outbreak on peas. The effects of treating pea seed and foliage with benomyl, a systemic fungicide, were examined in two glasshouse trials at the College. Where benomyl had been used as a spray, artificial inoculation with *S. sclerotiorum* from peas caused few lesions. In another experiment conditions which pre-dispose pea crops to attack were stimulated by scorching petioles with dinoseb weedkiller. Plants were exposed to discharging apothecia grown in this laboratory and again disease symptoms were less where benomyl had been used as a protective spray. Similar results were obtained in preliminary experiments here using benomyl on potatoes under glass.

The department has been equipped with a cooled incubator with interior fluorescent illumination. Cycling between temperatures or between lights on and lights off can be programmed, and the temperature and lights cycled together to simulate day and night. With these facilities sclerotia can now be induced to germinate throughout the year and to form mature apothecia very similar to those found in the field.

Studies with Dazomet, a soil fumigant, on sclerotia of *S. sclerotiorum* have been completed and a paper reporting the results[78] has been accepted for publication. 508

Soil Organic Matter

Microbial Decomposition and Synthesis. An account of the results of a study of the microbial decomposition of soil polysaccharide[68] has been accepted for publication. 305, 506

Investigations of the microbial synthesis of polysaccharide in soil, carried out in collaboration with Soil Organic Chemistry, have shown that temperature is an important factor in determining the types of sugar present in the

polysaccharide. Incubation experiments with ^{14}C-glucose as substrate, at temperatures of about 20°C, resulted in the synthesis of a polysaccharide which was low in pentose compared with the original soil polysaccharide. At lower temperatures, such as occur naturally during the winter, the newly synthesized polysaccharide contained the pentose xylose in a proportion comparable to that in the original soil polysaccharide. Examination of the microbial populations present showed that populations of bacteria were much smaller at low temperatures than at 20°C, whereas those of yeasts, fungi, actinomycetes and algae were relatively unaffected. Chemical analysis of pure cultures of micro-organisms isolated from the incubation experiments showed that xylose was produced by 85 per cent of the yeasts examined. Xylose-producing yeasts occurred at all incubation temperatures and on isolation were all found to grow at 5°C. In contrast, xylose was not synthesized by any of the isolated fungi or actinomycetes and was synthesized by only 3 per cent of the bacteria, all of which were isolated from soil which had been incubated at 20°C and only half of which could grow at 5°C. It seems reasonable to assume that xylose synthesis in soil occurs mainly at low temperatures and is achieved largely by yeasts. Only one soil micro-organism, a bacterium, has been found to synthesize arabinose, the other pentose commonly found in soil. This suggests that arabinose in soil arises largely from plant residues. The results of this work are being prepared for publication. 305, 506

Microbiology of Peat. Work has continued on the aerobic bacterial populations of the basin peat at the Lyne of Skene, and correlations between population numbers and physical and chemical parameters have been derived. 116, 503, 5701

A detailed account of the occurrence of wax fibres secreted by the aphid *Colopha compressa*, which colonizes the roots of *Eriphorum* spp. growing on the peat[67], has been accepted for publication. 208, 503

A technique for estimating anaerobic organisms in peat using a microdiluter technique is being developed and investigations are being undertaken to find a suitable growth medium. 503

Work has started on a study of the survival of the lytic myxobacterium *Cytophaga johnsonii* in peat and peat composts. Experiments have also been initiated to study damping off by *Pythium* spp. of Sitka spruce seedlings grown in a peat sand compost and the possibility of controlling it by the use of the myxobacterium. 501, 503

Production of Cell Material and Microbial By-products

The production of bacterial and fungal cell material using batch fermentation methods has continued. Preliminary studies of the feeding rate of the ciliate *Colpoda steini*, using ^{14}C-labelled *Aztobacter chroococcum*, have been made. Initial difficulties concerning the sampling and estimation have been encountered but it is expected that these will be overcome. Measurements have been made upon fungal spores of related species, using the Coulter Counter Model B, in the hope that this may lead to a method of differentiation and identification. The results obtained have been processed by Statistics. 502, 505, 5703

6. SOIL FERTILITY

The ultimate objective of the research programme remains the improvement of crop production through better understanding of the influences of soil properties, profile characteristics, environmental factors and husbandry practices. Complementary field, pot culture and laboratory investigations have accordingly been continued on the properties and nutrient relationships of selected contrasting soil series, chosen in consultation with Soil Survey, and on the effects of fertilizers, including trace element amendments, on the growth, development and nutrient content of the main agricultural crops. During the year, however, there have been some changes in emphasis, arising partly from changes in senior staff.

One major feature of the laboratory programme has hitherto been basic studies on the nature and properties of the compounds which comprise the organic phosphorus fraction in soils. These studies were the responsibility of Dr G. Anderson, and with his departure in January to become Head of Soil Organic Chemistry this work has been transferred to that department. Soil Fertility will, however, retain an active interest in the wider questions of the distribution of organic phosphates in different soil series and their implications in relation to the phosphate status of soils. In keeping with their complementary interests, close collaboration will be maintained between the two departments in this field and in the development of studies on other relevant topics, especially soil nitrogen and sulphur.

Even so, this redistribution of responsibilities entails an appreciable decrease in the organic chemical effort in Soil Fertility and advantage is being taken of this change to increase the coverage of inorganic and physico-chemical aspects of the nutrient status of soils. Partly to capitalize on the mineralogical information available from Pedology, detailed studies are being extended on the cation exchange relationships of different soil series, with particular emphasis on their potassium status. Mr A. H. Sinclair, who has just completed a research project in the Department of Soil Science of the University of Aberdeen in candidature for the degree of Ph.D., has been appointed, from 1st October, to work in this field.

Increasing attention is also being given to influences of soil physical factors on crop production. A research post to develop this work has been available for six years, but attempts to recruit a suitably qualified officer have so far been unsuccessful. As will be mentioned later, however, a start has been made in establishing facilities for making soil physical measurements. Following the transfer of the radioactivity facilities from Plant Physiology to Soil Fertility, possibilities of increasing the exploitation of radioisotope techniques are being actively considered. These would include such studies as field examination of the rooting systems of crops in relation to soil profile characteristics, physical conditions, and moisture patterns.

Advisory soil testing in collaboration with the North of Scotland College of Agriculture, and related consultative activities, have been continued, and representation has been maintained on several 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, a Working Group convened by the Department of Agriculture and Fisheries for Scotland to prepare a Code of Practice for Lime and Fertilizer Application for Arable Crops and Grassland, and the three Area Drainage Liaison Panels recently set up by the Colleges of Agriculture under the auspices of the Scottish Agricultural Field Drainage Group. Information has also been supplied to the Scottish Agricultural Development Council and to the Soil Science Committee of the Arable Crops and Forage Board of the Joint Consultative Organization for Research and Development in Agriculture and Food.

Dr B. W. Bache and Dr E. G. Williams attended the Tenth International Congress of Soil Science in Moscow in August, and the department was also represented at meetings of the British Society of Soil Science and the Biennial Conference of Scottish Grassland Workers.

Professor J. A. Robertson, Department of Soil Science, University of Alberta, Edmonton, Canada, is spending the main part of a year's sabbatical leave in the department, studying residual effects of phosphate in soils.

Fertilizer Responses of Crops

Anhydrous ammonia injected in bands 30 cm apart at a depth of 10-12 cm was compared at rates of 70 and 105 kg N per ha with broadcast ammonium sulphate in six field experiments on barley during the period 1971/73. In one case there was no yield response to nitrogen but the other five experiments gave sensitive comparisons. In three instances the maximum yield increase was between 70 and 150 per cent and anhydrous ammonia was significantly better than the ammonium sulphate. At the lower level of response of between 30 and 50 per cent in the other two experiments there was no difference between the two sources. 603, 608, 5701, 5703

In four other experiments on barley, in 1972/73, broadcast and combine drilled applications of urea were compared with corresponding ammonium nitrate treatments at rates of 35, 70 and 105 kg N per hectare. The broadcast comparisons showed no yield differences between the two fertilizers. At the 35 kg N rate combine drilling did not delay brairding and gave the same yield as broadcasting, with again no difference between the two fertilizers. When the 70 and 105 kg N rates of ammonium nitrate were combined drilled there was no serious delay in brairding and the yields at the lower rate were the same as from broadcasting, but at the higher rate the combine drilled treatments were slightly, but consistently, inferior. With the 70 and 105 kg N rates of urea, however, the combine drilling delayed brairding, especially at the higher rate, and the effect continued throughout the season so that the crop was later in reaching maturity. The final yields from urea combine drilled at the 70 kg N rate were significantly lower than from the corresponding broadcast treatment. At the 105 kg N rate, combine drilled urea was not only markedly inferior to the same amount broadcast but was also poorer than the combined drilled 70 kg N treatment. 603, 608, 5701, 5703

Other field trials on barley have shown practically no differences in effectiveness between solid and liquid forms of comparable commercial NPK fertilizers, irrespective of whether they were broadcast or combine drilled,

but the latter method of application has produced consistently higher yields. The results are awaited from further comparisons of this kind in which the fertilizers were placed also in bands at 5 cm to the side of the seed rows. Experiments to examine the NPK responses and requirements of two new semi-dwarf varieties of barley, Universe and Maris Mink, have also been started. 608, 5206, 5701, 5703

Field experimentation and supplementary analyses of soil and crop samples have again measured the effects of nitrogen, phosphate, potassium and magnesium applications on the yields and nutrient contents of crops and herbage on different soil series. The papers described in last year's report, reviewing the main principles and factors governing efficient use of fertilizers[32, 33], have now appeared. 608, 5206, 5701, 5703

Crop Growth and Development

Detailed studies on the effects of fertilizers, environmental factors and husbandry practices on the progressive accumulation of dry matter and nutrients by barley and swedes or potatoes have been continued at four contrasting field centres. These are instrumented to measure soil and air temperatures, rainfall, humidity, wind speed and soil moisture, and in two cases solar radiation. As summarized in last year's report, these experiments, now in their fifth full season, are successfully identifying the growth indices which determine yield and are filling major gaps in information on growth rates and variations in meteorological factors. To enable relationships with the latter to be examined, the experiments maintain sufficient continuity of treatments to give direct comparisons between seasons. Otherwise, modifications are being gradually introduced, and the current emphasis in the barley experiments is on the effects of nitrogen in relation to seed rates, depth of seed placement, and seed-bed compaction. Apart from their practical importance, the prime objective of examining these factors is to study influences on the final yield of changes in the pattern of early growth, especially differences in nitrogen uptake, because the indications are that under the conditions in north-east Scotland grain yield is largely determined by growth before ear emergence. This view is contrary to the generally held belief that grain yield is determined by the net amount of photosynthesis after ear emergence, and the question accordingly deserves fuller investigation. 607, 5206

Sprout Growth of Potatoes

Three accounts of work described in last year's report on the effects of calcium on sprout growth of different potato cultivars, including a joint paper with Plant Physiology, have been prepared for publication. 402, 607, 5206

Trace Elements

Mention has been made in the last two reports of an investigation on the boron status and requirements of barley in north-east Scotland, arising from the occurrence of crop boron levels which have been considered in other countries to indicate deficiency. The effects of broadcast seed-bed applications of 2·5 kg B per ha were examined at 17 centres in 1971/72. There

was no indication of any effect on the yield of grain or straw, but the boron contents of the crops were markedly increased. On the overall averages, the boron contents of the dry matter of the crops from the untreated plots were 4·6 ppm for samples of the young plants during June, 1·6 ppm in the mature grain, and 3·9 ppm in the straw, compared with corresponding values of 11·7, 3·8 and 8·6 for the boron treated crops. The contents in the grains and straws and the effects of the boron treatments were appreciably higher in 1972 than in 1973, possibly due to the considerably higher rainfall during April to August in the latter year. 609

Striking residual effects of copper have been found on a freely drained light sandy soil of the Corby series of the Corby Association. Dressings of approximately 5, 10, 20 and 100 kg copper sulphate per ha were applied in 1956, and clear residual effects, even of the lowest rate, were still visible on the 1973 oat crop, with increases of 0·4–0·6 t per ha in the grain yields. In the intervening period the area has been cropped with cereals and grass only, without any addition of farmyard manure. In two other experiments, started in 1973, one on a mineral soil and the other on a deep peat, the effects of high rates of nitrogen, up to 570 kg per ha, on the removal of trace elements in herbage cut three times per year are being examined to assess needs for supplementary dressings. 609, 5205, 5206

Inorganic Phosphorus

To extend the basis for a reassessment of possibilities of improving the practical evaluation of soil phosphate status for advisory purposes, further concurrent measurements of phosphate responses have been made for potatoes and swedes on different soil series in the field, and for oats, potatoes and ryegrass on the same soils in pot cultures. The field results confirm that potatoes and swedes give similar relative responses, and that substantial responses by barley, of the order of 10-25 per cent, are normally encountered only where the phosphate status would be classified as low. Otherwise, barley tends to give fairly constant small increases of about 100 kg grain per ha, illustrating the general desirability, on most soils, of applying some fresh phosphate to raise the intensity of the supply in the early stages of growth. Other objectives of this work are to clarify the influences of soil properties on Quantity-Intensity relationships in different soil series and to examine the uniformity of these in terms of ranges of properties in agricultural top soils. In the latter respect, while there are marked differences in the average values for critical properties such as phosphate sorption capacity and contents of soluble iron and aluminium, there are also two- to three-fold variations within the series, and hence considerable overlapping between them. 601, 608, 5613

Organic Phosphorus and Sulphur

An account of a study on the sorption characteristics of inositol hexaphosphate in acid soils[34] has been published. Treatment with this ester markedly decreased the ability of the soils to sorb inorganic phosphate, and though the patterns and mechanisms were different it appeared that the same sorption sites were involved. In collaboration with Soil Organic Chemistry

a wider examination of the distribution of inositol phosphates and inorganic phosphate in different soil series is therefore being carried out to clarify their interrelationships, including the influences of soil constituents, especially soluble aluminium and iron. An account of studies, summarized in last year's report, on the characterization of a number of novel phosphate esters isolated from sodium hydroxide extracts of soils[82], has been accepted for publication. Progress has also been made in investigations on the distribution of categories of organic sulphur in different soil series. 317, 602

Nitrogen

Monitoring of changes in nitrate and ammonium levels in field plots under contrasting cropping and nitrogen treatments has been continued. The rapid fall, mentioned in last year's report, in the initially high inorganic nitrogen contents of barley plots receiving 100 kg N per ha has again been found. In the case of swedes the corresponding changes are much slower, and where no nitrogen had been applied growth and uptake during the period from early spring to mid-summer were sufficiently slow to allow a detectable accumulation of inorganic nitrogen released from organic matter. 603, 607, 608

As mentioned above, in the section on Crop Growth and Development, field studies on barley have indicated that nitrogen uptake before ear emergence is a major factor determining the final yield of grain. Support for this view is provided by further work on the effects, summarized in last year's report, of phenyl phosphonic acid on oats grown in acid soil media in pot cultures. Progressive measurements of nitrogen uptake have emphasized that the substantial increases in grain yield that can be induced by incorporating suitable additions of phenyl phosphonic acid in the culture media follow considerable increases in the nitrogen contents of the plants before ear emergence. 603, 606

Soil Acidity and Cation Exchange

Further work has been done on the characterization of soils with respect to soluble and exchangeable aluminium. To establish more rigorous reference values for the composition of the equilibrium soil solution, a progressive saturation procedure has been developed; in this the water saturation extract is successively equilibrated with fresh lots of soil until a constant composition is attained. This has facilitated a more critical evaluation of the validity of estimates of the activity ratio $(a_{Ca})^3/(a_{Al})^2$ obtained by simpler extraction methods. Both the single saturation water extract and extraction with 0.004 M calcium chloride, at a soil:solution ratio of 1:1, gave values that were adequate indices of the aluminium status of the soils examined. An improved method has also been developed to investigate the displacement of cations from soils by salt solutions, in which small increments of leachate are obtained using a fraction collector. This has confirmed the virtual impossibility of distinguishing unequivocally between exchangeable and non-exchangeable aluminium in soils, but adequately approximate values for exchangeable aluminium can be estimated from aluminium release curves and by simple extraction, for example by shaking 5 g soil with

100 ml of 1·0 M potassium chloride or ammonium chloride for 30 minutes. An account of this work has been prepared for publication. 604

The nature of the aluminium ions adsorbed on soil surfaces and released into solution by salt extraction has for long been uncertain. An analytical method that distinguishes between mononuclear and polynuclear aluminium ion species in solution, based on differences in their rate of reaction with 8-hydroxyquinoline, has been used to study the proportion of polynuclear aluminium in salt extracts of acid soils. Surprisingly high proportions were found, reaching 70 per cent in 0·008 M ammonium acetate extracts buffered at pH 4·8 and 60 per cent in unbuffered 0·004 M calcium chloride extracts. These results are compatible with stronger adsorption of the more highly charged mononuclear ions, and greater desorption of these is probably the reason why the proportion of polynuclear aluminium in solution decreases with increasing salt concentration. 604

An account of the work, summarized in last year's report, on relationships of pH values of dilute calcium chloride extracts of acid soils with aluminium solubility and calcium-aluminium exchange reactions[53] has been accepted for publication. 604

Soil Physical Measurements

Laboratory facilities have been established for measuring the moisture release characteristics of soils. After preliminary tests on horizons from some typical local soil profiles, the following procedure has been adopted: An undisturbed cylindrical soil core, diameter 7·5 cm and height 5 cm, is successively equilibrated at suctions of 0·01, 0·05 and 0·10 bar on tension tables. It is then transferred to a pressure cell and equilibrated at 0·40 and 1·0 bar. The weight of the moist core is recorded after each equilibration, and following the treatment at 1·0 bar it is oven-dried and weighed to obtain the weight of dry soil. These determinations are done on triplicate core samples from appropriate horizons in the soil profile, and since the volume of the core is known the results also give the bulk density of the dry soil. Three sub-samples of normal air-dry <2 mm soil from the same horizon are then moistened and equilibrated in the pressure cell at 3·0 bar and 15 bar to obtain the moisture contents at these suctions. Having seven points on the moisture release curve facilitates the calculation of values for the water storage capacity of the profiles, and also of the hydraulic conductivity and pore-space relationships of the main horizons. Because of its importance in relation to the design of agricultural drainage systems, however, direct field measurements of hydraulic conductivity are being made by the single-well pump-in method when the profiles are sampled for the moisture characteristic determination. After detailed measurements on this basis have been carried out on a range of contrasting soil profiles from different parts of Scotland, it is hoped that a simpler procedure can be adopted for standard characterization of soil series and samples from field experiment areas. 612, 801

Comparative field measurements of bulk density, using a gamma-ray probe, and of soil compaction, using a penetrometer, are being tried to test

their usefulness in assessing influences of soil physical conditions on crop growth. 607, 608, 612

Chemical Composition of Plants

The concentration of organic anions in plants has been claimed by some workers to be a significant factor regulating growth rate and yield. In practice, the total organic acid content can be measured as so-called excess base by titration of the ash, or it can be calculated from normal mineral analyses of plant tissues as the quantity C–A, the difference between the total cations and inorganic anions. It has also been suggested that a certain level of C–A, characteristic of the particular plant, is necessary for maximum yield, so that treatments giving a lower value should also give a lower yield. To examine the validity and usefulness of these ideas, an examination has been made of relationships between yields and values of C–A calculated from analyses of samples of young leaves of oats, barley, swedes and ryegrass, based on the one hand on comparisons of varieties under uniform fertilizer treatment and on the other on the effects of different fertilizer treatments on the growth of a particular variety. Material has been collected during three seasons from field trials and from pot cultures. The results are not yet complete and detailed inter-relationships remain to be evaluated, but the indications are that the correlations between C–A and yield seldom exceed about 0·6, even for material from a single experiment, and are mostly much lower. When, as under normal agricultural conditions, the complicating influences of differences in soil type and season are also involved, it is therefore unlikely that any practically useful relationship will emerge. 606

Procedures for estimating the simpler nitrogenous constituents (nitrate, ammonium, amide and free amino acid nitrogen) in plants have been standardized and changes in these constituents in a selection of crops from field experiments on different soil series are being examined. 603, 606, 607, 608

Radioactivity

As mentioned earlier, the Institute radioactivity facilities are now centred on Soil Fertility, with the view to extending the application of radioisotopes in this field. A major duty of this unit, however, will continue to be collaboration with, and provision of services to, other departments. This frequently necessitates development of suitable techniques to meet the varied requirements that arise, and considerable experience has been accumulated over the years in the production of labelled plant materials. The requirements in this respect differ from those in normal tracer work. While ensuring that the materials are still adequately representative of the normal plants, much higher levels of activity have to be incorporated, so that there is enough left at maturity to cater for subsequent dilution effects and provide adequate levels for measurements at the end of the experiments. Much depends on the characteristics of individual isotopes and on the special demands in different kinds of studies. In assessing suitable specific activities and dosages there are therefore several factors to be considered, especially methods of incorporating the isotope into the plant, the location of different elements

within the plant in relation to effects of radiation on growth, metabolism and reproduction, and possible advantages from labelling with two isotopes of the same element, with different half lives and radiation characteristics. In a report being prepared the influences of these factors are discussed in relation to practical examples of the production of labelled plant materials for different purposes, such as wheat grain labelled with ^{59}Fe for human nutrition studies, ryegrass labelled with ^{65}Zn for chemical fractionation and animal nutrition studies, and beetroot labelled with ^{22}Na and ^{36}Cl for plant physiological investigations. 613

One potentially important effect that can be produced by exposure to radiation is alteration of the permeability of cell membranes. In collaboration with Plant Physiology, an examination has therefore been made of the effects on ion fluxes of subjecting onion roots to activities up to a hundred times greater than normally used in tracer studies. 407, 613

An account of collaborative work with Soil Organic Chemistry on the decomposition in soil of rye hemicellulose labelled with ^{14}C has been published[21]. Joint work with this department is also in progress to compare the effects on germination and growth, and on calcium distribution in the seedling, of two methods of incorporating ^{45}Ca into wheat seeds; in one case, the seed was produced by growing plants to maturity in a culture solution labelled with ^{45}Ca; in the other, the simpler method of immersing seed in a solution containing ^{45}Ca was used. 305, 309, 5613

Studies on the decomposition in soils of plant materials labelled with ^{14}C necessitate measurement of the activity of soil samples containing labelled material and of barium carbonate precipitates incorporating radioactive carbon dioxide which has been evolved and absorbed in barium hydroxide. Improvements have been made in the methods involved. For making stable suspensions of the soils and precipitates for liquid scintillation counting, the Swiss product Poly-Gel-B, which contains phosphor and is conveniently prepared for use by dissolving in hot toluene has been adopted in preference to finely powdered silica. Alternatively, the barium carbonate precipitates are complexed with EDTA and the solution made into a gel for counting, using Instagel. Developments have also been made in scintillation counting, to enable separate measurements to be made when simultaneous labelling with two isotopes is used, a technique for which there is an increasing demand. 613, 5613

Advisory Work

At nearly 4700, the total number of soil samples submitted by the Advisory Officers of the North of Scotland College of Agriculture was practically the same as in 1972/73. Except for about 100 samples from horticultural areas, they came entirely from agricultural land. The prime requirement in all cases was assessment of the lime, phosphate and potassium status, but in nearly one-third of the samples the magnesium status was also examined. Trace element problems, involving animal health as well as crop production, continue to be dealt with in collaboration with Spectrochemistry. Analyses

for cobalt were carried out on 312 soil samples and 23 crop samples, compared with 335 soils and 108 crops for copper. 610, 5205, 5206

Numerous enquiries, mostly verbal, continue to be received from the advisory services, and from technical, agricultural and administrative sources, concerning the fertilizer requirements, including trace elements, of different crops and soils, the effectiveness of different forms, times and methods of application, the manurial value of slurries and other waste products, and possibilities of economizing in fertilizer usage, especially phosphate. As in previous years, such enquiries provide an important channel for translating into practice relevant findings from the field experiment programme. 608, 609

In collaboration with Pedology, 131 samples of soil from forest nurseries were examined to assess requirements for phosphate, potassium, calcium and magnesium. 117, 608, 5206

7. STATISTICS

The principal function of the department is the provision of specialized advice and services relating to the design of experiments, statistical analysis, model-building, data processing and computer operation and programming. The balance between the statistical and computing aspects of the work is 2 to 1. Forty research projects, representing every department and all project packages, have been serviced.

While attending the Tenth International Congress of Soil Science in Moscow, Mr R. H. E. Inkson also visited the Museum of Earth Sciences of Moscow State University and the Dokuchaev Soil Institute. Miss J. M. Cooper was a joint recipient of the 1974 Silvicultural Prize of the Institute of Foresters of Great Britain. The award was for published work described below[1] and was presented to the recipients during the Study Tour and Annual Meeting of the Institute of Foresters. The department has also been represented at meetings of the Biometric Society, the Royal Statistical Society and the Agricultural Research Council Crop Science Model-Builders' Group, the third ARC Data Logging Symposium and a conference of the IBM Computer Users' Association.

Computing Service

The department is responsible for the organization and use of the IBM 1130 computing system. During the year various improvements and economies in operation have been effected; for instance the revision of input and output formats has reduced the computer time required as well as the quantity of cards and paper used.

The reorganization of user programs has also made valuable savings in computer time. A program to generate random numbers has been written and modified to provide pairs of random co-ordinates. 703

Pedology. A change has been made in the method of discrimination used on the composite mass spectra obtained from the decomposition products of pyrolysis. The new method uses principal components analysis and thus avoids the assumption of classes made in the method based on the training of a pattern recognition vector. The number of normalized peak heights which have to be measured has been reduced from 110 to 13 by this method of discrimination, a joint account of which[52] has been submitted for publication. 108, 703, 5703

The processing of data from X-ray silicate analysis and electron-probe microanalysis is now on a routine basis, the statistical methods and the programs having been established. 107, 109, 5703

The tabulation of results and plotting of pollen diagrams on the accumulated profile records of classified pollen counts has now been completed. The profiles have been zoned visually and for each profile the sums of the pollen percentages for the individual taxa occurring within the defined zones have been computed and tabulated. 113, 5703

The program PFATA, which converts readings from automated chemical analysis to concentrations of elements in samples, has been overhauled and substantially rewritten as the chemical analysis data for which it was designed have settled into a uniform group of patterns. 107, 703, 5703

Spectrochemistry. Collaboration has been given in the reorganization of a program for the simulation of electron paramagnetic resonance powder spectra. The program compares a plot of the spectrum for the sample material with that of a summation of single crystal spectra from many different orientations. The simulations, which can take several hours, are executed overnight and disk files used to store input and output data. 203, 703

Microbiology. Cell counts obtained with a Model B Coulter Counter have all been for the dual threshold case. Processing of the counts and plotting of the results are now performed on a routine basis. 502, 5703

Soil Survey. A regular data preparation and card punching service has been provided for results from botanical surveys. 801, 802, 5703

Advisory and Collaborative Work

Pedology. Treatment plans and random sampling schemes have been produced for two further NPK experiments to study the relationship between tree growth and nutrient uptake in pole-stage Sitka spruce. The experiment plans are based on the central composite design, with additional control treatments. Members of staff have had opportunities to assist in the field sampling of convenient experiments in this series, dealing with rainfall and litter collection at one experiment and whole tree sampling at another. This has allowed a better appreciation of the practical problems of these operations and of the reliability of the data. A new group of computer programs deals with the whole tree sampling data, covering sort routines, calculation of dry weights of tree parts, and foliage profiles. A new program FORET replaces an earlier version for the solution of log/log regression equations of the form $\log_e y = a + b \log_e x$. It incorporates a correction factor, $e^{\frac{1}{2}s^2}$, which multiplies the antilog of the predicted value of $\log_e y$ in order to provide an unbiased estimate of y. s^2 is the estimate of residual variance of $\log_e y$. When it is large, causing the correction factor to be considerably greater than unity, serious under-estimation of the predicted values of y could result from the omission of the correction factor. The program also includes an improved method of obtaining confidence limits for predicted totals (sums of the corrected antilogs of predicted values) estimated from stem size distributions. 115, 701, 703, 5701, 5703

A number of established forestry experiments at Culbin and Alltcailleach have also provided data for processing and statistical analysis. Growth assessments derived from both increment cores and girth band measurements have been calculated and compared, and annual values for height increment, diameter increment and chemical analysis of foliage examined for treatment effects. Regression, calibration and plotting have been used in much of this work. A joint account[1] of parts of the studies at Culbin has

been published and another[59] submitted for publication. An additional routine for supplementary division of treatment effects in one of the Culbin experiments has been made generally available by incorporation into the analysis of variance program RBWS. 117, 703, 5701

In a water level experiment the random selection of trees for felling has been made and statistical summaries of data on root weights have been provided. 110, 5701, 5703

Soil Organic Chemistry. A number of experiments on the microbial degradation of soil polysaccharide have been examined for treatment effects and differences at various points in a time series. Statistical analyses have been carried out on experiments on the increase in length of excised root segments. 305, 311, 312, 5701

Plant Physiology. Experiments of randomized block and factorial designs have provided data on nutrient content and ratios in plant and crop parts. Statistical methods used are analysis of variance and covariance, correlation and regression including log/log regression. An account of a study of iron chlorosis in pear leaves[30] has been published. 401, 402, 5701, 5703

Microbiology. The estimation with fiducial limits of population values of different protozoan species in rhizosphere and non-rhizosphere soil has been carried out on the results from two-fold dilution series with twenty-four steps. A description of a rapid laboratory procedure using a microdiluter and the statistical method for estimating bacterial and protozoan populations in soil and peat[75] has been accepted for publication. The method uses the loglog transformation, weighting coefficients and maximum and minimum working deviates to provide an estimate of the logarithm of the population density and fiducial limits for it. Comparisons have been made of the proportion of viable cells in samples with and without colpoda and of the total cell count obtained by Coulter Counter and other methods. A logarithmic transformation of the data was indicated since the standard deviations were proportional to the mean counts observed at different times.
504, 505, 701, 5701

Further work has been carried out on the relationship between the numbers of bacteria at various depths in peat and the chemical properties of the peat. Chi-squared tests have been made on results from experiments measuring germination rates of pure culture sclerotia. 503, 508, 5701

Soil Fertility. Experimental designs in current use for field experiments include randomized blocks, Latin squares, lattice squares, central composite designs and factorial arrangements, some of which have split-plots, confounding or partial confounding, and fractional replication.
601, 607, 608, 609, 701, 5701

Two continuing series of experiments of confounded factorial design are concerned with the detailed study of the pattern of growth and development of barley and swedes, and further experiments include seed rate and soil condition as factors. All provide data for analysis from samples taken at

different times throughout the growing season and involve both physical and chemical measurements on plant parts and estimates of growth rates.
607, 5701, 5703

In a number of investigations concerning crop yield, chemical composition and soil properties, correlation and regression analyses have been used.
601, 602, 603, 604, 606, 702, 5701, 5703

Soil Survey. Linear regression equations have been used to relate topsoil tension to borehole depth. In collaboration with the Statistics and Computer Departments at Rothamsted Experimental Station the classification program CLASPX has been used to classify by numerical methods two groups of soil profiles with data from 22 soil tests. 702, 801, 5701, 5703

8. SOIL SURVEY

The Soil Survey is primarily concerned with the description, classification and mapping of the soils of Scotland. In this report the incremental addition of the soil survey work for the past season is listed and a summary given of an area of Fife, combined Sheet 40/41 (Kinross/Elie), in which mapping is now completed. With the extension of the mapping into the highland areas, where semi-natural soils and vegetation occupy a greater proportion of the cover than arable land, it has been considered appropriate to include a summary of the main plant communities identified in the Vegetation Survey and their relationship to the vegetation classes established for Central Europe and to genetic soil groups.

Systematic survey on a scale of 1:25,000 has continued in the eight areas listed below. During the current season some 1600 km² (620 square miles) have been surveyed, 140 on Sheets 118, 119, 120, 121, 122 and part 117 (Orkney), 260 on Sheets 109 (Auchentoul) and 115 (Reay), 155 on Sheet 75 (Tomintoul), 120 on Sheet 74 (Grantown), 390 on Sheets 51 (Coll), 52 (Tobermory) and 51 (Ben Nevis), 65 on Sheet 47 (Crieff), 220 on Sheets 23 (Hamilton), and 31 (Airdrie) and 260 on Sheets 5 (Kirkcudbright) and 9 (Maxwelltown). Revision and correlation has been carried out on Sheets 85 (Rothes) and 31 (Airdrie) which are now completed.

Concurrent land use capability assessments have been made on all the sheets in progress and some headway made with assessments for soil maps published prior to the introduction of the Land Use Capability Classification. Sheet 66/67 (Banchory/Stonehaven) is nearing completion, Sheets 76 (Inverurie) and 77 (Aberdeen) are well advanced and a start has been made on Sheet 57 (Forfar) and Sheet 33/34 (Haddington/Eyemouth).

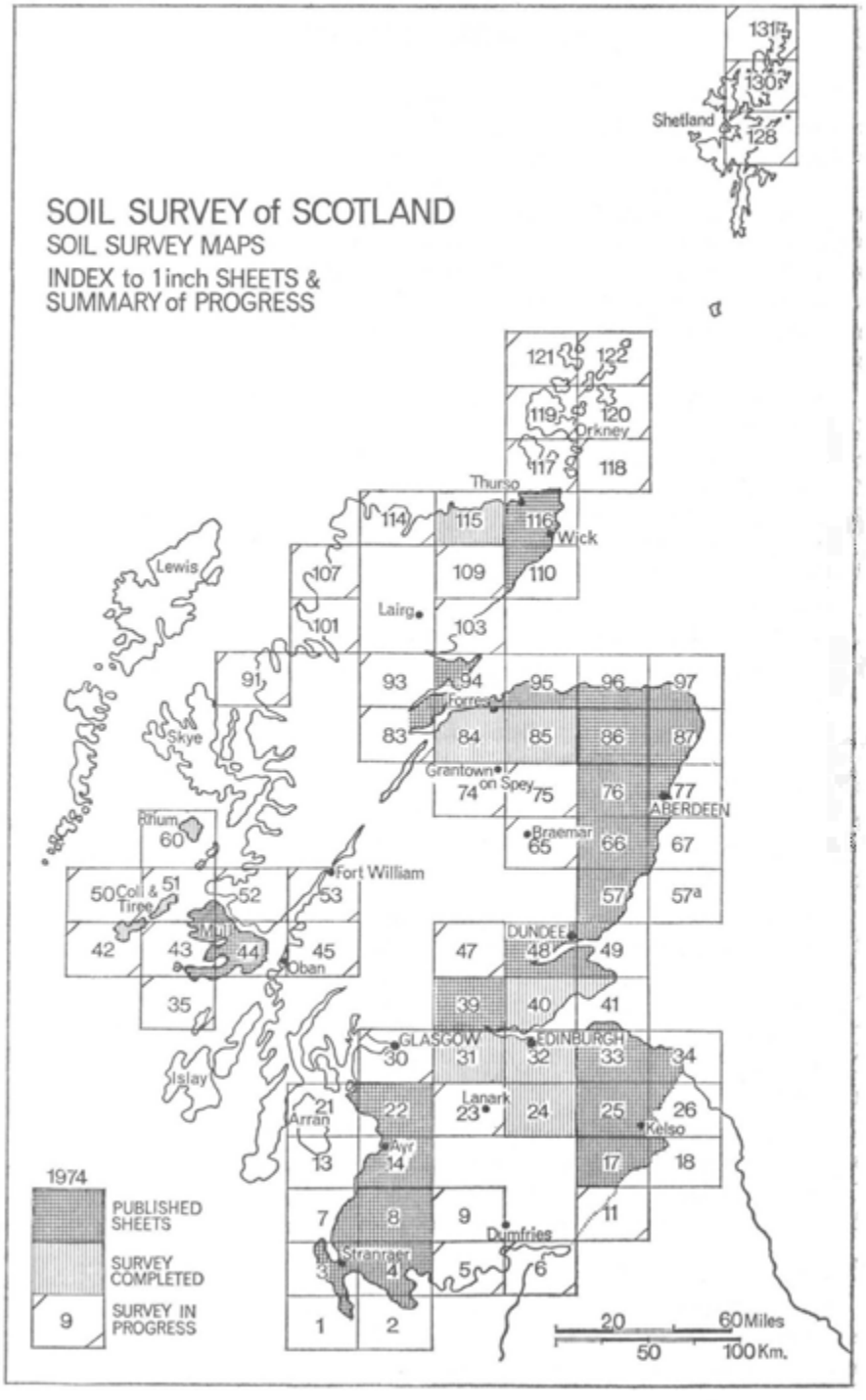
One hundred and ninety profiles have been described and sampled for analysis, mostly with the aid of a Smalley excavator. 801

Members of staff have attended meetings of the ARC Working Group on Soil Physical Conditions, the Ordnance Survey Advisory Committee, the British Association for the Advancement of Science at Stirling, the British Society of Soil Science at Edinburgh, the North of England Soils Discussion Group and a conference of the Council for British Archaeology. In August Dr R. Glentworth attended the Tenth International Congress of Soil Science in Moscow.

The department is represented on the Working Group on Field Drainage of the Department of Agriculture and Fisheries for Scotland and the related College Area Drainage Liaison Panels, 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 140 km² (55 square miles) have been surveyed in the parishes of Stenness and Sandwick in the West Mainland and on the island of Hoy. Thirty-one profiles have been described and sampled. In the West Mainland, Thurso Association soils are the most frequently encountered,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PUBLISHED SHEETS
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SURVEY IN PROGRESS
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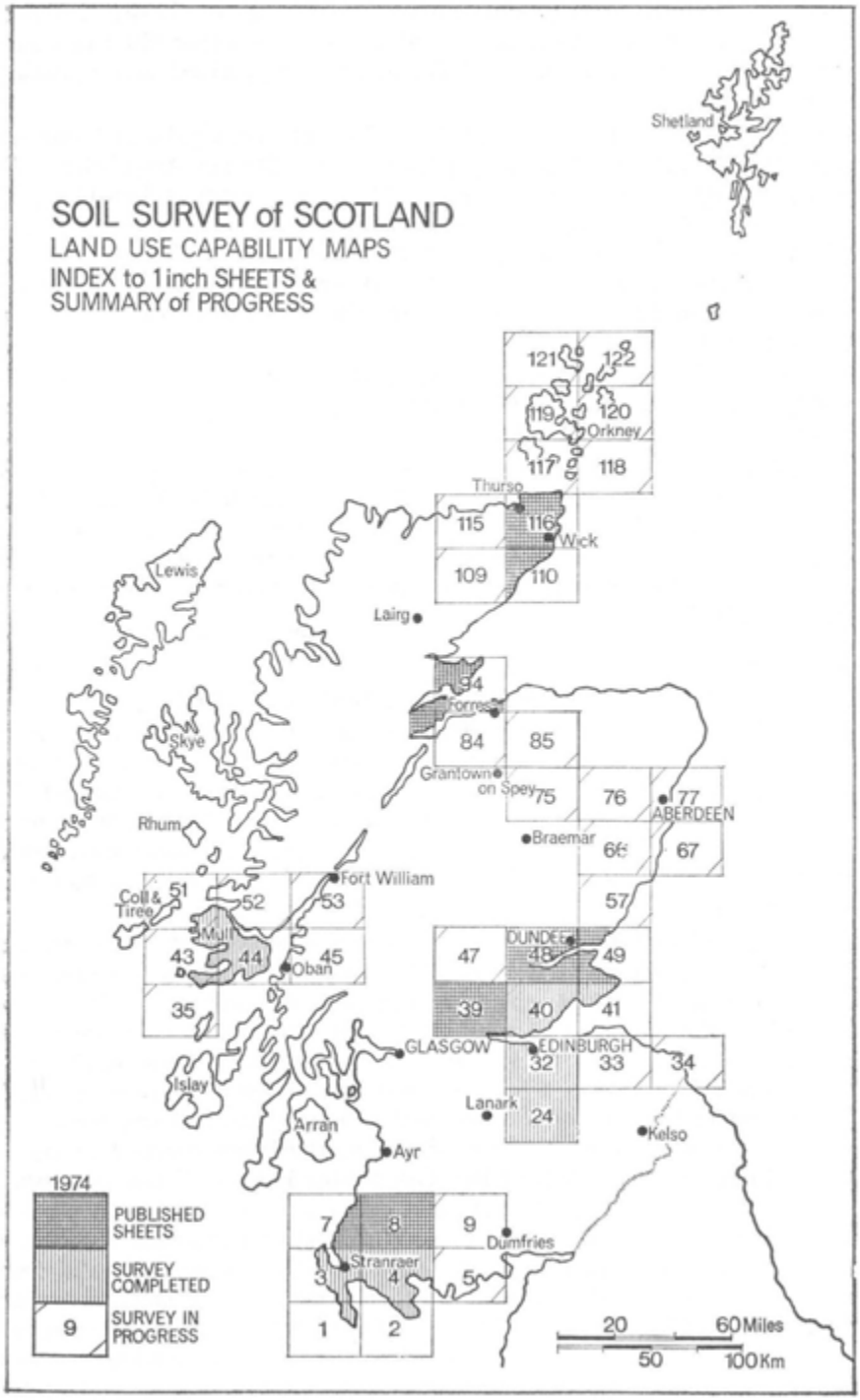
100 Km.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100 Km

with Bilbster series soils predominating; a large area of Bilbster complex has been delineated in Stenness. Small areas of Countesswells and Charr series have been mapped south of Yesnaby on a drift derived from a granite-schist complex.

The soil survey of Hoy was started in 1974. The principal soils found are shallow and deep peat and peaty podzols of the Dunnet Association with strong gleying above a thin iron pan. At lower altitudes, below 120 m to 180 m (400-600 feet), the thin iron pan is strongly developed but weakens with height, finally disappearing at about 250 m to 275 m (800-900 feet); at this height the vegetation cover becomes sparse, an eroded bouldery surface displays such features as stone stripes, and the soil mapped is akin to a sub-alpine podzol.

A narrow belt of peaty gleyed podzols developed on fluvioglacial sands and gravels has been mapped, extending eastwards for about two miles along the road from Rackwick.

Small areas of the Thurso series, the Bilbster series and peaty gleys of the Canisbay and Dunnet Associations have been found in the north of the island and along the north-eastern seaboard. A freely drained soil of the Darleith Association has been mapped on a drift derived from the Hoy lavas at Rackwick. Miscellaneous soils include peat-alluvium complex, saltings and colluvial fans. 801

Sheets 109 (Achentoul) and 115 (Reay)

About 260 km² (100 square miles) have been surveyed this season. Mapping took place in two districts. The first lies in the southern part of Caithness and comprises the area around the headwaters of the Dunbeath Water. Deep blanket peat is widespread, but the area also includes soils of the Countesswells Association and, to a lesser extent, of the Berriedale Association. These soils are mostly peaty podzols (the Charr and Berriedale series) although the mapping units are mainly soil complexes of peaty podzols and shallow peat.

The second district is in Sutherland and comprises the area around Forsinard, Kinbrace and Badanloch. The soils mostly belong to the Strichen Association although deep blanket peat is widespread and soils of the Berriedale, the Countesswells and the Corby Associations also occur. In the Strichen Association the soils are mostly peaty podzols and peaty gleys. In the Badanloch district peaty gleys and peaty fragogleys are widespread, but elsewhere the soils of this association mostly occur in soil complexes with peat or peat and rock. The soils of the Berriedale Association are on the Old Red Sandstone hills of Ben Griam Mor and Ben Griam Beg; peaty podzols (Berriedale series) and skeletal soils occur on the steep slopes and oroarctic soils on the hill tops. The soils of the Countesswells Association found in the eastern part of the district on parental material derived from the granite of the Strath Halladale Injection Complex, are almost exclusively peaty podzols (Charr series). The soils of the Corby Association are mostly peaty podzols (Tarbothill series) occurring in a soil complex with peat; they have a small but scattered distribution. 801

Sheet 85 (Rothes)

Following the completion of the survey by some minor revision and correlation, the field sheets are being edited and compiled for publication. 801

Sheets 76 (Inverurie) and 77 (Aberdeen)

The land use capability assessment based on the soil maps and field observations has been started and more than half the area has been covered. 801

Sheet 75 (Tomintoul)

About 155 km² (60 square miles) have been surveyed and 17 profiles described and sampled. Some of these profiles were taken with the aid of a Smalley excavator, which has also been used to establish the nature of parent materials.

Five-sixths of the mapping has been around Tomintoul and in Strath Avon and Glenlivet where most soils are formed from acid schists, slaty rocks, quartzite, granite and limestone which, with their derived drifts, give rise to soils of the Strichen, Foudland, Durnhill, Countesswells and Deecastle Associations, respectively. Around Tomintoul, conglomerates and associated sandstones of Old Red Sandstone age are overlain by a reddish brown drift, usually of a sandy loam texture. Soils formed on this parent material do not correlate well with other Old Red Sandstone soils in north-east Scotland and have been provisionally separated as the Tomintoul Association. Some soils near the village of Tomintoul were tentatively mapped as on a water-modified drift derived from Old Red Sandstone rocks until the excavator revealed sand at depth, the parent material of soils of the Boyndie Association.

Freely drained soils on the cultivated land have been mapped, where the parent material is derived from acid rocks, as cultivated phases of humus-iron podzols. These phases have been distinguished in the Strichen, Foudland, Countesswells and Boyndie Associations, and also on the Corby Association formed on gravels derived from acid rocks. Brown forest soils do, however, occur in these associations and are most frequent along the valley sides of Strath Avon where it is probable that, despite the absence of cultivation, the effects of birchwood cover and steep slope, and possibly enrichment of the soil from limestone outcrops, have retarded podzolization. Uncultivated humus-iron podzols are usually improvable for agriculture and the land is thus rated as Class 5; where peaty podzols occur, however, they are seldom improvable owing to the effects of a peaty H layer, an iron pan and a short growing season. Some soils with no iron pan but with a peaty H layer thicker than about 10 cm have been mapped as peaty podzols, for example in the Glenlivet area.

About 26 km² (10 square miles) have been mapped in Glen Gairn near the southern margin of the sheet. The Countesswells Association is not as extensive as the granite mass shown on the geological map because of the presence in the drift of acid schists, some of which may be locally derived. Soils of the Aberlour Association have been distinguished where the parent material is a drift derived from mixed granite and acid schists. 801

Sheet 74 (Grantown-on-Spey)

Approximately 120 km² (45 square miles) have been surveyed and 49 profiles sampled during systematic survey in two main areas.

In the sand and gravel outwash plain north of Aviemore, bounded by the Rivers Dulnain and Nethy, thick deposits of gravel are widespread, forming the parent material of soils of the Corby Association. Near Pityoulish, however, the gravel is replaced by bedded sands, sometimes with a thin capping of gravelly sand, and soils of the Boyndie Association have been identified. Except in peaty hollows, the soils are freely to excessively drained and have been mapped as humus-iron podzols. The terrain consists of subdued *Calluna*-dominated mounds with occasional well developed esker complexes, for instance near Kinchurdy.

The other area surveyed comprises the Monadhliath foothills between Kinveachy and Inverlaidnan. These foothills, underlain by schist, granite or granitized schist, are normally fringed by shallow slopes of rudely stratified gravelly loamy sands on which soils of the Dulsie Association form. On the lower concave slopes, however, the soils are developed on a sandy loam or loam till derived from mixed granite and acid schists of the Aberlour Association. A veneer of partially sorted or morainic material is widespread. The common occurrence of series of spring lines at the upper break of slope means that the soils are invariably poorly drained and they have therefore been mapped as peaty gleys or peaty fragogleys.

Soils on the upper convex slopes are formed mainly in shattered rock with a variable veneer of morainic drift. Drainage is free and humus-iron podzols are dominant. Complexes of minor rock outcrops and these podzols occupy the strongly glaciated summits. Of particular note is the sporadic occurrence of soils formed in completely weathered rock.

Reconnaissance surveys have also been conducted on selected transects along the valleys of the Rivers Spey and Findhorn and in the Monadhliath Mountains. Excepting slope complexes in the Findhorn Valley south of Dalmigavie Lodge, which will require further examination, all the soils encountered have been described previously.

The Monadhliath region presents considerable difficulties in access. Mainly above 600 m (2000 feet) and rising to approximately 900 m (3000 feet) it is underlain by rocks of the Moinian Assemblage. The mineral soils appear to be developed mainly in shattered rock or locally derived drift and below 750 m (2500 feet) are often overlain by hill peat. 801

Sheet 66/67 (Banchory/Stonehaven)

The land use capability assessment of this area is now almost complete and the draft field maps have been reviewed in consultation with advisory officers from the North of Scotland College of Agriculture. 801

Sheet 57 (Forfar)

The land use capability survey has begun and 40 km² (15 square miles) between Brechin and Forfar have been completed. 801

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

Survey of the areas on Sheets 51 and 52 underlain by granite, basalt and gabbro has been completed and the mapped complexes are now being subjected to a sample area analysis to characterize the included soil types and determine their relative proportions. In addition, 390 km² (150 square miles) have been surveyed, principally in the mountainous districts northwest of Loch Linnhe. Here the extremely steep terrain has made it difficult to delineate some mapping units. Steep slope phases of many of the complexes within Strichen and Countesswells Associations have been introduced in an attempt to avoid a multiplicity of complexes with little practical value. The soil profiles encountered frequently show the effects of mass movement of parts of the slope. Washouts, semi-circular seepage slips, colluvial and alluvial fans are common. Rock outcrop dominates the area underlain by schist and gneiss although the epidiorite gives rise to more even slope forms. For a large part of the landscape the effects of steep slope or of boulderiness largely rule out any prospect of worthwhile reclamation for agriculture.

Twenty profiles have been collected for analysis, mainly from the limited agricultural areas. 801

Sheet 47 (Crieff)

Approximately 65 km² (25 square miles) of new mapping has been completed in the important arable farming area around Madderty, between Crieff and Perth. This complex area straddles a pre-glacial course of the River Earn, now occupied by a tiny misfit stream—the Pow Water—flowing in the opposite direction to the main drainage of the area. Consequently the silty alluvial soils of the valley bottoms, at an altitude of approximately 38 m (125 feet), frequently cause drainage problems. Most of these are solved by orthodox methods, but occasionally more specialized treatment is necessary, as for example at Gorthy where the drainage from some 80 hectares (200 acres) is led into a drain/sump below the level of the Pow Water and when the water level reaches the limit of acceptability for agriculture, water is automatically pumped from the sump to the Pow Water some 3 m (10 feet) higher. The immediate valley sides rise to approximately 100 m (300 feet) in gently rolling drumlinoid topography. The underlying rocks are Lower Old Red Sandstone sediments with occasional east-west aligned igneous intrusions in the form of basalt dykes. All the soils encountered have been described previously and have been included in Alluvium or in the Balrownie, Carpow, Carbrook, Darleith, Forfar and Laurencekirk Associations. 801

Sheet 37 (Inverary)

During October 1973, when access to the main Survey area was restricted, a detailed survey of Lephinmore Farm (Hill Farming Research Organisation) was commenced, using a 100 m grid inspection system. The findings will be used to assist the compilation of a first draft key for Sheet 37, but it is hoped that an attempt will also be made to correlate some of the experimental data from the farm with selected soil parameters from various soil series, in order to enhance the usefulness of the soil map. 801

Sheets 23 (Hamilton) and 31 (Airdrie)

The soil survey of National Grid squares NS 86 and 96 has been completed, together with the northern parts of NS 65, 85 and 95, amounting in all to 220 km² (85 square miles). This completes the mapping of Sheet 31, which has also been revised. The areas north and south of the Forth and Clyde Canal have been correlated and a land use capability assessment of the northern area has been completed.

Most of the soils encountered have been assigned to the Darleith, Giffnock and Rowanhill Associations and have been described in memoirs and in earlier annual reports. The mapping of Sheet 31, the area south of the Forth and Clyde Canal, commenced in the north-east around the Falkirk-Grangemouth conurbation. During the past four years work has progressed from land near sea level under a rainfall of about 800 mm (32 inches) per annum to land at 185-290 m (600-950 feet) O.D. with an annual rainfall of 1000-1150 mm (40-45 inches). As expected, peat and peaty gley soils are more prevalent in these higher areas, but humose surface water gley soils also occur extensively and warrant delineation in both the Rowanhill and Giffnock Associations. Most of the humic gley soils are probably cultivated peaty gley soils, similar to Glaisnock or Scaurs series, which were ploughed about 150 years ago but, apart from 'rig and furrow,' were never artificially drained and have remained uncultivated since the middle of the nineteenth century. The very dark grey or black topsoils of these soils still retain an abrupt even boundary at the base of the plough layer. The texture is normally a sandy loam, though in a wet sample the high organic content induces so much coherence and sponginess that it can easily be mistaken for loam. Revision has revealed that these humose soils occur mainly on the higher parts of the Slamanan plateau to the east of Cumbernauld, east of Airdrie and around Shotts and Fauldhouse. In these areas gley soils occurring under arable crops or improved permanent grass are seldom humose. 801

Sheets 5 (Kirkcudbright) and 9 (Maxwelltown)

Surveying has been continued this season in two areas, one to the south-west of Dumfries around the group of hills of which Criffel is the most prominent and the other to the north around Queensberry. In all approximately 260 km² (100 square miles) have been mapped and 54 profiles described and sampled.

In the southern area a considerable number of distinctive soils were encountered. The most extensive are the soils of the Dalbeattie Association, occupying the hills and uplands formed by the outcrop of Criffel granite. The drift cover on the middle and upper slopes is shallow with rock outcropping in a number of areas and complex map units are widespread. On the lower slopes around the granite mass the loam and sandy loam drifts are of mixed derivation, but mainly comprise granite and greywacke materials in varying proportions. The brown forest soils developed on these materials are mostly naturally freely drained. Soils of the Darleith Association have been mapped on basaltic lavas outcropping in a small area around

Ladyland, and at Arbigland a group of soils has been mapped on sandy clay loam and clay loam tills derived mainly from sediments of Lower Carboniferous age. The natural drainage of the latter soils is commonly imperfect and series have been distinguished both on unmodified tills and on tills with a surface wash of sandy material or texturally modified upper layers. On the post-glacial raised beach around Kirkconnel Flow and at Drum Mains and Carsethorn silty clay and clay loam estuarine alluvial deposits have given rise to poorly drained soils of the Stirling Association. Between Southerness and Mersehead wind-blown sands have developed Links soils which are somewhat unusual in that profiles with distinct ochreous mottling predominate. At the head of the Nith Estuary soils of the Yarrow Association have been mapped on sands and gravels of fluvioglacial origin.

In the north, the hills and moorlands to the south-west of Queensberry are underlain mainly by Silurian greywackes and shales which together with their derived drifts have given rise to soils of the Ettrick Association. 801

Special Surveys

A9 Trunk Road. The site investigations on behalf of the Scottish Development Department of the Slochd-Dalmagarry and Dalmagarry-Bogbain sections of the proposed new A9 trunk road have been completed. This has involved the description and sampling of a large number of profile pits and some detailed examination of the underlying drift deposits.

The reconnaissance survey at 6 inches to 1 mile of several possible routes in the remaining Avielochan-Slochd section has also been completed. 801

Achany, Sutherland. The North of Scotland College of Agriculture farm at Achany, Lairg, Sutherland, with about 1800 hectares (4500 acres) of hill land, was revisited and a land use capability assessment made, particular regard being paid to areas where re-seeding might be possible. 801

Vegetation Surveys

The first draft of the bulletin on the Plant Communities of the Lowlands and Southern Uplands of Scotland has been completed. An account of the vegetation of Sheets 1, 2, 3 and 4 (Kirkmaiden/Whithorn/Stranraer/Wigtown) has been written for inclusion in the soils memoir of the area, and an account of the vegetation of Sheet 39 (Stirling) has been partly completed. The bulletin relating to the vegetation map of the Nairn and Cawdor district has been completed, apart from the chapter on soils.

A paper on the bioclimate of Shetland[35] was prepared and read at a symposium on Shetland organized by the Nature Conservancy in January 1974.

Recording of the vegetation, by plant sociological methods, of Sheet 85 (Rothes) and Sheet 75 (Tomintoul) was carried out and completed during May, June, July and August. Recording of the vegetation of Sheet 47 (Crieff) was commenced at the end of August. 802

The vegetation of Scotland displays great variety, due to the country's wealth of rock types and the sharp transitions in climate from west to east

and from low to high altitude. From the rugged western Highlands to the gentler hills of the east and south and the level carses in the Central Valley, the landscape is rich in colour and shape.

During the past twenty years, as the soil survey has progressed over the predominantly agricultural areas, the communities of the natural and semi-natural plant cover have been sampled and described. Initially the plant sociological methods elaborated by Dr Duncan Poore in 1955 were used to record some of the more clear-cut plant communities, while most of the vegetation was recorded in a more general manner after the methods used by Tansley. The description of vegetation in the earlier soil memoirs is thus based on the communities described by Tansley.

From 1961 onwards the vegetation in the areas under soil survey was recorded entirely by Poore's methods. By then a reasonable field knowledge of the vegetation had been acquired. Over a period of years, 1961/65, the methods of constructing floristic tables and of establishing plant associations and *noda* closely followed those of Poore. Descriptions of plant communities appearing in the soil memoirs during these years are comparable with those established by D. N. McVean and D. A. Ratcliffe of the Nature Conservancy. The dominant species and a group of constant species form the basic element of the communities.

By 1966 the major communities of the Lowland and Southern Uplands region had been drawn up in floristic tables and it was considered desirable to place these in the classification of the higher units, classes, orders and alliances, of Continental Europe. With this in view an approach was made to Professor R. Tüxen of West Germany, a leading European authority, and two visits were paid to his Arbeitstelle für theoretische und angewandte Pflanzensociologie at Rinteln. As a result of these discussions the tables of the Scottish plant communities have been reconstructed in accordance with the principles and methods of the Central European school of plant sociology. The main difference from Poore's methods is that plant associations are based on character and differential species instead of dominant and constant species. All accounts in future soil memoirs will be based on this redrawing of the community tables, and while delays in publishing may throw them chronologically out of sequence, little difficulty should be experienced in determining to which of the three periods an account belongs.

The main communities of the areas where soil survey has been conducted can now be described in terms of the classes set up for Central Europe. In 1971 a map of the Bioclimatic Sub-regions of Scotland was published and this, together with the genetic soil types derived from the soil maps, provides a useful framework on which to describe the vegetation.

There is little natural woodland in Scotland, apart from remnants of the Caledonian Pine Forest, but woodland communities of the lowland region can be ascribed to two principal classes, Querco-Fageta—broad-leaved woodland on the nutrient-rich brown forest soils, and Quercetea roboripetraeae—broad-leaved woodland on acid base-deficient brown forest soils. The most extensive Scottish community of the first-named class is Aceri-ulmetum glabrae. *Acer pseudoplatanus*, one of the naming species, is an

alien, but is very characteristic of the vegetation in steep-sided dens and policies woodland of the arable area. Galio saxatilis-Quercetum is the community on the drier acid soils of the second class. Three subassociations have been distinguished. One, named by bluebell, *Endymion non-scriptus*, occurs in the hyperoceanic and euoceanic parts of the country and a second, named by blaeberry, *Vaccinium myrtillus*, on the more podzolic soils; the third, the typical subassociation, occurs in the least oceanic area, the hemioceanic. The oak of the canopy layer has often been planted; under natural conditions there might be a larger proportion of silver birch, *Betula pendula*, and, north of the Highland Boundary Fault, of Scots pine, *Pinus sylvestris*. Vegetation of these two classes occurs mainly in the northern temperate and hemiboreal sub-zones but does extend into the (oro)boreal zone.

Many plantations of Scots pine and other conifers can be assigned to the class Vaccinio-Piceetea, northern coniferous forests, provided they have been planted on podzols, where the potential natural vegetation is coniferous forest or possibly the *Vaccinium myrtillus* subassociation of Galio saxatilis-Quercetum. One community on the drier podzols has been named provisionally the *Erica cinerea-Pinus sylvestris* community. It is generally found in the drier eastern part of the country and extends from the northern temperate to the upper oroboreal sub-zone.

The next stage to woodland, either in a downgrade or upgrade series, is scrub. Definite communities have yet to be established, but Rhamno-Prunetea, the class of scrub on drier soils, has been recorded.

Next in importance are the classes of the pastoral area. The first class, Molinio-Arrhenatheretea, is found on the richer soils, ranging from freely drained brown soils of moderate base status to non-calcareous gleys with mull A horizons and peaty gleys of moderate base status. The most widespread community is the Lolio-Cynosuretum association, the pasture of much of western Europe, which occurs on the drier soils and also on cultivated podzols where fertilizer treatment and grazing pressure are sufficient to maintain it. Two subassociations have been described. The typical subassociation is on the richest most heavily grazed pastures which contain a high proportion of perennial ryegrass, *Lolium perenne*, and species indicative of heavy grazing and treading such as great plantain, *Plantago major*, and annual meadow-grass, *Poa annua;* its extreme form is the temporary ley of arable rotation. The second subassociation, that with *Luzula campestris*, is found on the more acid nutrient-poor soils. As well as the naming species, a group of species including birdsfoot trefoil, *Lotus corniculatus*, and the moss *Rhytidiadelphus squarrosus* differentiate it from the typical subassociation. This vegetation grades into the less intensively used grassland of the second class, Nardo-Callunetea.

The second widespread community is the Potentillo-Juncetum acutiflori association, occurring on gley soils on which no drainage improvement has been carried out other than, possibly, the cutting of surface drains. The vegetation is usually dominated by the rush *Juncus acutiflorus*, associated with which are many wet meadow species such as marsh thistle, *Cirsium palustre*, tufted hair-grass, *Deschampsia caespitosa*, large birdsfoot trefoil,

Lotus pedunculatus, and ragged robin, *Lychnis flos-cuculi*.

The distribution of both these Molinio-Arrhenatheretea associations extends from the northern temperate sub-zone to the lower oroboreal sub-zone and even, in the case of the Juncetum, to the upper oroboreal sub-zone. Lolio-Cynosuretum, however, is more characteristic of the northern temperate and hemiboreal sub-zones, especially of the wetter oceanic half of the country, and its place in the colder boreal sub-zones is taken by grassland of Nardo-Callunetea.

The class Nardo-Callunetea is the vegetation *par excellence* of the Scottish scene. It includes the acid grasslands and the dry and moist heather moorland of so much of the foothill and upland regions. The soils are brown forest soils of low base status and humus-iron and peaty podzols. At the lowest altitude, or on soils derived from the richer rocks, the vegetation is the Achilleo-Festucetum tenuifoliae association (bent-fescue grassland). Three subassociations have been distinguished. The first is the subassociation with *Thymus drucei*, on soils derived from basic or lime-rich rocks. In addition to thyme, *Thymus drucei*, ribwort plantain, *Plantago lanceolata*, and spring sedge, *Carex caryophyllea*, differentiate it from the rest of the association. The second is the typical subassociation, the most extensive and the vegetation of many hectares of the best hill grazing. The third subassociation, that with *Holcus mollis*, has affinities with scrub or woodland, although woody species are entirely absent. The first subassociation is restricted to low to moderate base status brown forest soils. Under the other two subassociations signs of podzolization are often present in the soil, but these are perhaps relict from under a more heathy type of vegetation. Climatically the association ranges from the northern temperate sub-zone to the upper oroboreal sub-zone, although in the latter sub-zone it is found only on steep slopes with creep soils or on soils derived from basic rocks.

The second association, Junco squarrosi-Festucetum tenuifoliae, is characteristic of the hills of the Southern Uplands and the Central Valley. Its two subassociations can be equated with the *Nardus* grassland and the *Molinia* grassland of many descriptions of hill vegetation. *Nardus* grassland, the typical subassociation, can be found at all levels from sea-level to the orohemiarctic (subalpine) sub-zone on brown podzolic to podzolic soils, but its main distribution is in the oroboreal zone. The second subassociation, that with *Molinia caerulea*, generally occurs on peaty podzol and peaty gley soils. It is often associated with the first, occupying gentler slopes, and is widespread in the high rainfall area of the west. The climatic range of the *Molinia* grassland is almost as wide as that of the *Nardus* grassland with respect to temperature conditions, but it is much more closely linked with low moisture deficit.

The dry and moist heather moorlands of Scotland are clearly a continuum and any division into communities must reflect some significant geographic distribution related to climate. Two communities have thus been distinguished. The first, Carici binervis-Ericetum cinereae, is based on the association named Erico cinereae-Caricetum binervis set up for Ireland by J. Braun-Blanquet and R. Tüxen in 1950. In Scotland it is the heath of the

northern temperate sub-zone irrespective of degree of oceanicity, although in the hyperoceanic sub-sector it extends as far north as Shetland and thus well into the boreal zone. The second association has been named Empetro-Ericetum cinereae and is the boreal heath of the country. Its distribution begins in the hemiboreal sub-zone and extends up into the orohemiarctic (subalpine) sub-zone. Bearberry, *Arctostaphylos uva-ursi*, and fir clubmoss, *Lycopodium selago*, are character species of this association and blaeberry, *Vaccinium myrtillus*, cowberry, *V. vitis-idaea*, and crowberry, *Empetrum nigrum*, differentiate it from the first association. Both associations occur on humus-iron podzols and peaty podzols and a portion of each, designated as the sub-association with *Viola riviniana*, is found on brown podzolic soils.

The last important class of vegetation on grazing land is Oxycocco-Sphagnetea. Its grazing value is less than that of the other two classes and in many instances it must be little removed from the primitive condition. The vegetation of the blanket and raised bogs has been divided into three main communities. The first, Erico-Sphagnetum magellanici, is widespread in western Europe. In Scotland it is the lowland community, but in basin sites extends up into the foothill or even the upland region. It is split into three subassociations—the subassociation with *Cladonia uncialis* of the boreal zone, the typical subassociation of the northern temperate sub-zone, which extends into the boreal zone on slightly flushed sites, and the subassociation with *Molinia caerulea* of the western blanket peat. The vegetation of the hyperoceanic areas can be separated as an oceanic race or form, differentiated by the high constancy of the liverwort *Scapania gracilis* and the presence of *Pleurozia purpurea*. The peat under the association is very acid and varies from pseudofibrous to fibrous.

The second community is the upland blanket peat association, Vaccinio-Ericetum tetralicis. This was set up by J. J. Moore in 1962 for the hill peat vegetation of the British Isles. In Scotland it occupies the oroboreal sub-zone and extends up into the orohemiarctic (subalpine). The peat under it is extremely acid and often pseudofibrous in nature. Much of it is hagged and eroded.

At the highest level, extending from the orohemiarctic sub-zone into the oroarctic (alpine), the vegetation has been placed in a *Rhytidiadelphus loreus-Sphagnum fuscum* community. This is characterized by the common occurrence of *Sphagnum fuscum* and cloudberry, *Rubus chamaemorus*, together with the lichens *Cladonia uncialis*, *C. arbuscula* and *C. rangiferina*. Also, cross-leaved heath, *Erica tetralix*, is absent from the vegetation. The peat of this mountain community is acid and similar in character to that of the upland community, but it is in an even more severely eroded condition.

The alpine dwarf shrub heaths of the class Loiseleurio-Vaccinieta have been recorded and two communities have been established provisionally, more work being needed to establish their validity. Vegetation of this class falls largely in the lower oroarctic sub-zone and gradually gives way to the Caricetea curvulae class vegetation at the highest altitudes. Although some records of this last class have been made, no floristic tables have yet been

drawn up. Both these classes of mountain vegetation are dealt with in detail by D. N. McVean and D. A. Ratcliffe in a monograph on the Vegetation of the Highlands. 802

The classes of vegetation listed and briefly described above are the most extensive on the land surface of Scotland. This excludes the weed communities of arable land, the class Stellarietea mediae, which have been sampled but not to an extent adequate for establishing definite communities. There are also small sedge communities of the class Parvocaricetea and the vegetation of shallow rocky soils, Sedo-Scleranthetea, both of importance in the grazing regime of hill country, but they are of minor extent when compared with the classes described. Also of relatively minor extent but of great value for the enjoyment of our landscape, is the vegetation of the coast zone—of the salt marshes, Asteretea tripolii, of the building dunes, Ammophiletea arenariae, and of the fixed dunes, part of Sedo-Scleranthetea.

Soil Micromorphology

Preparation of soil thin sections has been restricted by working difficulties associated with supply shortages, and by preparations for the transfer of laboratory facilities to Craigiebuckler House. Over 130 soil thin sections have been prepared however, from soils of the Ettrick, Balrownie, Darleith, Castle Douglas and Sourhope Associations.

A paper on soils and archaeology in Scotland[87] was presented at the Council for British Archaeology conference on The Effect of Man on the Landscape: the Highland Zone, held at the University of Lancaster. 804

Other Survey Work

Collaboration has continued with the Department of Agriculture and Fisheries for Scotland and with the three Scottish Colleges of Agriculture on problems relating to drainage and reclamation, and in the selection of experimental sites. Liaison has been maintained with the Forestry Commission, the Nature Conservancy, the Department of Environment, the Hill Farming Research Organisation, the Highlands and Islands Development Board and with other departments of the Institute. 801, 802, 804

Several archaeological sites have been visited and advice given on the soils of the excavations. Details of the soils of specific areas have been provided, on request, to planning and engineering consultants, local authorities and other public bodies. There continues to be an increasing interest in the application of soil survey work to regional studies at universities, colleges and schools, resulting in many enquiries and requests for soils information. In addition, a number of talks have been given and field excursions led. Two day excursions were arranged and conducted for a party of 35 staff and senior students of the Department of Geography and Soil Science, University of Amsterdam, to examine the soils, landscape and land use in north-east Scotland. 801, 802, 804

An account of the soils of the Stirling area was prepared for the handbook for the Stirling Meeting of the British Association for the Advancement

of Science[36]. An exhibit illustrating the soil survey and land use capability classification of the district was staged, with the assistance of the Information Officer, and an excursion to demonstrate soils in relation to land use capability was organized and led. 801

Members of staff assisted in the arrangements for the autumn conference of the British Society of Soil Science in Edinburgh, including the compilation and editing of the guidebook. They also prepared and led several of the excursions. 801

A paper on the bioclimate of Shetland[35] was read at a symposium on Shetland organized by the Nature Conservancy. 802

Maps, Memoirs and Cartography

The Soil Survey map that covers parts of Sheets 35/36/43/44/51/52 (Island of Mull) has been published. Major modifications, which necessitated a second colour proof, were made on the first colour proofs of the Soil map for combined Sheet 24/32 (Peebles/Edinburgh). Final production by the Ordnance Survey is now awaited. The colour proof of the Land Use Capability map for combined Sheet 24/32 (Peebles/Edinburgh) has been corrected and returned to Ordnance Survey for final printing. A scribed negative and colour model of the Soil map for Sheet 40/41 (Kinross/Elie) has been submitted to Ordnance Survey for colour proofing. The negative for the Soil map of combined Sheet 84 and part of 94 (Nairn/Cromarty) has been scribed and the colour model is nearing completion. A coloured model has been prepared of the Land Use Capability map for combined Sheet 40/41 (Kinross/Elie) and work has begun on the scribed negative. A coloured hand compilation of the Land Use Capability map for Sheet 66/67 (Banchory/Stonehaven) is being revised before the final cartographic work is undertaken.

A second colour proof of the Nairn/Cawdor Vegetation map on the 1:25,000 scale has been received but has not yet been examined in detail.

Thirteen sheets have been added to the uncoloured 1:25,000 scale Soil Survey field sheets for restricted circulation, bringing the total to 115. The recent additions are twelve sheets from Fife and Angus and one from Easter Ross.

The galley proofs of the memoir for Sheets 48/49 (Perth/Arbroath) have been received and are being checked. 801

SOILS OF FIFE AND KINROSS

The Soil map of Sheet 40 (Kinross) with part Sheets 41 (Elie) and 32 (Edinburgh) has been completed and a preliminary summary of the main features and of the soil distribution can now be given. The district, which occupies an area of 1256 km² (485 square miles), covers the southern part of the area lying between the Firths of Tay and Forth and includes the central, eastern and southern parts of the County of Fife, almost the whole of Kinross-shire and a small area of East Perthshire.

There is a wide range in relief in the area mapped. Most of the north-western corner has hilly relief in the form of the eastern flanks of the Ochils, which have a north-east south-westerly strike, the height of land rising to 500 m (1630 feet). To the north the land falls gradually to the valley of the River Earn and to the south to the plain of Kinross in the centre of which is the 13 km² (5 square miles) expanse of Loch Leven. Surrounding the plain on the south-west, south and east are isolated but prominent hills, all over 300 m (1000 feet), with steep scarp faces on their north and west sides. The Saline-Cleish Hills lie to the south-west of the loch, Benarty Hill to the south and the Lomond Hills, now the Lomonds Country Park, to the east. The remainder of the mapped area extends along the northern coast of the Firth of Forth as far as Fife Ness, the eastern extremity of the Kingdom of Fife. Apart from two small but prominent hills, Largo Law, 270 m (952 feet), and Clatto Hill, 248 m (814 feet), the whole of this area consists of rolling and mainly arable fertile farmland lying below 150 m (500 feet). The coastal area from Culross in the west to Fife Ness tends to be smoothly sloping down to the 25-foot, low raised beach, the only steeply sloping part being behind Burntisland.

Geology

The configuration of the area, its shape and relief, is due to the type and structure of the rocks which underlie it and to the Pleistocene glacial drift, deposits of till and fluvioglacial sands and gravels which have smoothed the contours. The geological succession is:

Recent	Peat and Alluvium
Post-glacial	Raised beach deposits
Pleistocene	Glacial till, fluvioglacial sands and gravels
Carboniferous	Upper—Sandstones, mudstones and some coal seams
	Lower—Sandstones, shales, limestones and igneous rocks
Old Red Sandstone	Upper—Sandstones, mudstones and conglomerates
	Lower—Sandstones, conglomerates, lavas and tuffs

Recent deposits of alluvium and peat, post-glacial raised beaches and the Pleistocene glacial drift overlie two main geological formations—Carboniferous and Old Red Sandstone. Upper and Lower facies are recognized in both formations. The Upper Carboniferous rocks are mainly sandstones and mudstones with some coal seams; the Lower group contains limestones, sandstones and shales, with basaltic lavas, agglomerates and doleritic sills. The Upper Old Red Sandstone contains sandstone, mudstone and conglomerate strata, while the Lower group consists of sandstones and conglomerates with contemporaneous andesitic and basaltic lavas and tuffs.

Land-Form Regions

Five main land-form regions can be distinguished—the Ochil Hills; the interior lowland plain; the basalt hills (Cleish, Benarty, Lomond); the East Fife uplands; and the coastal lowlands.

The Ochil Hills are underlain mainly by andesite and basalt rocks of the Lower Old Red Sandstone formation, with smaller but frequent intercalations of olivine-basalt and andesitic and basaltic tuffs.

The interior lowland plain is underlain by Upper Old Red Sandstone sediments, mainly sandstone with some mudstone and conglomerate. West of Loch Leven the plain contains the Crook of Devon hills, a series of long narrow sand and gravel ridges 120 m to 180 m (400-800 feet) high, but east of the loch and north-east from the Lomond Hills stretches the wide Kinross Drift Plain, a flat fertile area extending north-eastwards through the Howe of Fife to the northern boundary of the map and beyond.

The basalt hills, lying to the south-west, south and east of Loch Leven, comprise a varied tract of high ground containing separated groups of hills and detached knolls which maintain a prevailing north-east to south-west trend. The group to the south includes the Saline and Cleish Hills, rising to 378 m (1243 feet) at Dumglow on the Fife/Kinross border, to 364 m (1195 feet) on Knock Hill and to 359 m (1178 feet) on Saline Hill. Immediately south of the loch is Benarty Hill, 356 m (1167 feet), while to the east the Lomond Hills, with the three prominent peaks of West Lomond, 522 m (1712 feet), East Lomond, 448 m (1470 feet) and Bishop Hill, 394 m (1292 feet), form the main hill mass in the survey area. Roughly circular in shape, with steep scarp slopes above 150 m (500 feet), the mass is composed of sandstones, mudstones and limestones capped by a massive sheet of dolerite. The peaks of West and East Lomond represent the infilled vents of volcanoes which penetrated the mass.

The East Fife uplands lie to the east of the Lomond Hills and north of the coastal lowlands, forming a tract of undulating relief with a complicated topography caused by the underlying quartz-dolerite sill. Most of the area is arable land, but there are several grass-covered hills marking volcanic necks, the highest and best known being Largo Law, 290 m (952 feet), a prominent landmark in east-central Scotland.

The coastal lowlands of Fife extend from Culross and Torry Bay in the west to Fife Ness, the most easterly point. Four local land-form regions can be recognized. A till plain extends from the western margin to beyond Dunfermline, the land rising in a north-easterly direction to around 120 m (400 feet). Along the coastal strip bordering this plain, from North Queensferry to Aberdour to approximately Kirkcaldy, is a belt of hilly country with extremely irregular relief where the land-form is determined by outcrops of dolerite sills and lava flows with a south-westerly dip and steep scarp slopes to the north-west. In this area prominent hills are the Binn of Burntisland, 193 m (632 feet) and Dunearn Hill, 222 m (727 feet).

From Lochgelly to Leven the till plain gradually descends to the valley of the River Leven. Around Lochgelly frequent disused coal bings are evidence of the former intensive mining. Present day coal mining is centred on the East Fife Coalfield, at the Seafield Colliery, now in operation at Kirkcaldy, and the Frances Colliery at Dysart. A number of pits have been closed because of faulting and frequent igneous intrusion in the extremely

complicated geological formations. The coastline from Leven to Fife Ness is generally rocky with occasional steep cliffs, but arable farmland on the drift plain extends to the cliff tops. Former raised beaches are recognizable in places all along the coastline, and are well developed round Kirkcaldy and Leven.

Glacial Geology

The general direction of the last glacial readvance was from west to east and glacial drift covers the whole area, with the exception of the summits of some of the higher hills where residual soils are formed on the rock. The middle and lower slopes of the Ochil Hills and the basalt hills are covered by till derived from the lavas and other basic igneous rocks. The flatter lands of the Kinross plain and the Howe of Fife are covered by a till derived mainly from Old Red Sandstone sediments with some lavas. The till covering most of the south and south-east is derived mainly from Lower Carboniferous sediments in which Calciferous Sandstone Measures and Lower Limestone Group strata are present, together with some igneous rock material. The igneous component is locally dominant. Raised beach deposits, mainly sands and gravels, extending up to the 30 m (100 feet) contour have been mapped extensively along the coast to the western boundary of the sheet.

Climate

For most of the year the prevailing winds are from west or south-west. Much of the moisture carried by these winds is removed by precipitation over the high ground to the west so that the eastern coastal areas are dry, with an average annual rainfall varying from 560 mm to 760 mm (22-30 inches). The annual rainfall rises steadily from east to west, reaching 890 mm (35 inches) in the central region and 1270 mm (50 inches) on the Ochil Hills. The coastal area has been classified as warm dry lowland with accumulated temperature (above 5·6°C) of 1375 day degrees C and a moisture deficit>75 mm, while the winters are fairly mild with accumulated frost of 20-50 day degrees C. On the cool uplands in the central and western parts of the district, accumulated temperatures range from 825 to 1100 day degrees C and the winters are rather severe with 110 to 230 day degrees C of accumulated frost. In common with the Tayside region to the north and with much of east Scotland, the district is moderately exposed and in spring and early summer is subject to easterly winds which bring in sea 'haar.' In addition, these winds, reinforced by sea breezes, cause a sharp fall in afternoon and evening temperatures in areas near the coast.

Soils

The sixteen soil associations listed in the accompanying table have been distinguished. All have previously been established in other parts of Scotland and, with the exception of Hindsward, Giffnock, Eckford, Darvel and Dreghorn, all have previously been mapped on Sheet 48/49 (Perth/Arbroath) to the north.

Association	*Parent Material*
Balrownie	Till derived from Lower Old Red Sandstone sediments, mainly sandstone.
Forfar	Water-sorted material generally >60 cm overlying till derived from Lower Old Red Sandstone sediments.
Kippen	Till derived from Upper Old Red Sandstone sediments, mainly sandstone.
Mountboy	Till derived from Old Red Sandstone lava and sediments.
Sourhope	Till derived from intermediate lavas of Lower Old Red Sandstone age.
Darleith	Drifts derived from basaltic lavas and basic intrusive rocks.
Hindsward	Till derived from Carboniferous sandstones and shales with a varying admixture of basic igneous material.
Rowanhill	Till derived from Carboniferous sediments, mainly shales with some sandstone.
Giffnock	Till derived from Carboniferous sediments, mainly sandstones with some shales, coals and limestones.
Gleneagles	Fluvioglacial sands and gravels derived mainly from Old Red Sandstone sediments and lavas with some Highland Schists.
Eckford	Fluvioglacial sand and gravel derived mainly from Upper Old Red Sandstone sediments.
Darvel	Fluvioglacial sand and gravel derived mainly from Lower Carboniferous igneous and sedimentary rocks.
Carpow	Upper terrace deposits, mainly coarse sands and gravels.
Panbride	Raised beach deposits derived mainly from Old Red Sandstone sediments.
Dreghorn	Raised beach deposits derived mainly from Carboniferous sediments.
Fraserburgh	Raised beach and wind-blown shelly sand.

Limited areas of soil developed on stabilized wind-blown sand, classed as Links, have been mapped along parts of the coast at the level of the lowest raised beach, 7·5-9 m (25-30 feet). Blanket peat is found on parts of the Ochil Hills and basin peat occurs frequently but inextensively in the lowlands; alluvium and peat-alluvium complex have also been separated. Where possible, soils developed on alluvial deposits have been sub-divided into series based on texture and drainage class.

The lava till covering the lower and middle slopes of the Ochil Hills provides the parent material of the Sourhope Association which occupies about 15 per cent of the total area. The till varies in colour from brown to pinkish brown and is generally of loam texture. From it is derived the dominant series, Sourhope, a freely drained brown forest soil first mapped extensively in the Borders between Jedburgh and Morebattle. On the upper slopes and hill tops, the till is absent or very thin so that the overlying soils are mainly residual and developed on decomposed lava rock. Because of the difficulty of separation from soil developed on till the

residual soil has been included in the Sourhope series. Under a grassland vegetation, the series has a dark grey brown surface horizon of loam texture overlying a brown or light reddish brown B_2 horizon with subangular blocky structure. This is underlain by a dark reddish grey or reddish brown B_3 layer of sandy loam texture, with a degree of induration varying from weak to strong. The C horizon, which may be weakly indurated at the top, is generally a gritty loam varying with depth to sandy clay loam till. The pH changes little down the profile and ranges from about 5·9 in the S horizon to 6·1 in the C. Percentage base saturation is moderate (20-60) in the S upper horizons and varies to high (>60) in basal layers, while amounts for total phosphorus are generally moderate throughout (100-300 mg P_2O_5 per 100 g soil). At altitudes above 300 m (1000 feet) with annual rainfall over 1000 mm (40 inches), a peaty surface horizon of variable thickness may be present, usually under *Nardus* grassland. These peaty brown soils have been separated as the Balquhandy series; this replaces the provisional name, Innerdouny (Annual Report No. 42, 1971/72). In some areas the Cowie series, a peaty podzol with thin iron pan, has developed; imperfectly or poorly drained in the surface layers, the series is freely drained below the iron pan. On or near some hill-tops, small areas of the Skythorn Complex, previously mapped on Sheet 39 (Stirling), have been separated. The main components of this complex are blanket peat, skeletal soil on intermediate lavas and a peaty ranker in which a peaty layer of variable thickness overlies rock. In the valleys, and on much of the lower ground, the till is generally of sandy clay loam texture and forms the parent material of the Bellshill series, an imperfectly drained brown forest soil with gleying. The pH is generally slightly higher than in the Sourhope series and base saturation is high or moderate to high throughout. Total phosphorus values are normally medium but may vary to low in subsoil horizons.

On certain lowland areas below about 155m (500 feet), both the Sourhope and the Bellshill series provide good quality arable land which can be placed in Land Use Capability Class 2. As much of the Sourhope series occurs on middle slopes of the Ochil Hills in the western part of the district, climatic factors, combined with the added restriction frequently imposed by induration, provide moderately severe limitations to arable cultivation and the land use class is not higher than 3 or 4. At higher altitudes land use is restricted to permanent pasture or to forestry.

The lowland area on the south side of the Ochils is covered by glacial and fluvioglacial drifts. In the Howe of Fife, and in the area around Loch Leven, the drift consists mainly of sands and gravels derived largely from the underlying sandstone sediments and from the lavas of the Ochil Hills. The soils developed on this parent material cover over 6 per cent of the district. Named, provisionally, the Edensmuir Association, they have now been correlated with the soils of the Eckford Association. In some areas, it has been possible to distinguish two series, the Hexpath series on sand and the Giffordtown series on gravel. Less extensive areas of an imperfectly drained series, Kilwhiss, and of a poorly drained series, Woodend, have also been separated. The Hexpath series has a high sand content and

except in surface horizons of cultivated soils, a clay content of less than 6 per cent throughout. Base saturation is moderate in the upper horizons but becomes high in basal layers. The total phosphorus is normally medium in the surface horizon and thereafter medium to low. The coarse texture of these soils results in a low moisture and nutrient-retention capacity and causes moderate limitations to arable cultivation; apart from small areas of the Kilwhiss series, the soils of the association cannot be rated higher than Class 3.

The northern portion of the Kinross Drift Plain extending from Loch Leven to the Howe of Fife is overlain by till derived mainly from Upper Old Red Sandstone sediments. This till forms the parent material of the Kippen Association, which covers 4 per cent of the area of the map. Where the till is formed from a mixture of Old Red Sandstone sediments and igneous rocks, it provides the parent material of the soils of Mountboy Association. Four series of the Kippen Association have been mapped in this area—Fourmerk, a freely drained brown forest soil, Kippen and Butterwell, brown forest soils with gleying, and Urquhart, a residual series developed on sandstone rock. The Mountboy Association contains two series—Garvock, a freely drained brown forest soil, and Mountboy, an imperfectly drained brown forest soil with gleying. Much of this part of the Kinross Plain is excellent arable land meriting a Class 2 rating. In most cases the soils are easily worked and the underlying till has a satisfactory moisture-holding capacity during dry periods. Induration in the B horizon of the Fourmerk and Garvock series is sometimes a limitation, while shallowness of soil profile in the Urquhart series sometimes restricts land use.

The soils occurring most extensively in east and south-east Fife belong to the Rowanhill Association developed on parent materials derived from Carboniferous sediments. Already distinguished in the north-east of the country, the association is most widespread of all the soils mapped in the district and covers 31 per cent of the total area. Over much of the association, the Caprington series, an imperfectly drained brown forest soil with gleying, is dominant; there are lesser areas of the Rowanhill series, a poorly drained surface-water gley. Two podzol series, Bathmoor, freely drained, and Devilla, imperfectly drained, occur to a minor extent throughout the area. The Caprington series has a dark grey brown loam to sandy clay loam surface horizon, with strong coarse angular blocky structure, overlying a brown or greyish brown sandy clay loam to clay loam B horizon, with coarse angular blocky structure tending to prismatic. The C horizon, weakly prismatic or massive, is a dark grey brown to dark grey clay loam varying to clay at depth. Decomposing shale is often present throughout the profile but is most common in the C horizon where it frequently obscures the horizon colour. In the Caprington series, the value for exchangeable calcium is frequently high (>8 me per 100 g) throughout the profile, the percentage base saturation is high and pH values range from 6·0 to 7·5, but are always lower when decomposing shale is prominent throughout the profile. The total phosphorus values are normally medium to low. The Winton series, an imperfectly drained brown forest soil with gleying, is also present in small

scattered areas. It is distinguished from the Caprington series mainly on the basis of colour, being developed on a reddish brown sandy clay loam or clay loam till derived mainly from Carboniferous sandstone.

From Dunfermline westwards to the boundary with Sheet 39 (Stirling), the till of the coastal plain contains a high proportion of sandstone; this becomes increasingly evident in many of the soils derived from Carboniferous parent materials. The soils in which Carboniferous sandstone is dominant have been separated as series of the Giffnock Association which covers 7 per cent of the total map area and occurs extensively on Sheet 39 to the west. The Aberdona series, an imperfectly drained brown forest soil with gleying, and the Giffnock series, a poorly drained gley, have both been mapped. When the Rowanhill and Giffnock Associations are compared it is apparent that the B and C horizons of the Giffnock soils are normally browner and that the sand content is generally higher than in the soils of the Rowanhill Association. Residual soils developed on decomposed Carboniferous sandstones have been mapped as the Forestmill series of the Giffnock Association. It should be noted that the Forestmill series now includes residual soils previously named, provisionally, Allanhill, a series of the Rowanhill Association mapped on Sheet 48/49 (Perth/Arbroath) to the north.

Towards the west of the district the Carboniferous till is generally of finer texture and, under the increased rainfall, poorly drained peaty gley soils mapped as the Scaurs series of the Giffnock Association are extensively developed contiguous with the areas of basin peat. The series has a peaty surface horizon 20 cm (8 inches) thick overlying a grey clay loam which below 30 cm (12 inches) passes into till with over 40 per cent clay. The pH (<4) and the percentage base saturation (<20) are both low throughout. Because of their fine texture the surface-water gley soils of the Rowanhill and Giffnock Associations are subject to severe agricultural limitations. This is particularly evident in south and south-west Fife where, on the wetter sites, permanent grass is the most satisfactory crop. The frequent occurrence of *Juncus*-infested pasture and the marked contrast with such limited areas as have been successfully drained emphasize the need for a sound drainage system.

A highly important group of soils are the water-sorted series occurring in the till-covered lowland areas. These soils are developed on coarse-textured deposits, generally more than 0·6 m (2 feet) thick, derived from till which has a water-worked surface. Soil series developed on water-sorted parent materials have been separated in the Sourhope Association (Gellyknowe), in the Kippen Association (Butterwell), in the Giffnock Association (Kennet) and in the Rowanhill Association (Macmerry and Butterdean). Butterdean is a poorly drained series of limited extent. Because of their coarse textures, water-sorted soils are easily worked and the underlying fine-textured till ensures an adequate supply of moisture in time of drought. Physical limitations to arable cultivation are few and the imperfectly drained soils tend to provide good Class 2 land.

On parent materials derived from the igneous rocks which form the basalt hills brown forest soils have developed and have been mapped as series of the Darleith Association. In the initial stages of the survey in this district all freely drained brown forest soils in this association were included in the Darleith series. It has since been decided to distinguish, mainly on the basis of texture, two freely drained series. Fine-textured soils developed on drifts derived from basaltic lavas or basic intrusive rocks have been mapped as the Darleith series; coarse-textured soils derived mainly from dolerites and basic agglomerates have been classed as the Drumain series. The former suggestion that the Drumain series might be included in the Sourhope Association (Annual Report No. 39, 1968/69) has now been discarded.

Examination of analytical data indicates that the pH throughout the Drumain series is generally lower than in the Darleith series. Total phosphorus is generally higher in the Darleith, with the values tending to increase down the profile; in the Drumain they tend to decrease. A peaty podzol with thin iron pan has been mapped extensively on Bishop Hill in the Lomond Hill group. Named, provisionally, the Munduff series (Annual Report No. 38, 1967/68), it has now been included in the Baidland series of the Darleith Association and is comparable with the Cowie series of the Sourhope Association; it occurs above 300 m (1000 feet) under a dominantly *Nardus* vegetation. The Dunlop series of the Darleith Association, an imperfectly drained brown forest soil, is found on lower and middle slopes of the Cleish Hills and the Lomond Hills and on the high ground behind Burntisland.

In the vicinity of the igneous intrusions, the Carboniferous till frequently contains a notable proportion of igneous material and the derived soils have been included in the Hindsward Association. The dominant soil is the Reidston series, an imperfectly drained brown forest soil with gleying, while smaller areas of poorly drained gleys have been mapped as the Hindsward series. Although similar in texture and structure to the Caprington and Rowanhill series, the parent materials of the Reidston and Hindsward series contain a moderate to high content of igneous stones or rock fragments and the B and C horizons of the soils normally show dark brown colorations due largely to the presence of decomposed igneous material.

Developed on fluvioglacial sands and gravels derived largely from Carboniferous sediments and igneous rocks with some Old Red Sandstone material, the soils of the Darvel Association are found in scattered areas throughout the Carboniferous region. Two series have been mapped, Darvel, a freely drained brown forest soil being dominant; Duncrahill, a brown forest soil with gleying, occurs only in small areas. In most cases coarse texture and frequent stoniness, often combined with the added restriction imposed by moundy topography, limit land use capability of these soils to Class 3. On more level ground the imperfectly drained series occasionally provides Class 2 land.

In the north-east corner of the district a narrow strip of soil stretching down the coast from the northern margin as far as Fife Ness represents the southern extension of the Panbride Association which occurs widely on

Sheet 49 to the north. The sands and gravels on which the Panbride series is developed are coastal raised beach deposits derived mainly from Old Red Sandstone rocks. The raised beach deposits extending along parts of the coastline from Crail westwards to Torry Bay are formed largely from Carboniferous rocks and the derived soils have been included in the Dreghorn Association already mapped in East Lothian on the south side of the Forth estuary. Dreghorn, the dominant series, is a freely drained brown forest soil, while Quivox is an imperfectly drained brown forest soil with gleying which normally owes its impeded drainage to the presence of fine-textured subsoil horizons. Some of the best arable land in the warm dry coastal areas of Fife is provided by these raised beach soils and much of it has been rated at Class 2. Because of their coarse textures, the Panbride and Dreghorn series are easily worked, with few soil limitations, and the till which generally underlies the beach deposits at depth provides a valuable moisture reservoir in time of drought. In a few areas the presence of gravel restricts the rating to Class 3.

The areas of Balrownie, Forfar and Carpow Associations, which occur at the northern margin of the district, are of only minor extent and represent the southern extremities of more widespread areas of these associations mapped on Sheet 48/49. Alluvial soils cover some 17 square miles, approximately 3·5 per cent of the total area, and 14 series have been separated on the basis of texture and drainage. Coarse-textured series (loams, sandy loams and loamy sands) are the more common and, in most cases, having only minor limitations, they fall into Land Utilization Capability Class 2. Fine-textured series (silty clays and clays) have been mapped in certain areas, mainly in East Fife. Similar in texture, drainage and situation to the low raised beach soils of the Stirling Association, these soils have moderate limitations which make careful management essential and as a result they are placed in Class 3.

Agriculture

Farming is the principal occupation in Kinross-shire, and despite the encroachment of open-cast mining and industrial building, Fife is essentially an arable county, with a higher proportion of its total area under crops and grass than any other county in Scotland.

On the slopes of the Ochils, the Lomonds and the Cleish Hills, the upper limit of cultivation is usually 244 m (800 feet), land above this level being under permanent grass or woodland. Lower and middle hill slopes generally support *Agrostis-Festuca* grassland, while on upper slopes *Nardus* is dominant, with *Molinia* common on the wetter areas and *Calluna* on the drier. On upland and marginal farms the emphasis is on livestock rearing, which depends largely on the proper management of grassland. On many farms hay is still used for winter keep, but grass silage is increasingly being made.

On most of the lower-lying parts of the district cash cropping, with cattle and sheep feeding, is the main agricultural pursuit; dairying is important near towns.

The closure of the factory at Cupar has put an end to the growing of sugar-beet in Fife, which in the late 1960's was producing up to 37 per cent of the Scottish beet crop. Sugar-beet grows well on the coarser-textured well drained soils in the coastal areas and many farmers are now looking to vegetables and soft fruit as possible replacements.

In the south and south-west of the district coal-mining was formerly carried on extensively, and before 1947 some 30 collieries were in operation. In the Cowdenbeath/Lochgelly area, the soil pattern is complicated by the frequent occurrence of made-up ground produced in the levelling of old coal bings or in the reinstatement of open-cast coal sites. Areas only recently levelled are mostly limited in use to pasture, but areas reinstated 15 to 20 years ago are now capable of some crop rotational cropping.

Forestry

Woodland covers an area of some 5220 hectares (12,900 acres) of which 2720 hectares (6720 acres) belong to the Forestry Commission and the remainder is privately owned. A further 380 hectares (940 acres) of Commission-owned land has yet to be planted.

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 loan schemes. A list of periodical holdings is available on request.

It is becoming increasing difficult to maintain holdings of books and journals at a satisfactory level in view of the constant struggle against ever-soaring prices. No additional journals could be considered this year. One hundred and thirty-four books were added to stock. The Institute still largely relies on other libraries to provide much of the material requested by members of staff, and this year 1018 items were borrowed. Two hundred and forty-two external loans were made.

The world-wide interest in the research work of the Institute is reflected in the number of requests for reprints of papers published by members of staff; 4502 reprints were distributed this year. Lists of available publications are sent out periodically to individual scientists and institutions, and anyone wishing to receive these should apply to the Librarian. No charge is made for reprints.

Volume 10 of the Collected Papers of the Institute, covering the period 1970/72, was issued during the year.

PUBLICATIONS

(A) *Published*

1. Changes in amount and distribution of stem growth in pole-stage Corsican pine following application of nitrogen fertilizer. By H. G. Miller and Jean M. Cooper. (*Forestry*, **46**, 157-190, 1973.)

   Stem analysis of pole-stage Corsican pine growing on sand dunes of low nitrogen status at Culbin forest, Morayshire, showed that tree growth had declined progressively with time, a feature ascribed to the continuing immobilization of nitrogen in the humus layer. On fertilizing with ammonium sulphate, at rates supplying from 252 to 1512 kg nitrogen per hectare, marked increases in growth occurred, but whereas maximum basal area increment was associated with a needle nitrogen level of 2·2 per cent, height response declined above 1·6 per cent, and it is estimated that volume growth would be maximized at just over 2·0 per cent nitrogen. Despite an increase in volume growth of 2·6 times, the fertilizer applications had little or no effect on the distribution of growth up the tree or the distribution of relative growth between trees sizes, although in absolute terms there was a widening in the range of tree sizes. No effect of fertilizer treatment on the pattern of growth with time was observed.

2. A new interpretation of the structure of disordered α-cristobalite. By M. J. Wilson, J. D. Russell and J. M. Tait. (*Contrib. Miner. Petrol.*, **47**, 1-6, 1974.)

   A silica phase previously described as disordered α-cristobalite has been studied by a variety of techniques. It is concluded that this type of silica, which occurs widely in sedimentary deposits, would be more appropriately called disordered α-tridymite.

3. A gas flow proportional counter for Na K_α X-radiation. By W. J. McHardy and A. C. Birnie. (*J. Phys.*, **E7**, 318, 1974.)

   A gas-flow proportional counter in the X-ray spectrometer attachment for the scanning electron microscope has been modified to improve its sensitivity for sodium.

4. Occurrence of imogolite in some volcanic ash soils of New Zealand. By N. Yoshinaga, J. M. Tait and R. Soong. (*Clay Miner.*, **10**, 127-130, 1973.)

   Imogolite, a hydrated aluminosilicate of tubular structure, is widely distributed in volcanic ash soils, but its presence has not previously been reported in the ash soils of New Zealand. Examination of acid-dispersed clay from three New Zealand soils by electron microscopy, electron diffraction, X-ray diffraction, and differential thermal analysis has established its presence, although in small amount.

5. Hydrothermal formation and alteration of laumontite in hornblende schist near Huntly, Aberdeenshire. By M. J. Wilson. (*Mineralog. Mag.*, **39**, 448-454, 1973.)

   During a study on rock weathering and soil formation, laumontite, a hydrous calcium aluminium silicate, was found in a deeply decomposed hornblende schist near Huntly, Aberdeenshire. The mineral is an alteration product of sodic plagioclase felspar and breaks down to a mixture of halloysite and prehnite.

6. 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.)

   The behaviour of iron in the natural weathering of biotite has been studied using the Mössbauer effect. In the biotite investigated, it was found that extensive oxidation of ferrous iron occurred during the early stages of weathering and that later there was a tendency for ferric iron to prefer certain structural sites.

7. 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.)

Two soil humus types, mull and mor, can be readily distinguished by analysis of the volatile materials given off during the pyrolysis of whole soil samples. Mass spectrometry and computerized pattern recognition of the spectra are employed. The method also allows the recognition of humus types transitional between the two extremes.

8. Kilphedir—hut circle excavation site. By J. C. C. Romans and S. E. Durno. (*Proc. Soc. Antiq. Scotl.*, **103,** 95-99, 1970/71.) *No reprints.*

   The significance of chemical and pollen analyses carried out on soil and peat samples taken at the Kilphedir site is discussed.

9. Response of seedlings of *Pinus contorta* and *Picea sitchensis* to oxygen concentration in culture solution. By R. Boggie. (*New Phytol.*, **73,** 467-473, 1974.)

   Some plants have an ability to grow under waterlogged conditions whereas others require good aeration of the rooting substrate. A laboratory technique has been devised for studying the growth of seedlings under conditions of varying oxygen tension from the equivalent of waterlogging to that of very good drainage. This arrangement has been employed to compare the growth of lodgepole pine and Sitka spruce in culture solutions saturated with gas mixtures containing concentrations of oxygen in the nominal range 0-21 per cent. Lodgepole pine is capable of some growth at very low oxygen concentrations; Sitka spruce is less tolerant and does not grow at low oxygen concentrations.

10. The determination of mercury in soils and related materials by cold-vapour atomic absorption. By A. M. Ure and C. A. Shand. (*Analytica chim. Acta,* **72,** 63-77, 1974.)

    A method for the determination of mercury using a cold-vapour, reduction-aeration atomic absorption technique is described. The mercury in the reduced sample solution is partitioned, by agitation, between the liquid phase and a fixed volume of air which is then blown through an absorption cell for measurement. Three preparative methods were developed, two of which used acid digestion and wet oxidation and the other direct oxidation in an oxygen-flask combustion technique. Comparative analysis of natural samples using the three methods was used to validate the techniques developed, since no authenticated reference samples were available.

11. The surface structures of gibbsite, goethite and phosphated goethite. By J. D. Russell, R. L. Parfitt, A. R. Fraser and V. C. Farmer. (*Nature, Lond.*, **248,** 220-221, 1974.)

    Surface hydroxyl groups on an aluminium and an iron hydroxide, both common soil minerals, can be detected in infrared spectra. Interactions between these hydroxyls and adsorbed species are therefore accessible to investigation. It is shown, for example, that phosphate replaces one type of hydroxyl on the goethite surface.

12. The infrared spectra of minerals. Edited by V. C. Farmer. (*Monogr. mineralog. Soc.*, No. **4,** 1974. London: Mineralogical Society. £16.00.)

13. Instrumentation and techniques. By J. D. Russell. (*Monogr. mineralog. Soc.*, **4,** 11-25, 1974.)

    A brief outline of the instrumentation, techniques and experimental methods employed in the identification and characterization of minerals by infrared spectroscopy.

14. Symmetry and crystal vibrations. By V. C. Farmer and A. N. Lazarev (Institut Khimii Silikatov im I. V. Grebenschikov, Leningrad). (*Monogr. mineralog. Soc.*, **4,** 51-67, 1974.)

    A convenient and rapid method for obtaining the number and symmetery species of the vibrations of crystals is described, using the tables below (No. 15).

15. Site group to factor group correlation tables. By V. C. Farmer. (*Monogr. mineralog. Soc.*, **4**, 515-525, 1974.)

16. The anhydrous oxide minerals. By V. C. Farmer. (*Monogr. mineralog. Soc.*, **4**, 183-204, 1974.)
The relationship between structure and infrared spectrum is examined in detail for oxides with rutile, corundum, and spinel structures. Applications of infrared spectroscopy to characterizing ion-coordination, impurity ions, order-disorder, and solid solutions in anhydrous oxide systems are reviewed.

17. Orthosilicates, pyrosilicates, and other finite-chain silicates. By V. C. Farmer. (*Monogr. mineralog. Soc.*, **4**, 285-303, 1974.)
Applications of infrared spectroscopy to determining the structure and composition of orthosilicates and the simpler condensed silicates are reviewed. An analysis of the factors that influence the spectra of these silicates leads to an improved understanding of cation-anion interactions and to the recognition of the distinctive features associated with SiOSi bridging bonds.

18. The layer silicates. By V. C. Farmer. (*Monogr. mineralog. Soc.*, **4**, 331-363, 1974.
The use of infrared spectroscopy in characterizing the composition, structure and reactions of clay minerals and other layer silicates is reviewed.

19. Vibrational spectroscopy in mineral chemistry. By V. C. Farmer. (*Monogr. mineralog. Soc.*, **4**, 1-10, 1974.)
An assessment of the role of vibrational spectroscopy in mineral chemistry distinguishes four important functions: firstly, as the most informative single technique to use in a preliminary examination of a mineral specimen; secondly, as a tool for studying the bonding and reactivity of water, hydroxyl and other covalently bonded groups in minerals; thirdly, as an aid to X-ray crystallography; and fourthly, as a guide to bond characteristics.

20. 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.) (*Geoderma*, **11**, 63-66, 1974.)
Infrared spectroscopy and chemical analysis have been used to show that protein-like constituents of soil organic matter decompose above 100°C to yield ammonia, which is retained as exchangeable ammonium ion when the clay organic complex is in an acid form. This may contribute to the increased availability of nitrogen in the top few inches of soil following burning of vegetation.

21. Transformation of sugars when rye hemicellulose labelled with ^{14}C decomposes in soil. By M. V. Cheshire, C. M. Mundie and H. Shepherd. (*J. Soil Sci.*, **25**, 90-98, 1974.)
Pentoses in the hemicellulose fraction of rye straw obtained by extraction with alkali are degraded to a much greater extent during incubation in soil than those in the intact straw. This is thought to be due to the higher solubility of the extracted hemicellulose. About 4 per cent of the isolated rye hemicellulose is transformed to glucose within the first two weeks of incubation.

22. Co-operative action by endo- and exo-β-(1→3)-glucanases from parasitic fungi in the degradation of cell-wall glucans of *Sclerotinia sclerotiorum* (Lib.) de Bary. By D. Jones, A. H. Gordon and J. S. D. Bacon. (*Biochem. J.*, **140**, 47-55, 1974.)
The plant pathogen *Sclerotinia sclerotiorum* and its parasitism by two other fungi have been the subjects of previous publications. The present paper describes biochemical aspects of the parasitism: in particular the mechanism by which sclerotia of the host are disintegrated. The sclerotia consist of masses of cells

with very thick walls, the chief constituent of which is a glucan of a special type. This resists the glucan-hydrolysing enzymes produced by many fungi but is rapidly degraded when an exo-β-(1→3)-glucanase is also present. Both parasitic species produce the latter in abundance.

23. The contribution of β-glucanases to the lysis of fungal cell walls. By J. S. D. Bacon (pp. 61-73 of *Yeast, Mould and Plant Protoplasts*. Edited by J. R. Villanueva *et al.* London: Academic Press. 1973.)

Polysaccharides composed of glucose are major components of the cell walls of all fungi so far examined. This paper reviews existing knowledge of the enzymes that attack these glucans and concludes that their action is the way to the degradation of the fungal cell wall. They are thus of importance for the destruction of pathogenic fungi in the soil, and for the sequence of microbial degradation of organic matter there. Closer investigation has shown that many different β-glucanases exist, and some are much more effective than others in attacking particular fungi. Reference is made to recent research at the Institute on the role of β-glucanases in the parasitism of sclerotia-forming plant pathogens by other soil fungi.

24. 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.)

The growth of pea root segments in a culture medium is stimulated by added hydroxyproline. Termination of cell elongation in such tissue is accompanied by an increase in the amount of hydroxyproline in the cell-wall proteins, an increase which is reduced by the addition of hydroxyproline to the culture medium. The mechanism of this inhibition probably involves either iron metabolism, since the chelating agent $\alpha\alpha'$-dipyridyl prevents the formation of hydroxyproline in pea root segments and many other plant tissues, or the development of peroxidase activity.

25. Protein-bound hydroxyproline and root growth. By D. Vaughan and Evelyn Cusens. (*Biochem. Soc. Trans.*, **2**, 124-126, 1974.)

It has been shown, using 2 mm long sections cut serially from the root tips of pea seedlings, that after cells have reached their maximum growth rate there is a dramatic increase in the hydroxyproline associated with their cell-wall proteins. It is suggested that wall-bound hydroxyproline is present in a distinct group of proteins which are not degraded, probably because the hydroxyproline becomes attached to the cell-wall carbohydrates by a linkage with the sugar arabinose.

26. A possible mechanism for humic acid action on cell elongation in root segments of *Pisum sativum* under aseptic conditions. By D. Vaughan. (*Soil Biol. Biochem.*, **6**, 241-247, 1974.)

Evidence strongly suggests that the growth stimulation by humic acid of pea root tissue is caused by a mechanism involving the binding of iron within the plant by this soil organic matter fraction. Thus there is a close resemblance between the effects of $\alpha\alpha'$-dipyridyl, which complexes ferrous iron, and humic acid on several changes in protein metabolism which are closely associated with the growth of the tissue.

27. Effects of hydroxyproline and other amino acid analogues on the growth of pea root segments. By D. Vaughan, P. C. DeKock and Evelyn Cusens. (*Physiol. Plant.*, **30**, 255-259, 1974.)

The increase in the growth rate of excised root segments, cultured under aseptic conditions, is accompanied by an increase in protein synthesis. Results obtained using amino acid analogues support the current view that the elongation of plant roots depends on continuous protein synthesis, but in addition indicate that the

cell-wall proteins play a major role in determining the rate and duration of cell elongation and so may serve as a basis for the interpretation of the effects of humic acid on cell growth.

28. 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). (*Pl. Soil,* **40,** 429-434, 1974.)
Using various humic acid fractions from a *Sphagnum* peat, a relationship was observed between the development of invertase activity in slices of beetroot storage tissues and the numbers of sporangia formed in several species of aquatic actinomycetes. Biological activity is discussed in terms of an 'aromatic core' present in the humic acid.

29. Uptake by beetroot tissue and biological activity of ^{14}C-labelled fractions of soil organic matter. By D. Vaughan, M. V. Cheshire and C. M. Mundie. (*Biochem. Soc. Trans.,* **2,** 126-129, 1974.)
Previous work has shown that humic acid stimulates the development of invertase activity, an enzyme closely associated with plant growth. The present investigation showed that although all ^{14}C-labelled soil organic matter fractions became incorporated into disks of beetroot storage tissue, only the low molecular weight components of humic acid, or its water and acid boiled residue components, stimulated the development of invertase or peroxidase activities. This indicates that factors other than differences in molecular weight account for the different biological activities of soil organic matter fractions.

30. 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). (*An. Edafol. Agrobiol.,* **32,** 101-108, 1974.)
Pear (*Pyrus communis* L.) trees suffering from lime-induced chlorosis were given soil or spray treatments with chelates of iron with EDTA or EDDHA. The effects on the mineral composition of the leaves were studied. Significant relationships were found between major and trace elements in the leaves, and the ratios of phosphorus to iron and of potassium to calcium showed a marked positive correlation. The citric acid and malic acid contents of the leaves tended to vary inversely with each other.

31. *Apusomonas proboscidea* Alexeieff 1924: an unusual phagotrophic flagellate from soil. By K. Vickerman (University of Glasgow), J. F. Darbyshire and C. G. Ogden (British Museum). (*Arch Protistenk.,* **116,** 254-269, 1974.)
The protozoan, *Apusomonas proboscidea,* has been isolated in small numbers from three soils from the north-east of Scotland. The only previous report of this flagellate was made by Alexeieff in 1924 from a few living specimens in a week-old infusion of horse dung collected in Finland. The detailed morphology of this flagellate is described with the aid of microscopy.

32. Soil properties limiting the efficiency of fertilizers. By J. W. S. Reith: (*Proc. VII Fert. World Congr., Baden, Austria, 1972,* 275-2781, 1973.)
The implications of soil conditions controlling the supply of nutrients to crops depend on the chemical and physical processes which regulate the solubility and availability of the different nutrients. Attention is drawn to some of the ways in which nitrogen can be lost. With phosphorus, effects of soil acidity, texture, organic matter and calcium carbonate contents, extractable aluminium and iron, and sorption capacity are considered. Results are given for comparisons of broadcasting and placing phosphorus and of different times of applications. The supply of potassium is affected by clay content and type of clay mineral, and

placement can be beneficial on soils with low reserves. Other factors, including deficiencies or excesses of trace elements and unsatisfactory soil physical conditions, can adversely influence the efficiency of fertilizers.

33. The effectiveness of different methods and times of applying fertilizers. By J. W. S. Reith. (*Phosphorus in Agriculture,* **62,** 61-76, 1974.)

The effectiveness of both fertilizers and trace element supplements in improving the yields and mineral composition of crops and herbage can be markedly affected by the method and time of application. It is important to ensure that adequate supplies of nutrients are positionally available during the early stages of growth without inducing harmfully high concentrations of salts in the root zone. The requirements in these respects are reviewed in relation to the influences of soil properties and the chemical characteristics of the different plant nutrients.

34. 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. (*J. Soil Sci.,* **25,** 51-62, 1974.)

Studies on a range of acid soils from north-east Scotland have shown that they can adsorb higher amounts of phosphate in the organic form as inositol hexaphosphate than as inorganic orthophosphate. The mechanism of sorption is different but the same sorption sites are involved, the organic phosphate being preferentially adsorbed and depressing the sorption of inorganic phosphate. Up to a certain level of addition, which varies with the soil, inositol hexaphosphate, unlike inorganic phosphate, is completely sorbed. This helps to explain the extreme stability of the naturally occurring inositol phosphate which accounts for up to one-quarter of the total phosphate in these soils.

35. Bioclimatic characteristics of Shetland. By E. L. Birse. (pp. 24-32 of *The Natural Environment of Shetland.* Edited by R. Goodier. Edinburgh: The Nature Conservancy, 1974.)

Because of their open position in the northern latitudes of the Atlantic Ocean, the Shetland Islands experience an extremely oceanic boreal (northern) type of climate. The cool moist conditions of summer encourage blanket peat development, except on soils on basic and ultrabasic rocks. Exposure is such that only in relatively sheltered positions can trees attain anything near to their normal stature. The best quality agricultural land, because of the severity of the climate, falls into land use capability class 4, i.e., with moderately severe limitations that restrict the choice of crops.

36. Soils. By B. M. Shipley. (pp. 66-82 of *Scientific Survey of the Stirling Region. Handbook of the British Association Meeting, 1974.* Edited by D. Timms, Stirling University, 1974.)

The soils of the Stirling Region are described with reference to the effects of the principal soil forming factors, especially the nature of their parent materials. The distribution of the main soil associations and of the major soil groups is described and two maps illustrating these are included. The wide range includes brown forest soils, gleys, podzols, montane and organic soils. Reference is made to the Land Use Capability Classification and its application to the soils of the region.

37. Petrofabric analysis. By J. S. Bibby. (Appendix to a paper by E. W. Mackie). (*Phil. Trans. R. Soc. Lond., A,* **276,** 191-194, 1974.)

Petrofabric diagrams drawn from data collected at Kintraw, Argyllshire, are compared with diagrams from Peeblesshire. It is concluded that neither scree formation nor solifluction processes can account for the genesis of the stone layer at Kintraw. An orientation analysis on a stone horizon from Sheep Hill, Dunbartonshire, known to be man-made, compares well with the Kintraw diagrams.

38. Soils in the Cairngorms. By R. E. F. Heslop. (pp. 222-227 of *The Cairngorms*. Edited by D. Nethersole-Thompson *et al.* London: Collins, 1974.)
Below an altitude of about 675 metres (2250 feet) most mineral and peaty soils are both leached and podzolized; they include humus-iron and peaty podzols. Above that height many soils are freely drained and strongly leached, but although the more developed profiles may have podzolic features the loose and humose nature of upper horizons is more evident. Peat, often eroded, becomes less common with increasing elevation.

(B) *Awaiting Publication at 30th September, 1974*

39. 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.*)

40. Highways and byways in thermal analysis. By R. C. Mackenzie. (*Analyst. Lond.*, **99**, 900-912, 1974.)

41. The removal of organic matter from soil extracts by bromine oxidation. (By B. D. Mitchell and B. F. L. Smith. (*J. Soil Sci.*, **25**, 239-241, 1974.)

42. 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 *Soil Components. Vol. 2. Inorganic.* Edited by J. E. Gieseking. Berlin: Springer.)

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

44. 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.)

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

46. Classification of soil silicates and oxides. By R. C. Mackenzie. (To appear in *Soil Components. Vol. 2. Inorganic.* Edited by J. E. Gieseking. Berlin: Springer.)

47. Heavy minerals. By the late W. A. Mitchell. (To appear in *Soil Components. Vol. 2. Inorganic.* Edited by J. E. Gieseking. Berlin: Springer.)

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

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

50. Imogolite from New Guinea. By R. L. Parfitt and W. J. McHardy. (*Clays and Clay Miner.*, **22**, 269-371, 1974.)

51. Iron oxide and clay minerals in some red and yellow podzolic soils from the Sydney region, New South Wales, Australia. By B. G. Davey, J. D. Russell and M. J. Wilson. (Submitted to *Geoderma.*)

52. Humus type discrimination from mass spectra by a simplified statistical treatment. By J. M. Bracewell, G. W. Robertson and G. J. M. Stephen. (Submitted to *J. Soil Sci.*)

53. Thermal decomposition characteristics of humus horizons from Culbin Forest. By J. M. Bracewell and G. W. Robertson. (Submitted to *J. therm. Analysis.*)

54. 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.*)

55. 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.*)

56. 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.*)

57. Physical and chemical properties of peat. By V. Puustjarvi and R. A. Robertson. (To appear in *Peat in Horticulture.* Edited by D. W. Robinson. Canterbury: Horticultural Education Association.)

58. Nutrient transfer from nitrogen-fertilized Corsican pine to the soil surface. I. Transfer in litter fall. By H. G. Miller and J. D. Miller. (Submitted to *J. appl. Ecol.*)

59. Nutrient transfer from nitrogen-fertilized Corsican pine to the soil surface II. Transfer in rainwater. By H. G. Miller, Jean M. Cooper and J. D. Miller. (Submitted to *J. appl. Ecol.*)

60. Effect of water table level on nitrogen mineralization in peat. By B. L. Williams. (*Forestry*, **47,** 195-202, 1974.)

61. Trace element problems on Scottish soils. By R. L. Mitchell. (*Neth. J. agric. Sci.*, **22,** 295-304, 1974.)

62. A triple-flow gas-sheathed D.C. arc for spectrochemical analysis. By H. K. El-Kholy, J. C. Burridge and R. O. Scott. (*Analytica chim. Acta,* **74,** 247-252, 1975.)

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

64. 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.)

65. The characterization of soil minerals by infrared spectroscopy. By V. C. Farmer and E. Palmieri. (To appear in *Soil Components. Vol. 2. Inorganic.* Edited by J. E. Gieseking. Berlin: Springer.)

66. Comment on *Spectroscopie infra-rouge de quelques acides humiques,* by J. R. Bailly. By J. D. Russell and H. A. Anderson. (*Pl. Soil,* **41,** 695-696, 1974.)

67. The occurrence of aphid wax in peat. By R. E. Wheatley, M. P. Greaves and J. D. Russell. (*Soil Biol. Biochem.*, **7,** 35-38, 1975.)

68. Decomposition of soil polysaccharide. By M. V. Cheshire, M. P. Greaves and C. M. Mundie. (Submitted to *J. Soil. Sci.*)

69. Soil polysaccharides and carbohydrate phosphates. By M. V. Cheshire and G. Anderson. (Submitted to *Soil Sci.*)

70. The effect of salicylic acid on the growth of *Lemna gibba.* By P. C. DeKock, Flora B. Grabowska and Alison M. Innes (University of Aberdeen). (*Ann. Bot.*, **38,** 903-908, 1974.)

71. Cortical cell fluxes and transport to the stele in excised root segments of *Allium cepa* L. I. Potassium, sodium and chloride. By A. E. S. Macklon. (Submitted to *Planta.*)

72. Cortical cell fluxes and transport to the stele in excised root segments of *Allium cepa* L. II. Calcium. By A. E. S. Macklon. (Submitted to *Planta.*)

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

74. Effects of temperature and chlorpropham on the storage of the yam. By A. O. Olorunda and A. D. McKelvie (School of Agriculture, Aberdeen) and A. E. S. Macklon. (*J. Sci. Fd Agric.*, **25,** 1233-1238, 1974.)

75. A rapid micromethod for estimating bacterial and protozoan population in soil or peat. By J. F. Darbyshire, R. E. Wheatley, M. P. Greaves and R. H. E. Inkson. (*Revue Ecol. Biol. Sol*, **11,** 465-475, 1974.)

76. Soil protozoa-animalcules of the subterranean environment. By J. F. Darbyshire. (To appear in *Soil Microbiology*. Edited by N. Walker. London: Butterworths.)

77. Ultrastructure of the stipe and apothecium of *Sclerotinia sclerotiorum*. By D. Jones. (*Trans. Br. mycol. Soc.*, **63,** 386-389, 1974.)

78. Fungicidal effects of the fumigant dazomet on sclerotia of *Sclerotinia sclerotiorum* in soil. By D. Jones. (*Trans. Br. mycol. Soc.*, **63,** 249-254, 1974.)

79. 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.*)

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

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

82. The nature of alkali-soluble soil organic phosphates. By G. Anderson and R. E. Malcolm. (*J. Soil Sci.*, **25,** 282-297, 1974.)

83. Soluble aluminium and calcium-aluminium exchange in relation to the pH of dilute calcium chloride suspensions of acid soils. By B. W. Bache. (*J. Soil Sci.*, **25,** 320-332, 1974.)

84. Erico-Sphagnetum magellanici J. J. Moore (1964) 1968 in the Sullom Voe area, Shetland Islands, Scotland. By E. L. Birse. (Submitted to *Phytocoenologia.*)

85. 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.*)

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

87. Soils and archaeology in Scotland. By J. C. C. Romans and L. Robertson. (To appear in *Proc. Council for Brit. Archaeology Conf., 1974.*)

88. 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, Ontario, Canada, 1973.*)

89. 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 *Geoderma.*)

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

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

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

93. Soils developed on Carboniferous sediments and their derived drifts in Scotland. By J. M. Ragg. (Submitted to *Proc. N. Engl. Soils Discuss. Grp.*)

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

94. Extended legend of soil map of part Taieri Uplands, Otago, New Zealand: Explanatory notes. By J. M. Ragg and R. B. Miller (Soil Bureau, Lower Hutt, N.Z.). (Part of *Publ. N.Z. Soil Bur.*, No. **503,** 1973. 8 pp.)

(D) *Thesis*

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

The weathering of layer-silicate minerals, with special reference to chlorite, in some Scottish soils. By D. C. Bain.

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 reports or periodical reports summarizing the research work that is in progress. Full details can be obtained from the secretaries of the institutes concerned.

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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.
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Hannah Research Institute	Ayr, KA6 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.

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Animal Virus Research Institute	Pirbright, Woking, Surrey, GU24 0NF.
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Grassland Research Institute	Hurley, Maidenhead, Berks, SL6 5LR.
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John Innes Institute	Colney Lane, Norwich, NOR 7OF.
Long Ashton Research Station	Long Ashton, Bristol, BS18 9AF.
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National Institute for Research in Dairying	Shinfield, Reading, Berks, RG2 9AT.
National Vegetable Research Station	Wellesbourne, Warwick, CV35 9EF.
Plant Breeding Institute	Maris Lane, Trumpington, Cambridge, CB2 2LQ.
Rothamsted Experimental Station	Harpenden, Herts, AL5 2QJ.
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Wye College, Department of Hop Research	Ashford, Kent, TN25 5AH.