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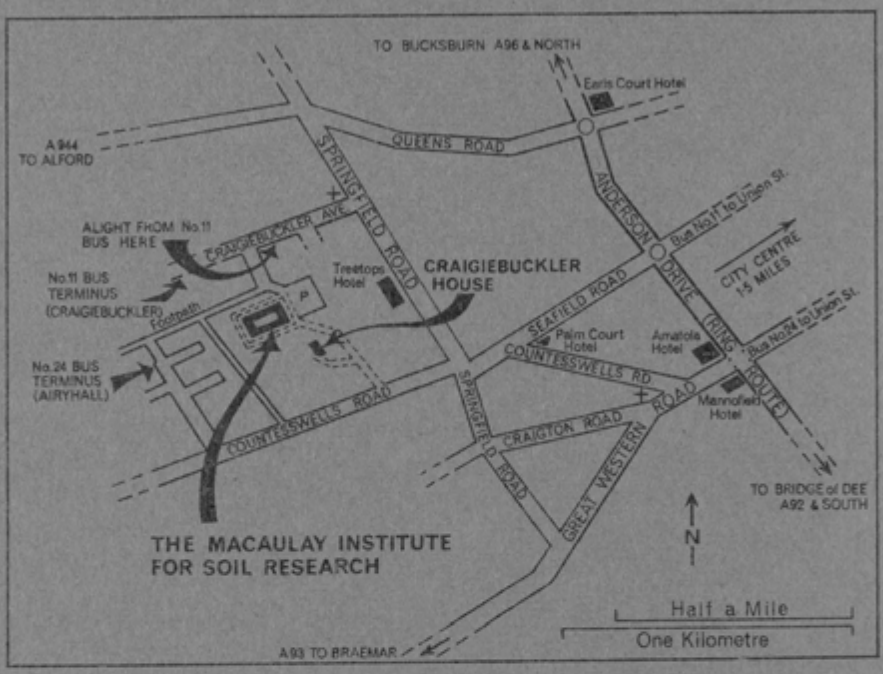

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

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**Ph.D. Student.*

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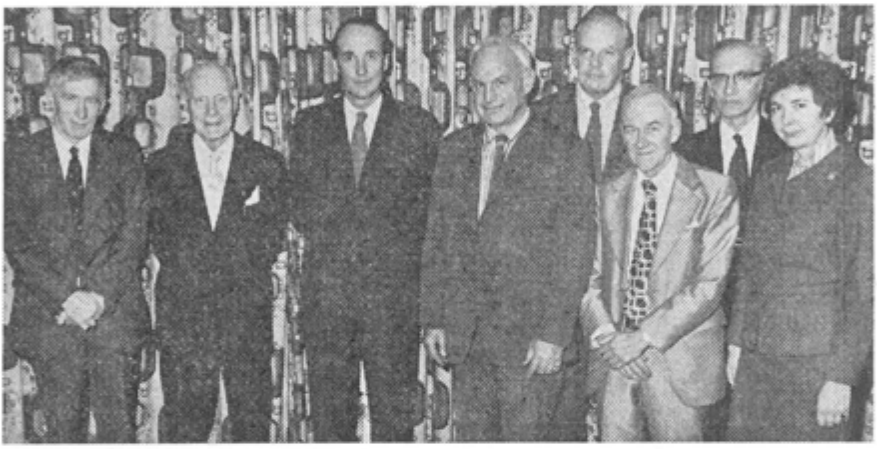
INTRODUCTION

T. S. West

During the year 1977-78 substantial progress has been made in many areas of the Institute's programme of applied and fundamental research. Well over 90% of the arable soils of Scotland have already been systematically surveyed and their mineral, nutrient and trace element compositions evaluated and catalogued; this inventory of information is now being processed, correlated and rearranged for ease of access and use in a computerized soil data bank. Such data have been entered for *ca.* 450 soil profiles. When the data bank becomes fully operational it should provide an invaluable information service not only for the staff of the Institute but, through them, to the other agricultural research institutes, the colleges of agriculture and the community at large in relation to the influence of soil factors on crop husbandry, pasture quality and animal nutrition. During the year we have initiated a rapid (small scale) survey of the hill lands at the request of the Department of Agriculture and Fisheries for Scotland. This will produce land use capability assessments and maps for agriculture and forestry simultaneously with the soil maps. Unless unforeseen circumstances intervene this operation should be completed during 1980-81. Appropriately, therefore, this should yield a fairly complete coverage of all the soils of Scotland and an assessment of their land use capability during the Institute's jubilee year. It is perhaps best to stress here that the hill soils information provided by this " crash " programme will necessarily be very much less detailed than that for the arable area. Very substantial progress has also been made in the practical application of soil fertility studies to agriculture and in the use of modern remote sensing technology using satellite imagery and aerial photography, particularly for peat and vegetation surveys. The information provided in these two areas to Regional Councils, the Highlands and Islands Development Board and to the advisory services of the North of Scotland College of Agriculture are examples of the immediate practical help provided by the Institute to the community. The report entitled " Fertilizer Recommendations " published by the North of Scotland College of Agriculture arising from joint work with the Institute is an example of the manner in which such help is provided to farmers.

A programme has now been initiated on nitrogen fixation in soil in the rhizosphere of cereal crops. If, as we hope, this work confirms earlier studies it could in due course make a significant contribution to nitrogen nutrition, particularly as we may now have to look towards a time when the energy requirements and cost of nitrogenous fertilizers may necessitate changes in the pattern of intensive agricultural practice. Much of the nitrogen in peat is also unavailable to plants and consequently work on nitrogen mineralization and fixation in peat, which is now being increasingly used as a horticultural substrate, is another long-term objective of this new programme. Other studies on peat have revealed the structural changes it

undergoes following repeated use for the growth of tomatoes and have shown up significant changes in its microbiological population. During the year, work on the essential trace element contents of a wide variety of Scottish peats has shown that these can be very variable. Some, for example, have total cobalt contents of only 0·02 ppm (w/w) — a value that would be sufficiently low to cause cobalt deficiency symptoms in livestock grazing on herbage on a mineral soil — whilst others have shown cobalt, nickel and molybdenum (w/w) contents higher than the typical levels of these elements in mineral soils. Since, however, peat has a much greater volume than mineral soils these data cannot be compared directly without making due allowance for this difference.



Macaulay Lecture Group (left to right): Mr R. A. Eden (Council), Professor T. C. Phemister (Chairman), Professor J. C. Bowman, Dr P. C. DeKock, Dr G. Anderson, Dr R. O. Scott, Mr R. Grant, Miss E. A. Piggott.

It has long been known that the organic matter content of soil has a pronounced effect on the maintenance of its fertility in relation to crop growth. During the past year, studies have continued on the decomposition of plant material in the soil, and several subtle effects of various organic fractions of the soil on plant nutrition and growth have been revealed. Fundamental work has also shown how soil organic matter contributes to the release and uptake by plants of essential trace elements. A synthetic "soil organic material", devised previously as a model compound to study such behaviour under more carefully controlled conditions than is possible with the "natural" material, has continued to show remarkably similar behaviour to humic substances both in its ability to affect plant growth in the presence of nutrients and to influence trace element uptake. Work on tree nutrition, undertaken in conjunction with the Forestry Commission, has shown that despite the atmospheric input of nutrient species *via* their canopies, referred to in earlier reports, trees continue to make significant

demands on forest soil reserves of nitrogen, phosphorus and calcium throughout their life cycle. Particularly interesting experiments on the influence of trees in modifying the nature of acid rain that would otherwise reach the soil are linked to other work on their evolutionary adaptation on nutritionally deficient soils and to their reaction to pollution and other abnormal inputs.

A long-term experiment on the effects of sewage sludge on the trace metal contents of soils and plants has continued to show little change in the amounts of deleterious trace elements extractable from the treated soils over the nine year period or in the enhanced levels of copper, nickel and zinc in plants, though it was noticeable that the chromium contents of herbage remained at a normal level. Present experience tends to show that the heavy metals are likely to remain in the top 30 cm of the soil, but since nine years may be too short a time to prejudge long-term effects of such accumulation it is obviously an experiment that must be pursued over a much longer period in the interests of the welfare of the community. Whilst such sludges are often added to soil on the basis that they may provide valuable nitrogen supplements, and of course that the water authorities need to get rid of them, other work in the Institute on the direct treatment of soil clays with gaseous ammonia has shown that the clay mineral vermiculite which is widely distributed in Scottish soils, can trap the ammonia between the layers of the weathered mica as ammonium ions to form a valuable source of nitrogen that is slowly released for plant nutrition. The retention of ammonium nitrogen in this way obviously has attractive features.

As befits the nature of soil research, much of the Institute's programme is of a long-term fundamental nature, but in this area too several interesting developments have taken place during the past year. For example, the use of gas chromatography has shown that there are great variations in the soil atmosphere—i.e. the atmosphere in cracks and fissures below ground level in which roots and micro-organisms live and transpire; concentrations of nitrogen, oxygen, carbon dioxide and argon varied markedly over sampling sites less than one metre apart. Other work on the weathering process by which minerals release nutrients into soils for plant-growth has shown that whereas it is generally considered that mica weathers by depletion of potassium from the edges of the flakes this is not always supported by experimental investigation. Our scanning electron microscope has shown that in at least some sand-sized biotite particles the potassium has been retained in the edges and released from the centre of the flakes. Furthermore, and quite significantly, biotite flakes found in Old Red Sandstone sediments have been found to be fairly fresh, contrary to commonly held views. These two examples of pedological work, involving the use of an electronoptical instrument, typify the importance of equipment of a sophisticated nature to the progress of further investigations of the nature and properties of our soils. In this respect it is particularly satisfactory that considerable progress has continued in the development of spark source mass spectrometry (SSMS) as a means of establishing simultaneously, on a

single sample, the minor and micro-trace element composition of soils, plant materials and soil extract concentrates. The comprehensive analysis of soils (and rocks) by SSMS is now being applied to a range of the topsoils and soil profiles provided by the Department of Soil Survey and it is being extended to the determination of some 40-50 elements in a variety of plant materials and biological tissues ranging from small marine animals to bovine liver. As experience of this advanced sophisticated technique grows, the vital objective of quantitatively following the transfer of a wide range of trace elements from the rock, through the soil and through plants to the animal becomes more and more a realistic and practical proposition. Plans eventually to link this work with studies on the influence of trace elements on animal nutrition at the Rowett Research Institute, and on human nutrition and health at the University of Aberdeen, are now being discussed. It is obvious that this link will involve all Departments of the Institute, e.g. our fundamental knowledge of the distribution of different types of soil (Soil Survey), their mineral and organic matter composition (Pedology and Organic Chemistry), their trace element composition and that of crops (Spectrochemistry), their fertility as decided by chemical, physical and crop studies (Soil Fertility), together with increased knowledge of the movement of trace elements into and up through plants (Plant Physiology), the influence of soil microbes on plant nutrition and their ability to extract bio-significant trace elements (Microbiology), together with a meaningful analysis of the exceedingly complex inter-relationships that exist between all these phenomena (Statistics). Newer work on difficult-to-determine, but biologically significant elements that exist at very low levels, e.g. selenium and molybdenum by recently introduced analytical techniques of radio-frequency plasma emission spectrometry and microprocessor-controlled electrochemistry are now strengthening our fundamental ability to contribute to such collaborative work as do studies by Mössbauer and Electron Spin Resonance spectrometry that provide hitherto unavailable data on the chemical forms in which trace elements exist in soils and plants. Infrared absorption spectrometry continues to be invaluable in showing the manner of retention of such species by clay minerals, etc., and electro-ultrafiltration and microcalorimetry in their release and movement through the soil solution. Similarly, well established techniques such as X-ray spectrometry, thermo-analytical work, gas-liquid chromatography interfaced with mass spectrometry, radiochemical studies, emission spectrography, atomic absorption and atomic flourescence spectrometry and, of course, chemical analysis all continue to add to the store of knowledge and to solve particular problems as they arise.

Thus in many ways the long-term fundamental work of the Institute's departments is geared to immediate practical research investigations as well as to maintaining it in a position to be able to provide answers to questions that can scarcely be formulated at the present time and to continue increasing our fundamental knowledge of soils, particularly in relation to the plant, animal and human life that depend on it for their existence and welfare.

New Instrumental Capabilities

During the past year, funds have been provided by the Department of Agriculture and Fisheries for Scotland for several items of equipment. A new Siemens 102 Transmission Electron Microscope has been purchased to replace the obsolescent instrument that was becoming increasingly difficult and costly to maintain in a condition sufficient to yield the more detailed information required by advanced electron microscopy of minerals, microbes and plants. The new TEM has already begun to prove its worth. A multi-purpose Digitizer has been acquired to allow the numeration of data acquired from aerial survey photographs and satellite imagery and this has already been interfaced directly with the central IBM 1130 computer and is producing invaluable data, particularly for peat and vegetation survey. Another important acquisition in this respect is the new Image Analyzer installed in the Department of Microbiology. This extremely versatile instrument, which is mainly intended for the detailed study of features of photographs and micrographs in a way that allows various factors, shown up by their intensity, to be differentiated and thus enumerated, has already resulted in the evolution of a new direct microscopic technique for measuring root growth and microbial colonization of plant roots in soil. The potential of the Image Analyzer to provide information from aerial/satellite remote sensing images has already been utilized by the Department of Pedology and similarly the instrument is likely to be of considerable use to the Department of Soil Survey in studying the micromorphology of thin sections of soil. Plans are afoot to link this instrument directly to the central IBM 1130 computer. A new adjunct that considerably improves the capabilities of our scanning electron microscope is an Energy Dispersive Unit that complements the wavelength dispersive system which alone was previously available when the SEM was purchased some years ago. Considerable difficulty has been experienced in the supply of a field control unit for the SSMS due to the continuing inability of the manufacturer to supply the equipment. Escalations in the cost of a commercial microwave induced plasma emission spectrometer for multi-element analysis have led us to undertake the construction of an instrument for ourselves, but no difficulties arose in the purchase of an electrothermal atomizer, a multi-channel magnetic tape recorder, an additional liquid scintillation counter for our radiochemical work, and various replacement items such as a large crop-drying oven, a precision guillotine (for the Technical Services Unit) and two Kjeldahl digestors for nitrogen analyses.

Once again our budget for instrumentation has been used almost entirely to replace obsolete equipment and to extend the capabilities of more recent instrumentation, but this year the addition of the Image Analyzer and the Microwave Excited Multi-element Analyzer have extended our instrumental capabilities beyond their previous scope.

Visitors to the Institute

In September the Institute was visited by Lord Porchester, the newly appointed Chairman of the Agricultural Research Council. Visits were also received from other members of both ARC and DAFS throughout the year.

Dr I. V. Dektyarev, former Rector of the Moscow Institute of Engineers of the Organisation of Land Exploitation, and Dr Y. V. Fedorin, Head of the Department of Soil Research and Land Classification, State Scientific Research Institute of Land Resources, Ministry of Agriculture, USSR, visited the Institute as part of a British Council organized tour to enable them to study British experience in soil and land classification, in the efficient use of land resources and the assessment of land value. In all, short-term visitors from twenty-three countries were received at the Institute during the year.

Group visits included parties from: the pre- and post-conference tours of the Sixth International Clay Conference; ARC Photographers; Aberdeen Mechanical Society; University of Aberdeen Geographical Society; Physics Teachers on In-service Courses, and various parties from the Universities of Glasgow and Aberdeen of both post-graduate and honours students in soil science, chemistry and agricultural chemistry. We also welcomed a group of staff from Rothamsted Experimental Station during the year.

EVENTS AND PEOPLE

THIRD *T. B. Macaulay Lecture*

The Third T. B. Macaulay Lecture was delivered by Professor J. C. Bowman, Director, Centre for Agricultural Strategy, Reading, entitled " Ill Fares the Land ". This took place on 23rd November, 1978, in the Marine Suite of the Amatola Hotel before an audience of over 200. Professor Bowman's lecture is presented as the Appendix to this report.

Meetings and Lectures

A Symposium at Aberdeen University on Trace Metals — The Soil-Plant-Animal Interface — the programme of which was arranged by the Institute and the Rowett Research Institute, was attended by several members of staff and papers were given by Dr R. O. Scott, Dr A. M. Ure, Dr B. A. Goodman and Mr J. C. Burridge of the Department of Spectrochemistry, Dr W. J. McHardy, Pedology, and Dr J. W. S. Reith, Soil Fertility.

External speakers who gave lectures in the colloquia series during the year were: Dr J. K. R. Gasser, Scientific Adviser, Research Division (Plants and Soils), Agricultural Research Council, on " Soil-Plant Work in the ARS Stations "; Dr J. M. M. Cunningham, Director, Hill Farming Research Organisation, Penicuik, on " Reflections of a Directing Director "; Dr C. W. Childs, University of Auckland, New Zealand, on " Aspects of Soil Research in New Zealand "; Dr G. Horlick, University of Alberta, Canada, on " Spectral and Spatial Studies of the Inductively Coupled Plasma with Photodiode Array Spectrometers "; Dr P. Violante, University of Naples, Italy, on " Some Aspects of the Genesis of Terra Rossa Soils "; Professor J. F. Loneragan, School of Environmental Life Sciences, Murdoch University, Western Australia, on " Relationships among nutrient supply, mobility and requirement in Plants "; Dr J. M. Lynch, ARC Letcombe Laboratory, Wantage, on " Some Microbiological Effects on Plants and the Soil "; Professor N. Yoshinaga and Professor K. Wada, Department of Agricultural

Chemistry, Ehime University and Faculty of Agriculture, Kyushu University, Japan, on " Allophane and Imogolite "; Professor V. N. Kudeyarov, Deputy Director, Institute of Agrochemistry and Soil Science, U.S.S.R. Academy of Sciences, Puschino, Moscow Region, on " Studies on the Nitrogen Supplying Capacity of Soils "; Dr R. C. Burns, Department of Microbiology, University of Kent at Canterbury, on " Soil Enzymes."

Internal speakers who gave lectures in the colloquia series to junior staff were: Mr R. A. Robertson (Pedology, Peat and Forest Soils) on " Peat Resources and their Utilization "; Dr B. W. Bache (Soil Fertility) on " Soil Chemistry and Crop Production "; Dr P. C. DeKock (Plant Physiology) on " The Plant and the Soil "; Mr R. H. E. Inkson (Statistics) on " How Vital are Statistics? "; Mr G. C. Stove (Pedology, Peat and Forest Soils) on " Scotland Seen from Space "; Dr J. F. Darbyshire (Microbiology) on " Soil Microbes "; Dr M. V. Cheshire (Soil Organic Chemistry) on " Studies on Soil Organic Matter "; Mr J. C. Burridge (Spectrochemistry) on " Spectrochemical Determination of Trace Elements " and Mr J. D. Russell and Dr B. A. Goodman (Spectrochemistry) on " Infra-red, Mössbauer and Electron Paramagnetic Spectroscopy."

Honours and Appointments

Dr D. Jones (Microbiology) was awarded the Second Prize in the Transmission Electron Microscopy Class of the Royal Microscopical Society's Biennial Micrograph Competition. The prize consisted of a certificate and cheque and the ceremony was held after the RMS Presidential address at The Royal Society.

Dr R. C. Mackenzie (Pedology) delivered the plenary lecture at the Sixth International Clay Conference in Oxford and has been elected President, for the next three years, of the Association Internationale pour l'Etude des Argiles. He is the first British scientist to be honoured in this way. He was also appointed to the Editorial Board of the Transactions of the Royal Society of Edinburgh and accepted appointment as a Visiting Professor in the Soil Department of the Faculty of Agriculture of the University of Riyadh (Saudi Arabia) for a two week period in December, 1977. Dr H. G. Miller (Pedology) was elected Chairman of the Sylvicultural Group of the Royal Scottish Forestry Society during the year. Dr B. L. Sharp (Spectrochemistry) has been appointed joint editor of the " Annual Reports on Analytical Atomic Spectroscopy " by The Chemical Society. Mr R. Grant and Mr J. S. Bibby (Soil Survey) have been appointed to the ADAS Soil Survey Working Group.

Lectures and Visits Overseas by Institute Staff

The Director accepted an invitation from the organisers of the EUCHEM Conferences as principal speaker on atomic spectroscopy at their meeting on the analysis of complex substances, held in Baden bei Wien, Austria in May. He was also the principal overseas guest speaker at a symposium on environmental pollution arranged by the Institute of Industrial Engineers of Navarra at Pamplona, Spain, in June and delivered two lectures on analytical atomic spectroscopy and its application to pollu-

tion problems in soils and surface waters. This visit was sponsored by the British Council. In August he attended the EUROANALYSIS III Conference in Dublin and gave a plenary lecture on Atomic Spectrochemical Analysis in relation to Trace Element Analysis in Soils. He also accepted an invitation to give the plenary lecture on atomic fluorescence spectrometry at the Analytiktreffen (1978) Symposium of Karl-Marx Universittät, Lepzig at Finsterbergen (German Democratic Republic) in December. In his capacity as President of the Analytical Division of IUPAC, he attended a meeting of the Division Executive Committee at Oak Ridge, Tennessee, in July and of the IUPAC Bureau at Brussels in August.

With funds made available by DAFS, several members of staff made very useful visits to various research establishments and scientific conferences abroad. Dr M. J. Wilson (Pedology), Dr M. L. Berrow (Spectrochemistry), Dr M. V. Cheshire (Soil Organic Chemistry), Dr J. F. Darbyshire (Microbiology), Dr P. C. DeKock (Plant Physiology), the Deputy Director, Dr E. G. Williams and Dr J. W. S. Reith (Soil Fertility), Mr R. H. E. Inkson (Statistics) and Mr J. M. Ragg (Soil Survey) all attended the Eleventh Congress of the International Society of Soil Science, Edmonton, Canada, in June. Dr J. F. Darbyshire also visited the Microbiological Centres at Vancouver, Spokane, Portland, San Francisco and Denver after the congress. Dr G. P. Sparling (Microbiology) visited the Institut fur Bodenbiologie, Forschungsanstalt fur Landwirtschaft, Braunschweig, Germany, and the Centre de Pedologie Biologique, Nancy, France, in June. Mr R. A. Robertson (Pedology) attended, as Vice-President, a meeting of the Praesidium of the International Peat Society at a Symposium on Peatland Agriculture and Forestry at Brumunddal, Norway, in August. Mr A. H. Knight (Soil Fertility) attended the annual meeting of the European Society for Nuclear Methods in Agriculture (ESNA) in Brno, Czechoslovakia, in September.

New Postgraduate Research Students

Three new research students have joined the work of the Institute's staff. Mr B. Thornton is working on the translocation and distribution of major nutrients in the whole plant in the Department of Plant Physiology. Mr P. Wilson is studying laser remote sensing of agricultural atmospheres in the Department of Spectrochemistry, whilst Mr S. D. Young is working on the study of soil aluminium organic complexes in the Department of Soil Fertility. All three students are being supported by Agricultural Research Council grants. The total number of postgraduate Ph.D. researchers in the Institute during the year was fourteen. Arising out of the work of Dr V. C. Farmer (Spectrochemistry) on synthetic imogolite and the granting of a patent, the National Research Development Corporation offered the Institute funding to allow the appointment of a temporary member of staff to carry out work in the Department of Spectrochemistry to investigate the preparation and properties of imogolite. Dr M. J. Adams, Chemistry Department, Imperial College, London, has accepted this period appointment and has started work in the Institute.

Overseas Research Workers

As well as the postgraduate research students listed above, several other long-term workers have visited the Institute from Finland, Hong Kong, Iraq, Italy, Japan, New Zealand, The Netherlands, Poland, South Africa, Spain and the U.S.S.R. Six of our distinguished overseas visitors were funded by The Royal Society (Drs Childs, Kudeyarov, Powell, Stawinski, Tejedor and Wada), two by the Inter Universities Council (Mr Naidu and Mr Yeung) and one (Dr Rahim) by the Underwood Fund of the Agricultural Research Council. We are grateful to all three bodies for providing the funds that allowed us to have these visitors work with us for substantial periods of time.

Broadcasts

Following the publication of the previous Annual Report, radio interviews were broadcast with Dr J. F. Darbyshire (Microbiology), Dr P. W. Dyson (Soil Fertility), Mr R. A. Robertson (Pedology) and the Director. Mr R. Grant (Soil Survey) also appeared in a television broadcast on land use in Scotland. Professor Bowman gave a radio interview on the subject matter of his Macaulay Lecture.

Institute Events

It is with regret that the death, during the year, of Emeritus Professor J. R. Matthews, a former Chairman of the Council of Management (1948-57) is recorded. The appointment of Mrs A. H. W. Dickie, ALA, as Librarian took place early in the year The Institute's news magazine, Profile, has continued to be produced regularly and has served as a vehicle for the dissemination of news of an official nature as well as of the activities and interests of the staff. It has now reached its 31st issue. Changes in the regulations concerning the membership of safety committees have been accommodated and the Consultative Committee has met to discuss local matters of concern to the staff. Two committees and several sub-committees have been set up to discuss programmes and arrangements for the celebration of the Institute's Jubilee in 1980 and matters are now well in hand for two Open Days on 25th and 26th June of that year.

The Council of Management met twice, on 22nd May, and 24th November, and as in the past year, copies of the Council's list of agenda were provided to the Institute Section of the IPCS.

The departmental responsibilities for individual research projects are discussed in the Report 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 indentification, 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.

(a) Characterization of Minerals and Major Constituents

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.

(b) Trace Element Characterization

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 Nature, distribution and properties of humic soil substances.

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 facilitates other investigations of 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.

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

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

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

508 Soil-borne fungal parasites.

510 Investigation of soil protozoan populations.

512 Microbial degradation of soil organic matter.

513 Interrelationships of soil actinomycetes, bacteria and protozoa with plant-roots.

514 Asymbiotic nitrogen fixation by soil microbes in the rhizosphere of agricultural plants and in peat.

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 agriculture, horticulture and forestry.

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.

(a) Soil-Nutrient Relationships

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.

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

614 Electrochemical studies on soil-nutrient-plant relationships.

(b) Soil-Plant Relationships

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.

612 Soil physical conditions and crop growth.

701 Theory of experimental design and statistical analysis.

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 and application of radioisotope 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 radioisotope facilities.

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

5703 Data preparation and computer processing.

1. PEDOLOGY

R. C. MACKENZIE

The work of the department has continued along the previously established lines of elucidating the origin and properties of the soil and obtaining information relevant to the better utilization of poor, highly organic soils.

As recounted in previous reports, invaluable information on fine particles and biological materials has been obtained by electronoptical techniques. A transmission electron microscope has been in constant use for this work since 1963, but its performance is not up to the requirements for 1978 and maintenance has been causing increasing problems. It is very gratifying, therefore, that this instrument has been replaced by a Siemens Model 102 transmission electron microscope which is now in operation. As an example of improvement in standards over the years, the new instrument has *ca* 4Å resolution as against *ca* 15Å on the old: this is well revealed in the appended micrograph (Fig. 1) which shows individual layers, each about 7Å thick, of the manganese oxide buserite. Thus, in addition to the shapes of individual particles, the "bricks" they are composed of can also be investigated. Moreover, the more convenient electron diffraction arrangement will be of considerable advantage in detailed structural studies. The combined scanning electron microscope and electron microprobe system has also been improved through the addition of an energy-dispersive analyzer which both increases enormously the speed with which microprobe analyses can be performed and enables the microprobe to be used in the analysis of samples, such as biological materials, with low element concentrations.

The specialized techniques available in the department have been extensively utilized by other departments of the Institute and by outside bodies, e.g., the Rowett Research Institute, the University of Aberdeen, and Robert Gordon's Institute of Technology. Close collaboration has continued with the Highlands and Islands Development Board, the Scottish Development Department, the Department of Industry (Space Division), Regional Councils and other organizations, especially in relation to the survey and utilization of peat. Information and advice on peat resources and their development have also been supplied to individual research workers and to organizations.

Several visiting workers have contributed to the programme of work of the department. Dr M. Isabel Tejedor-Tejedor, University of Madrid, Spain, has completed her studies on the synthetic manganese oxide buserite (see Fig. 1) that may well be a precursor of some soil manganese oxides; the investigation of the occurrence of poorly-ordered aluminosilicates in soils has been advanced by the work (in the Institute) of Dr P. Violante, Universita degli Studi di Napoli, Italy, on the presence of imogolite in some Italian soils; the project on surface characteristics of soil particles has been furthered by Dr J. Stawinski, Institute of Agrophysics, Polish Academy of Sciences, Lublin, Poland, who has determined adsorption isotherms for water on some Polish soils.

Members of staff have attended meetings of, *inter alia*, the British

Ecological Society, the Botanical Society of Edinburgh, the Forest Soils Discussion Group, and the Clay Minerals Group of the Mineralogical Society. Papers were read at some of these as well as at an ARC-NERC joint meeting on air pollution, a symposium on acid rain, a symposium on trace elements at the soil-plant-animal interface and the fifth ARS conference on electron microscopy. Dr H. G. Miller presented an invited paper at the meeting of Division 1 of the International Union of Forest Research Organizations in Edinburgh and several papers were given orally or at the

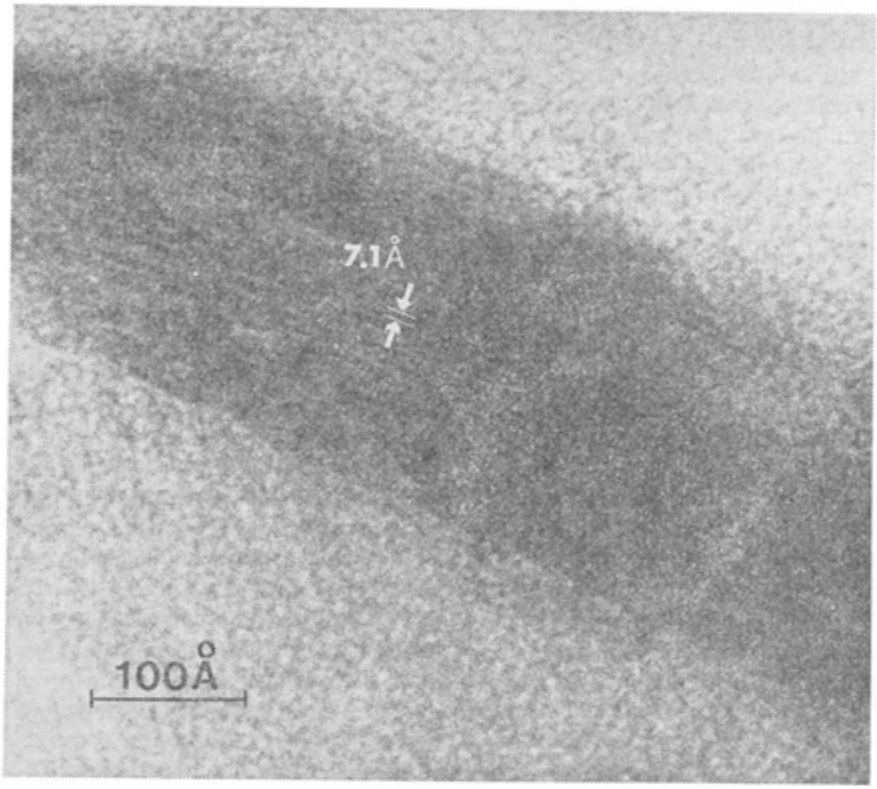


Fig. 1. High resolution electron micrograph of a buserite crystal sectioned to show the 7.1Å layers.

poster session at the Sixth International Clay Conference in Oxford: at the latter the plenary lecture[49] was delivered by Dr R. C. Mackenzie.

Dr R. C. Mackenzie acted as Visiting Professor at the Soil Department, Faculty of Agriculture, University of Riyad, Saudi Arabia, for a period of two weeks in December, 1977: during this time he consulted with staff on the clay mineralogy of Saudi Arabian soils and visited three areas (the Asir, Wadi ar Rimah and Al Hasa regions) to examine a range of soils in the field. Dr M. J. Wilson attended the 11th International Soil Science Congress at Edmonton, Alberta, Canada, and participated in one of the pre-

conference excursions. Mr R. A. Robertson participated in a symposium on peatland agriculture and forestry at Brumunddal, Norway, and thereafter, as Vice-President, attended a meeting of the Council of the International Peat Society.

CHEMISTRY AND MINERALOGY

Certain aspects of the work of the department, although connected with both chemistry and mineralogy, are most appropriately covered by the term " soil analysis ", analysis being used in a rather broad connotation.

Soil Analysis

Chemical Studies. Systematic chemical and physical examination of all profile samples collected in 1975 and 1976 and of samples from a number of high-priority profiles collected in 1977 have been completed. Profile samples, surface horizons and synthetic and natural organic components have also been subjected to analysis for other departments of the Institute. 101, 201, 304, 512, 513, 801

In relation to the pilot study, in collaboration with the Department of Statistics, for the Institute soil data bank, the data from the 430 selected profiles from 4 soil Associations (Countesswells, Ettrick, Rowanhill and Strichen) have now been processed, and assessment of results is in progress. 101, 703, 801

To assess the variation likely to occur in point samples taken in the field—a critical factor when assessing the validity of results for profile samples—one specific horizon, the A_2 of a peaty podzol, was sampled at distances varying from 0.5 m to 8 km. Analysis of variance showed that variations in type or organic matter, exchangeable cation content, pH and total phosphorus content over a distance of 0.5 m could account for a considerable proportion of the total variance[50]. 101, 108

The degree of polymerization of silica tetrahedra in crystalline and non-crystalline silicates can be assessed, after reaction with trimethylchlorosilane, from the relative proportions of the various derivatives as measured by gas chromatography. The relationship between the degree of polymerization of silica and weathering is being studied for some of the principal soil parent materials in north-east Scotland. 101, 104, 105.

The acquisition of a new X-ray diffractometer has enabled the old dual-purpose instrument to be used primarily for Xray fluorescence spectroscopy (XRF), thus removing restrictions on the number of samples that can be examined by this technique. Major and some minor elements have been determined in Scottish and Italian soils and major elements in profile samples from the principal soil series in the Orkney Islands (Sheets 118, 119, 120, 121, part 117). A method for the XRF determination of zirconium in soils has been developed for samples in the form of pressed powder pellets. Direct measurement of mass absorption is possible using an attachment made by Technical Services for the scintillation counter and results are also corrected for interference by strontium. Results for standard rocks are within 10 per cent of the recommended values, the lower limit of detection

is 4 ppm and the coefficient of variation for replicates is 2 per cent. Pressed powder discs have also been used in determinations of potassium in soils supplied by the Department of Soil Fertility. The sulphur contents of herbage samples, carried out at the request of the Rowett Research Institute, fell into the range as previously—namely 0·1-0·4 per cent.

104, 611, 801, 5107

Variation in the soil atmosphere over small distances has been checked using a portable stainless steel sampling probe at two sites—one on the Countesswells Association, where the parent material is a till derived from granite and gneiss, and the other on Links sand. Concentrations of nitrogen, oxygen, carbon dioxide and argon varied markedly over distances of less than one metre and six to ten replicate samples were required to give a reliable mean value. The study of major element concentrations in stream waters from soil Associations in north-east Scotland has been extended to include the Leslie Association, developed on a shallow till derived from serpentinite. As in other Associations, silica predominates, being indeed higher in concentration (mean 20 ppm) than in any other; magnesium, as might be expected, was also present in high concentrations, the mean (17 ppm) being some 6-8 times that in other streams studied. 101, 107, 108

Electron probe microanalysis combined with scanning electron microscopy provides both chemical and morphological information on surfaces and, as mentioned above, the microprobe facility has been markedly improved by addition of an energy-dispersive analyser. This system is currently being used to study the occurrence of titanium in grains and aggregates from selected Scottish soil profiles and the composition and occurrence of manganese pans and pseudoconcretions, particularly in the B horizons of imperfectly drained surface-water soils. 106, 107, 109

Thermoanalytical Studies. Thermal analysis can be traced back to the curiosity of early man about the effect of heat on his environmental materials[51], but developments over the past thirty years or so have been particularly rapid. This had led not only to improvements in commercial equipment, but also to difficulties in nomenclature and classification that are only now being solved[52]. The methods—differential thermal analysis, thermogravimetry and differential scanning calorimetry are the most common—are essentially techniques for phase analysis and their increasing use in pure and applied chemistry[53] is reflected in their wide application in the department to study mineral and organic materials[54]. Recent investigations have shown that, with a controlled atmosphere of carbon dioxide around the sample, it is possible to identify and estimate soil-occurring carbonate mineral species down to a level of 0·25 per cent in a 50 mg sample[55].

101, 103, 104, 105, 107

Soil Mineralogy

One of the principal criteria in classifying Scottish soils is the lithological nature of the parent material, which determines to a large extent the physical features and the inherent fertility of the soil. Thus, the weathering of primary minerals releases nutrients with the formation of secondary minerals that can themselves retain nutrients in available or unavailable

form. To obtain interpretable information it is often necessary to fractionate the soil, but it must be stressed that methods used for fractionation can so affect individual fractions that the results, even when integrated to represent the whole soil, are not necessarily directly applicable to the soil in the field. Moreover, processes that occur in the field cannot necessarily be replicated by extractions in the laboratory. Studies on potassium reserves in Turkish soils, using dilute hydrochloric acid to extract the potassium, revealed the importance of the clay fraction in determining reserves[1] and has led to further work on the clays present. A similar investigation is also in progress on soils of the principal Associations in Scotland: preliminary results on the amounts of extractable potassium and clay mineralogy are now available and correlation is in progress. A method for quantitative X-ray diffraction requiring neither calibration curves nor internal standards is currently being devised and should be of great help in such studies.
101, 107, 103, 104

The weathering of feldspar and mica minerals may well be of considerable importance in releasing nutrients into the soil. Recent observations under the scanning electron microscope have shown the surfaces of feldspar crystals in many Scottish soils to be extensively etched. That the etching pattern is associated with crystal dislocations has been confirmed by comparison with experimentally etched matching cleavage surfaces of orthoclase-microperthite. The controlling influence of exsolved perthitic lamellae during etching has been established and studies are in progress on other feldspars. In mica it is generally considered that weathering in the soil occurs by depletion of potassium from the edges of the flakes inwards. However, this picture is not always supported experimentally, since scanning electron microscope and microprobe evidence shows some sand-sized biotite crystals to have the potassium concentrated around the edges and absent in the centre: an explanation based on oxidation of ferrous iron and the lattice strains thus caused was proposed in a paper presented at the Sixth International Clay Conference in Oxford. Biotite in Old Red Sandstone sediments has been found to be fairly fresh[56] despite reports to the contrary. A device enabling X-ray powder diffraction patterns to be obtained from small areas of thin sections[2] has been found invaluable in such studies on pedogenic weathering.
104, 109, 901

The composition, stratification and mode of formation of deposits in field drain systems is being examined in tile drains laid comparatively recently in humic gley soils in Argyllshire. The deposits are less well structured than those observed previously in heavy textured surface-water low-humic gleys[57].
103, 106, 109, 801

Several collaborative studies have been carried out with the Department of Spectrochemistry. In the A horizons of podzolic soils the scanning electron microscope and electron microprobe have shown that chemical, and possibly also physical, weathering processes lead to accumulation of titanium in the fine fraction, but not to downward translocation, suggesting that titanium going into solution is rapidly reprecipitated as fine-grained anatase[58]. The heavy metal content of some serpentinite soils of north-east

Scotland has also been related to their mineralogy[59]. Mössbauer spectroscopy has shown that chlorites containing appreciable amounts of ferric iron (>30% total Fe) had iron in both tetrahedral and octahedral positions whereas ferrous ion occurred mainly, if not entirely, octahedraly. After heat treatment and acid extraction low-iron chlorites were partially vermiculitized whereas high-iron specimens were not[60]. The fact that nontronites yield an 060 spacing in the trioctahedral region on X-ray diffraction patterns can be explained by the occurrence of iron in the tetrahedral sheet[3].

101, 104, 109, 201, 203

The dominant component in red altered basalt at Morvern, Argyllshire, is montmorillonite (>80%) which is accompanied by a small amount of hematite. The montmorillonite, which is naturally calcium-saturated and has a high aluminium and a low iron content, is being further characterized and its mode of genesis is being investigated. Thaumasite, an unusual hydrated silicate mineral, has been detected in weathered furnace slag heaps at Merthyr Tydfil, Wales[4]. 103, 104

Clay Fraction. Through its mineralogy, the clay fraction of a soil gives information on the origin of that soil and, because of its very large surface area, it has a disproportionate effect on soil properties. For these reasons a systematic examination of clay mineralogy of representative profile samples collected by the Department of Soil Survey is customary. Such an examination frequently makes use of prepared interlayer or intercalation compounds for X-ray identification[61]. Soils of the Orkney Islands (Sheets 118, 119, 120, 121, part 117) reflect in their clay fractions the mineralogy of the sedimentary rocks from which they were derived, inheritance thus predominating over the effects of pedogenic factors. Foreign soils, examined mineralogically for comparison with Scottish soils, have included samples from India, Iran, New Zealand, Poland, Saudi Arabia and Sudan. The Polish soils contained three-component interstratifications that could be identified only by comparing X-ray diffractograms with theoretically calculated traces[5, 62]. Wadi soils from Saudi Arabia were rich in palygorskite whereas the clay mineralogy of sedentary soils reflected that of the underlying rock. The clay fractions of a typical cracking Vertisol and a non-cracking Entisol from the Blue Nile clay plain of Sudan are dominated by a ferriferous beidellite: the very high clay content of the former may contribute to the occurrence and frequency of cracking[63]. A Vertisol chronosequence from Southern Turkey is meantime being studied.

101, 103, 104, 105, 109, 801

The mineral imogolite, which occurs as extremely fine, long, hollow fibres, and a less highly ordered form, proto-imogolite, have been detected in Italian soils developed on volcanic ash[64]. The occurrence of imogolite in Scottish soils[6] unaffected by volcanism has, however, established that it is not universally associated with pyroclastic material. Collaborative studies with the Department of Spectrochemistry on the effect of sodium carbonate solutions on allophane and imogolite[7] and particularly on the prolonged heating of aqueous suspensions of imogolite have suggested that, in the long term, imogolite is metastable relative to halloysite and gibbsite.

105, 107, 109, 207

Surface Properties of Soils and Clays. A sorption balance system based on a null-point electrobalance has been devised for studying water-vapour adsorption isotherms 106, 107

Studies have continued on the manganese oxide buserite, which, as mentioned last year, has a layer structure (Fig. 1) with readily exchangeable cations and may be a precursor of secondary manganese oxides in soils. Variation in lattice spacing with exchangeable cation and with relative humidity indicates the presence of sheets of hydrated cations between the layers[65]. The effect of saturation with the transition cations cobalt, nickel and copper is now being checked. In conjunction with the Department of Spectrochemistry an examination is being made of akaganéite, the beta form of ferric oxyhydroxide that precipitates from partially neutralized ferric chloride solutions in rods, the length of which is dependent on the hydroxyl: iron ratio. Variations also occur depending on the anion present. Although the thermal decomposition is affected by the presence of chloride, DTA curves generally exhibit a sharp exothermic peak similar to that obtained from ferrihydrite; this peak is, however, markedly suppressed in an oxygen atmosphere. 105, 106, 109, 201

Organic and Biological Materials. In collaboration with the Department of Soil Organic Chemistry, derivatives in the form of partially methylated alditol acetates of glucose, galactose, mannose, xylose, arabinose, rhamnose and fructose have been separated and identified by gas chromatography/mass spectrometry (GC/MS) from the complex reaction mixture obtained during the reduction and methylation of acetylated polysaccharides. The use of deuterium at the reduction stage, carried out with the aid of the Food Research Institute, aided mass spectrometric identifications considerably. From these identifications it has been possible to locate the bond linkages between sugar rings in the polymer structure[66]. Organic acid derivatives obtained by treatment of soils, peat and lignite hydrolysates, including polycarboxylic acids based on a single aromatic ring and on straight aliphatic chains up to 5 carbon atoms in length, have been separated and identified by GC/MS. 108, 304, 305

Particle-size fractions separated from peats of different origin—blanket bog and raised bog—give, on pyrolysis-gas chromatography, relative abundances of heterocyclic compounds similar to those from mor humus, irrespective of particle size. Whereas lignin-derived compounds predominate in the coarser particles ($>500\mu$m) the amounts of nitrogen-containing compounds, toluene and benzene increase with decreasing particle size, thus demonstrating compositional differences in the fine fractions. 108, 116

Fractions of specific gravity greater than 1·9 (representing organo-mineral material), separated from the A horizon of a brown forest soil and an iron podzol, were found by pyrolysis-gas chromatography to be more highly humified than the lighter fractions. Possible effects of mineral components during pyrolysis have been checked: whereas crystalline clay minerals have negligible influence, large amounts of hydrous oxide gels have a catalytic action affecting the relative amounts of products. The value of pyrolysis-

gas chromatography in distinguishing podzolized brown forest soils has been established in collaborative studies with the Department of Soil Survey[8]. 108, 801

PEAT AND FOREST SOILS

Peat Survey and Evaluation

Survey, classification and evaluation of Scottish peat resources, which cover some 800 000 ha or 10 per cent of the land area, have continued to provide information of practical as well as of scientific importance. Acquisition of a multi-purpose digitizer has greatly assisted the development of remote sensing and of photogrammetric techniques that are being increasingly employed to support topographic, hydrologic and vegetation surveys. Results of this work are incorporated in appropriate Soil Survey memoirs[67] and in more detailed maps and reports concerned with peatland drainage, afforestation and cultivation and with the production and utilization of peat for industrial purposes. 110, 111, 112, 114, 801

At the request of the Highlands and Islands Development Board, a detailed survey of the former milled peat fields at Braehour, Caithness, has been undertaken to establish the reserves still available and the effect of drainage on the quality of the peat remaining. Field work in the Orkney Islands has been completed and a survey of high-level blanket bogs in the Monadhliath Mountains (Sheet 74) is now in progress. Mapping and evaluation of the major peat resources in the Central Region are being carried out in collaboration with the local planning authority, and further surveys concerned with the improvement of the A9 trunk road have been completed, following requests from the Highland Regional Council and the Scottish Development Department. 112, 114, 801

The value of aerial survey and photogrammetric techniques in peat survey has been significantly increased by the development of an aircraft camera mounting rig for vertical stereo-photography in conjunction with an intervalometer, designed and produced in the Institute. This flexible system enables conventional aerial photographic surveys to be performed from various types of light aircraft available for commercial charter, and during the year nine flight-paths, yielding some 750 stereopairs with 60-80 per cent overlap, have been flown. 107, 112, 901, 902

Acquisition of a Ferranti-Cetec solid-state digitizer and electronics for automated photogrammetry and cartography is particularly important for the development of photogrammetry and remote sensing[68]. A direct link has been established between the stereoplotter, the electronic console of the digitizer and the main Institute computer; a secondary link to a mini computer and then via the System/4 electronic console to the IBM System/7 computer is being introduced. By mounting a camera assembly above one of the plate carriers of the stereoplotter, an analogue method has been devised for the production of rectified negatives of aerial photographs at any desired scale—a facility of considerable advantage to all engaged in field mapping. A combined numerical and analogue rectification method has

also been developed using the stereoplotter and digitizer to determine the absolute tip and tilt corrections to be applied before plotting or computer storage of digital terrain models. 107, 112, 902, 5703

Photogrammetric mapping of peat, vegetation and land-use categories on the Isle of Lewis has progressed satisfactorily. Regional test areas already plotted at scales of 1:10 000 and 1:25 000 have been ground truthed and a final map legend selected. The experimental phase being complete, systematic mapping on a scale of 1:25 000 is now proceeding. In the Arnish area, peatland and vegetation types plotted from true colour photography at a scale of 1:5 000 have also been ground truthed—an exercise principally designed to correlate reflectance measurements from multispectral satellite imagery and to assist investigations on mire morphology, hydrology and the production of thematic maps. 112

From the 1977 specialist photographs, acquired through the Grampian Region Aerial Survey Programme, a detailed ground control framework of aerial survey targets in the Cairn o' Mount area, Kincardineshire, has been surveyed and related to the National Grid. Using the ground control points, colour transparencies have been restituted in the stereoplotter and subsequently used to contour the peatland area at 2 m intervals; spot heights have been obtained with an accuracy of ± 5 cm. 112

Research on the applications of Landsat multispectral imagery is primarily directed towards image identification, automated mapping and spatial analysis. Increasing use is being made of the original digital ground reflectances sensed by the satellite and stored as numerical values on high density magnetic tapes. Three good quality ground tapes—for Lewis, Grampian Region and Central Region—have already been acquired. Ground reflectances are being classified from photogrammetric plots of ground control sites in Lewis. Software has been developed on the new Honeywell 66/80 computer at Aberdeen University to read and classify the picture elements on these tapes. Production of false colour composite images from the Landsat film positives, using colour enhancing methods, continues to be of value in reconnaissance ground surveys. 112, 902

Preliminary studies with the new image analyser in the Department of Microbiology have indicated its value in the rapid delimitation of specific ground reflectances and the computation of areas for each feature. Crude area measurements can be made from the unrectified aerial prints or positives, but the rectified products produced by the analogue method described above are essential for precise scaling and exact area computations. 107, 112

Reconnaissance aerial photography, initiated in 1977, has been continued and extended. Spring, summer and autumn sorties using twin 35 mm cameras bracketed together have yielded some 160 pairs of true colour and infra-red false colour transparencies. Seasonal changes in ground conditions are very clear and provide an important historical record for correlation with Landsat image reflectance studies and for other specific research projects concerned with peatland erosion, hydrology, vegetation and land-use. 112

Pollen Analysis and Quaternary Research

Statistical analysis and computerisation of accumulated pollen counts is continuing along the lines indicated previously. Assessment of the spatial distributions obtained from preliminary isopollen maps suggests that the effects of such variables as altitude on the qualitative and quantitative pollen content of the various deposits sampled should be further investigated. 113, 5701

Palynological study of the Lang Lochs Mire, a deep basin mire near Brindister, Shetland, has shown that the accumulation of deposits probably began over 9000 years ago, in the late Devensian era. This site is proving to be of considerable significance in the study of the vegetational and environmental history of Shetland[70], and further work including macro-fossil analysis and radiocarbon dating is in progress. 112, 113

A 7 m deep high-altitude basin peat in the eastern Grampians has been surveyed and sampled for pollen analysis. The results of this study will be used with others to assess the relative rates of formation of upland blanket and basin peats in north-east Scotland. 112, 113

In collaboration with the Department of Soil Survey, pollen counts are being made on samples from an altitudinal range of blanket bogs in Shetland. Other material of archaeological, pedogenic and vegetational importance from an ancient turf layer exposed in a dig at Strageath Roman camp near Crieff, Perthshire, is also being investigated. 113, 801

Root and Moisture Studies in Peat

Changes occurring in the chemical and physical characteristics of peat soils following the reclamation of blanket bog on the Isle of Lewis are being investigated with respect to peat type, management practice and time. At most sites, surface seeding with a grass-clover mixture has been preceded by the application of up to 10 tons shell-sand per acre and a compound fertilizer. Such application not only reduces the competition from heather and other plants, thus promoting establishment of sown species, but also initiates transformation of the peat in the upper part of the profile. Sampling and analyses are now in progress to investigate the effect of the treatments on characteristics like bulk density, air-water relationships, moisture retention and rates of nitrogen mineralization. 110, 116

The experiment on blanket peat at Lon Mor, Inverness-shire, designed to investigate the effects of controlled ground-water level on soil characteristics[9] and on the growth of lodgepole pine and Sitka spruce continues. After 15 years growth, the yield classes for pine are estimated as <4 for the waterlogged treatment, 4 for treatments where the water in the ditches is maintained at 10-20 cm below the surface, and 8 where the water in the ditches is at 30-50 cm. After 5 years the competition from heather has been reduced and spruce is responding well, foliage analysis now showing satisfactory levels of the major elements in the driest plots. 110

The physical properties of many organic horticultural substrates have been examined during the year. Some of the samples have been exchanged

with overseas research workers with a view to standardising methods of analysis and criteria for assessment. Further work in the glasshouse using bark as a mono-ingredient substrate has revealed that some of the material on the market is insufficiently composted and contains phenols, and possibly other substances harmful to plant growth. 114

Nutrient Uptake from Forest Soils

Diagnosis of nutrient deficiencies from the levels of nutrients in foliage sampled from the topmost branch-whorl of young conifers is now a well-established technique. However, in more mature trees, the top whorl is difficult to reach and its foliage can show large annual variations in nutrient levels in response to climatic factors[10]. Consequently, some effort is now being devoted to finding improved or more convenient means of diagnosing deficiencies in established coniferous forests. Studies centred on the nitrogen fertilizer experiments at Culbin (Laigh of Moray Forest) suggest that both the species composition of the ground vegetation and the levels of nitrogen in the humus can be used as indicators of nitrogen stress, the latter perhaps being the more generally useful[11]. To explore the possibility of utilizing tree tissues other than top-whorl foliage, lower crown foliage, recently fallen needle litter, inner bark (including phloem) and shallow roots are being sampled annually from the new series of spruce experiments. Indications are that analyses of some of these components, apart from that of the inner bark, may be of value. Work is continuing to check whether the indicator levels so far determined remain consistent from year to year. 117

The ability to select the precise organ, time of sampling and type of analysis that most accurately reflect the nutrient status of the tree requires a clear understanding of the sink-source relationships within the tree and of the uptake and release of nutrients by the tree. Models of nutrient cycling derived from investigations on Corsican pine deficient in and fertilized with nitrogen have iilustrated the importance to future growth of nutrients accumulated within tree tissues, and this aspect has been examined in relation to the wider cycles transferring nutrients to and from the trees and the total forest site[73]. The same models have been used to show that tight cycling and low rates of immobilization, coupled with effective retention of relatively high atmospheric inputs, probably represent the adaptive mechanism that enables pines to thrive on soils low in potassium and magnesium. However, high rates of immobilization and low rates of atmospheric input mean that, despite the maintenance of tight cycles, the trees continue to make significant demands on the soil reserves of nitrogen, phosphorus and calcium throughout their life-cycle[74]. 115, 117

Investigation of nutrient cycles in relation to tree growth and pedogenesis is now concentrated on six crops of Sitka spruce selected to cover the bioclimatic sub-regions in which the species is planted. A full sampling of the above-ground components of the trees and of the soil organic layers was made at the outset of each experiment, and at the two oldest sites a second sampling has now been carried out in both fertilized and unfertilized plots. At one of these experiments the total root-systems of eight trees

have also been excavated and sub-sampled for analysis. At all six sites the input and transfer of chemical elements is being closely monitored, and there have been some useful developments in the concepts and techniques employed[75, 76]. Of increasing interest is the information this study is providing on the significance of "acid rain" (caused by the rain dissolving anthropogenic sulphur dioxide and oxides of nitrogen). Present results suggest that the effects of acid rain are not likely to be of great harm, but they also emphasize the very considerable effect trees have on modifying the nature of the water reaching the soil surface. Information is now becoming available that will enable informed discussion of the significance of this process in pedogenesis, in the evolutionary adaptation of trees to soils of low nutrient status, in the succession of species, and in the reaction of different ecosystems to pollution or other abnormal inputs[77]. 115

The nutrient advisory service provided to forest nurseries on the basis of soil analyses carried out by the Department of Soil Fertility has continued. 117, 608

Nitrogen Mineralization in Peat and Mor Humus

The effects of afforestation with lodgepole pine on the rate of nitrogen mineralization and related factors in peat are still being assessed. Comparison of the contents of the major plant nutrients and exchangeable cations and of acidity in peat from adjacent sites under natural and induced vegetation[12] has been extended to peatland in Lewis where shell-sand is traditionally used as a source of lime on improved grassland. Marked differences have been observed in the upper 100 mm horizon, peat from reclaimed areas producing more mineral nitrogen during aerobic incubation than that from untreated sites. About 60% of the mineral nitrogen in the surface layers of the re-seeded peat occurred as nitrate, a form not present in the untreated peats. 111, 116, 5701, 5703

In a joint study with the Department of Microbiology, samples of peat have been taken from the controlled water-table experiment at Lon Mor, Inchnacardoch Forest, Inverness-shire. The amounts of ammoniun nitrogen and readily-soluble phosphate are highest and show the greatest seasonal variation in the upper horizons but no nitrate nitrogen was detected in the profiles sampled. 110, 116, 503

The experiment in pole-stage Scots pine at Culbin (Laigh of Moray Forest) continues to be a source of material for investigating the effects of lime in combination with nitrogen and phosphorus fertilizers on the chemical composition and rate of nitrogen mineralization in the mor humus layer. 115, 116, 117

2. SPECTROCHEMISTRY

R. O. Scott

The work of the department continues to progress along the two main lines previously established (a) investigations into the distribution of known and potentially important trace elements in rocks, soils and plant materials, and (b) the examination of the composition, reactivity, and structure of inorganic and organic components in soils and plants.

In the first category, the experimental approach continues to be by the use of various spectrochemical methods of analysis including flame, arc and spark emission, flame and electrothermal atomic absorption and fluorescence, and spark source mass spectrometry. These techniques are used both for research purposes and to provide a service for the analysis of samples from other departments. Because of the very low levels of the biologically-important elements being determined, often about 0·01 ppm, and also because of interest in other elements of potential importance, investigations are continuing into more sensitive specrochemical techniques: new items acquired this year are an IL Model 555 Controlled Temperature Furnace Atomizer and a Radyne Model R50P Inductively-Coupled Plasma Generator. In the second category, infrared spectroscopy is being used to characterize clay minerals and soil organic matter, Mössbauer spectrocopy to investigate the forms of iron, and electron paramegnetic resonance spectroscopy (EPR) some of the forms of copper, iron, manganese, molybdenum and vanadium in soils and plants.

During the year several graduate students have been working towards the degree of Doctor of Philosophy on projects of relevance to the work of the Department. Miss Jilla Khalighie, a former student of the National University of Iran and of Imperial College, London, Mr A. R. Morrison, an ARC Research student, and Mr S. Forbes, an SRC research student working conjointly in the Departments of Soil Fertility and Spectrochemistry, have completed their studies and will be submitting their theses later this year. Miss Karen Murphy, a graduate of St Andrews University, who was awarded a SAC studentship of the Chemical Society, has completed her first year on the development of trace element concentration methods suitable for use with the spark source mass spectrometer.

Several visiting research workers have carried out investigations in the department: Professor A. A. Verbeek, Department of Chemistry, University of Natal, South Africa, on the determination of ten major and minor elements in small mineral samples; Dr S. A. Rahim, Chemistry Department, University of Mosul, Iraq, on radiofrequency inductively-coupled plasmas; Mr H. L. Yeung, Department of Geography and Geology, University of Hong Kong, on spectrochemical analyses of soils; Dr D. G. Lewis, The Waite Agricultural Research Institute, Adelaide, Australia, on infrared and Mössbauer studies of iron and aluminium hydroxides; and Dr H. J. K. Powell, Department of Chemistry, University of Canterbury, Christchurch, New Zealand, and Dr C. W. Childs, DSIR Soil Bureau, Lower Hutt, New Zealand, on EPR and Mössbauer studies respectively. Professor

K. Wada, Faculty of Agriculture, Kyushu University, Fukuska, Japan, visited the department on an exchange scheme under the auspices of the Royal Society of London and the Japanese Society for the Promotion of Science, to discuss developments in the synthesis and characterization of allophane and imogolite.

Lectures were given by Drs R. O. Scott, B. A. Goodman, A. M. Ure and Mr J. C. Burridge at a conference in Aberdeen, organised by Scientific Symposia Ltd., on Trace Elements—the Soil, Plant, Animal Interface; by Drs V. C. Farmer and B. A. Goodman to the Sixth International Clay Conference in Oxford and by Dr V. C. Farmer to the Sixth Ceramic Chemists Conference in Llandudno. Dr B. A. Goodman also presented papers to the International Symposium on the Soil-Root Interface in Oxford, and to the International Conference on Chemical Aspects of Electron Spin Resonance in Cardiff. Contributions were made by Mr J. C. Burridge, in collaboration with Dr R. L. Mitchell, to the Royal Society Discussion Meeting on Environmental Geochemistry and Health in London, and by Dr A. M. Ure to the Euroanalysis III Conference in Dublin. The widespread interest in laser remote sensing is reflected in the number of lectures given by Dr B. L. Sharp on this subject, *viz.;* to the Institute of Physics, to the Association of Scottish Industrial Analysts, and three to various subgroups of the Chemical Society.

During the year, Dr M. L. Berrow attended the Eleventh Congress of the International Society of Soil Science in Edmonton, Canada, and the department was also represented at meetings of the following societies or committees: the Analytical Division of the Chemical Society; the DOE Standing Committee of Analysts (Group 8·0; soils and sewage sludges); the Association of Scottish Industrial Analysts; and the Interservices/DTI Panel on Spectroscopy.

Trace Elements in Soils, Plants and Biological Materials

Collaborative analysis of the ten large soil samples (Ann. Repts. No. 45, 1974/75; No. 47, 1976/77) from different soil series throughout Scotland have continued. Results for extractable copper, manganese and zinc obtained by the Institute, the East of Scotland College of Agriculture and West of Scotland Agricultural College are reasonably consistent. Slight differences in the results for extractable cobalt, obtained at the three centres, are being further investigated. 201, 205, 206

Soils and Soil Parent Materials. Investigations into the value as a soil extractant of the naturally-occurring chelating agent, 2-ketogluconic acid, have continued. A 0·1 M solution at pH 7 generally extracts more cobalt, nickel and zinc and considerably more copper, iron, titanium and vanadium than 1 M ammonium acetate at the same pH, suggesting that the 2-ketogluconic acid extractant is chelating a portion of the non-exchangeable forms of these metals in the soil. In the limited number of soils analysed so far differences in the amounts of cobalt, copper, manganese, nickel and zinc extracted by this reagent were reflected in the contents of the pasture herbage species growing on them. With copper, which is strongly associated with organic

matter in soils, lowering the pH of the 2-ketogluconic acid solution from 7·0 to 4·5 resulted in only a small decrease in the amount of copper extracted, while a similar change in the pH of a 0·05 M EDTA extractant greatly reduced the amount removed. This indicates that the naturally-occurring chelate would be able to complex copper in soils at the acid pHs normally found in Scottish soils. 201 502

Major and trace elements have been determined in fractions of differing molecular weight obtained from a soil solution, prepared by the Department of Soil Organic Chemistry by compression of a moisture-saturated poorly drained soil. The combined total amounts, expressed as ppm in the dry soil, were 0·003 Co, 0·04 Cu, 0·16 Mn, 0·01 Ni and 0·03 Zn, amounts much less than would be extracted by the reagents, such as acetic acid and ammonium acetate, normally used for assessing the trace elements status of soils. 201, 309

The determination of trace elements in selected soil profiles sampled by the Department of Soil Survey has continued. Work on soils from the areas covered by Sheets 32 and 24 (Edinburgh and Peebles) has been completed and work on Sheet 84 (Nairn and Cromarty) and Sheets 40 and part of 41 and 32 (Kinross, Elie and Edinburgh) is well advanced. Work has also started on soil profiles from the Sheets 43 and 44 (Isle of Mull). As one aspect of the Institute's Soil Data Bank studies, a computer-based storage and retrieval system has been developed, in collaboration with the Department of Statistics, to facilitate the manipulation and interpretation of trace element data in relation to other soil characteristics such as texture, pH, cation-exchange capacity, etc. Using this system, a group of basal horizon samples from the Ettrick association is being studied to assess the homogeneity of this association throughout the south of Scotland. A paper on the lead content of the soils of the Wigtownshire area of Scotland has been accepted for publication[78]. 101, 201, 703

Collaborative studies with the Department of Pedology on trace elements in peat profiles have continued. One hundred and eighty samples from thirty profiles in Caithness, Ardnamurchan, Peebles, Fife, Isle of Mull and Wigtownshire have been analysed for their total trace element contents. As many of these are present in peats in much lower amounts than in soils, they were determined by ashing the peat in the same manner as a plant material, followed by chemical concentration using 8-hydroxyquinoline, tannic acid and thionalide. The contents of individual samples varied widely depending upon the parent material on which the peat had developed and on its depth within the profile. The levels of cobalt, chromium, iron, nickel, titanium and vanadium were often greater in the surface horizon than in horizons immediately below. These elements also showed variability with increase in depth with usually a sharp increase close to the parent material. In many profiles lead was relatively high in the surface horizon and tended to decrease with increase in depth. The ranges of contents, expressed as ppm in the dry peat, in the two hundred and fifty-three samples so far analysed were: Co 0·02-39·0, Cr 0·22-54, Fe 240-40 000, Mo 0·08-59, Ni 0·25-93, Ti 9·1-1 250 and V 0·16-48. A striking feature was the high

content of molybdenum (*ca.* 50 ppm) in the basal horizons of some peats from the Caithness area; in all profiles from other areas the values were less than 10 ppm. 112, 201

Papers on the origin and significance of extractable titanium and vanadium in Scottish podzols[58] and on the mineralogy and heavy metal content of some serpentinite soils in north-west Scotland[59] are awaiting publication. 104, 201

Soil Status and Plant Uptake. Soil profiles sampled in areas where distillery wastes have been disposed off for many years (Ann. Rept. No. 47, 1976/77) have been examined for total cadmium, copper, manganese and zinc by an aqua regia digestion prior to atomic absorption analysis (see Spectrochemical Methods of Analysis). Upper horizons (0-10 cm) of some of the treated soils contained about 300 ppm Cu, 70-80 per cent of which was extractable by EDTA. In comparable horizons of untreated soils the contents were about 20 ppm of which only about 40 per cent was EDTA-extractable. Total cadmium ranged from $<0{\cdot}24$ to 2·4 ppm. In soils treated with copper-rich pig slurry total copper levels in the topsoils of up to 45 ppm have been found, about 40 per cent of which was extractable by EDTA, while comparable untreated soils contained about 20 ppm of which about ten per cent was EDTA-extractable. Total cadmium ranged from $<0{\cdot}5$ to 1·6 ppm. The proportions of copper extracted by EDTA from these contaminated sites reflects those from the corresponding untreated soils, the distillery wastes being disposed mainly on upland soils with relatively high organic matter contents in their surface horizons, and the pig slurries on arable land 201, 609

Analysis of soils and plants from the long-term sewage-sludge experiments at the ADAS Experimental Horticulture Stations has continued, the main effort being on samples collected from Lee Valley. The results of analysis of soils from this site show similar effects to those at Luddington on a different soil type. There was little decrease in the extractable amounts of such potentially deleterious trace elemnts as cadmium, chromium, copper, nickel or zinc nine years after application of sludge. The tendency for the ratio between acetic acid- and EDTA-extractable zinc in the treated soils to reach a constant value, irrespective of the levels initially present in the different sludges used, is apparent at both centres. Contents of the mixed herbage from the Lee Valley site showed treatment effects similar to those already reported[13, 79] for timothy grass at Luddington in 1976, i.e. enhanced levels of copper, nickel and zinc but no change in chromium content. 201, 202

The analysis of samples from the field experiments (Ann. Rept. No. 46, 1975/76), carried out in collaboration with the Department of Soil Fertility, on the uptake of selenium by plants grown at four sites on soils derived from granite, Old Red sandstone, and basic igneous parent materials, has continued and, although many samples have still to be analysed, some preliminary conclusions can be drawn. At the start of the experiment sodium selenite or sodium selenate was applied to young herbage, at levels

equivalent to additions of 0, 0·04 and 0·12 ppm Se in the top 25 cm of soil. In the first year the contents in the plant materials from all the untreated plots ranged from less than 0·01 to about 0·05 ppm Se with no clear differences between three types of plant material or the three soil types. All the plant samples at the four sites showed an increase in content with both levels of applied selenium, decreasing from ryegrass, to mixed herbage to clover. At the high rates of application (0·12 ppm Se) of both selenite and selenate the plant contents were about three times those from the soils treated at the low rates (0·04 ppm Se). Selenate additions produced about five times greater contents than selenite, and in the first cut in the first year the plants from the high selenate treated plots had contents which in some cases exceeded 3 ppm Se. In the second year, plants from selenite treated plots showed a negligible effect, and selenate only a small effect of the treatment. Further work is necessary before reliable and safe soil treatment can be recommended. 201, 202, 609

Conifer samples from a site at Wareham, Dorset, have been analysed to assist a Forestry Commission investigation of copper deficiency in sitka spruce and Douglas fir. Useful background information for such studies is provided by the continuing analysis of conifer samples from the Peat and Forest Soils section of the Department of Pedology. 115, 202

In addition to the regular analysis of advisory and research samples for the Department of Soil Fertility, miscellaneous materials examined include a zeolite for Robert Gordon's Institute of Technology, samples of cassiterite for the University of Aberdeen, various diets, for rats, sheep or cattle, for the Rowett Research Institute, copepods for the Institute of Marine Biochemistry, NERC, Aberdeen, sitka spruce needles for the Forest and Wildlife Service, Research Branch, Co. Wicklow, Eire, and some potential standard reference materials, e.g. grass and liver samples for the Moredun Institute, ADRA, Edinburgh. 5205, 5206

A general paper on trace elements in soils and crops was presented at a Royal Society meeting in London [80]. 201, 202

Spectrochemical Methods of Analysis

During the year the central system used for air-conditioning the rooms housing the spectroscopic instruments has been replaced by individual room units and the effect on instruments requiring good temperature control is being assessed.

Because of the poor sensitivities of the determinations of cadmium and zinc by cathode layer d.c. arc emission spectroscopy, investigations have been made into the possibility of determining the total amounts of these and other elements by acid digestion procedures followed by alternative techniques such as atomic absorption spectrometry. About five hundred determinations have been made on both untreated soils and ones to which wastes, such as pig slurry and sewage sludge have been applied, and it would appear, by comparison with emission spectroscopic data, that an aqua regia digest dissolves a large proportion of the total amounts of many potentially toxic elements present in such samples. Papers on some aspects of atomic

spectrochemical analysis in soil research[81], on early British contributions to atomic spectroscopy[82], and on the construction of thermostated electrodeless discharge lamps for atomic spectrometry[83] have been submitted for publication. 201, 205, 206

Flame Techniques: Emission and Atomic Absorption. The existing flame emission technique for the simultaneous determination of calcium, potassium and sodium, using the laboratory-built 3-channel instrument, continues to be used without modification to carry out analysis as a service to other departments of the Institute. No changes have been made in the atomic absorption methods, using a Varian-Techtron AA4 spectrometer, for the determination of calcium, copper, magnesium, manganese and zinc. The numbers of analyses have again increased during the year, particularly for calcium (*ca.* 40%). 5206

Determination of cobalt in acetic acid extracts of soils and of aluminium in miscellaneous samples supplied by other departments are now being carried out by atomic absorption using the newly installed Instrumentation Laboratory Model 751 dual-channel double-beam atomic absorption/emission spectrometer. This instrument is also being used for the determination of the total contents of the major and minor elements, Al, Ba, Ca, Fe, K, Mg, Mn, Na, Si and Ti, in soils and in small (*ca.* 50 mg) samples of rocks and minerals. Potassium and sodium are determined by emission using an air-acetylene flame, whilst the others are measured by atomic absorption using nitrous oxide-acetylene. In the process of developing this method it was found that the stability of the acetylene flow-rate and the precision of atomic emission analysis for Al and Ba, for example, could be improved by regulating the emitted intensity of a cyanogen band head (CN 387·2 nm). This was achieved by monitoring the CN intensity with one channel of the IL751 and, by means of this, servomechanically controlling the acetylene flow rate, the other channel being used to determine the Al or Ba[84]. This principle has been shown to be superior to the use of the CN band emission as an internal standard, and the technique should also be applicable for the atomic absorption determination of refractory elements whose atomization is critically dependent on the fuel-oxidant ratio. 206, 5206

Because of the large demand by other departments for the determination of magnesium and low concentrations of calcium, a 3-channel atomic absorption spectrometer for the simultaneous determination of these elements and aluminium, using a high temperature nitrous oxide-air-acetylene flame, has been designed and built in the laboratory. This will supplement the 3-channel flame photometer for the determination of Ca, K and Na. The burner design allows the solution of an ionization suppression element, e.g. K or Na, to be introduced continuously by one nebulizer and the sample solution by a second. This will eliminate the need to add the ion supressor to each sample solution and should result in a considerable saving in time. Digital read-out has been provided for subsequent calculation of concentrations using a programmable Texas SR52 calculator. A

paper on the use of " atom-trapping " as a means of concentration in atomic absorption spectrometry, reported last year, has been submitted for publication[85]. 206

Electrothermal Atomization: Atomic Absorption and Fluorescence. A description of the method, reported last year, for the simultaneous determination of lead by atomic absorption and cadmium by atomic fluorescence spectrometry using a carbon-rod atomizer has now been published[14] and two papers on recent developments in atomic fluorescence spectroscopy are awaiting publication[86, 87].

Microwave Plasma Emission. Studies on the determination of selenium by microwave plasma emission reported last year have continued. By volatilizing selenium from an electrically heated platinum filament into a free-flowing argon plasma 0·25 ng Se can be detected using the line at 206·279 nm. An even lower limit of detection can be achieved by preconcentration using electro-deposition of the selenium in a solution sample on to the platinum filament cathode before volatilization into the microwave plasma. 206

The determination of nitrogen isotope ratios using molecular nitrogen emission spectra from a discharge in ammonia/argon mixtures under reduced pressure has been studied using an Optica scanning monochromator. A preliminary report[88] has shown that a simple procedure using ammonia-filled discharge tubes obviates the traditional preliminary conversion to nitrogen by the Dumas or Rittenberg techniques. The method has been used to determine the ^{15}N content of various soil-nitrogen fractions derived from a Department of Soil Fertility incubation study. 205, 603

Radiofrequency Plasma Emission. A 5 kW, 27 MHz Radyne plasma source unit has been commissioned and studies are under way to characterize the operating parameters of the source in relation to the determination of trace elements in soil extracts by optical emission spectrometry. Preliminary work on molybdenum has been carried out using a 28 mm diameter Greenfield type plasma torch, but this is currently being replaced by a smaller 21 mm Fassel type torch which should yield improved analytical sensitivity. Initially, a large quartz spectrograph and a double grating monochromator are being used for the investigatory studies of spectral line selection and the effect on background of changes in matrix composition. 206

Laser Spectroscopy. Preliminary testing of the individual sub-assemblies of the remote sensing system developed from equipment supplied by The Royal Society, the Agricultural Research Council and the Science Research Council has begun. Computer system software is now complete and integration of the system has begun. A one metre test cell has been designed to enable measurement of the differential absorption cross-section of sulphur dioxide to be made as a preliminary to *in situ* measurement of this species in the atmosphere. A description of the laser remote sensing equipment has been submitted for publication[89]. 206

Other Methods of Trace Element Analysis

Cathodic Stripping Voltammetry. A description of the method for the determination of selenium by cathodic stripping voltammetry, worked out

conjointly with the Department of Soil Fertility has been submitted for publication[90]. The selenium content of soils and plant materials determined by this technique are in good agreement with those obtained by the spectrofluorimetric procedure. The method mentioned in last year's report for the determination of selenium by differential pulse polarography has now been published[15]. 206, 614

Spark Source Mass Spectrometry. The techniques evolved for the quantitative determination of over fifty trace elements in soils and rocks have now been described in detail together with examples of the computer-drawn 62-element fingerprints used to facilitate comparison of soils[16]. A study of the elemental content of a group of surface soils derived from a wide range of parent materials has been submitted for publication[91]. Several international rock standards have been analysed and a report on their trace element contents is in preparation. It has been confirmed that for soils, rocks and alumina-based chemical concentrates (8-hydroxyquinoline-tannic acid-thionalide) of soil extracts, matrix effects on sensitivity are small for most elements, provided that superpositional interferences, which differ in these matrices, are identified and corrections made. A detailed account of interferences and their correction in the determination of the rare earth elements in soil and rocks has been accepted for publication[92]. The efficiency of the 8-hydroxyquinoline-tannic acid-thionalide concentration process is being tested for the precipitation of elements such as As, Nb, Se, Th, U and W for which hitherto no sufficiently sensitive spectrochemical method has been available. Other concentration procedures, including cementation techniques, are under development and appear promising for the collection of, for example, the platinum metals. 205

The main development work during the year has been on the evaluation of techniques for the analysis of plant and biological materials. This has involved the identification and correction of superpositional interference effects, which differ considerably from those in soils and rocks. Interfering species identified have included molecular ions derived from combinations of the major elements Al, Mg, Ca, Cl, K, Na, O, P and S. For one such interference on the indium internal standard (by Ca_2Cl and K_2Cl ionic species) a correction procedure has been worked out. In addition, as an alternative, barium, determined independently by atomic absorption or emission spectrometry, is being used as a variable internal standard. Because of the lack of standard reference materials, it is proving necessary to prepare more synthetic standard samples than were required for soils and rocks, in order to standardise the analysis and calculate Relative Sensitivity Coefficients (RSCs). 205

In plant materials, ashed at 450°, over forty elements can be determined. These include Ag, B, Ba, Bi, Cd, Ce, Cl, Cr, Cs, F, Fe, Ga, La, Mn, Mo, Nd, P, Pb, Rb, S, Sb, Sc, Si, Sn, Sr, Tl, Th, U, V, Y, Zr and all the rare earth elements. Some of these elements can at present only be determined semi-quantitatively as suitable RSCs have not yet been calculated. Some elements such as As, Co, Cu, Ge, Ni, Se and Zn have not been included in the above list as severe interference effects occur. Corrections

appear feasible for As, Ge and Se, but some form of prior separation may be required for Co, Cu, Ni and Zn. For many of the elements, for example Fe, Mg, Mn, Na, P, Rb and U, the RSC's have proved to be similar to those obtained for soil and rock samples. A paper on the rare earth content of water lily and the NBS standard reference material Orchard Leaf (SRM 1571) has now been published[17]. 205

The situation is similar for biological samples of animal origin. In ashed liver samples for example, the principal interferences on elements of biological importance are those on Co and Ni. The interferences on Cu and Zn can generally be neglected in such samples since their contents are much greater than in plant material. A summary of this work has been published[18]. 205

Molecular Spectrometry of Soil Constituents

Optical Absorption Spectrometry. The large surface areas and reactivity of the poorly ordered hydrous oxides of aluminium, iron, and manganese, and the aluminosilicates allophane and imogolite, can have a dominating effect on soil physical and chemical properties; these complex systems are difficult to characterize, but infrared spectroscopy can play an important role in characterizing both their surface properties and the underlying chemical structure. Currently, work is in progress on the iron hydroxides akaganéite and ferrihydrite, on the effects of aluminium substitution in iron hydroxides, on hydrous manganese oxides, and on aluminosilicate systems, mostly in collaborative investigations with the Department of Pedology. Synthesis of these phases is often necessary to characterize their properties, as they seldom appear in pure form in nature, and such synthesis can reveal the existence of compounds not previously recognised in soils. Thus work on the synthesis of imogolite[93] has shown that related more poorly ordered aluminosilicates should also form under soil conditions, and this has led to the recognition of proto-imogolite as a soil component[64]. Allophanes are too poorly ordered to be characterized by diffraction techniques, but they give characteristic infrared spectra, which have revealed major structural differences between aluminosilicate precipitates formed in acid and alkaline solutions, the former resembling imogolite, and the latter hydrous feldspathoids. Similar phases occur naturally. The product formed when allophane or imogolite is digested with hot sodium carbonate[7], an extractant widely used to dissolve amorphous clay components, has now been recognised as a hydrous feldspathoid. Studies on the properties of aluminium hydroxides have led to a full interpretation of the spectrum of boehmite[94]. 105, 106, 109, 207

The hydrous oxide systems discussed above play a major role in the adsorption and release of the fertilizer anions, phosphate and sulphate, and are also involved in cation adsorption, particularly transition metal cations. The layer silicate clay minerals, however, are more important for cation adsorption and exchange phenomena, and vermiculites, which are widely distributed mica weathering products, are of particular importance because of their ability to trap and then slowly release potassium and ammonium ions. Normally, these ions do not penetrate very deeply into the inter-layer

space of vermiculites, because of the collapse of this space that they provoke. Neutral ammonia molecules can, however, penetrate rapidly and deeply between the layers before being converted to trapped ammonium ions. This process makes ammoniated vermiculite a valuable source of slowly liberated ammonium for plant nutrition[19]. Ammonium vermiculite can be formed *in situ* in soils containing naturally-occurring vermiculites by injecting gaseous ammonia, or can be prepared on a laboratory or industrial scale by treatment of mined vermiculite with ammonia gas. 207

Infrared studies on iron-containing clay minerals, in collaboration with Mössbauer and X-ray investigations, have continued. A strong correlation between iron content, infrared spectrum, and cell dimensions has been found in nontronites[3]. These clays are of interest because of the readiness with which iron in their structure can undergo oxidation-reduction reactions, with pronounced colour changes which probably contribute to the blue shades of gleyed soils; these reactions are readily followed by infrared and Mössbauer spectra [95]. Infrared spectra have also been found to be sensitive indicators of the compositions of the ferruginous micas celadonite and glauconite[20], and the magnesian carbonates of the dolomite-ankerite series[21], which are important magnesium-rich sources of lime. They are also useful in characterizing the sulphide minerals[22] that can form in water logged soils. 105, 203, 207

A chapter on water on soil surfaces is now in proof[96]. An invited review of the applications of infrared spectroscopy in mineral and inorganic chemistry was presented at the Sixth Ceramic Chemists' Conference, and will be published in the Proceedings[97]. The volume entitled " International Clay Conference 1978 " has been edited and is ready for printing, within three months of the Conference[98]. 207

Collaborative studies with the Department of Soil Organic Chemistry and Microbiology have continued. In an investigation of the chemical structure of soil polysaccharide, using standard methylation and hydrolytic techniques, infrared spectroscopy has played a supporting, though important, role in establishing the extent and type of methylation of the polysaccharide prior to hydrolysis. Among the functional groups methylated those identified by infrared were alcoholic hydroxyl, carboxylic acid and secondary amide[66].

A paper on the characterization of various organic matter fractions from a podzol[23], and a critical note on some erroneous conclusions drawn from infrared spectra of contaminated soil organic matter fractions[24], have been published. Further characterization of humic and fulvic substances has resulted from a study of the changes in their infrared spectra following heat treatment. Thus, the appearance of absorption bands arising from five-membered anhydride rings in spectra of heated humic and fulvic acids seems to be specific to podzolized mineral soils. A similar result for the synthetic fulvic model compound, polymaleic acid, leads to the conclusion that the anhydride rings are not necessarily associated with aromatic structures. A manuscript on this topic is in preparation. 208, 304, 305

Work is in progress on the further characterization by infrared and chemical means of the melanin-like pigments from *Sclerotinia sclerotiorum* (see Ann. Rept. No. 40, 1969/70), and on the more detailed applicability of polymaleic acid as a model for both fulvic and humic acid. 208, 301, 507

Mössbauer Spectroscopy. Work on the characterization of iron in soil-forming minerals has continued. Detailed investigations of the effects of isomorphous substitution of aluminium for iron in goethite (α-FeOOH) have confirmed the preliminary experiments reported last year, which indicated that goethites may not always show the usually-characteristic 6-peak spectrum at 77K. A report of this work (in collaboration with Dr D. G. Lewis, a visiting research worker) is currently being prepared. The work on synthetic akaganéites (β-FeOOH) has been extended (in collaboration with the Department of Pedology and Dr C. W. Childs, a visiting research worker) and, in addition to the two types of iron environment, reported last year from room temperature investigations, a further component has now been observed at 77 K. By considering the effects of particle size and surface modification it can be concluded that the three forms all arise from structural iron, the different sites being generated by the presence of additional OH groups, which compensate for the presence of Cl^- ions in channels in the structure, and the interactions of the Cl^- ions with adjacent octahedra. Mössbauer spectroscopy has been shown to be of value in the identification of iron-containing minerals in soil samples and a paper on the application of the technique to the study of iron oxides in red and yellow/brown soil samples is awaiting publication[99]. Further work on the distribution of these oxide components in soil profiles is in progress. Investigations on layer silicates have also been extended: a paper on an alternative assignment of the spectra of nontronites has been published[25] and papers on the presence of iron-rich impurity phases in some montmorillonites[100], the reduction of nontronites[95] and a range of chlorites and their decomposition products[61] are currently awaiting publication. 104, 107, 203, 207

The work, in collaboration with the Department of Soil Organic Chemistry, on the effect of pH on the reaction between iron and humic acid reported last year is awaiting publication[101]. 203, 307

Further extension of the investigations of the forms of iron in plants, in collaboration with the Department of Plant Physiology, has been made. With the aid of a superconducting magnet at the Department of Physics, Liverpool University, a number of samples have been studied in external magnetic fields of up to 6 T at 4·2 K. The results permit a greater distinction between different ferric components than had previously been possible and a paper describing this work is in the course of preparation. 203, 401

Electron Paramagnetic Resonance Spectroscopy. Work in collaboration with the Department of Soil Organic Chemistry on the nature of free radicals and metal complexes with soil organic matter components has continued. A comparison between aqueous extracts of soil and the fulvic acid derived from the same soil has been made, and it has been shown

that the variation of distribution of paramagnetic metal contents with molecular size is different for Fe (III), Mn (II) and Cu (II) in the aqueous extract. Alkaline extracts from various fungi have been studied in collaboration with the Departments of Microbiology and Soil Organic Chemistry and one species showed detailed proton hyperfine structure from the free radical component of the spectrum. By studying the variation of the spectrum with time it has been shown that there are at least three components present and that these appear to be related to one another by reversible reactions. The magnitudes of the proton hyperfine coupling constants from one component are similar to those from an alkaline solution of humic acid, although with the fungal extract there were more protons of each type. 203, 304, 307, 512

Also in collaboration with the Department of Soil Organic Chemistry studies of the uptake of the metal ions Cu (II), Mn (II), VO (II) by wheat roots have been started and a preliminary report of some of this work is awaiting publication[102]. The results indicate that amino acid complexes are formed with Cu (II) and VO (II), probably in the " free-space " within the root. 203, 309

In relation to the work on metal ion uptake by roots, an in-depth investigation of the influence of pH and relative concentrations of the reactants on the nature of the complexes formed between amino acids and VO (II) and Cu (II) has been carried out, partly in collaboration with Dr H. K. J. Powell, a visiting research worker. By working with isotopically-enriched ^{63}Cu and D_2O solutions it was possible to distinguish not only uncomplexed Cu (II) and the 1:1 and 1:2 Cu (II)-amino acid complexes, but also, at physiologically-important pH values, two different 1:2 complexes which are presumed to correspond to the N atoms arranged in *cis* and *trans* configurations. With the VO (II)-amino acid complexes there was also a greater variation in metal hyperfine coupling with different types of amino acids, and it seems that the EPR method could be developed to distinguish the various types of vanadyl-amino acid complexes. 203

Investigations of soil-forming minerals with low total contents of paramagnetic ions have continued. The work on montmorillonites of low iron content, reported last year, is awaiting publication[100] and an investigation of feldspars has begun. With the latter mineral, results from both powders and single crystals showed the presence of Fe (III) and Mn (II) ions. Preliminary interpretations indicate that in the specimens studied, Fe (III) occurs predominantly in structural sites, whereas Mn (II) appears to occur largely in exsolved phases. 104, 203

3. SOIL ORGANIC CHEMISTRY

G. ANDERSON

The research programme of the department is concerned with the origin, nature and properties of the organic components of soil, and their role in crop production. Investigations have continued on humic substances, particularly fulvic acid components and water-soluble polymers, and on polysaccharides, phenolic acids and nitrogenous compounds. Co-operative studies with the Department of Soil Fertility have been carried out on organic sulphur components and with the Department of Spectrochemistry on metal-organic complexes. Other joint studies include an examination, with the Department of Microbiology, of the role of various microorganisms in the synthesis and degradation of organic compounds in the soil. A paper outlining the chemical nature of soil organic matter and the methods used in its analysis has been accepted for publication[103].

Increasing attention is now being paid to reactions and processes at the soil/root interface. Dr D. J. Linehan and Dr D. Vaughan attended an international symposium on this topic held at the University of Oxford in March. Members of the department also took part in a symposium on soil/root relationships held in the Macaulay Institute, at which representatives from the ARC, Letcombe Laboratory and Rothamsted Experimental Station were present.

During the year Dr M. V. Cheshire attended the Eleventh Meeting of the International Society of Soil Science at Edmonton, Canada. Other members of the department attended the Inaugural Meeting of the Federation of European Societies of Plant Physiology at Edinburgh, and meetings of the British Society of Soil Science at York and of the Society for Experimental Biology at Newcastle.

Soil Polysaccharide

Further work has been carried out on the chemical nature, stability and origins of polysaccharide in soil, and papers have been published on the changes occurring during the decomposition of ryegrass in soil[26] and the effects of temperature and moisture levels on glucose transformation[27].

When young grass plants uniformly labelled with ^{14}C had decomposed in soil for a year at field temperature, only 18% of the glucose, 22% of the arabinose and 26% of the xylose remained, these being the three predominant sugars of the grass. A previous study on the decomposition of mature cereal rye straw gave similar values for the persistence of the sugars. After incubation the soil was fractionated by a flotation technique and the fractions extracted with acid and alkali. The distribution of sugars and radiocarbon in the isolated products was compared with results from a soil incubated with ^{14}C glucose, which gives rise only to microbial polysaccharide. Neither the plant nor the microbial polysaccharide exactly simulated the native soil polysaccharide in composition, but of the two the microbial product was the closer. 305, 5613

Studies have continued in collaboration with the Department of Microbiology on the effect of soil conditions on the growth of microorganisms and the nature of their carbohydrate. A paper[104] on the effect of temperature and moisture on yeast growth has been submitted for publication.
305, 512, 5613

A joint investigation on the structure of soil polysaccharide has been carried out with the Department of Pedology, using GC-mass spectrometry to characterise hydrolysis products after complete methylation. The studies showed that hexose components were mainly present in 1→4 and 1→3 linkages and pentoses in 1→4 linkage. Deoxyhexoses occurred in fairly uniform proportions of 1→2, 1→3 and 1→4 linkages. About 20 per cent of the residues were in branching positions and these residues were more commonly hexoses and deoxyhexoses than pentoses. A paper describing these findings has been submitted for publication[66]. Similar studies are being carried out on fractionated polysaccharide and on the products of partial hydrolysis.
108, 305

A general account of the nature and properties of soil polysaccharide has been prepared for an encyclopedia of earth science[105].

Water Soluble Humic Substances

Soil solutions and water extracts have been prepared from a number of agricultural soils and the humic substances isolated by membrane ultrafiltration. A paper relating the amounts of these water-extractable polycarboxylates to the drainage status of the soils and to the amounts of hydrous iron and aluminium oxides in the soils has been published[28] and work is continuing on the influence of other soil factors on these polymers. It has been shown that in soils whose pH has been modified by the addition of lime over a number of years, the amounts of soluble polycarboxylates increase with increasing pH, being twice as high at pH 7·0 as at pH 5·0, and they appear to be related to the calcium status of the soil rather than the pH *per se*.
304, 309

Spectrochemical analyses of fractions from the soil solution have shown that major amounts of the micronutrient cations iron, manganese, copper zinc, cobalt and nickel are associated with polycarboxylates. The nature of some of the complexes is being investigated in collaboration with the Department of Spectrochemistry, using electron paramagnetic resonance spectroscopy.
201, 203, 304

Synthetic polymaleic acid, structurally similar to naturally occurring soluble humic substances (Ann. Rept., No. 47, 1976/77), has been shown to be absorbed by plants[106] and to maintain iron in forms available for uptake by plants, as do the naturally occurring polymers[107]. Investigations on the uptake of other micronutrient cations are under way using nutrient solutions to which hydrous metal oxides have been added to simulate more closely the soil environment. It has already been shown in this system that the availabilities of both manganese and zinc to wheat seedlings are greater in the presence of the polycarboxylates, presumably because the extent to which they are adsorbed by the oxides is reduced.
304, 309

In such investigations it is difficult to distinguish cations absorbed into root cells from those merely adsorbed on root surfaces. To obtain more information on the mechanisms involved, a study of the uptake of several paramagnetic micronutrients, including manganese, copper, and vanadium, has been initiated in collaboration with the Department of Spectrochemistry, using EPR spectroscopy. Copper uptake from solutions containing Cu^{2+} involves initial immobilisation on root surfaces followed by the formation of soluble copper-amino acid complexes within the free space of the root[102]. In roots held in an aqueous environment, the complexes rapidly diffuse away from the root into the solution whereas in roots held in a moist atmosphere, their concentrations increase to very high levels within the free space of the root. Plants growing in soil are likely to be exposed alternately to each of these environmental conditions so that the rates of copper uptake in soil may be very different from those measured in nutrient solutions. 203, 309

Metal Complexes of Humic Acid

Studies on metal complexes of humic acid have been continued in collaboration with the Department of Spectrochemistry. The effect of humic acid on the oxidation state of iron at different pH values has been examined using Mössbauer spectroscopy. Reduction of Fe^{3+} to Fe^{2+} occurs in the presence of an aqueous suspension of humic acid as the pH is lowered to 2 or less, whereas reoxidation occurs on increasing the pH so that at pH 4 all the iron is in the Fe^{3+} form. This cycle of reduction and oxidation can be repeated. A paper describing these observations has been submitted for publication[101]. 203, 307

It has been shown that humic acid depresses the uptake of iron by wheat roots in nutrient solutions containing complexing agents such as EDTA and citrate[108]. It was found that uptake was also depressed by increasing pH and in all cases was higher from ferric EDTA than from ferric citrate. A parallel study of the behaviour of these complexes in solution and their interaction with humic acid showed that in both cases a proportion of the iron was bound by humic acid. In the absence of humic acid, ferric EDTA was stable in solution whereas in the case of ferric citrate, a proportion, which increased with increasing pH, behaved as if it was of high molecular weight, probably resulting from its hydrolytic polymerisation. 309

Fungal Pigments

A joint study with the Department of Microbiology (described in their report) on the effects of the fungicide Dazomet on polyphenoloxidase activity in the colourless exudate of sclerotia from *Sclerotinia sclerotiorum* has now been completed and a paper prepared for publication[109]. 301, 508

Experiments are now being carried out jointly with the Departments of Microbiology and Spectrochemistry to compare substances produced by soil microbes with humic substances and with products synthesized in the laboratory. Humic and melanin-type pigments from *S. sclerotiorum*, *Rhizoctonia solani* and *Aspergillus niger*, and pigments produced by various fungi isolated from litter horizons of a forest soil, are being examined by spectrochemical techniques such as infra-red spectroscopy and electron paramagnetic resonance spectroscopy. 203, 208, 301, 307, 507, 512

Phenolic Acids in Humification Processes

In collaboration with Letcombe Laboratory, an examination is in progress of the ether-soluble compounds produced during the decomposition of couch grass rhizomes in the soil. The major phenolic compounds identified to date include mono- and dihydroxyphenylacetic and phenylpropionic acids. The absence of the corresponding substituted benzoic acids is of interest especially since the latter compounds are the major phenolic products released by hydrolysis of soil organic matter. 108, 304

Samples of lignites from two sources have been examined by hydrolysis and extraction procedures to compare these products with soil organic matter fractions. The humic acids isolated from the lignites by sodium hydroxide extraction give ether-soluble hydrolysis products which are typical of those from humus derived from a monocotyledonous type of vegetation. One major difference is seen in the alcohol-toluene soluble fraction of the lignites. Whereas the soil fraction is usually composed mainly of long chain aliphatic compounds, the lignite fractions are composed almost entirely of a related group of tri- and tetracyclic diterpene hydrocarbons, the major product being identified as α-phyllocladane. 108, 304

Papers dealing with the extraction[23], fractionation[29] and hydrolysis[30, 31] of soil organic matter have now appeared.

Polymaleic Acid as a Soil Organic Model

Chemical studies have continued to indicate that polymaleic acid is similar to certain fractions of soil organic matter, and experiments are under way to examine the fate of the synthetic polymer when incubated in soil and its effect on other soil processes. The stability of the polymer in an agricultural top soil of the Countesswells series has been studied using polymaleic acid derived from 2,3-^{14}C-maleic anhydride. The label is thus incorporated in the polymer " backbone " and can only be released as $^{14}CO_2$, during incubation if deep-seated degradation of the polymer takes place. The polymer has, however, proved to be very stable over a six-week incubation period at 22°C, during which soil respiration appeared normal; less than 1 per cent of the added label was evolved as $^{14}CO_2$. In this experiment the polymer was added in aqueous solution to the top of a soil column and little diffusion appears to have taken place. The polymaleic acid was probably incorporated, *via* surface adsorption, into the soil organic polymer matrix, since after six weeks the label (92 per cent) was distributed evenly between the humic and fulvic acid fractions, with a small amount (5 per cent) in the preliminary hydrochloric acid extract and the balance in the insoluble soil residue. Further work is in progress.

Whereas the ^{14}C-polymaleic acid was added to the soil in very small amounts (0·2 per cent) in terms of the soil organic matter content, larger amounts (10 per cent) have been added to study the effect on the carbohydrate and nitrogen metabolism of the soil. During eight weeks of incubation, both amended and control soils showed a decrease in ammonium-N and an increase in nitrate-N. Whereas the controls showed only a marginal increase in amino acid-N, however, in the amended soils this nitrogen frac-

tion increased to a greater extent. The amended soils also showed a greater loss of reducing sugar released on hydrolysis. The addition of polymaleic acid to soil causes a decrease in pH which can be counteracted by liming. Such treatments, with increasing amounts of polymaleic acid and sufficient lime to counteract the pH effect, did not appear to affect the growth of perennial ryegrass (*Lolium perenne*); the contents of polysaccharide and protein in the subsequent shoots and roots did not differ from those of controls. 303, 304, 5613

Soil Organic Nitrogen and Sulpher

Treatment of soils with refluxing 6M hydrochloric acid is a routine method for protein hydrolysis prior to amino acid analysis. When whole soils are treated in this way, a considerable amount of inorganic material is also dissolved, and transition metal cations in solution can disrupt subsequent analyses by poisoning the analytical resin columns. Various methods for the pretreatment of the hydrolysates have been studied and it has been found that solvent extraction is more effective than a chelating resin for removing these contaminants. Extraction, for example with diethyl ether, leads to the subsequent recovery of about 20 per cent more of the amino acids and 40 per cent more of the amino sugars than treatment with resin. Resin treatment has the additional disadvantage that it introduces the contaminant iminodiacetic acid, presumably arising from the hydrolysis of the resin.

A joint study has continued with the Department of Soil Fertility on the sulphur-containing amino acids in soils, and a paper is in preparation. During this work it was found that performic acid pretreatment, necessary to diminish the loss of the sulphur-containing amino acids during subsequent hydrolysis, also led to an increase in the recovery of some of the other amino acids. 303, 602

A recent report from two Norwegian workers described the measurement of bacterial DNA in soil by fluorimetric analysis of isolated bacterial fractions. Values obtained agreed well with measurements of DNA derivatives in soil made earlier at this institute (Ann. Rept., No. 30, 1959/60) but the authors misquoted one of the conclusions reached here at that time. A note restating the facts has been accepted for publication[110]. 317

Effects of Soil Organic Components on Plant Enzymes

Work has continued on the effects of humic substances on peroxidase, invertase and phosphatase activities in plant homogenates (Ann. Rept., No. 47, 1976/77) and four papers have been accepted for publication[111, 112, 113, 114]. In addition it has been shown that *p*-hydroxybenzoic, vanillic, *p*-coumaric, ferulic and syringic acids, all of which are found in aqueous soil extracts (Ann. Rept., No. 46, 1975/76), will inhibit polyphenoloxidase activity in homogenates of potato tissue when L-DOPA is used as the substrate. This inhibition is competitive and is influenced by the pH of the assay medium. None of these phenolic acids inhibits polyphenoloxidase activity when catechol is used as substrate. In contrast caffeic acid inhibits polyphenol-

oxidase activity in the presence of catechol but not L-DOPA. Only 2,5-dihydroxybenzoic acid has been shown to inhibit polyphenoloxidase activity irrespective of the substrate used. 311, 317

Tests have also been carried out on the effects of soil organic matter on the activities of some root surface enzymes. Humic acid inhibits root surface invertase of winter wheat, but no consistent effect was observed for root surface phosphatase. A report on this work has been accepted for publication[115]. A paper on the effects of humic acid on invertase synthesis in disks of beetroot storage tissue during ageing, and excised pea root segments during elongation, has also been accepted for publication[116]. 311, 317

Field Plots

The effects of different cropping systems on the equilibrium levels of a number of organic components in the soil and on soil enzyme activities are now being studied in small field plots situated in the Institute grounds. Each plot measures 2·5 by 2·3 metres, and they are arranged in five rows each comprising six plots. Four crops were grown this year, namely potatoes, barley, ryegrass and peas. The activities of the enzymes invertase, phosphatase and amylase in the soil are currently being monitored and measurements made of the total water-soluble organic matter and the water-soluble phenolic acids. 311, 317

Effects of Light and Gravity on Plant Growth

Further investigations on germination and seedling development in relation to the physical environment have led to a reinterpretation of the evidence (Ann. Rept., No. 47, 1976/77) regarding the effect of gravity on the early growth of the mustard seedling. The previous report[32] purported to show that the application of an axial force resulted in the promotion of radicle growth and pigment synthesis in the early stages of seedling development, thus demonstrating a tonic effect of gravity on growth and development. However, more rigorous investigation of this effect has revealed that mustard seeds are hypersensitive to excess moisture and there is a critical stage of growth when development of the seedling is retarded if diffusion of oxygen through the mucilaginous seed coat is reduced by the presence of excess moisture. The apparent effect of axial force on pigment development is attributable to the removal of excess moisture. The promotion of root growth by axial force is only partially accounted for in these terms and a positive, although reduced, geotonic effect remains. An account of this work has been accepted for publication[117].

A tonic effect of gravity on the growth of cress roots has also been demonstrated and is particularly marked in light-grown roots. Growth of roots in the horizontal plane is an inverse function of light intensity and this inhibition can be counteracted by a gravitational or axial force. In a paper accepted for publication[118], the evidence has been interpreted as indicating that root growth, both as regards elongation and georeaction, is regulated by the interaction of a basipetal flow of an inhibitor from the root cap and a countervailing axial force. It is argued that the inhibitory effect of light

on root growth is due to the formation in the root cap of a growth inhibitor which induces a heightened geosensitivity in the root. Confirmation of this hypothesis is provided in a further paper[119] accepted for publication in which it is shown that roots treated with 2-chloro-9-hydroxy-fluorene-9-carboxylic acid—a compound which suppresses the ability of a plant to respond to gravity—show no evidence of light inhibition. Attempts are now being made to identify the chemical nature of the root-cap inhibitor formed in the presence of light and, in collaboration with the Botany Department of the University of Aberdeen, to resolve the possible involvement of phytochrome in the root response. 309

Other Physiological Investigations

In collaboration with the Department of Plant Physiology a study has been made of the adverse effects of galactose on the growth of the duckweed *Lemna*. *Lemna* grown in solutions containing 0·1% galactose become chlorotic, but the effects can be prevented by adding glucose. Using ^{14}C labelled galactose it has been shown that the plant glucose becomes extensively labelled, including that in the cellulose fraction. The results do not support a theory relating the effect of galactose to the blocking of reactions involving glucose-1-phophate or to the prevention of cellulose synthesis. A paper on this work has been accepted for publication[120]. 305, 402

In another joint paper the effects of the growth regulators abscisic acid and benzyladenine on the inorganic and organic composition of *Lemna* are discussed[121]. 311, 402

4. PLANT PHYSIOLOGY

P. C. DeKock

During the year progress has been made in the inter-relationships between growth hormones and mineral elements. It has been demonstrated that the ratio of elements alter in precise ways when the ratio of growth-promoting and growth-retarding hormones is altered. These concepts are applicable to all such active substances. Further studies have been made on calcium deficiency. It would appear that most calcium deficiency diseases can be avoided if edaphic factors can be suitably evaluated.

Dr P. C. DeKock attended a Symposium on Plant Roots at Wadham College, Oxford, and presented a paper at The Eleventh International Soil Science Congress at the University of Alberta, Edmonton; subsequently he lectured at two research stations in British Columbia and also at the University of Alberta. Dr A. E. S. Macklon attended the Inaugural Meeting of the Federation of European Societies of Plant Physiology in Edinburgh.

Iron Metabolism

The concept of " active " iron was proposed some years ago because the degree of chlorosis in leaves showed little relationship to the total iron content, whereas the iron in an acid extract of the leaf powder did. But even though, more recently, etherised extracts of fresh leaves have been used, the method is laborious. We have shown that a highly significant linear relationship exists between the active iron fractions and the ratios of total phosphorus to total iron in leaves, when no relationship between active iron and total iron could be found. As these two latter analyses are easily obtained, it is evident that the phosphorus to iron ratio as proposed in 1955, is an accurate parameter of the iron status of leaves. A report of this work has been accepted for publication[123]. 401

Growth Studies

It was reported previously that abscisic acid (ABA) causes plants to senesce or become dormant and that cytokinins such as benzyl adenine (BA) reverse these effects. Studies have now been made of the hormonal effects on the mineral metabolism of duckweed, as this plant can be readily maintained under precisely controlled conditions. Moreover, growth rate is closely related to the relative amounts of these two hormones present in the nutrient solution, and they are paralleled by changes in the ratios of total phophorus to total iron and of total potassium to total calcium, thus demostrating the involvement of these ratios in the growth process. A collaborative paper with the Department of Soil Organic Chemistry on this work is in press[121]. 402

Certain sugars also act as growth inhibitors; joint work on galactose toxicity has now been accepted for publication[120] and the study extended to glucosamine and galactosamine. Work so far shows that glucosamine which inhibits tumour growth in both plants and animals is an effective growth inhibitor for Lemna. 402

Water Stress

Plants are sensitive to water stress and growth is slowed down as water stress increases. The duckweed *Lemna* can be employed in an apparatus designed for studying moisture stress on seedlings. Increasing water tensions were found to slow down the growth of *Lemna* progressively and finally, at the highest water tension achieved, the plants became dormant. Our results show that dormancy is accompanied by the same changes in mineral composition as are induced by ABA which is known to increase as water tension is increased. 402

Selenium

Work on selenium uptake by plants has progressed over the year, using the radioactive isotope ^{75}Se, as the micro-analytical methods for selenium have associated difficulties which still have to be resolved satisfactorily. Antagonism by sulphate of selenate uptake is now unequivocal. Growth rates of the duckweed in presence of increasing amounts of selenium and its effects on mineral composition, enzymic changes and micro-structure are all being pursued. 401

Calcium

Further studies on Blossom-End Rot (BER) of tomatoes have confirmed the findings that the ammonium ion is the main factor which induces calcium deficiency diseases. Computer studies on BER incidence using nutrients containing varying amounts of nitrate and ammonium fed to the varieties Grenadier, Gannet and Moneymaker have been completed. A paper on the changes in mineral nutrition of healthy and BER-affected tomatoes has been accepted for publication[124]. Further biochemical and enzymic studies on BER have been made and a paper is now in preparation. A paper on reduction of nitrate in plant leaves will be published shortly[125].

As cavity spot of carrots is prevalent in the areas south of Aberdeen, plot experiments have been laid out in two areas, in both of which severe cavity spot has been noted. The areas have been sampled periodically and results should be ready for evaluation in the coming months, but it already would appear that carrots with cavity spot give no free nitrate test whereas those with only traces of cavity spot or which are healthy give a positive test for free nitrate.

Work on potatoes in relation to soil pH previously reported has now been accepted for publication[126, 127] and further work on nutrient distribution within the tuber is in progress. 402

Ion Flux Studies

Previous work has characterized, over a wide concentration range, the nature of calcium ion fluxes in the cortical cells of onion root segments, and has shown that over the range of calcium concentrations normally found in soil solution (1-10 mM) calcium entry to the cell is by passive diffusion. There is at the same time, an efflux of calcium maintained by means of a metabolic pump. Of necessity, these findings were obtained by somewhat indirect methods, and it is, therefore, desirable to obtain additional evidence

to confirm these conclusions. To this end work has now started on the effects of the calcium ionophore A23187 (Lilly Research Centre Ltd., Windlesham) on calcium fluxes in onion root segments. The ionophore is a natural antibiotic which is considered to facilitate calcium transport across cell membranes by becoming incorporated in the membrane and enclosing the hydrated ions. As far as we are aware, this is the first use of A23187 in other than studies of subcellular fractions of plant cells; the initial results indicate that calcium uptake into the root cortical cells is indeed facilitated by the ionophore, and that efflux may also be increased (possibly in response to the tendency towards higher internal concentrations). What is quite clear, however, is that the ionophore increases the size of the fraction of radio-isotope labelled Ca which is transported to the central core of conducting tissue in the root segments. In the control this amounts to about $3{\cdot}6 \times 10^{-2}$ μeq $g^{-1}h^{-1}$, whereas in the presence of 5 mg/l A23187 in the wash-out solution, this rises to about $7{\cdot}0 \times 10^{-2}$ μeq $g^{-1}h^{-1}$.

Similar studies on potassium fluxes, using the synthetic ionophore benzo-18-crown-6, have been initiated in collaboration with the Department of Molecular Structures at the Rothamsted Experimental Station. It has been found that this polyether induces leakiness of the membrane to potassium. A concentration of 0·1 mM benzo-18-crown-6 caused a reduction of 30% in apparent ^{42}K uptake compared with the control rate of about 1 μeq $g^{-1}h^{-1}$, and 1 mM benzo-18-crown-6 brought about a 90% reduction in uptake relative to the control. Half-times for exchange of K^+ were much faster in the presence of 0·1 mM and 1 mM "crown", especially across the tonoplast. Analysis of the contents of K, Na and Ca showed that the root segments lose the ability to take up the monovalent cations and to exclude Ca. These findings, together with the observations that "crown" treated segments become flaccid, suggest that benzo-18-crown-6 has a generally deleterious effect on the membrane. It remains to be seen whether some of the larger molecule "crown" compounds, containing two, rather than one, benzene rings, have a more specific effect on K^+ fluxes. 407

Calcium Uptake and Translocation in Wheat Seedlings

Earlier and continued work on calcium fluxes in wheat leaves and root segments is now being complemented by translocation studies in whole wheat seedlings at the 4 to 8 day (first leaf) stage. Net uptake by root segments and root systems is rather small, but there is a large exchangeable Ca fraction. Current work is concerned with exploring in the whole seedling the occurrence of light stimulated Ca^{2+} uptake in the leaves, which has been earlier demonstrated to occur in chopped wheat leaves. The simple expedient of comparing uptake to the several seedling parts in light and dark is likely to show a correlation with evapotranspiration, and obscure any link with photophosphorylation. However, in the absence of any controlled environment equipment in which evapotranspiration could be equalized between different light treatments, measurements of water utilization by the seedlings under each light regime have been made. As expected, Ca translocation to the shoot is largely governed by the volume of water transpired, but one interesting point has emerged. Whereas Ca uptake by the leaf is

less in the dark than in the light, uptake to the coleoptile is greater in the dark than in the light. Examination of this phenomenon is continuing, together with a consideration of other effects of light on uptake besides those mediated through evapotranspiration and photophosphorylation. 407

Calcium Uptake and Translocation in Tomato Plants

As has been widely reported by others, cation contents, particularly of Ca, were found to be lower in ammonium fed plants than in plants whose nitrogen source in the nutrient solution was either nitrate or nitrate plus ammonium.

As an extension of this work, undertaken in relation to studies on the cause and occurrence of blossom end rot in glasshouse tomato crops, plants were detopped, and before being harvested, sap exuding from the cut stump of xylem was collected for analysis. The amount of exudate collected varied widely between and within treatments and from one experiment to another, but the concentration of ions in the sap was a much more constant feature within treatments, particularly when comparing the intial collections of sap made during the first 3 hours after detopping. The proportion of each cation in the sap generally reflected the relationships found in the plant leaves, with Ca being lowest in ammonium fed plants. Several explanations for these effects have been proposed in the literature. Our results seem to discount two of them: cation competition cannot be a major factor since total cation uptake is reduced in the presence of NH_4^+, and although some of the latter ion appears in the sap, it does so in amounts far too small to balance the reduction in Ca and K concentration; pH effects are a possible explanation of depressed cation uptake (the nutrient solution has a tendency to become very acid when NH_4^+ is the only N source) but pH of the solutions was adjusted daily, and in some experiments, pH drift was minimised by using very dilute nutrient solutions. A more likely explanation is the lack of sufficient readily absorbed anion (nitrate), the associated problems of an excess of hydrogen ions of which to dispose, and the lack of excess OH^- from nitrate reduction for the formation of organic acid anions. 407, 402

5. MICROBIOLOGY

J. F. DARBYSHIRE

The research programme of the department is concerned with the role of micro-organisms in soils and in soil-root relationships, i.e. research package 5. Some reorientation of the research projects and a greater collaboration with other departments has been effected during the year. Contact has also been maintained with several other research institutes and with University departments with similar interests. During the year three members of staff visited research institutes overseas and six attended scientific meetings in connection with their research projects.

Interrelationships of Plant Roots and Microbes

Following the arrival of three new members of staff, this year has seen the establishment of a research group concerned with asymbiotic nitrogen fixation. Previous work in the department (Annual Report 1975/76) in collaboration with Dr Neal, visiting research worker, was concerned with an electron microscope study of a nitrogen-fixing bacterium inside the roots of Canadian wheat. This obligately anaerobic bacterium was previously isolated from rhizosphere soil in Canada by Dr Neal from one selected line of wheat. It is intended to continue this research with wheat and to search for similar associations in barley and oat cultivars. The preliminary work of this research group has been concerned with methodology. The acetylene reduction assay has been used satisfactorily as a rapid indicator of nitrogen fixation with clover nodules and pure cultures of known nitrogen-fixing bacteria (*Azotobacter chroococcum* and *Klebsiella* spp.). A gas chromatograph devoted to this technique can detect as little as 0·1 ppm ethylene, and acetylene reduction was detected in some Scottish soils amended with *A. chroococcum*. Existing growth media for the culture of nitrogen-fixing bacteria were found to be unsuitable and they have been modified. An important objective of this programme is to trace the fate of the fixed nitrogen in cereal plants and soil using ^{15}N tracer techniques. The possibility of using emission and mass spectrometry for ^{15}N studies is being investigated in collaboration with the Spectrochemistry Department. Various incubation chambers for acetylene reduction tests and ^{15}N tracer experiments using intact plants have been designed and tested. 514

A new technique for observing root growth in soil with the aid of an incident ultra-violet light microscope has been developed. This technique will enable microbial development and distribution on root surfaces to be studied in more detail. 513

Field studies of the microbial populations and nitrogen status of the rhizosphere soil around the roots of spring barley in collaboration with the Department of Soil Fertility and the North of Scotland College of Agriculture have been published[33]. Amendments of aqueous ammonia to 2 local soils increased take-all disease in spring barley to a greater extent than nitrate in 2 glasshouse experiments in 1975 and 1976. The least take-all

disease was observed when nitrogen was supplied to barley plants as foliar sprays of urea. The results of these glasshouse experiments have been submitted for publication[128]. 513, 603

Fungi

Ultrastructure. A paper describing the exterior of narcissus flowering stems and leaves as seen in a scanning electron microscope (S.E.M.) has been published[34]. These results together with data on the preservation of cytosori of *Spongospora subterranea* in the S.E.M. were exhibited as a poster at " Micro 78 ", the International Symposia and exhibition organised by the Royal Microscopical Society. The results of this exhibit were published subsequently[35]. The resting spores (cysts) of *S. subterranea* exhibited wart-like protuberances on their outer surfaces in the S.E.M.[36]; this has not been reported previously by other workers using the light microscope and should prove invaluable in taxonomic studies. 507

Sclerotia. An account of the biology of *Sclerotinia sclerotiorum*, its effect on the host plant, and some information on its geographical distribution has been published in collaboration with the North of Scotland College of Agriculture[37]. 508

Studies on the resistance of pigmented fungal material to decay by soil microbes are important, because it is believed that humic substances in the soil are partly derived from pigmented fungal residues. The formation of a melanin-like pigment in the rind of sclerotia of *S. sclerotiorum* can be prevented by Dazomet, a commercial fumigant for soils. Unpigmented cut surfaces of sclerotia of *S. sclerotiorum* darken after a few days exposure and this colour change is also due to the synthesis of the melanin-like pigment. A clear liquid, which exudes from developing sclerotia of this fungus, contains the enzyme phenolase. It has been discovered that the activity of this enzyme is also inhibited by Dazomet, as well as by sodium azide and cysteine. These enzyme inhibitions can be prevented by the presence of Cu^{2+}. Dazomet and Cu^{2+} similarly affect the activity of mushroom (*Agaricus campestris*) phenolase. The results of these studies in collaboration with the Department of Soil Orgnic Chemistry have been submitted for publication[110]. Further studies will include other soil microbes besides *S. sclerotiorum*. 301, 507, 508

Protozoa

Systematics. A description of the ultrastructure of a common soil flagellate, *Spiromonas angusta* has been published[38]. This colourless flagellate belongs to the sub-order Bodonina, which contains several other common soil flagellates. 510

Ecology. In collaboration with Dr K. M. Old, Department of Biological Sciences, University of Dundee, a paper dealing with several feeding trials with a giant soil amoeba of the family Vampyrellidae has been published[39]. This amoeba occurs in many soils and can devour the spores of many fungi as well as many other soil microbes. 512

Organic Matter

Microbial decomposition and sythesis. The contribution of the yeast microflora to the synthesis of the xylose fraction of soil polysaccharide has been investigated further in collaboration with the Department of Soil Organic Chemistry. Earlier studies (Annual Report 1976/77) showed that yeast growth and xylose synthesis were enhanced when the soil had been dried, remoistened and incubated at 5°C. Investigations over a 6 month period have shown that yeasts survived in dried soil relatively better than other soil microorganisms and that when the soil was remoistened the yeasts could become dominant. As most soils in temperate regions remain moist for most of the year, it is concluded that plant residues and not yeasts are the major source of soil xylose in Britain. A paper describing these investigations has been published[27] and a further short communication has been submitted for publication[104]. 305, 512

Contribution of plant and microbial fractions to soil organic matter. Several attempts were made to separate ^{14}C-labelled organic material from soil by sedimentation and filtration. Soils were incubated with either ^{14}C-glucose or ^{14}C-ryegrass. In the glucose incubations the labelled fraction was derived entirely from microrganisms, but in the ryegrass incubations both plant and microbial material were labelled. The lightest soil fraction (density $<2{\cdot}0$) contained the bulk of the ^{14}C-label in both glucose and ryegrass incubations. Filtration through 8 μm pores increased the specific activity (i.e. concentrated the organisms in the <8 μm fraction) in the glucose incubations but not with ryegrass. None of these incubations produced material with a distribution of ^{14}C-label in the various fractions identical to native soil organic matter, although the ^{14}C distributions from ryegrass incubations were the closest. 305, 512

Soil Phenolic Acids. Some effects of water-soluble phenolic acids on plant growth were studied in collaboration with the Department of Soil Organic Chemistry. Addition of either p-hydroxybenzoic, p-coumaric, vanillic or ferulic acids to soil resulted in a rapid increase in soil respiration, invertase activity and numbers of micro-organisms, although the correlations between these indices of microbial activity were low. Many soil microorganisms, particularly fungi, are able to utilise soil phenolic acids as their sole carbon substrate and this may account for the low levels of these acids found in soil. The addition of phenolic acid-degrading microbes to nutrient solutions containing winter wheat and either hydroxybenzoic or ferulic acid rapidly reduced the concentration of these acids and alleviated their phytotoxicity. A paper describing this work is in preparation. 301, 512

Peat. The survey of the anaerobic bacteria of a deep basin peat at Lyne of Skene near Aberdeen has been completed. Anaerobic bacteria were found at all depths down to the base of the peat deposit at 6 m. The largest microbial populations were found in the top metre (Aerobes 10^3 and Anaerobes 10^3/g fresh peat). At deeper levels the anaerobic population varied between 10^2 and 10^1/g fresh peat. The results of this survey are being prepared for publication. 503

In collaboration with the Department of Pedology the inter-relationships between microbial numbers and water content in peat are being studied at the Lon Mor experimental site near Fort Augustus. The data for 1977 show a strong inverse correlation between total microbial numbers and water content at different depths. The populations of ammonifying, nitrifying and denitrifying bacteria are also being estimated at different depths. Nitrifying bacteria and nitrate have not been detected in these experimental plots at any depth. 503

The study of the microbiology of peat composts is mainly concerned with the influence of moisture and plant nutrients on microbial respiration. The rate of respiration is determined by gas chromotography. 503

In collaboration with the Organic Geochemistry Unit at Bristol University, significant amounts of triterpeniods have been detected in pure cultures of *Bacillus polymixa* and *Acinatobacter calcoacetieus*, which were isolated from local deposits of peat. 503

6. SOIL FERTILITY

E. G. WILLIAMS

Complementary field, pot culture and laboratory studies have been continued and extended on the properties and nutrient relationships of selected contrasting soil series; on effects of fertilizers, environmental factors and husbandry practices on the growth, development and chemical composition of crops; and on the development and calibration of laboratory methods for evaluating the nutrient status of soils. The programme as a whole continues to be directly aimed at practical improvement of soil fertility and crop production through better understanding of soil-nutrient-crop relationships. In the summary reviews of the main topics below, particular attention may be drawn to the coverage being given to various aspects of the nitrogen responses of crops, to the detailed studies on potassium, magnesium, sulphur and phosphate status of soils, and to the development of work on the physical properties of soils.

Major effort continues to be devoted to translation of research findings into practice through the medium of advisory soil testing in collaboration with the North of Scotland College of Agriculture. Together with allied consultative activities, this service also draws valuable attention to practical problems requiring experimental investigation. A notable development during the year has been the production of a joint publication[49], College Bulletin No. 15, entitled Fertiliser Recommendations, prepared in collaboration with the North of Scotland College of Agriculture. This supercedes previous advisory leaflets and updates and expands practical information on the characteristics, effects and use of lime, fertilizers, trace element amendments and organic manures, and recommends suitable dressings for agricultural and horticultural crops in North Scotland. Collaboration has also been maintained with various technical committees, including currently the Scottish Standing Committee for the Calculation of the Residual Values of Fertilizers and Feeding Stuffs, the Working Group on the Disposal of Sewage Sludge on Agricultural Land, and the Consultative Committee for the Development of Spectrochemical Work.

Dr E. G. Williams and Dr J. W. S. Reith attended the Eleventh International Congress of Soil Science in Edmonton, Canada, in June, 1978. By invitation, Dr B. W. Bache presented two papers[129, 130], including one of the principal lectures, at a meeting on Effects of Acid Precipitation on Terrestrial Ecosystems, organised by the N.A.T.O. Ecosciences Panel, in Toronto, Canada, in May, 1978. Soil acidification is a continuing natural process in humid climates, due to displacement of soil cations, mainly calcium and magnesium, by hydrogen ions. The main paper[129] accordingly assesses the amounts of acid arising from different sources and identifies the important parameters of the cation exchange system of soils that are necessary to estimate the acidification that can be expected in particular instances. The second paper[130], on the sensitivity of soils to acidification, expands on some of these issues. Mr A. H. Knight took part in a Meeting of the European Society for Nuclear Methods in Agriculture in Brno, Czechoslovakia, in September, 1978.

The Department was also represented at the following meetings in Britain: a Joint ADAS/ARC Symposium on Maximizing Yields of Crops, Harrogate, January, 1978 (Dr P. W. Dyson); a Soil-Root Interface Symposium, Oxford, March, 1978 (Dr B. W. Bache and Dr W. M. Crooke); a conference on Microprocessors in Chemistry, Cleveland, Yorkshire, March, 1978, under the auspices of the Chemical Society and the Royal Institute of Chemistry (Dr T. E. Edmonds); a Symposium on Soil-Plant-Water Relations, London, April, 1978, held by the Agriculture Group of the Society of Chemical Industry (Dr G. D. Buchan); a conference on Utilization of Sewage Sludge on Land, Oxford, April, 1978, organized by the Water Research Centre, and a meeting of the Scottish Arable Crops Group, July, 1978, organised by the West of Scotland Agricultural College (Dr J. W. S. Reith); a Symposium on Trace Elements: The Soil-Plant- Animal Interface, Aberdeen, June, 1978 (Dr J. W. S. Reith and Dr T. E. Edmonds), to which Dr Reith contributed a paper on Trace Metals in Soils — Some Case Histories; an International Workshop on Acid Precipitation, Galloway, September, 1978, organized by the Central Electricity Research Laboratories (Dr B. W. Bache); the Annual General Meeting of the British Society of Soil Science, Exeter, September, 1978 (Dr E. G. Williams). Members of the staff also visited several Research Centres in England, including Rothamsted Experimental Station, the National Vegetable Research Station, the School of Agriculture of the University of Nottingham, the Plant Breeding Institute in Cambridge, and the Central Electricity Research Laboratories at Leatherhead.

It was a particular pleasure during the year to welcome to the Department Professor V. N. Kudeyarov, Deputy Director, Institute of Agrochemistry and Soil Science, Pushino-on-Oka, Moscow Region, USSR, who came for four months under an exchange agreement between the Royal Society and the USSR Academy of Sciences. During his stay, Professor Kudeyarov visited all the Departments of the Institute and initiated some collaborative work with the Department of Soil Organic Chemistry, mentioned later, on transformations of added inorganic nitrogen in soil. He also gave a Seminar reviewing work in the Soviet Union on the Nitrogen Supplying Capacity of Soils.

With the resignation of Dr G. P. Bound, electrochemical studies on selenium relationships in soils and exploratory work on possible gaseous loss of nitrogen from soil have had to be temporarily suspended.

Crop Responses to Fertilizers

Field investigations and supporting crop analyses have been continued to extend and update practical information on lime, fertilizer and trace element responses and requirements of different soils and crops. In this programme attention is paid to residual as well as immediate effects, to implications of form, rate, time, method and frequency of application, and to needs to ensure adequate nutrient content in crops for animal nutrition. The resulting information has provided the main basis for formulating the practical fertilizer recommendations incorporated in the revised Bulletin[40]

mentioned above, and for calibrating advisory soil tests to enable these to be adjusted to suit particular farms and fields.

601, 603, 608, 609, 5206, 5701, 5703

Fertilizer Placement for Swedish Turnips. To cater for changes in fertilizer composition, the series of experiments started in 1975 has been continued to compare applications broadcast on the cultivated land just before ridging with dressings placed 5 cm directly below the seed. The importance of covering seasonal variations has again been demonstrated. As described in last year's Report exceptional weather considerably affected the results in 1976. In some respects this happened again in 1977, when the summer rainfall was about 30 per cent below average and dry weather during the two to three weeks after sowing made the conditions unfavourable for good establishment. As a result, early growth was reduced, yields tended to be below average, and the results were rather variable. In three experiments with ammonium nitrate (Nitram) the mean yields from dressings supplying 50 and 100 kg N/ha were practically identical for the two methods of application. At 150 kg N/ha, a rate higher than would normally be recommended for swedes, placement tended to be slightly inferior. In three other experiments a granular fertilizer with an $N:P_2O_5:K_2O$ ratio of 1:1:1 was placed at rates supplying 25, 37.5 and 50 kg P/ha and compared with broadcast dressings of a normal turnip fertilizer with a ratio of 1:2:1, supplying 50, 75 and 100 kg P/ha. As in previous years, this ensured that the corresponding treatments of the two fertilizers supplied virtually the same amounts of N and K, whereas the placed treatments supplied only half as much P as the broadcast dressings, in the expectation from earlier work that on responsive soils placement should at least double the effectiveness of water soluble P. This expectation was confirmed. At all three centres, the half-rates placed gave practically the same yields as the full rates broadcast. The results also confirmed that placement of fertilizers based on ammonium phosphate and ammonium nitrate directly below the seed should normally be safe. The results from the 1978 experiments are not yet available, but growth appears to have been normal and satisfactory yields are expected. 603, 608, 5701, 5703

Comparison of Solid and Liquid Fertilizers on Barley. To complete this series of experiments, granular and liquid forms of fertilizers with an $N:P_2O_5:K_2O$ ratio of 2:1:1 were tested at three centres in 1977. Three methods of application, broadcasting, combine-drilling and placing 5 cm to the side of the seed were compared at rates of 60, 80 and 100 kg N/ha. During early growth at two of the centres the barley plants in some of the plots combine-drilled with the highest rate of liquid fertilizer had a temporary yellowish appearance, but there was no adverse effect on subsequent growth and the various fertilizer treatments increased grain yields by 50 to 100 per cent. One general conclusion from this series of nine experiments, carried out during 1975 to 1977 on soils with a range of phosphorus and potassium contents typical of moderately good agricultural land, is that no clear differences are to be expected between broadcast applications of granular and liquid fertilizers. Except on phosphate responsive sites, where

placement of phosphate may be beneficial, combine-drilling granular fertilizer can be expected to give practically the same yields as broadcasting. This should usually be true for liquid fertilizer also, although there may be a slight risk from combine-drilling high rates. Placement 5 cm to the side of the seed eliminates such risk, and has consistently given yields as good as from broadcasting or combine-drilling a corresponding rate of granular fertilizer. 608, 5701, 5703

Time of Application of Nitrogen to Barley. In this series of experiments effects of 50 and 100 kg N as Nitro-chalk applied at seed time and about six weeks later, at the two to three leaf stage, are being compared, with particular reference to the amount of intervening rainfall in different seasons. Three more experiments were carried out in 1977. There was at least 80 mm of rain between the seed time and later treatments, but as in the previous two seasons there was practically no difference between them. In agreement with earlier work, therefore, there has so far been no indication of any gain from later application of nitrogen, and, conversely, no suggestion of any loss of efficiency of the seed time dressings due to leaching. Such loss is more likely to occur on light textured soils and three more experiments were laid down in 1978 to check this possibility. 603, 608, 5701, 5703

Effects of Minimum Cultivation Methods on Barley. Further results have been obtained from the experiment started in 1975 to compare normal ploughing, chisel ploughing and no ploughing. As mentioned in Annual Report No. 47 weed control has been a problem, especially in the chisel-ploughing and no-ploughing plots. Regular use of appropriate herbicides has now provided a satisfactory, but expensive, method of controlling couch and other grasses, broadleaved weeds and wild oats. In autumn, 1976, however, there were so many grass weeds in the chisel-ploughed plots that for once they had to be ploughed to the normal depth of about 25 cm, as the only way of getting a satisfactory seedbed. The general level of yield in 1977 was about average, and there were significant responses to added superphosphate, with the broadcast and combine-drilled applications giving similar yields. The level of response, however, was higher on the plots receiving regular normal ploughing; for example, with the top rate of 27·5 kg P/ha these gave 1·1 t/ha more grain, compared with about 0·7 t for the no-ploughing and chisel-ploughing plots, even though the latter had on this occasion been normally ploughed. Irrespective of phosphate treatment, however, the average grain yield following normal ploughing of the chisel-ploughing plots was about 0.4 t/ha greater than from the plots receiving regular normal ploughing, which, in turn, gave about 0·5 t more than the no-ploughing treatments. The reason for these differences are not clear. Apart from any effects of weeds there could be several other factors involved, such as differential mineralization of organic soil nitrogen. All the plots received the same basal dressing of 100 kg N/ha as Nitro-chalk, but a higher rate could be necessary on the no-ploughing plots. 608, 5701, 5703

Nitrogen on Grass—White Clover Swards. The Department is collaborating in a national series of grassland experiments (ADAS/ARC Grass: White

Clover Experiment GM23), being carried out at widely distributed contrasting sites in Britain to study the nitrogen economy of swards of S23 ryegrass, alone or in combination with S100 or Blanca white clover. Swards were established at an experimental area in Kincardineshire in 1977 and ammonium nitrate treatments ranging from 0 to 100 kg N/ha/cut were started in 1978, six cuts per annum being taken at monthly intervals. Three treatments involving combined applications of boron, cobalt, copper, molybdenum and zinc have also been included, and botanical separations as well as chemical analyses are being carried out on the herbage samples.
603, 608, 609, 5206, 5701, 5703

Crop Growth and Development

To promote fuller understanding of the effects and interactions of fertilizers, environmental factors and husbandry practices, detailed measurements of the progressive accumulation of dry matter and nutrients by barley and swedes or potatoes have been continued at four contrasting centres. An intensive study of the effects of nitrogen on the growth of barley and oats has also been continued. At two sites in 1977 and 1978 experiments have been done with 8 levels of fertilizer N, ranging from 0 to 140 kg N/ha, with particular reference to the form of the response "curve" relating barley yield to applied N. The results strongly suggest that the relationship is best described by intersecting straight lines rather than curvilinear functions. In all four experiments at least 120 kg N/ha was required to give the maximum yields, which were 2·0-3·3 t/ha greater than the yields with no N. Yield increased at the rate of 25-30 kg of oven-dry grain/kg N/ha to a point of inflexion, after which it increased at about 8 kg/kg N/ha. This pattern of response is compatible with data collected from earlier experiments in the series, but these included only 5 N levels and did not allow the form of the individual response curves to be estimated accurately.
607

At one site in 1978 the effects of soil pH on the growth of barley have been studied at 5 rates of fertilizer N. The soil had a pH, in water, of 5·0 and was limed to give intended values of 5·0, 5·45 and 5·9. Contrary to expectation, the yields of grain at pH 5·45 and 5·9 were similar, provided that adequate fertilizer N had been applied. At pH 5·0, however, the yields were substantially lower, especially in the absence of fertilizer N. This experiment will be repeated for at least one more year on the same plots. The Foudland series soil concerned has also been used in a pot culture experiment on the effects and interactions of soil pH, P and N, in 2:1 soil: sand media in 18 cm plastic pots. In earlier experiments, described in the previous Annual Report, barley was found to be surprisingly tolerant of low pH under pot conditions. The pH levels imposed were, therefore, 5·45, 5·0 and 4·5, the latter treatment being acidified with aluminium sulphate. The effects of pH were tested in full factorial combination with two rates of P, O and 0·2 g P/pot, and four rates of N, 0, 0·25, 0·5 and 1·0 g N/pot. With 0·2 g P and pH 5·45, the response to N was linear, and as might be expected, both low pH and the absence of added P restricted yield at the higher N levels. This experiment will be repeated using a wider range of all the factors.
607, 605, 606

Studies summarized in last year's Annual Report on the potato cultivar Record showed that while the normal practice of burning off the foliage around the third week in August restricted the yield of ware sized tubers, delayed destruction did not reduce the yield of seed tubers. With the view to assessing the wider applicability of this finding, a comparison has been made of the growth of Record and three other cultivars (Maris Piper, Pentland Crown and Pentland Ivory), using three rates of N and K. The main objective was to compare changes in the yield of seed sized (32-57 mm) tubers. Preliminary analyses of the results indicates that all four cultivars can be expected to behave in a broadly similar manner. The cold weather in July, August and September, however, caused slower than normal tuber growth and the yield of seed tubers did not reach a maximum until about 7 September. Presumably due to the cold weather and incidence of blight in the foliage, there was little further increase in total yield after this date. Thus, though the yield of seed tubers remained constant the conditions did not allow the question to be answered whether it would have decreased had there been a further rapid increase in the yield of ware. 607

Two papers[131, 132] have been submitted for publication. One[131] deals with methods of sampling swede roots for estimation of dry matter and nutrients. The conventional method of core sampling was compared with cutting segments through the central vertical axis. Except for phosphate, large and variable differences were found, indicating that the core values were inadequately representative of the whole root for purposes requiring accurate absolute values. The other paper[132] deals with changes in straw dry weight during the grain filling period in barley in relation to grain yield. Earlier work showed that in north-east Scotland the amount of carbohydrate accumulated during grain filling is frequently insufficient to account for grain yield. This phenomenon can now be explained on the basis that the stems of the barley plants can store up to 3t/ha of soluble carbohydrate before and during the first week of grain filling, thereby providing a reserve which can be drawn upon in the later stages of filling. 607

Chemical Composition of Crops

Studies in this area continue to be closely integrated with work, described above, on crop growth and development. The main objectives remain, better understanding of the effects of lime, fertilizers and growth conditions, and assessment of the usefulness of plant composition parameters at early growth stages as indices of nutritional status, yield and fertilizer requirements, especially nitrogen. 606, 607

Barley. To extend earlier work on carbohydrate changes in barley straw during maturation accompanying changes with time in chlorophyll content are being studied, as a guide to the decline in the photosynthetic efficiency of the straw. The results indicate rapid decrease in photosynthetic activity in the straw after ear emergence, fully compatible with the previously observed fall in carbohydrate content.

Vegetative plant material (6-7 leaf stage) from a soil pH experiment in pots with barley has been used to study the effects of pH and form of

fertilizer N on different fractions of Ca and Mg, separated by sequential extraction with simple solvents: H_2O, NaCl, acetic acid and HCl. In the case of HCl and water the fractions are well defined and consist of oxalate and complexed salts of organic acids, respectively. The salt solution is thought to remove bound Ca and Mg, probably in the form of pectates, while acetic acid removes di- and tri- calcium phosphates. In fact over 80 per cent of the total Ca and 90 per cent of the total Mg was removed by the first two extractions. Only small amounts, therefore, were accounted for by the last two reagents and by the final residue after ashing. As could be expected, total Ca and Mg in the plant increased with increasing soil pH. So also did the amount and proportion of Ca removed by water, in keeping with the pH-dependent increase in excess base, itself a measure of the level of the organic acids in the plant. Magnesium in the water fraction increased with pH by about 10 per cent in the case of one barley cultivar, but remained constant at about 70 per cent of the total in another. The proportions of Ca and Mg removed by NaCl tended in general to decrease with increasing soil pH, but the overall picture involving two cultivars and two N forms (NH_4 and NO_3) was not entirely consistent. Acetic acid removed more Ca, and in most cases more Mg, from plants grown at high pH, but only to the extent of 1 to 2 per cent of the total content. Hydrochloric acid soluble Ca fell with increase in soil pH, but this category of Mg was less clearly influenced. Despite the lower total Ca and Mg contents of plants grown with ammonium compared with nitrate nitrogen, the proportion extracted by NaCl was higher for the former. The distribution of Ca and Mg fractions between young and old leaves was also studied. The differences were surprisingly small, particularly in view of the fact that Ca, at least, is regarded as being relatively immobile in plants. 606, 607, 605

Oats. Changes in carbohydrates in oat straw during maturation have also been monitored, to assess their contribution to grain yield and for comparison with earlier results from similar field experiments with barley. The higher total N content of oat plants compared with barley grown on the same soil is being studied in relation to levels of applied N, and to its possible use along with excess base as an early determinant of grain yield. 606, 607

Trace Elements

As mentioned earlier, an account of experimental work carried out by the Institute during the past 40 years was contributed to a trace element symposium on the soil-plant-animal interface. This summarized work on cobalt, copper, molybdenum and nickel, with particular reference to remedial soil treatments for correcting deficiencies or reducing toxicities. 609

Copper. A field experiment started in 1976 has been continued to compare the effectiveness of copper sulphate, copper oxychloride and a commercial copper slag. The area is under a temporary ley of mixed grasses and white clover. This was cut for silage in 1977 and 1978, but there was no significant yield response to copper. Further samples of herbage and crops have been collected from areas which have received major amounts of copper from distillery wastes or regular dressings of copper-rich pig slurry. 609, 5205, 5701

Selenium. Sampling of herbage from four field experiments started in 1976 has been continued, to examine, in collaboration with the Department of Spectrochemistry, the immediate and residual effects of dressings of sodium selenite and sodium selenate on the selenium content of ryegrass and clovers. Many of the samples remain to be analysed, but the results to date indicate that dressings which had marked effects in the year of application in 1976 had little residual effect a year later in 1977. As quoted in last year's report, dressings of 0·1 and 0·3 kg Se/ha as sodium selenite increased the Se content in ryegrass from below 0·03 to about 0·2 and 0·6 ppm, respectively, whilst sodium selenate was much more effective, giving increases about five times greater. In 1977, however, the residual effects of both rates of the selenite and of the lower rate of the selenate were practically negligible. The only increase in uptake in the second year was from the higher rate of selenate. Application of selenate at this rate, however, might raise the selenium content of herbage in the first year to levels potentially dangerous to animals. 609, 203, 202, 5703

Nitrogen

To supplement studies on nitrogen responses of crops mentioned in the sections above, further measurements have been made of inorganic N in soil samples from field plots. Samples of drainage water from two ditches have also been analyzed, one collecting water from fields on four farms on the Countesswells Association and the other from fields on two farms on the Foudland Association. Ammonium and nitrate N were estimated in samples collected at weekly intervals from April to October, 1977, and April to September, 1978, and at approximately monthly intervals from November, 1977, to March, 1978. The average monthly concentrations of ammonium N in both ditches were less than 0·5 ppm, with a tendency in both years for the highest value to occur between April and August. The average monthly contents of nitrate N at the Countesswells site ranged from 2·5 to 6·7 ppm, with an overall mean of 4·5. The corresponding range for the Foudland site was 5·6 to 8·1, with an overall mean of 6·7. The lowest nitrate concentrations tend to occur in summer or autumn, not in winter. These nitrate levels are below the maximum value of 11·3 ppm nitrate N regarded as acceptable in drinking water, and in general compare favourably with values elsewhere. 603

As mentioned earlier, Professor V. N. Kudeyarov, Institute of Agrochemistry and Soil Science, Puschino-on-Oka, USSR, spent four months in the Department during which he initiated collaborative work with the Department of Soil Organic Chemistry to study transformations of added inorganic nitrogen during laboratory incubation with soil. Ammonium sulphate enriched with ^{15}N was added at the rate of 100 ppm N to a basic igneous soil of the Insch series and incubated at 60 per cent water holding capacity at 25°C for 30 days. The soil N was then fractionated into nitrate, exchangeable and non-exchangeable ammonium, amino acids, amino sugars, and components, including amides, which release ammonia on hydrolysis. The distribution of ^{15}N in these fractions is being examined. 603, 303

Total nitrogen in crops has hitherto been determined using macro-Kjeldahl digestion equipment. It is intended to replace this with a recently purchased Tecator block digestor which is currently being tested. Initially the two digestion systems are being compared using the standard H_2SO_4-Keltab procedure. Tests are also planned, however, with the H_2SO_4-H_2O_2-Se method, with the view to determining major cations as well as nitrogen in the digests, thereby reducing needs for separate ashing.

603, 606, 607, 608

Phosphorus

Evaluation of Soil Phosphate Status. With the collaboration of the Department of Statistics, progress has been made in a major reappraisal of the usefulness of various laboratory measurements of soil P an indices of phosphate status, with particular reference to influences of soil series and soil properties. The main objective is to assess possible improvements in advisory soil testing, by modification of methods and/or the interpretation of results. Responses of swedish turnips to fertilizer phosphate were measured in over 20 field experiments on each of four soil series (Countesswells, Insch, Foudland, Tarves) and on a group of Old Red Sandstone soils combining the Stonehaven and Laurencekirk series, all from north-east Scotland. To lessen disruptive influences of soil and seasonal variations, each set of experiments was confined to one soil group in one season. Relationships between yield response to phosphate and measurements of readily soluble P by several well-known conventional procedures, including the acetic, lactate, bicarbonate and resin methods, have been examined using linear, quadratic and hyperbolic functions of the soil P values. The quadratic and hyperbolic functions consistently account for a higher percentage of the variation in field response to phosphate than the linear equation, and the correlations for individual soil series are usually substantially higher than the overall coefficients for the combined series. In most instances, including the loss on ignition of the soil in the regression equations significantly improves the correlations, and the highest coefficient is usually given by phosphate extracted with anion-exchange resin. This method also performed relatively well in accounting for variations in the field response of potatoes to phosphate over a range of 26 centres combining the various soil series; similarly, it gave the best relationships with the phosphate responses of oat grain in soil-sand mixtures in pot cultures covering a wider range of 72 soils, representing three series each from the North, East and West College areas. Even when account is taken of soil series, however, the levels of the best correlations obtained with field responses still leave considerable room for improvement. For example, the proportion of the variation in the field responses of swedish turnips accounted for by the highest correlation coefficients with the hyperbolic and quadratic functions of soil P values by the resin method varies from 50 to 80 per cent for the individual soil groups, and is only 40 per cent for the combined series. The reasons for these variations and limitations require further investigation, and as indicated below fuller information is being obtained on the extraction of phosphate from soils by anion-exchange resins.

601, 608, 5701, 5703

An account[41] of work on the phosphate status of some Alberta soils, described in last year's Report, was presented in Edmonton at the recent Eleventh Congress of the International Society of Soil Science. 605

Phosphate Extraction by Anion-Exchange Resins. A detailed examination has been made of the extraction of phosphate from soil suspensions by anion-exchange resins Strong-base exchangers, Dowex 21K saturated with chloride and Zerolit FF saturated with bicarbonate, were used, and the amount of resin, the time and the salt concentration were varied systematically. Phosphate release from the soil is a consequence of the low P concentration that the resin can maintain in solution. At equilibrium, which was reached in about 100 hours, salt concentration was the most critical variable, because it determined the phosphate/total anion ratio in solution, and hence the efficiency of absorption of P by the resin. The increase in calcium concentration and the drop in pH during the extraction with chloride resin indicated that for a slightly acid soil P release was caused by both the dissolution of a calcium phosphate phase and the desorption of surface P by hydroxide ions. The desorption component was greater when the exchanging anion was bicarbonate than chloride, partly due to the concomitant increase in hydroxide concentration. The bicarbonate resin removed three times as much P as the chloride resin from a strongly acid soil, but the two resins removed equal amounts from a slightly calcareous soil. Above a level of 1 g moist resin per 2 g soil in 100 cm^3 water, the effect of amount of resin added was comparatively small, but variations below this level were considerable, enabling P desorption isotherms to be determined. 605

Sulphur

Use continues to be made of radioactive sulphur in pot cultures to assess available soil sulphur, and an account[133] of a survey, reported last year, of the sulphur status of representative agricultural soils in north Scotland has been accepted for publication. This showed that some soils are low in phosphate—extractable sulphate (<12 ppm S), and in particular that sandy soils of the Boyndie series may be susceptible to sulphur deficiency. To investigate further the implications of these findings, 10 soils with a range of extractable sulphate contents, and representing several series with contrasting properties, were selected to examine threshold values for onset of sulphur deficiency in oats in pot cultures. Three of these soils were also used for pot measurements of sulphur response of barley and ryegrass, and at the corresponding field sites experiments on barley were carried out to compare the effects of potassium sulphate and potassium chloride. Field comparisons of these two fertilizers have also been made with swedish turnips. To characterize the sulphur status of the various crops determinations of total sulphur, total sulphate, total N/total S ratio, and protein and non-protein nitrogen were made on samples taken at different stages of growth. The field trials on barley and swedish turnips have given no indication of any higher yield response to potassium sulphate compared with potassium chloride, but until all the results, including the crop analyses, have been evaluated it would be

premature to draw conclusions about the sulphur status of the various soils. To clarify the practical field situation, extension of field tests of the effects of sulphur amendments to other soils and crops, especially clover and ryegrass, is also necessary. 601, 608

Collaborative work has been continued with the Department of Soil Organic Chemistry on the nature of organic sulphur compounds in soils. 602, 303

Soil Acidity and Cation Exchange

Research is continuing on the cation absorption and exchange reactions that occur during soil acidification. Acids may be added in acidified rainfall or, more importantly, produced by the decomposition of organic residues or by the nitrification of ammonium salts added in fertilizers. Three different experimental approaches are being used in the laboratory: leaching of soil columns with acid solutions, successive extractions of soils with acid solutions, and direct measurement of pH buffer curves. There is approximate equivalence between acid added and calcium and magnesium desorbed from the soils until the pH drops below 5. Then the added acid is only partly adsorbed, soluble aluminium is liberated and the amount of calcium + magnesium released become less than the amount of acid adsorbed. Rates of acidification are also being measured in a field experiment.

As mentioned in the introduction, Dr B. W. Bache contributed two papers[129, 130] on soil acidification at a meeting in Canada on Effects of Acid Precipitation on Terrestrial Ecosystems. Publication is also pending of five articles[134–138] prepared for an Encyclopaedia of Soil Science. 604

Potassium and Magnesium

Three accounts[139–141] of work started in 1975 on the short-term and long-term K supplying powers of selected Scottish soils, representing soil series with contrasting mineralogical composition, have been submitted for publication. Some of this work was described in last year's Report. Uptake of K reserves by ryegrass in pots was greater by a factor of a least 1·9 than the initially available K evaluated from the Quantity/Intensity isotherms. The initially available K, however, was a good index of K uptake over the entire cropping period, the closest correlation occurring after six cuts (34 weeks). The uptake rates suggest two categories of initially non-exchangeable K reserves. The release of both of these may be controlled by diffusion, because both show good relationships between K uptake and $\sqrt{\text{time}}$. One category, taken up at a faster rate and appearing after only a few weeks of cropping, is closely related to the initially available K, and should provide a useful source of K for grass grown in the field. The other category, taken up at a slower rate in the later stages of cropping, gives soil K diffusion coefficients ranging from 10^{-20} to 10^{-22} cm^2s^{-1}. This represents a long-term reserve of K which probably comes from the mineral matrix of the clay and silt size fractions. A detailed examination of the decomposition of these minerals at various stages of cropping should clarify this conclusion. In their ability to release the second category, the soils fall into three groups broadly consistent with soil series.

The intensity of the soil K was reduced in all the soils to a narrow range close to the mean value of 3 x $10^{-4}M^{\frac{1}{2}}$ for the equilibrium activity ratio, $AR^K = a_K \sqrt{a_{(Ca, Mg)}}$, corresponding to a K concentration of 3×10^{-5}M in 10^{-2}M $CaCl_2$ solution. The small individual variations about this mean are unlikely to preclude its use as a reference point for practical soil testing.

Laboratory tests have been carried out to examine possible release of K induced by changes in temperature and moisture content of soils which have been intensively cropped. The K status of the fresh depleted samples was not affected by freezing and thawing, but was raised when the soil was dried at 30° and then rewetted. The increases were inversely related to the percentage K saturation of the fresh depleted soils, and above a residual saturation of 1·4 per cent there was no release of K in this way. Laboratory and glasshouse investigations have also been started to examine release of K and Mg from sub-soils, and rates of K release from soils using electro-ultrafiltration are being compared with K uptake by ryegrass to evaluate the usefulness of this technique for predicting the K supplying power of soils. 611, 5206

Electrochemical Techniques

Further work has been done on the application of differential pulse polarography in concentrated nitric acid to determine molybdenum in soil extracts. The results should not normally be affected by the concentrations of common inorganic ions in such extracts, but the method has been found to be susceptible to interference by organic constituents. These, however, are readily eliminated by igniting an evaporated aliquot at 450°C for 4 h in a muffle furnace and then acidifying with a few drops of concentrated nitric acid before taking up in 10 cm^3 of the background electrolyte. Substantial lowering of the detection limit has been achieved by more sophisticated data processing. To this end an Intel SBC 80/10 micro-computer has been interfaced to a digital storage oscilloscope to provide a powerful signal acquisition and data processing system. Signals from a few millivolts to 200 volts can be accommodated and duty cycles from a few micro-seconds to over six hours can be accurately digitized. The digital data from the oscilloscope is read out to the microprocessor and stored in a laboratory built memory, with sufficient storage to accommodate two separate scans and further space for processed data. A programme residing in the microcomputer's own memory carries out ensemble averaging, background subtraction and digital filtering on the data received from the oscilloscope. This system has lowered the detection limit by a factor of four, to about 3 x 10^{-9} M in pure solution. Because of higher background noise, however, the detection limit is still not sufficiently low to measure molybdenum in water extracts of many soils. With the view to possible further development of the method, therefore, the precise reaction pathway of the electrochemical reduction of Mo^{VI} to Mo^{III} is being studied. 614

Soil Physics

Soil Energy Balance. A preliminary theoretical study of the energy balance at the soil-air interface has now been made. The basic framework of an

analytical model in which surface temperature appears as an explicit variable has been constructed to describe the balance for bare soil and, more approximately, for short vegetative cover. With the co-operation of the North of Scotland College of Agriculture, an experimental site has been established near Dyce Meteorological Station so that data recorded there can be used in applications of the model. Present instrumentation at the site includes thermistors for the continuous hourly recording of air temperature and of soil temperatures under both bare soil and short grass plots. Other measurements include hourly-integrated solar radiation, and spot measurements of surface reflection coefficients. An initial analysis of some of the field data is in process to facilitate further development of models for surface energy balance and soil temperature variation. The programme of field measurements will be expanded to include the monitoring of the soil water regime, using a neutron probe. This will allow both a more accurate evaluation of soil thermal properties and a direct comparison of measured and predicted evapotranspiration under field conditions. Since stones and gravel are major components of Scottish soils, it is intended, in due course, to study their influence on the energy balance at the surface, and theoretical analysis is being used to plan experimental work on their effects on thermal and moisture conductivity in the bulk soil. 612

Instrumentation. A battery-operated multi-channel magnetic cartridge data logger has been obtained and is currently being prepared for field use at the energy balance site. By eliminating much of the need for manual processing, this instrument will make possible quicker and more extensive analysis of field data. 612

Characterization of Soil Series. The experimental work has now been completed and the data are being processed for an initial evaluation of physical measurements for soil survey purposes. The main part of this work has investigated nine soil profiles from each of the following nine series: Countesswells, Tarves, Pitmedden, Terryvale, Insch, Tipperty, Balrownie, Corby and Stirling. Profiles from several other series have also been examined. Stone content was measured at the site and also bulk density using the displacement method. Triplicate core samples 55 mm x 74 mm diameter were taken from the main horizons for moisture content measurements at suctions of 0·01, 0·05 and 0·10 bar, together with triplicate cores 15 mm x 29 mm diameter for measurements at 0·5, 3·0 and 15 bar. The resulting moisture release characteristic has enabled pore size distribution and available water contents to be calculated. Particle size composition was measured by the hydrometer method. It has proved impracticable to make field measurements of saturated hydraulic conductivity by rapid methods, especially when, as in most arable land, the water table occurs at depth, but approximate values can be calculated from the pore size distribution measured in the laboratory. 612

Radioactivity

Radioisotopes are extensively used in soil and plant studies by several Departments, and advice, services and collaboration continue to be provided

throughout the Institute. To meet the continually increasing demands for counting of low energy beta emitting tracers, especially ^{14}C and ^{35}S, an additional automatic Liquid Scintillation Spectrometer, Packard Model 3255, has been acquired. A Packard automatic Gamma Spectrometer is also being obtained, to cater for increasing use of gamma emitting tracers, particularly ^{75}Se, ^{54}Mn and ^{65}Zn. A paper, mentioned in last year's Annual Report, on long term culture methods for the production of isotopically labelled plant material has appeared[42] and an account of collaborative work with the Department of Soil Organic Chemistry has been published[27]. 613, 5613, 601, 605, 305, 407, 512

Advisory Work

Nearly 6,400 soil samples submitted by the Advisory Officers of the North of Scotland College of Agriculture were examined during the year. Except for 154 samples from horticultural areas these all came from agricultural land. Lime, phosphate and potassium status was assessed in all the samples, and magnesium in 660. In collaboration with the Department of Spectrochemistry, trace elements were determined in 550 soils and 92 crop and herbage samples. Most of the problems concerned related to animal health, necessitating estimation of cobalt in most of the samples and molybdenum in nearly 220. Problems of crop growth also continue to be encountered, and samples of barley plants from about 20 fields with suspected manganese dificiency were analysed. Plant samples from the deficient areas taken during late May to early June contained less than 15ppm Mn in the dry matter and the soils normally had less than 2ppm exchangeable Mn. 610, 5205, 5206

Four instances of patches of poor growth were examined in the field. All were found to be associated with shallow topsoil, 15 to 20 cm deep, directly on a compacted subsoil layer. In the corresponding areas of good growth, the depth of topsoil was about 25 cm and the compacted subsoil layer did not start until 30 to 45 cm. In the fields concerned, however, the depth at which the compacted layer occurred varied considerably, sometimes even within a distance of 1 m. 610, 612

Numerous enquiries, mostly verbal, continue to be received from the Advisory Services and various agricultural sources concerning major and trace element requirements, the effectiveness of different forms, methods and times of application of fertilizers, and the value and possible hazards of waste products, especially sewage sludge. These enquiries are welcomed as an important means of channeling into practice the results of research and experimental work, not only from the soil fertility programme, but also from other Departments of the Institute. 610

To assist the Peat and Forest Soils section of the Department of Pedology, 119 soil samples from the forest nurseries were analyzed to assess requirements for phosphate, potassium, calcium and magnesium. In three of these samples the copper status was also examined. 608, 117, 5206

7. STATISTICS

R. H. E. INKSON

The main activities of the department are concerned with the provision of specialized advice and services in the application of statistical methods. The subject areas covered include the planning of experiments, with the choice of the appropriate design and consequent method of statistical analysis, model-building, data processing and computer operation and programming. The project numbers referenced below show that all departments and all project packages are featured in the year's work.

Members of staff have attended meetings of the Biometrics Society, the Royal Statistical Society, the Mathematical Ecology Group, the ARC Crop Science Model-Builders' Group and of ARS statisticians, a Symposium on the Soil-Plant-Animal Interface, and a conference on the Design of Experiments arranged by the Sir Ronald Fisher Memorial Committee. Mr R. H. E. Inkson attended the Eleventh International Congress of Soil Science in Edmonton, Canada, and a symposium on 50 years of Biometry at East Malling Research Station.

Computing Service

The department is responsible for the management and development of computing facilities, the necessary programming support and data preparation equipment. The IBM 1130 and System/7 installation has a card read/punch, a paper tape reader, a graph plotter, a line printer and operator consoles. A direct link to the IBM 1130 *via* the paper tape reader interface has been provided for a Ferranti Cetec Digitiser. During the year a Commodore PET desk-top computer was purchased. It has a 14 kilobyte memory for the resident operating system and 8 kilobytes of user memory, a keyboard, a 9 inch video display unit and cassette storage. The programming language is BASIC.

The soil data bank working group has designed a simplified coding form for the transcription of profile information from the accummulated " historical " records. This will allow a large amount of valuable information to be brought into the files. Mr D. A. P. McKay, an ARC postgraduate research student, has continued work on a pilot study which includes four soil associations and 430 profiles. A study has been made of the normality of the distribution of soil properties and of the associations between them.

701, 703

Improvements and additions have been made to programs in the statistical library. 701, 703

Pedology. Vegetational data from sites in nine peatland areas have been added to those already stored on file. Cover abundance matrices have been produced for these areas and the programme of classification analysis of the stored data by various clustering techniques continues. A data processing service has also been provided for a study of air/water relationships in volume samples from Lewis peatland reclamation schemes.

110, 112, 701, 703, 5703

A new series of programs is being developed for reading, storing and plotting x, y and z co-ordinates from a Ferranti Cetec Digitiser which has a direct link to the IBM 1130 computer. The data stored can be used for digital thematic mapping of information such as peat, vegetation and soil categories, and also for digital terrain modelling, e.g. contoured relief maps, profiles or sections. A combined analogue and numerical method for digital rectification of any given stereo-pair of photographs on the stereoplotter is being developed on the Commodore PET computer. 112, 703, 5703

The punching and processing of data from X-ray silicate analysis and from the analysis of rainwater, peat samples and plant material (mostly foliage, bark, etc., of trees) continue on a regular routine basis. There has been an increase in the plotting against time of data such as mm rainfall and the amounts of elements present in the rain water reaching the forest floor by various routes for a number of experiment sites.
104, 111, 112, 114, 115, 116, 117, 703, 5703

Spectrochemistry. Collaborative work is continuing on the development of a computer-based storage and retrieval system to facilitate the analysis and classification of trace element data in relation to other soil properties such as texture, pH, cation exchange capacity, mechanical analysis, etc. Assistance has also been given to members of staff and visiting research workers in the use of existing programs for the processing of data from infra-red, Mössbauer and electron paramagnetic resonance (EPR) studies which have continued on a regular basis. 101, 201, 203, 207, 701, 703, 5703

Microbiology. Coulter Counter data on kaolin in distilled water have been processed by the dual theshold program JACCO. Investigations have continued on the comparison of different methods of estimating the density of organisms in bacterial cultures using data obtained by the dilution series method. 513, 514, 701, 703, 5703

Soil Fertility. Regular use is made of programs that have been developed for the input and processing of data, analysis of variance, and correlation and regression analysis. A new program modification allows for repetitions of the zero level of one factor at each level of another factor.
703, 5701, 5703

Soil Survey. The program for the processing of plant sociological data is in regular use. Plant community tables are produced, examined visually and repeatedly modified until the best groupings of species and sequences of stands are obtained. Habitat factors of each stand are stored permanently on disk so that a listing of these factors can be made for each plant community established. Similarly soil factors for stands (not on a one-to-one correspondence with habitat factor records) are available for listing whenever needed. A data storage and retrieval system is being established for soil and site data of profiles on soil complexes at Ardnamurchan, Morven and the Isle of Mull. 801, 802, 703, 5703

Advisory and Collaborative Work

Pedology. Field sampling procedures for whole tree sampling have been modified and the computer programs amended accordingly. Further NPK

experiments of central composite design with additional control treatments have been planned for Sitka spruce seedlings in the glasshouse. Both forest and glasshouse experiments in this series regularly provide data for processing and statistical analysis. Such data includes annual growth assessments, concentration of elements in rainfall components, weight and chemical composition of a range of tree parts. In addition to the standard analysis of variance, response equations and response surfaces have been fitted and compared for factorial and central composite designs. Random sampling schemes have been prepared for a number of experiments.
115, 117, 701, 703, 5701, 5703

An account[12] of a study of the nutrient content and other properties of peat from planted and unplanted sites, described in last year's Report, has now appeared. 116, 5701, 5703

Three climatic factors, mean annual temperature, altitude and precipitation, have been used in correlation and regression studies with pyrogram ratios for whole soil, sand, silt and clay. 108, 5701, 5703

Spectrochemistry. Correlation and regression analyses were used to investigate further the relationships of extractable and total lead with other soil properties for six soil associations. 201, 5701, 5703

Soil Organic Chemistry. In work on the activity of sugars the logarithmic transformation was used since the standard deviation was found to be proportional to the mean for properties such as xylose expressed as a percentage of total sugars and ratios of the total activity of different sugars relative to xylose. In a factorial experiment on this subject the sub-class numbers were disproportionate. In an experiment on lemna the observations examined were reducing sugars, sugar activities and RNA. Models of an exponential type of decay, $y = Ae^{-kt}$, and hyperbolic type, $1/y = a + bt$, have been used to relate the percentage of sugars remaining in soil during decomposition of grass to time. 305, 311, 701, 5701

Plant Physiology. A joint account of experiments on cabbage and cauliflower with nitrogen, calcium and molybdenum factors, mentioned in last year's Report, will appear in the proceedings of the Long Ashton Symposium on Nitrogen Assimilation of Plants[125]. Other collaborative work which has reached the publication stage includes series of experiments on plant leaf composition[123], factors affecting the growth of Lemna[120], and a study of blossom end rot in tomatoes[124]. 401, 402, 5701, 5703

The effects of inhibitors and other factors on the growth rate of Lemna, measured on a logarithmic scale, have been assessed from a range of experiments. From experiments on a number of different crops, standard methods of analysis of variance and covariance have been used to examine nutrient contents, their ratios and relationships. 401, 402, 5701, 5703

The nutrient content and the catalase and peroxidase activities of potato core sections from heel to rose end have been examined by curvilinear regression to establish the pattern of variation. Joint accounts of this work[126, 127] have been accepted for publication. 402, 5701, 5703

Microbiology. Analysis of variance has been used in a number of experiments designed to test the effects of different factors on such variables as microbial counts, microbial respiration in soil, microbial decomposition of plant roots, CO_2 evolution and measurements of pH, NO_3^- and NH_4^+ in soil. The microbial counts were obtained by one of the computer programs referred to above and using the dilution series method. 512, 513, 5701, 5703

Soil Fertility. The field experiment programme contains 46 new or continuing experiments which will provide data for processing and statistical analysis. The designs include randomized block, factorial arrangements, with and without confounding, split-plot and central composite designs, lattice squares and a hyper-Graeco-Latin square.
601, 603, 607, 608, 609, 701, 5701

In summarizing the results from a group of 21 NPK (4^3) experiments on potatoes a subroutine was written to obtain the mean values for the 4 levels of one factor averaged over selected combinations of the levels of the other two. A considerable amount of computing and statistical evaluation has been done on data from three series of phosphate experiments—121 field experiments on swedes, 26 field experiments on potatoes and 72 pot experiments on oats. The ultimate objective is to classify the phosphate status of the soils according to their responsiveness. So far linear, parabolic and hyperbolic equations have been fitted to the various sets of data using each of six different soil phosphorus values and testing the addition to these equations of pH and/or percentage loss on ignition. Soils types have been treated separately and also combined. 601, 608, 701, 702, 5701, 5703

Analysis of variance, and correlation and regression methods have been used in experiments on surface tension, saturation vapour pressure, sulphur supply, soil copper status, swede variety trials and barley experiments with soil pH as a factor. 601, 604, 606, 609, 612, 5701, 5703

A further series of field experiments has continued the study of the pattern of growth and development of barley and swedes. Regression equations have been fitted to selected groups of data from the accumulated results, relating straw loss and grain yield. To the recorded dry weight and tiller or ear number throughout the growing season, two methods of smoothing have been applied. Fitting quadratic curves to successive sets of five points in time was superior to fitting straight lines to successive sets of three points in time. 607, 701, 5701, 5703

Soil Survey. Data processing and tests of significance have been done in a study, over a period of years, of tree growth in coniferous forests. Nine different areas and several species were included. Tests have been made of the relationship between the presence or absence of an A_2 horizon and other soil properties of the Hythie soil series. 801, 802, 5701, 5703

8. SOIL SURVEY

R. GRANT

An important development affecting the programme of the department has been the formal request from the Department of Agriculture and Fisheries for Scotland to implement the proposed scheme for a more rapid survey of the remaining unsurveyed areas, mainly upland, of Scotland. This survey will record the information on soils and vegetation necessary for the production of a set of maps at a scale of 1:250 000 for the whole country, to be followed by corresponding maps giving land use capability assessment for agriculture and for forestry. To enable the Survey to complete the task in the agreed time provision has been made for the necessary additional staff, transport and support.

A start has been made with the new survey and approximately 7000 km^2 have been completed, mainly in the north-west, west and south-west. In all other areas preliminary reconnaissance work has been carried out.

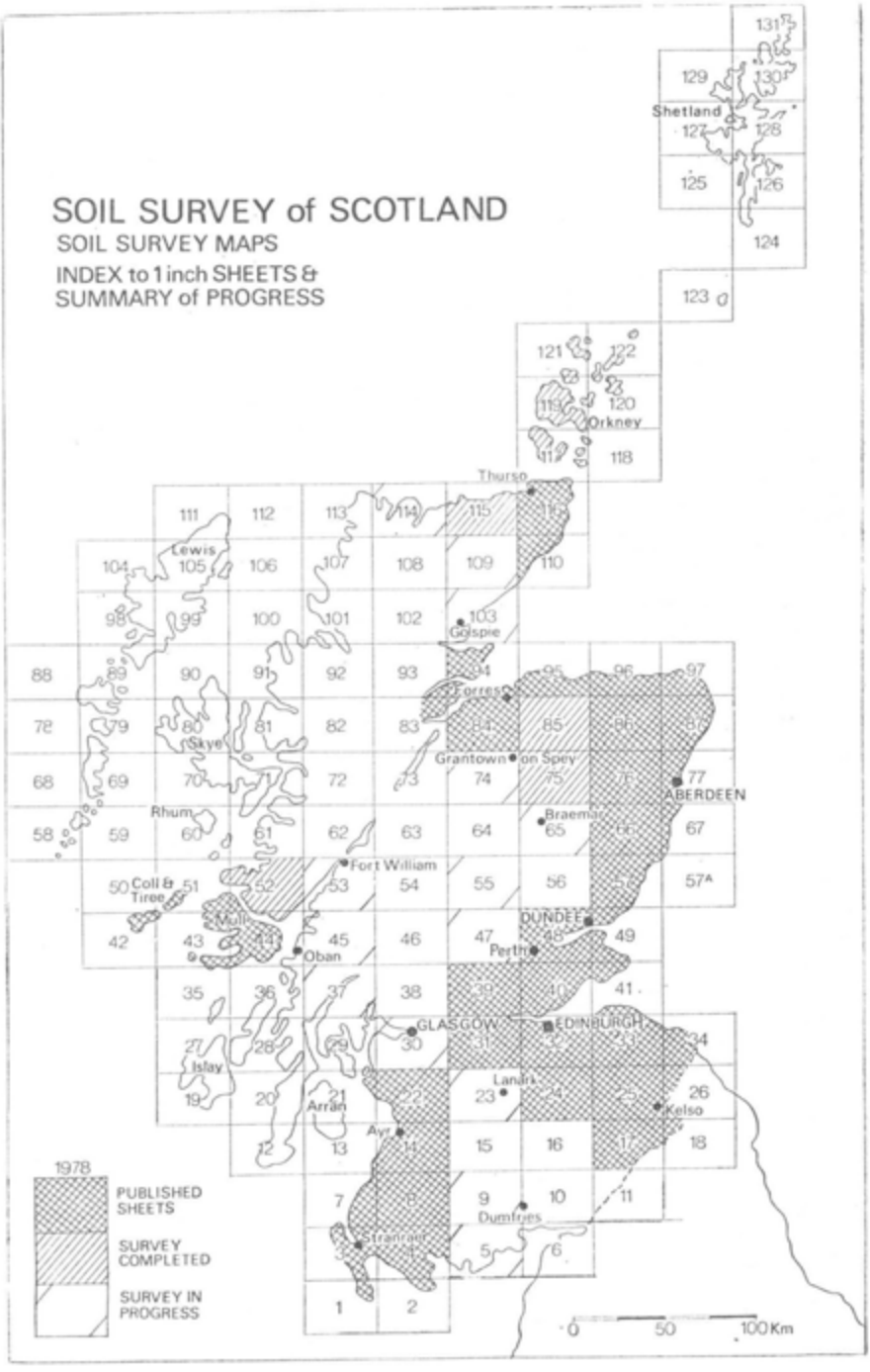
Although the systematic survey for the production of soil maps at 1:63 360 will be suspended temporarily, during the current season some 250 km^2 of survey at 1:25 000 has been carried out on Sheets 119, 120, 121, 122 (Orkney), 74 (Grantown), 47 (Crieff) and 23 (Hamilton). Sheet 95 (Elgin) has been revised for publication with Sheet 85 (Rothes) as a combined sheet. Five special surveys at larger scales have been made.

Work has continued on the backlog of land use capability assessments for published soil maps. Sheets 25 (Kelso), 26 (Berwick-upon-Tweed), 87 (Peterhead), 97 (Fraserburgh) and 95 (Elgin) have been completed, and on Sheet 86 (Huntly) about 100 km^2 have been revised and assessed.

One hundred and fifty-four profiles have been described and sampled for analysis.

Members of staff have attended the meeting of the British Society of Soil Science at Exeter, where Mr R. Grant contributed a paper to one of the symposia, and the meeting of the Scottish Ecological Group in Caithness. Mr J. S. Robertson attended the Joint Meeting of the British Ecological Society and the B.S.S.S. at York on Soil-Plant Relationships in Reclamation of Derelict Land. Mr J. M. Ragg attended the 11th Congress of the International Soil Science Society in Edmonton.

The department continues to be represented on the Ordnance Survey Advisory Committee, the DAFS Field Drainage Group and West of Scotland Field Drainage Group, the DAFS Working Party on Hill Land Classification, the Scottish Development Department Working Party on Rural Land Use Information Systems, and the MAFF/ADAS Working Party on Land Use Capability Classification, where attention has been given to the development of a unified land classification for Britain, to the definition of its classes and to guidelines for their recognition. The department welcomed two new surveyors, Mr J. S. Bell and Mr J. A. Hipkin, and was pleased to have Mr R. Siebinga, a student from the Agricultural University, Wageningen, (Netherlands), work with the Survey during the field season.


SOIL SURVEY of SCOTLAND
SOIL SURVEY MAPS
INDEX to 1 inch SHEETS &
SUMMARY of PROGRESS
Shetland
Orkney
Thurso
Lewis
Golspie
Forres
Grantown on Spey
Skye
Rhum
Braemar
ABERDEEN
Fort William
Coll & Tiree
Mull
Oban
DUNDEE
Perth
GLASGOW
EDINBURGH
Islay
Arran
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SURVEY COMPLETED
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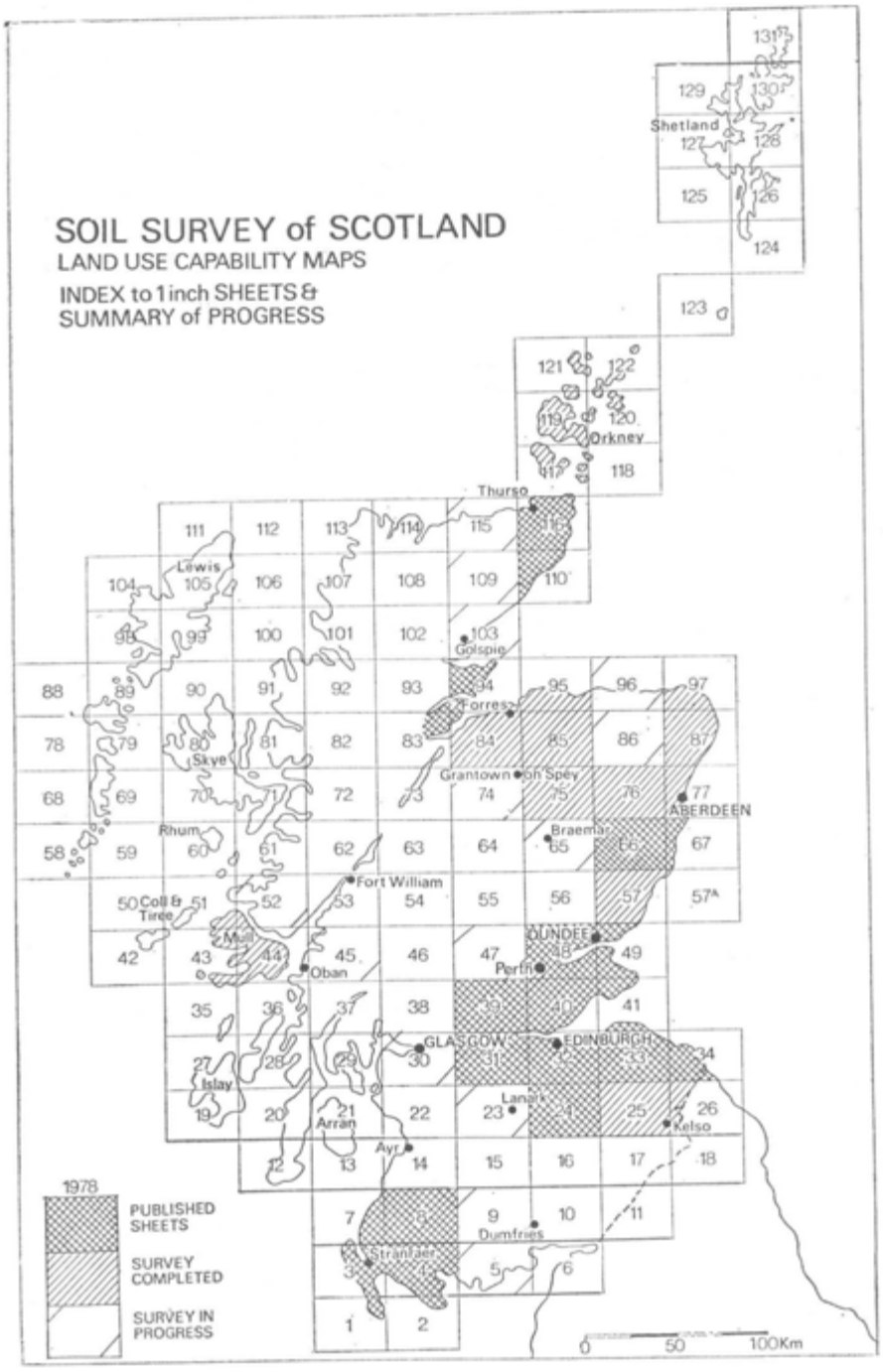
SOIL SURVEY of SCOTLAND
LAND USE CAPABILITY MAPS
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SUMMARY of PROGRESS
Shetland
Orkney
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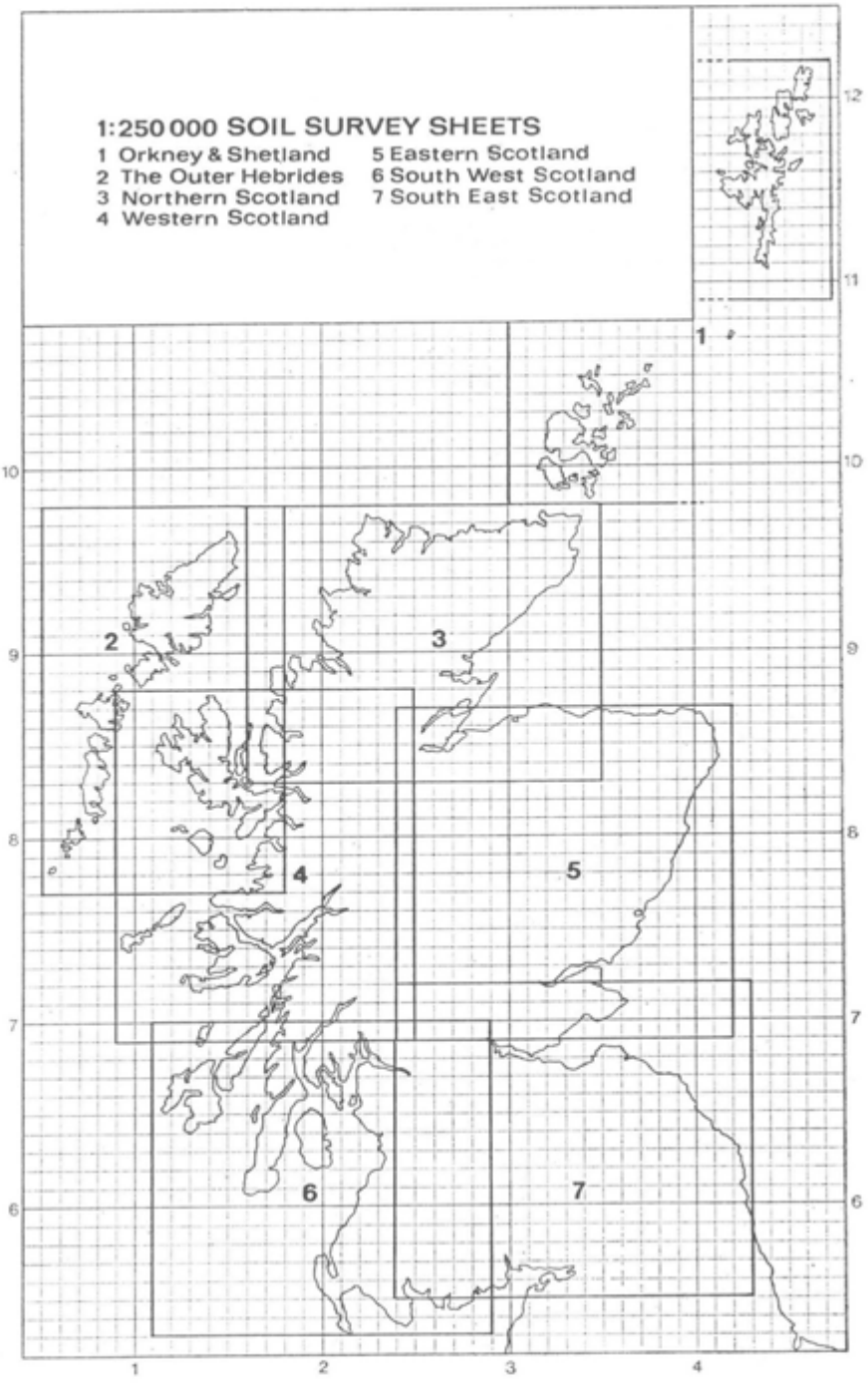
1:250 000 SOIL SURVEY SHEETS
1 Orkney & Shetland
2 The Outer Hebrides
3 Northern Scotland
4 Western Scotland
5 Eastern Scotland
6 South West Scotland
7 South East Scotland
1
2
3
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A new Soil Survey Office has been acquired in the premises of the East of Scotland College of Agriculture in Perth. 801, 802, 804

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

With the surveying of the islands of Egilsay, Fara, Flotta, North Ronaldsay, Shapinsay and Wyre—a total of approximately 50 km², the soil and land use capability surveys of the Orkney Islands group were completed. No new soil associations or series were encountered, the landscape being dominated by soils of the Canisbay, Thurso and Fraserburgh Associations. Revision continued, particular emphasis being placed on the distribution of the deep-topped phase of the Bilbster series and on further consideration of the areas of Sordale complex and Ulbster complex. Correlatory visits were made to Westray and Hoy. With the completion of mapping, a soils key has been drawn up and work has begun on the soils memoir and maps.

A preliminary summary of the soils is given later in this report. 801

1:250 000 Survey. Sheet 3 (Northern Scotland)

The area surveyed covers about 2000 km² of north-west Sutherland. It lies approximately north of Kylestrome and west of Bettyhill, but excludes the previously surveyed land between Loch Eriboll and Kyle of Durness.

A provisional list of soil associations and mapping units was first compiled, based on soil survey information available for the eastern half of Sutherland, the Durness district and part of Wester Ross. Air photographs (scale 1:20 000 or 1:26 000) were examined and provisional units identified and delineated. Land use capability classes and subclasses were tentatively assessed for each unit. Field work consisted of checking the air photograph interpretation and collecting descriptions of soil, site and vegetation.

The mapping units in each association are complexes of major soil subgroups, each associated with a particular type of topography. The most common soils are peat, peaty gleys and peaty gleyed podzols; brown forest soils, humus-iron podzols, non-calcareous gleys and oroarctic soils occur far less frequently. Parent materials are coarse textured and stony. Vegetation is predominantly moorland, the most common communities being moist Atlantic heather moor, bog heather moor, blanket bog, and upland variants of all three.

Most of the area may be classified as belonging to land use capability Classes 5 and 6, the major limitations being wetness, climate, topography and soil.

Soils of the Strichen Association predominate in the eastern part of the area and are developed on parent materials derived from the underlying Moinian granulites and schists. The most common mapping units are gently rolling moorland with peat, peaty gleys, and peaty gleyed podzols; moderately rocky, rolling landscape with peat, peaty gleys and peaty rankers; and areas of hummocky drift (moraine) with peaty gleyed podzols and peat. Oroarctic soils are present on the higher ground in the western part of the Moinian area.

Soils developed on parent material derived from Lewisian gneiss (provisionally the Lochinver Association) occur in the west of the area. A map-

ping unit of rocky, strongly rolling topography with peat, peaty gleys and peaty rankers covers much of the area.

Soils of the Durnhill Association are present on the narrow strip of Cambrian quartzite lying between Moinian and Lewisian rocks. The main mapping units are rocky hills with oroarctic soils and lithosols, and moderately rocky ground with peat and peaty gleys.

Soils developed on parent material derived from Torridonian sandstone, provisionally named the Torridon Association, are present in the far northwest of the area. The main landscape units are gently rolling moorland, moderately rocky slopes, and exposed hill summits. At the time of writing, much of this association has still to be investigated.

Soils developed on parent material derived from the syenite in the Ben Loyal district have been placed in the Countesswells Association. Mapping units include non-rocky areas with peat and peaty gleys and high ground with oroarctic soils.

As well as being a major constituent of many mapping units, peat is sometimes sufficiently extensive to be mapped separately. Two units, deep peat and undifferentiated peat, have been used. The most extensive areas of peat occur in the area of Moinian rocks. 801

Sheet 87/97 (Peterhead/Fraserburgh)

The main land use capability assessment of this area has now been completed with the classifying of 310 km² this season. Class 3 land predominates, covering approximately 80% of the area, and further assessment of this class is now being made in order to assign the land to one of three sub-divisions.

About 1 km² of Class 2 has been mapped, most of the land being in the Allathan area on soils of the Foudland Association. Class 4, accounting for about 5% of the area, is widespread and includes shallow and very stony soils, peaty gleys, some peaty podzols, and Fraserburgh Association and Links soils. It is common on the Countesswells, Durnhill, Hatton and Skelmuir Associations. Most peat has been assessed as Class 5 which occupies just over 5% of the area. Class 6, covering less than 5% of the area, comprises the peaty podzols (Durnhill series) of Mormond Hill, coastal dunes, and some steeply sloping ground as in the Tore of Troup. Class 7 is confined to sand and gravel pits and coastal cliffs. 801

Sheet 95 (Elgin)

The soil map of this area has been revised. Additional mapping units on alluvium and on the raised beach, storm beach and blown sand deposits have been separated, and a few areas of Kindeace Association soils have been mapped. Air photographs aided the revision of the soils of coastal areas, Monaughty Forest, and the moorland around the Hill of Stonyslacks.

The land use capability of Sheet 95 has been assessed. West of Elgin on loamy alluvium of the River Lossie 0·3 km² of Class 1 has been mapped. Carden Association and some Duffus Association soils have been rated as Class 2, as have deep topsoil areas on till and fluvioglacial sand and some alluvium. The class occupies about 5% of the area. Class 3 land is the

most extensive and covers two-thirds of the area. Poorer Corby and Boyndie soils have been assigned to Class 4. They often occur on moundy topography as around Lhanbryde. Shallow stony soils of Monaughty Forest and Whiteash Hill and soils on stabilized blown sand bring the total area of Class 4 to about 70 km² or roughly a fifth of the area. Land in Classes 5 and 6, with a total of about 10% of the area, comprises blown sand and storm beach deposits together with moorland soils around Hill of Stonyslacks and areas of mixed bottom land. Class 7 is limited to sand and gravel pits and contemporary beach deposits. 801

Sheet 86 (Huntly)

Revision and land use capability assessment have begun and approximately 100 km² have been surveyed to the south and south-east of Huntly. 801

1:250 000 Survey. Sheet 5 (Eastern Scotland)

Soil and land use capability mapping for publication at the 1:250 000 scale has been carried out in areas of one-inch Sheets 64 (Kingussie) and 65 (Balmoral), and approximately 450 km² have been surveyed. Soils of the Countesswells, Strichen, Foudland, Tarves, Durnhill, Insch, Leslie, Aberlour and Corby Associations have been distinguished.

Below about 700 m the most extensive soils are subalpine podzols, peaty podzols and humus-iron podzols which support boreal heather moor and native pinewood and coniferous plantations. Peat is also extensive, the vegetation usually being mountain blanket bog. Mineral soils (brown forest soils, cultivated podzols and non-calcareous gleys) occur up to 600 m and are often on the more base-rich parent materials. On these soils there are several communities which include *Nardus* grassland (often a richer variant with alpine bistort, *Polygonum viviparum*), herb-rich boreal heather moor, bog myrtle scrub, and rye-grass—crested dog's tail pasture. Because of the small mapping scale, it was seldom possible to map soil series individually, and soil complexes were used. These included complexes of podzols and peaty gleys with and without peat, a mineral and peaty soil complex, and a complex dominated by rock or scree.

Above 700 m alpine soils are extensive. On the granite and quartzite-derived soils of the Countesswells and Durnhill Associations respectively a complex of oroarctic soils, boulder lobes, rock outcrops and scree is predominant. On the Strichen, Foudland and Tarves Associations, however, oroarctic soils have also been mapped, alone or as a soil complex with peat. The vegetation on oroarctic soils below about 1000 m is usually *Loiseleuria*—woolly fringe-moss heath, but in the south-western sector of Sheet 65 and on Sheet 64 the brown bent—woolly fringe-moss heath is also present. Above 1000 m three-leaved rush heath is the dominant community.

Class 3 land occupies a very limited area, on some of the alluvial and Corby Association soils in the Dee Valley downstream from Balmoral. Class 4 land occurs below about 380 m and Class 5 land is sometimes found as high as 440 m, but land in Classes 3, 4 and 5 combined occupies a much

smaller area than Class 6 land which extends to about 700 m. Land above about 700 m, and areas dominated by rock or scree, have been assessed as Class 7.

Fifteen profiles were described and sampled for analysis. The majority of the profiles were systematically located at 10 km grid intersections. 801

Sheet 74 (Grantown-on-Spey)

The start of the field season saw the secondment of one of the team to Central Scotland, prior to the opening of the new regional office at Perth.

To facilitate the change-over from the normal systematic soil survey to the soil mapping project at the scale of 1:250 000, a limited amount of field work at the scale of 1:25 000 was undertaken. During this operation a further 24 profiles were exposed by the Smalley excavator, of which 13 were sampled. Damage to the towing Land Rover, and a long delay awaiting spare parts, curtailed the original profile programme.

1:250 000 Survey. Sheet 5 (Eastern Scotland)

The area allocated to the Grantown-on-Spey office for the 1:250 000 soil and L.U.C. maps is roughly triangular in shape, covering *ca* 5200 km². It is bounded by a north-south line through Loch Avon, an east-west line through Glen Spean with the Great Glen limiting the area to the north-west. Lying within that part of the Grampian Highlands described by the Geological Survey as the Northern Grampian Nappe Complex, excluding the " Ballappel " area, it is made up mainly of rocks of the Moinian Assemblage with major intrusions of Granites and complexes of the " Newer Granite " association, together with the associated syntectonic migmatites. The derived soils should be accommodated within the Strichen, Countesswells and Aberlour Associations.

Along the shores of the Moray Firth and extending south-westwards to Foyers, occurs an extensive area of the middle division of the Old Red Sandstone. The Kindeace, Kessock and Mount Eagle Associations, together with the Drummossie complex, should account for most of the derived soils.

Outwith the latter region, and excluding the alluvial valleys of the Findhorn, Nairn and Spey-Laggan axis, much of the ground is mountainous. The altitude of the bulk of the Monadhliaths exceeds 700 m, whereas most of the Cairngorms exceeds 1000 m. These surfaces represent the remnants of a former peneplain, presenting an open rolling landscape with large embayments and rounded hills indented with massive corrie-cliffs. There is, however, a transition in a south-west direction. There the topography becomes more severely dissected with narrower and steeper valleys occupied by deep lochs and hummocky moraines. Such landscapes are transitional to those in the west already described. Pending correlation it is proposed to use the complexes and series already erected to accommodate similarly derived soils, especially the colluvial phases.

During July, soil survey was undertaken to the north of Calvine and west of Pitlochry from the new office in Perth. The field work was devoted to two main objectives—the establishment of mapping units for the produc-

tion of a 1:250 000 soil map and the examination of soils exposed during excavation on the 14-mile Calvine-Dalnaspidal section of the new A9 Trunk Road.

The soils along Loch Tummel are all developed on drift from acid schist of the Highland Series and most will be included in the Strichen Association. On the lower slopes of the valley, the drift is in the form of morainic mounds. Following correlation, this drift may be separated from the Strichen Association and included within the Dulsie Association. The dominant soils on the lower valley slopes have been tentatively correlated with the acid brown soils, as previously described on Sheet 47 (Crieff). Two such profiles have been described and sampled. The steeper slopes of the valley support well developed podzols or broad expanses of peaty gley. A further topographic unit occurs along the steep, rocky ridge crests, where a complex pattern of soils, including peaty podzol, peaty ranker, shallow and deep peat is present.

Soils belonging to the Corby, Dulsie and Strichen Associations have been distinguished along Glen Garry between Calvine and Dalnaspidal. The valley bottom is generally restricted in width so that alluvial soils tend to be absent. However, where the valley bottom does widen out, terraced Corby deposits have been identified. Moundy terrain is conspicious along the lower valley sides. These mounds may either be rock-cored, e.g. north of Calvine, with a thin veneer of stony gravelly loamy sand overlying schist rock, or may have an identical veneer overlying water-worked or heavy textured schist-derived till, e.g. at Edendon Bridge. 801

Sheet 47 (Crieff)

Approximately 70 km² have been completed during the current field season and the survey of the Crieff Sheet is now complete. Although some 30 representative soil profiles have been described and sampled this season, there still remains a good deal of sampling to be done and some final correlation and revision to be carried out.

The new mapping has included more of the complex Highland Border Zone between Crieff and Comrie where some new soils developed on an extensive diorite intrusion were encountered. There is very little drift cover over the intrusion and the soils are developed directly from the dioritic rock—they have tentatively been correlated with soils of the Insch Association of Aberdeenshire.

The soil pattern is extremely complex and many of the soils show trace element deficiency, especially cobalt. Other soils encountered have all been described previously and have been included in the Aberlour, Callander, Corby, Darleith, Doune, Foudland, Gourdie and Strichen Association.

Part of the field season has been occupied by preliminary reconnaissance work for the 1:250 000 survey of the Highlands. Areas outwith the normal survey areas have been visited with a view to formulating mapping units appropriate to correlate successfully with the already completed more detailed mapping. In this transition area from the drier east to the wetter west, it is especially important to set up mapping units which can properly represent this transition from one side of the country to the other. 801

1:250 000 Survey. Sheet 4 (Western Scotland)

The 1978 field season has been devoted to the 1:250 000 mapping programme requested by the Department of Agriculture Working Party on Hill Land Classification. Although weather conditions for mountain survey have been poor, an encouraging start has been made.

The West Scotland region extends to 14 300 km² of which 2600 km² have been previously surveyed at a scale of 1:63 360. Using mapping units similar in concept to those developed for the 1:63 360 programme (soil complexes based on parent material, major soil subgroups and topographic characteristics) 2900 km² have been mapped in the current season, principally in the Isle of Skye (1700 km²), North Lorn and western Rannoch Moor (1000 km²) and the Isle of Bute (200 km²). Aerial photographs at a scale of approximately 1:25 000 were used in the field to control ground traverses at maximum intervals of 5 km and for data plotting. These were subject to subsequent photo interpretation and the units recognised transferred to base maps at a scale of 1:50 000 which will be used for compilation of the 1:250 000 soil map. Sampling has been carried out at 10 km intersects of the national grid and on some agriculturally important soils that were not selected by this process (40 profiles). Profile descriptions have been taken at 5 km intervals and other inspection sites recorded on maps in the traditional manner.

Isle of Skye. Map units on the plateau basalts were similar to those found during the survey of the Isle of Mull. Considerably less rock is exposed in some parts of Trotternish Peninsula and a new complex consisting of peaty gleys and shallow peat, but without the rock outcrops characteristic of Cruachan complex was recognised. It was also possible to recognise and map complexes in which hagging peat was prominent in the upper oroboreal climate zone.

The soils derived from Mesozoic rocks are more extensive than on Mull, those in the south of the island being sandy and mapped in known complexes. In the Trotternish area, however, a clayey parent material gives rise to quite different soils. Much of the ground is covered by deep peat, but a complex of poorly drained non-calcareous gleys with humic and peaty channels forms agricultural land in the coastal fringe from Uig to Staffin.

The granites and gabbros of central Skye were mapped in the Countesswells and Insch Associations respectively, with the mixed parent materials of the Torosay Association playing only a minor role. In north Raasay and Rona acid gneisses of Lewisian age occur, while in Sleat rocks of similar age are more basic in character. Soils of an un-named association were identified in complexes on Cambrian limestone between Torrin and Broadford. A restricted area of quartzite was mapped in the complexes of the Durnhill Association, but the Torridonian rocks of north-eastern Sleat require a new association, provisionally named Torridon Association. The complexes within the Torridon Association are similar in landform to those of Strichen Association, but the soils are sandier.

Loch Etive—Loch Leven and Western Rannoch Moor. Much of the area is underlain by granite and the principal mapping units used had been

recognised in a previous survey. The morainic Sanda complex covered much of Rannoch Moor. Along the valley of the Tulla, however, extensive fluvioglacial sand and gravel deposits were found (Corby Association).

The quartzites of the Loch Leven and Glencoe areas were mapped in the Durnhill Association for which a new set of complex names will be necessary, and the Leven phyllites and slates which give a group of fine sandy and silty soils were included in the Foudland Association. An attempt was made to map the andesitic and rhyolitic rocks of Glen Coe into separate associations, but the relationships are complex and weathering of interbedded lavas frequently produces a mixed drift. Much of the ground is very rocky and a new association may need to be proposed.

The several limestone bands in the area are not sufficiently developed to afford separate map units although their influence on drift and vegetation pattern can be recognised occasionally.

The gravels of Ballachulish, Appin, Benderloch and North Connel have been mapped in the Corby Association and small areas of marine clay occur at North Shian and in the push-moraine of South Shian. The clays are very limited in extent and naming awaits further survey and correlation elsewhere. 801

1:250 000 Survey. Sheet 6 (South-West Scotland)

Isle of Bute. The northern end of Bute is underlain by Beinn Bheula Grits of Dalradian age and contains soils belonging to the Strichen Association. Central Bute has soils of the Foudland Association derived from phyllites with subsidiary sandstones also of Dalradian age, while the south of the island is underlain by rocks of Upper Old Red Sandstone age which have provided a red till as the parent material for many of the soils. Small areas of basalt lava occur at Ascog, Quien and Garroch Head which, although containing an element of drift from other sources, have been accommodated in the Darleith Association.

Raised beaches with soils of the Corby Association occur between Ettrick Bay and Kames Bay, but at some sites the gravels are almost entirely composed of phyllite and may require mapping separately at larger scales. Many areas mapped as raised beach by the Institute of Geological Sciences are cut in till. The raised beaches in the Kilchattan area are derived from rock of Old Red Sandstone age. They, like the red tills of the south of the island, have not yet been correlated with mapping units in other parts of Scotland. The red tills are extensively water-modified below 76 m and in some places ridges of red sand with free drainage are found in close association with the more usual imperfectly drained sandy loam and sandy clay loam soils. Apart from the sandy and gravelly soils of the raised beaches most of the cultivated soils of the island are gleys. Many probably had a peaty surface horizon, but this has largely been destroyed by cultivation and is seen only in a few remnants and on the higher ridge crests. 801

Sheet 23 (Hamilton)

Mapping has centred on two areas—south-west of East Kilbride and around Tinto Hill. Grid square NS93 has been completed which, together with mapping near the western margin of the sheet, accounts for 115 km^2.

The dominant soil around East Kilbride was found to be the Caprington series (Rowanhill Association) with the Darleith series (Darleith Association) occurring where the ground rises on to the Cunninghame Hills.

The Tinto Hills, an area of fine grained acid igneous rocks, form the dominant feature of grid square NS93 and give rise to mapping units of the Bemersyde Association. An area of fluvioglacial sands and gravels has been encountered adjacent to the River Clyde with the Symington series (Symington Association) forming the dominant mapping unit. To the north of the Tinto Hills soils of the Balrownie and Sorn Associations have been mapped while to the south-west, Sourhope Association soils have been identified. Much of the till to the north and east of the Tinto Hills is rich in both large and small fragments of felsite, as well as Lower Old Red Sandstone sediments. The soils developed in this till have been tentatively identified as unnamed mapping units within the Bemersyde Association. 801

Sheets 25 (Kelso) and 26 (Berwick-upon-Tweed)

A provisional assessment of land use capability classes and subclasses has been prepared using the soil maps published in 1959. Most of the original soil mapping units were found to form a satisfactory basis for this interpretation, but some revision has been found to be necessary. Alluvial soils were unclassified in the original survey and many of these areas have had to be re-examined. The imperfectly and poorly drained soil classes have also required reassessment. Many areas of poorly drained soils, especially in the southern parts of Sheet 25, have been found to be imperfectly drained while imperfectly drained soils, not originally identified in the Hobkirk and Lauder Associations, have had to be distinguished.

Some correlation has been initiated as a result of the Land Use Capability work referred to above. Imperfectly drained soils developed in a till of sandy clay loam texture have been identified around Earlston and Mellerstain (Ettrick and Roxburgh District). These soils are equivalent in almost all respects to the Largs series mapped to the south of West Kilbride. To the north of West Kilbride and around Largs the soils mapped as Largs series have been found to be freely drained sandy loams of the Hobkirk series as shown in Table 1. To the north-east of the village of Sorn, soils of the Reppoch Association developed in drifts derived from sediments of the Silurian system in the Hagshaw Hills have been re-examined. The rocks, of Downtonian age, consist of hard, grey greywackes and shales, and their derived drifts are identical with those of the Ettrick Association. As soils of Ettrick Association have already been mapped on similar drifts to the east of the Lesmahagow inlier (also of Downtonian age), it is proposed that the two soils associations be correlated as shown in Table 1. 801

1:250 000 Survey.

Sheets 6 (South-West Scotland) and 7 (South-East Scotland)

Mapping (1 : 250 000) has started to the south-east of the Douglas Water where provisional mapping units have been established on drifts derived from Lower Old Red Sandstone lavas and sediments. Existing soil maps (1 : 63 360) have been used as a basis for preparing manuscript maps of

TABLE 1

Correlation of soil series within the Hobkirk and Largs Associations, and the Ettrick and Reppoch Associations. Obsolescent series and association names are shown in italics.

Associaton	Parent Material	*Brown Forest Soils*		*Iron Podzols*	*Peaty Podzols*	*Non-calcareous Gleys*			*Peaty Gleys*	
		Freely Drained	Imperfectly Drained	Freely Drained	Freely Dr. below TIP*	Imperfectly Drained	Poorly Drained	Very Poorly Drained	Poorly Drained	Very Poorly Drained
Hobkirk *(Largs)*	Drifts derived mainly from Upper ORS sandstones. Some Lower ORS sediments may be present	Hobkirk	Largs	Harelaw	Faw *(Haupland)*		Cessford *(Kelburn)*		Wauchope *(Reoch)*	
Ettrick *(Reppoch)*	Ordovician and Silurian greywackes and shales and derived drifts	Linhope	Altimeg	Minchmoor	Dod *(Glen Garr)*		Little-shalloch			Dochroyle
	Clayey till derived from Silurian and Ordovician greywackes and shales					Kedslie	Ettrick *(Cleuch)*	Peden *(Cawdron)*	Alemoor	Hardlee *(Reppoch)*

* TIP – Thin iron pan.

parts of North Ayrshire, Lanarkshire and the Lothians. Most of the mapping units are based on the dominant series in association with other specified soils. Map legends have not yet been prepared and await decisions on legend format, content and correlation.

During the 1978 field season, survey from the Dumfries office has concentrated on the collection of information for the production of the 1:250 000 map sheets for South-West and South-East Scotland. In addition, 55 profiles have been described and sampled.

On one-inch Sheets 5 (Kirkcudbright) and 9 (Maxwelltown) mapping was carried out in two areas, previously unsurveyed at the 1:25 000 scale, in detail appropriate to the 1:250 000 scale. Along the south-west bank of the Water of Cairn between the Jarbruck Burn and the Old Water, the underlying rocks are greywackes and shales and the soils mainly those of the Ettrick Association. Tracts of alluvium occur along the river and a narrow belt of the Yarrow Association has been mapped on fluvioglacial and upper river terrace gravels bordering the alluvial areas. On the valley slopes the freely and imperfectly-draining brown forest soils of the Linhope and Altimeg series predominate while on the upper hill slopes and moors the Brochloch and Darnaw complexes are widespread.

In the area lying between Auchencairn, Gelston and Dalbeattie, on Sheet 5 (Kirkcudbright), the soils also belong mainly to the Ettrick Association. The area is characterized by an abundance of outcropping rock and the complex map units, Achie complex and Glenlee complex, are extensive. On some upper slopes, as on Screel Hill, areas of Darnaw complex have been mapped. Along the Potterland Burn and around Auchencairn Bay raised beach gravels carry soils of the Yarrow Association. Along the lower reaches of the Water of Urr grey estuarine silts and clays carry soils of the Stirling Association, and to the south of Dalbeattie the areas of severely eroded granite with an abundance of outcropping rock have been mapped as the Aerie and Dinnins complexes.

To the east of Dumfries, survey for the 1:250 000 map has been carried out throughout the greater part of one-inch Sheets 10 (Dumfries) and 6 (Annan). Between Dumfries and Bankend brown forest soils of the Holywood Association are developed on the thin drifts derived from the red sandstones and conglomerates of Permian age. Soils of the Yarrow Association are developed extensively on the fluvioglacial gravels around Locharbriggs south-east of which the Lochar Moss is one of the largest and best known low-lying peat mires in south-west Scotland.

The large and fertile basin around Loch Maben is underlain by Permian sandstones and conglomerates and the reddish brown loam and clay loam tills derived from these strata are generally thick and are often found to be deeply modified and watersorted in the upper layers. The soils are freely and imperfectly-draining brown forest soils of the Holywood Association, together with extensive areas of soils of the Yarrow series and alluvial soils.

Extending inland between the Solway coast from Clarencefield to Gretna a low undulating till plain is underlain by sediments of the Calciferous Sandstone and Permian periods. The reddish brown, plastic, clay tills

overlying these strata are generally thick and do not show any characters that can be consistently associated with differences in the underlying rocks. The tills and soils developed on them appear similar in most respects to those of north-west England. Brown forest soils with gleyed B and C horizons, together with non-calcareous gley soils, predominate. Fine textured grey sediments on the Post-Glacial raised beach carry non-calcareous gley soils of the Stirling Association and on the Late Glacial raised beach the gravels and partially-sorted tills carry free-draining brown forest soils. Between Dalton and Middlebie a few areas of the Darleith series have been mapped on shallow drifts derived from basic igneous rocks.

The most extensive soils, however, are those of the Ettrick Association developed on Silurian greywackes and shales and their derived drifts. In this area, east of the River Nith, the soils and their relationship to the landscape closely resemble the descriptions given for the Hawick and Jedburgh area. At Tinwald and Mouswald, at Lockerbie and in the Annan Valley south of Moffat, the drifts derived mainly from greywackes, are red in colour and the soils developed on these drifts have been grouped with those mapped around Castle Douglas and the Rhins of Galloway. 801

Special Surveys

Meikle Clinterty and Mains of Tertowie, Aberdeenshire. A detailed soil survey at a scale of 1:2500 was made of these farms (160 ha.) for the Clinterty Agricultural College.

Rahoy Estate, Morvern. At the request of the Highlands and Islands Development Board a soil map at a scale of 1:10 000 was prepared of Rahoy Estate, Morvern. The estate is being developed as a commercial deer farm and the map was used to determine compartmentation.

Melfort Estate, Kilmelford, Argyll. A survey was carried out and estimates of areas suitable for surface seeding prepared for the West of Scotland Agricultural College.

Rigg and Kellaside Farms, Kirkconnel, Dumfriesshire. At the request of the Department of Agriculture the soils of two proposed open-cast extraction sites have been examined, profiles of the main soil types described and sampled and a report on the soils and land use capability prepared.

Ballantrae-Auchencrosh Road Re-alignment, Ayrshire. At the request of the Strathclyde Regional Council a map showing the main soil characteristics along several proposed road alignments has been prepared.

Conrick Farm, Sanquhar, Dumfriesshire. At the request of the West of Scotland Agricultural College a soil map, at a scale of 1:10 000, of this 100 ha. farm which will be used for demonstration purposes has been prepared. 801

Vegetation Surveys

Sampling of the bracken and heather substitution plots at Glen Saugh, Kincardineshire, was completed in October. Soil samples from the two profiles collected were submitted to the Department of Pedology for routine

chemical and physical analyses. In addition special analyses will be carried out on the soil organic matter content by the Department of Soil Organic Chemistry.

A first copy of the vegetation map of the Cairnsmore of Fleet area was prepared from the field mapping on aerial photographs. Further work was carried out on the setting-up of the basic plant communities of the area, using the additional records collected during the summer of 1977.

During the summer months of 1978 the mapping of the Cairnsmore of Fleet vegetation was completed and further sampling of the vegetation was carried out to characterize the full range of vegetation encountered. In particular the hay fields were recorded just prior to mowing and the Arrhenatherion vegetation of roadsides and the former railway embankment was sampled in late summer.

At the end of August a reconnaissance of the vegetation of the North-West Highlands was carried out to select an area for a future intensive vegetation survey; the vicinity of Gairloch was chosen provisionally.

During the winter, the environmental data stored in the computer was revised and updated to include phytosociological records collected over the last three years. A provisional key to the common plant communities of Scotland was prepared and distributed to the soil surveyors for testing in the field.

The summer months were largely spent in visiting the survey teams involved in the Upland Survey. The purpose of these visits was three-fold: to check the surveyors' identification of plant species and communities, to gather phytosociological data for use in defining those communities, and to analyse any communities which had so far been either under-recorded or not yet encountered. The provisional key to plant communities will be amended in light of the experience gained in its application and will form the basis for a future publication.

The vegetation of the Orkney Island of North Ronaldsay (part of Sheet 122) was mapped at a scale of 1 : 10 000 using aerial photographs. The final map will be produced at a scale of 1 : 25 000. 802

Soil Micromorphology

After some intial modification and development work the new Jones and Shipman 540VS surface grinding machine is now fully operational and some 200 soil thin sections have been prepared. A set of soil monoliths has been specially collected and prepared for a North of Scotland College of Agriculture display at the 1979 Highland Show.

Twenty-seven profiles have been sampled specifically for the preparation of soil thin sections during the current year. These include a number collected in preparation for post-conference tours in Scotland following the 6th International Working Meeting on Soil Micromorphology to be held in London in 1981. Several more from archaeological sites at Carwinning Hall, Ayrshire, and North Mains, Auchterarder, Perthshire, were examined in collaboration with Scottish Development Department (Ancient Monu-

ments) Central Excavation Unit. Most of these profiles have been selected in connection with continuing studies on clay mobilization, translocation and deposit within the soil profile.

A paper on some characteristics of the brown forest soils of Scotland[8] has been published and a paper on the micromorphology of young soils from South-East Iceland[142] has been submitted for publication. A short account of the micromorphology of some buried soils in sand dunes at Torrs Warren, Wigtownshire, has been prepared. 804

Other Work

Collaboration has continued with the Department of Agriculture and Fisheries for Scotland and the three Scottish Colleges of Agriculture mainly on drainage problems and land classification. In particular, a number of DAFS Lands staff have spent some time with surveyors in the field, to be introduced to Soil Survey methods. Liaison with the Forestry Commission has included consultation on a Land Use Capability Classification for forestry, provision of a one-week course on Soil Survey for three head foresters, the describing and sampling of six profiles for a visit of the International Forestry Groups and on-site consultation on potential for grazing and forestry at Kennacraig and Achnancarranan estate.

Many requests for soils information continue to be received, especially from Regional and District Councils; for example, information on soil conditions on a pipe-line route from Nairn to Lossiemouth has been supplied to Moray District Council Planning Department and liaison has continued with the Highland Regional Council on site investigations for the A9 Trunk Road.

Liaison has also continued with the Nature Conservancy Council, the Institute of Terrestrial Ecology, the Highlands and Islands Development Board, the Countryside Commission, the Scottish Institute for Agricultural Engineering, and, increasingly, with other Departments of the Institute.

Talks on the work of the Soil Survey has been given to a joint conference of the Royal Scottish Forestry Society and the Royal Highland Agricultural Society, to students of various departments of the Scottish Universities and to local societies. Field excursions have been organised and led for students of the Geography Department, St Andrews, the Department of Biological Sciences, Dundee, and the Forestry Department, Aberdeen, and soils have been demonstrated in the field at three meetings of the Royal Scottish Forestry Society.

Papers on the characteristics of brown forest soils[8] and the use of air photo interpretation for land evaluation[43] have been published, as have two Floras[44, 45], one including a chapter on soils and the other a chapter on geomorphology and soils. A paper on the moisture regimes of six soils[143] and a note on land use capability evaluation[144] have been accepted. An account of the soils of the county has been written for inclusion in "The Sutherland Book"[145]. 801, 802, 804

Maps, Memoirs and Cartography

The 1 inch Soil Survey map and the 1 inch Land Use Capability map for Sheet 31 (Airdrie) have been published.

Colour proofs of the Land Use Capability maps for Sheet 57 (Forfar) and combined Sheet 84/94 (Nairn/Cromarty) have been corrected and returned to Ordnance Survey for final printing. Colour proofs for Land Use Capability combined Sheet 35/36/43/44/51 and 52 (Island of Mull) have been received from Ordnance Survey and are awaiting examination.

The scribed negative and colour model for Soil Survey combined Sheet 85/95 (Rothes/Elgin) has been sent to Ordnance Survey for colour proofing. Scribed negatives and colour models for Land Use Capability combined Sheets 76/77 (Inverurie/Aberdeen), 85/95 (Rothes/Elgin) and 87/97 (Peterhead/Fraserburgh) have been completed and are being held in abeyance whilst additional consultation is undertaken. Work has started on the scribed negative and colour model for Soil Survey 1:50 000 combined Sheet 52/44/51 (Ardnamurchan and Morvern).

Topographic base maps to cover the whole of Scotland on the scale of 1:250 000 have been designed and work on their compilation is proceeding. The country is covered by seven sheets which are based to a large extent on components of the Ordnance Survey 5th Series 1:250 000 maps.

The following limited circulation maps have been prepared: Soils of Rahoy Estate, Soils of Conrick Farm, Sanquhar, Soils of Bakrajon Research Farm, Iraq, all on 1:10 000 scale; Land Use Capability of Gatehouse of Fleet on 1:25 000 scale and Soils of Ardnamurchan on 1:50 000 scale.

Fourteen sheets have added to the uncoloured 1:25 000 Soil Survey field sheets for restricted circulation: three from the Moray Firth area, one from the Aberdeen area, one from Ayrshire, two from West Lothian and the remainder from Fife.

Microfilm recording of the Soil Survey's original field sheets has been started and to date 401 aperture cards have been produced.

The memoir to accompany Sheets 1, 2, 3 and 4, The Soils of the Country round Stranraer and Wigtown[146], is at the proof stage.

Papers on Soil Survey maps[46] and the design and production of 1:25 000 multicolour land use capability maps[47] have been published. 801

SOILS OF ORKNEY

The Orkney archipelago comprises some 90 islands and skerries extending 80 km from north to south and 62 km from east to west with a land area of approximately 970 km^2.

Geology

The Orkney Islands consist almost entirely of relatively gently inclined sedimentary rocks and subordinate lavas and tuffs of Middle and Upper Old Red Sandstone age. A crystalline Basement Complex composed of metamorphic rocks of Moinian types and Caledonian granites crops out as a series of inliers within a north-west-trending belt extending from the

Island of Graemsay to Yesnaby, the largest outcrop forming the hilly ground immediately north and west of Stromness. A high proportion of the complex is made up of coarse, pink or greyish, poorly foliated granite which grades locally into granite-gneiss.

The general succession is:

Upper Old Red Sandstone	Hoy Sandstones
	Hoy Volcanics
Middle Old Red Sandstone	Eday Beds
	Rousay Flags
	Upper Stromness Flags
	Lower Stromness Flags
Moinian	Basement Complex

The Stromness Flags and the Rousay Flags consist largely of flagstones and are made up of rhythmic sequences of thinly bedded and, in part, laminated grey and black carbonate-rich siltstones and silty mudstones alternating with generally thin beds of fine-grained sandstones or sandy siltstones. The Eday Beds comprise three sequences of yellow and red sandstones with pebbly lenses, the Lower, Middle and Upper Eday Sandstones separated respectively by the Eday Flags and the Eday Marls, a sequence of interbedded red sandy and micaceous marls, red and green marly sandstones and occasional yellow sandstones.

Beds of the Upper Old Red Sandstone are confined to the Island of Hoy and consist of red, pink and yellow sandstones with subordinate bands of marl. The sandstones are underlain by a variable thickness of basalt lava and tuff which rests on an eroded surface floored by faulted and gently folded members of the Middle Old Red Sandstone sequence.

With the exception of western Hoy, Rousay and western Westray, the Orkney Islands have a gently undulating landscape of subdued relief. The dominant characteristic of the topography is its drowned appearance. The hills of north Hoy excepted, most hill slopes are convex, the lower, normally concave, slopes being submerged with the many bays and sounds representing drowned valleys. Submersion was such that river systems were severely truncated and only small streams remain.

Landform Regions

For descriptive purposes the island group can be divided into four units.

1. The East Mainland, the south isles, the Longhope district of the parish of Walls, Hoy and the north isles with the exception of Rousay and western Westray.
2. The West Mainland, i.e. the Mainland area west of Kirkwall.
3. Western Hoy.
4. Rousay and Western Westray.

Unit 1 offers a gently rolling landscape of low and open relief with geological influences on topography modified by drift cover. A number of south-west to north-east or south to north-trending ridges and escarpments

reflect the influence of geology and particularly, the presence of thick resistant beds of sandstone upon topography. Areas of hummocky moraine-like drift occur in the south-western part of the parish of Holm and in the Toab area of the parish of St Andrew and Deerness.

The West Mainland of Orkney has an amphitheatre-like appearance, a low-lying interior with a mean height of about 15 metres, that area occupied by the Loch of Harray and the Loch of Stenness, and a surrounding girdle of rounded hills. The hills reach their greatest heights, 193 metres (Mid Hill) and 221 metres (Mid Tooin), in the Evie hills ranging the eastern border of the West Mainland and in the Orphir hills to the south-east with Ward Hill, at a height of 268 metres, the highest hill in Mainland Orkney. The hills of the western edge are somewhat lower with Vestra Fiold (127 metres), Hill of Miffia (158 metres) and Hill of Lynedardy (136 metres) the major prominences. The eastern hills, broken by the Finstown gap and Settascarth gap, display striking east-facing escarpment slopes.

Areas of hummocky moraine-like drift occur on the central lowland feature. The most extensive area extends westwards from the head of the valley above Finstown for some 3 km along the Stromness road and for approximately 2 km north-westwards between the Loch of Harray and the Dounby road. Other large areas of moraine are found along the Dounby road in the vicinity of the Loch of Bosquoy and The Shunan.

Western Hoy consists of a range of rounded and relatively steep-sided hills extending from The Berry (199 metres) in the south to Cuilags (433 metres) in the north. Much of the central part is over 300 metres in height and rises to 479 metres on Ward Hill, the highest point in Orkney. Ward Hill is an isolated, steep-sided eminence bounded by the glacial valleys of the South Burn and the Ford of Hoy. The plateau summit of Ward Hill displays strongly developed patterned-ground features such as stripes and terraces. Similar features, varying in their degree of development, are found on Cuilags, Knap of Trowieglen and plateau summits of heights down to the level of approximately 250 metres.

Rousay and western Westray display a strikingly rugged topography, yet it is markedly dissimilar from that of western Hoy as a consequence of differing geology. The bedrock of Rousay and Westray is composed of gently dipping sediments, flagstones and sandstones of variable resistance to weathering. Weathering and erosion have evolved a stepped hillside topography often with craggy risers (hamars). This type of landform is found in its most extreme development along the south-east-facing hillside between Frotoft and Mansemass Hill in Rousay and on the south-facing slopes of Fitty Hill in Westray.

Climate

The climate of the Orkney Islands is governed basically by three factors, namely the intimate relationship with the sea, an open, gently undulating topography and a high latitude. Orkney lies at a mean latitude of 59° north but the more extreme climatic aspects of such a latitude are ameliorated by the moderating influences of the sea and the climate is not nearly so severe as in some regions of similar latitude.

The relatively low evaporation associated with low summer temperatures and high relative humidities makes the mean annual average rainfall of about 950 mm relatively excessive. Add to this the high incidence of strong winds and lack of natural shelter and the climate assumes a bleak and inhospitable aspect, but the area suffers no great extremes of heat or cold. The very severe cold winters of more southerly eastern regions generally do not occur. The area has a good sunshine record and during the summer months experiences prolonged daylight which compensates for the dismal days of winter. Overall, the climate is of cool but equable nature.

The average annual rainfall varies from approximately 800 mm along the southern and eastern seaboards to over 1000 mm on the hills of Rousay, the West Mainland and Hoy and to over 1200 mm on the highest hills exposed to the south-west with much of the archipelago, and the greater percentage of arable ground, having an average annual rainfall of between 900 mm and 1000 mm.

Rainfall is distributed more or less evenly throughout the year with May, on balance, the driest month and October the wettest. A feature of the annual rainfall is the high number of days with recorded rainfall.

The annual range of average mean monthly temperature is around 8·9 °C, increasing from 3·4 °C in February to 12·3 °C in August. Although winter temperatures are not very low, there is only a slow build up of temperature and winter and spring tend to be rather prolonged.

In the scheme of bioclimatic sub-regions for Scotland employed by the Soil Survey of Scotland, the area lies totally within the hyperoceanic subsection, but the increase in rainfall and general severity of the climate from east to west and the greater elevations of north-west Hoy are reflected in the wide range of thermal sub-zones and moisture sub-divisions. The East Mainland, the south isles and Longhope, the north isles (Rousay excepted) and the central lowland of the West Mainland lie within the humid hemiboreal sub-zone, passing into the humid southern boreal and lower oroboreal sub-zone with increase in height and exposure. The principal areas of arable agriculture lie within these sub-zones.

The peat-covered hills of the West Mainland, Rousay and Hoy fall within the humid upper boreal sub-zone with passage into the perhumid upper boreal sub-zone on the wetter, higher, middle slopes of the Hoy hills. The upper slopes and the lower plateau summits of the higher Hoy hills and the highest parts of the West Mainland and Rousay lie in the very humid orohemiarctic sub-zone with peat development on the more base-rich parent materials of the West Mainland and Rousay but with podzols and only sparse peat development in favoured situations on the more acid Hoy hills. The extremely exposed, eroded and patterned ground of the highest plateau summits on Hoy fall into the very humid lower oroarctic sub-zone with oroarctic podzols.

Soils

Superficial deposits cover approximately 85% of the area, with till and peat being the most extensive. Wind-blown sand is locally extensive, while fluvioglacial deposits and alluvium are of minor extent.

Four types of till have been recognised:

1. Till of moderately fine texture is generally widespread throughout the island group. It occurs most extensively on the East Mainland and South Ronaldsay, on Shapinsay, Stronsay and Westray and in the parishes of St Ola, Orphir and Stenness in the West Mainland. The till is of local occurrence throughout the West Mainland and on Rousay, Wyre, Egilsay and Eday. It is a firm compact deposit of sandy clay loam or clay loam texture and is commonly strongly weathered with rotten stones throughout. The till is of variable thickness; the average is some 100-125 cm, but deeper sections occur where valleys and bays have been infilled. Shell fragments are often encountered at depth in till-cliff sections and the occasional profile is found to be calcareous within profiling depth.

2. Till of a coarse or moderately coarse texture is almost exclusively restricted to Hoy but areas of a similarly textured till occur on Eday and very locally on the West Mainland.

3. Till of a moderately coarse or medium texture is common throughout the West Mainland and of local occurrence on the East Mainland. The till occurs quite extensively throughout the north isles.

4. Till, of a morainic nature and landform, with a moderately coarse or medium texture, occurs locally on the Mainland.

A widespread feature of the last two types of till is the presence of an indurated horizon in the upper part of the deposit.

Blanket peat is extensive on Hoy, on the Evie and Rendell hills, on the Orphir hills and on Rousay and Eday. Basin and valley peat occurs locally throughout the area, in some instances being underlain by marl. Wind-blown shelly sand deposits occur round many of the more open, shallow bays of the area. Approximately one-third of Sanday and of North Ronaldsay is covered by shelly sand and there are extensive deposits on Westray. Wind-blown sand of an essentially non-calcareous nature is much less extensive, the largest area occurring around the Loch of Doomy on Eday. Fluvioglacial deposits occur as ridges and terraces in the valley of the South Burn, as isolated mounds at the Ford of Hoy on Hoy and as small, isolated mounds extending westwards from Stromness along the Innertown-Outertown road.

Twenty-eight soil series and fourteen soil complexes have been mapped and they represent the following ten soil associations:

Association	*Parent Material*
Stromness	Drift derived from sandstones and breccias of the Middle Old Red Sandstone and rocks of the granite-schist complex of the Moinian
Lynedardy	Drift derived from flagstones and sandstones of the Middle Old Red Sandstone with rocks of the granite-schist complex of the Moinian
Thurso	Drift derived from strata of the Stromness Flags and the Rousay Flags of the Middle Old Red Sandstone
Canisbay	Drift derived from strata of the Stromness Flags, the Rousay Flags and the Eday Beds of the Middle Old Red Sandstone

Flaughton	Drift derived from sandstones of the Eday Beds of the Middle Old Red Standstone
Darleith	Drift derived from basic lavas and intrusions
Dunnet	Drift derived from strata of the Upper Old Red Sandstone
Rackwick	Fluvioglacial sands and gravels derived from strata of the Upper Old Red Sandstone
Boyndie	Fluvioglacial sands
Fraserburgh	Shelly sand

In addition, deep peat, thin peat, their cut-over and eroded phases, links, alluvium, peat-alluvium complex, hill dunes, colluvial fans, saltings and mixed bottom lands have been delineated.

The soil series mapped represent nine major soil groups/sub-groups of which the most widespread are podzols, peaty podzols, non-calcareous gleys and peaty gleys. Brown calcareous soils, oroarctic podzols, calcareous gleys and saline gleys are locally extensive, while peaty brown soils are of very limited local extent.

The Orkney landscape is dominated by four principal soil associations, the Thurso, Canisbay, Dunnet and Fraserburgh Asociations and peat.

The Canisbay Association is probably the most extensive in the area, the soils of the association being developed on a reddish brown or, occasionally, red drift with usually a sandy clay loam or clay loam texture. The drift is commonly strongly weathered and a local predominance of weathered sandstone in the drift results in a sandy loam texture.

Tresdale series, a non-calcareous gley, is the dominant series of the association. There is little doubt that in many instances the soil profile is the result of cultivation and continued husbandry of peaty gley soils, for profiles with fossil evidence of their former peaty surface nature, a dark grey or very dark greyish brown plough layer of moderate or high organic matter or an A/B horizon of organic matter enrichment immediately below the plough layer, are met commonly. The relationship between soils still bearing witness to the former peaty nature and soils where any evidence of their former status has been totally destroyed is very complicated and indefinite—often merely the product of the vagaries of plough depth within an individual field—so that separation of non-calcareous gleys and cultivated peaty gleys on the soil map has not proved itself feasible and consideration of variance within the soil series remains for discussion within the soil memoir.

Typically, the Tresdale series exhibits a dark greyish brown S or S(g) horizon with a loam, silty loam or sandy loam texture and a depth of 25 cm. Beneath the surface horizon a narrow, often lenticular, brown horizon of organic matter enrichment is sometimes encountered. A reddish brown, strongly mottled and gleyed B_2g horizon with a sandy clay loam or clay loam texture and most usually a strongly developed prismatic structure underlies the S, S(g) or A/B horizon. The B_2g horizon is usually up to 30 cm in thickness. The Bg/Cg or C(g) horizon is reddish brown or red in colour with a sandy clay loam or clay loam texture and usually massive. The soil is commonly strongly weathered throughout, the rock components

of the drift being readily broken down. Total soil depth rarely exceeds 120 cm. Certain profiles examined are found to be calcareous at a depth of 120-180 cm.

The soils exhibit the typical characteristics of a surface-water gley in that the B_2g horizon shows stronger gleying and mottling features than does the C horizon.

Analyses usually indicate medium levels of exchangeable cations although high amounts of exchangeable calcium are occasionally recorded in some C horizons, and, as with most of the soils of Orkney, high levels of exchangeable sodium are common throughout. pH values increase generally from slightly acid pH 6-6·5 in the S horizon to above 7 in the C horizon. Total P_2O_5 is generally low below the S horizon.

The Ocklester series is a freely or imperfectly drained soil, a podzol, which has been derived from a peaty podzol by cultivation. The noteworthy feature of the profile is an indurated reddish brown sandy loam, loam or, very rarely, sandy clay loam B_3 horizon usually immediately beneath a dark greyish brown sandy loam or loam S horizon. The junction of the S and B_3 horizon is commonly marked by a thin iron pan of either a discrete or fragmentary nature. In some instances a thin zone of mottled and gleyed material occurs between the S and B_3 horizon. The pH values are usually within the range 6-6·5 and medium levels of exchangeable cations associated with high levels of exchangeable sodium are usually observed. Total P_2O_5 tends to be low in horizons beneath the S horizon.

In an intensively cultivated landscape, Canisbay series, a peaty gley, Warth series, a peaty podzol, Gaira series, a very poorly drained non-calcareous or humic gley and Dalespot series, a very poorly drained peaty gley often associated with thin peat, are of minor extent and are subjected constantly to the processes of reclamation.

Gessan series is the saline gley of the Canisbay Association. The soil is profoundly influenced by salt-spray and sea-gusting and is found along the eastern seaboard of the county. A feature of the soil is the very coarse prismatic or columnar structure in the Bg horizon, the structure units being vividly expressed by translocated organic matter along the ped faces. The surface horizon is usually thin, rarely exceeding 20 cm and is usually of a peaty nature. A grey or brownish grey A_2g horizon with a clay loam or silty clay loam texture and a massive or coarse prismatic or columnar structure underlies the surface horizon and merges into a strongly gleyed Bg/Cg horizon. The parent material is strongly weathered and such is the gleying that much of the reddish brown colour of the parent material is lost.

The soils are moderately acid with high levels of exchangeable cations in the surface horizon and very high exchangeable sodium throughout. The soils support a maritime heath vegetation with plantains, *S. verna, E. nigrum, C. vulgaris* and *T. drucei.*

The Thurso Association is the dominant soil association of the West Mainland, Rousay and western and northern Westray. The principal soil of the association is Bilbster series. Bilbster series is a freely or imperfectly drained soil which has been derived from a peaty podzol by cultivation and

as such is the counterpart to the Ocklester series of the Canisbay Association. The soils are developed on a brown or yellowish brown, commonly stony, sandy loam or loam drift with usually a strongly indurated B_3 horizon immediately below a shallow brown or dark greyish brown S horizon of loam, sandy loam or silt loam texture. The interface between the S and the B_3 horizon is commonly marked by a thin iron pan and there may be some gleying above the thin iron pan—the possible remnants of an A_2g horizon. It has proved possible to map a deep-topped phase of the Bilbster series, where, in a " plaggen " type soil, the total thickness of the S horizon exceeds 75 cm.

Soils of the Bilbster series are principal components of the Sordale complex (formerly Bilbster complex). Total soil depths commonly exceed 100 cm in a non-moraine landscape as well as in a morainic landscape, but where bed-rock is within 50 cm of the surface a shallow phase of the Bilbster series is mapped.

Analyses usually indicate medium values of exchangeable cations, but with high exchangeable sodium in the S horizon and commonly low exchangeable calcium in the B and C horizons, while pH values vary from moderately to slightly acid. Total P_2O_5 is usually low below the S horizon. A Bilbster series, deep-topped phase, shows very high total P_2O_5 in the S horizons.

The Thurso series is a non-calcareous gley developed on a yellowish brown or greyish brown loam or sandy clay loam drift. Profile morphology in the Thurso series is typically that of a surface-water gley; grey colours predominate, with associated coarse ochreous and pale brown mottling, while structure in the B_2g horizon is usually coarse prismatic, the ped faces having grey sandy coatings. As with the Tresdale series there can be little doubt that many of the Thurso series soils are the product of reclamation and continued improvement of peaty gleys.

Values for exchangeable cations are usually medium—high exchangeable sodium in the S horizon—but high amounts of exchangeable calcium are occasionally recorded in some C horizons. Similarly, pH values are slightly acid in the S horizon increasing to 7 in the C horizon. A pH value of 7·9 is noted in the basal sample of one Thurso series soil. Total P_2O_5 is generally low in the B and C horizons.

Soil depth rarely exceeds 120 cm and is often much shallower.

Olrig series, a peaty gley, developed on a loam or sandy clay loam drift occurs under a wet *Calluna* moor vegetation. The profile is characterized by a peat horizon, up to 50 cm thick, a dark brown organic-stained A horizon immediately below, a grey-brown A_2g horizon with some organic staining and a few drab mottles, and a B_2g horizon of sandy clay loam texture and usually prismatic structure. The series displays most dominantly the features of ground-water gleys with a grey or olive-grey C horizon, but surface-water peaty gleys are included within the same unit.

Values for pH vary from 4·0 in the organic horizons to 5·3 in the C horizon. Values of exchangeable cations, with the exception of exchangeable calcium, are usually medium in the mineral soil: values of exchangeable calcium are low.

Camster series, a peaty podzol, is developed on a brownish yellow stony loam or sandy loam drift on moderate slopes under a usually wet *Calluna* moor vegetation. The profile displays the characteristic features of a peaty podzol with a thin iron pan, an occasional friable B_2 horizon and an indurated B_3 horizon. The C horizon is usually brownish yellow in colour. The pH values on the organic surface horizons are about 4 while the C horizon varies from pH 5·5 to 6·3. Exchangeable cations show low or medium values in the mineral soil.

Mousland series is the saline gley soil of the association and is found along the western seaboard of the archipelago. The soil is developed on strongly weathered and gleyed drift or rock and displays commonly a striking coarse prismatic or columnar structure in the Ag and Bg horizons. Structure in the C horizon is usually massive, but sometimes the horizon retains the banded structure of the original rock. The prismatic structure is emphasised by intense organic staining along the ped faces. Those soils immediately adjacent to the cliff edge have worked upper horizons, commonly of a banded appearance with the admixture of wind-borne or water-borne small rock fragments. Not surprisingly the soils have a high sodium content throughout and a high exchangeable magnesium value in the upper horizons. The high exchangeable magnesium content results in a reversal of the standard Ca : Mg ratio.

The soils support a maritime heath or pasture vegetation.

The Ness series is a non-calcareous gley developed in a loam drift over weathered rock.

Hunster series is a very poorly drained non-calcareous or humic groundwater gley of flushed sites. A very small area of oroarctic podzol, Knitchen series, occurs on the plateau summit of Knitchen Hill on Rousay.

Soils of the Dunnet Association are confined to the island of Hoy and two soil series have been mapped: Dunnet series, a peaty podzol, and Trowieglen series, provisionally an oroarctic podzol.

The Trowieglen series exhibits a very dark grey, organic loamy sand surface horizon of less than 10 cm thickness underlain by a brown to dark brown A/B horizon with low organic matter content and a sand texture. Structure is weak and consistence friable. The A/B horizon has a maximum thickness of about 15 cm. The B horizon has a strong brown or brownish yellow colour usually with a slight degree of mottling and a loamy sand texture, but with pockets of sandy loam and even sandy clay loam material. The C horizon has similar colours to the B horizon and a loamy sand texture. A soil profiled on the Knap of Trowieglen has red or light reddish brown parent material. Total soil depth exceeds 120 cm. Values of pH vary from *ca* 5 in the surface horizon to *ca* 5·5 in the C horizon. Standard nomenclature of such " alpine " soils remains to be clarified.

Soils of the Fraserburgh Association are developed on wind-blown shelly deposits which occur locally around some of the bays and more extensively on Sanday, North Ronaldsay and Westray. They are characterized by extreme sandiness, loose consistence and high pH. Fraserburgh series, a brown calcareous soil, occurs on freely drained low stable dunes. Below the dark grey or dark brown A horizon of sand and organic matter there is

a weakly developed pale brown B horizon and a slightly paler-coloured C horizon. Whitelinks series is a calcareous ground-water gley. Characteristic of this profile are a coarsely mottled Bg horizon and a Cg horizon of grey wet sand.

Soils of the Stromness Association are limited to the hilly ground fringing Stromness with an outlier on the north side of Graemsay and small isolated pockets to the north-west of Stromness. One soil series, Stromness series, a peaty podzol, has been mapped and is of minor extent. The parent material of the Lynedardy Association bears similiarity to that of the Thurso Association in its colour and texture, but is sufficiently contaminated with rocks of the granite-schist basement complex to warrant a separate association. Four soil series, Millfield series, a peaty podzol, Midgarth series, a non-calcareous gley, Fleets series, a saline gley and Lynedardy series, a peaty gley, were encountered in a narrow belt trending north-westwards from Stromness.

Soils of the Flaughton Association occur on drift derived from Eday sandstone. One soil series, Flaughton series, a peaty podzol, has been mapped on the coarse textured parent material. It is a soil of limited extent. A soil of very limited extent is the peaty brown soil of the Darleith Association. It is confined to the island of Hoy and developed on basic lavas and two isolated volcanic necks.

Fluvioglacial sands and sands and gravels are of very minor extent in Orkney, but two associations have been mapped, the Boyndie Association and the Rackwick Association. A humus-iron podzol, Boyndie series, and a peaty podzol, Rackwick series were mapped.

Three series were recognised on the Links deposits, a freely drained soil, Dornoch series, an imperfectly drained soil, Elgie series and a poorly drained soil, Morrich series.

The extensive deposits of peat have been mapped as shallow (50-100 cm) and deep (peat depth in excess of 100 cm) and eroded and cut-over phases noted. Much of the peat is of the blanket bog type, but a number of well-defined basins of peat have been met. A shallow peat deposit on the exposed St John's Head on Hoy contains an appreciable amount of wind-blown mineral matter.

Areas of wind-blown quartzose sand on the summit of Ward Hill in Hoy have been mapped as hill dunes.

Land Use Capability Classification

The rigours of the Orkney climate limit the highest land use capability Class to Class 3.

Areas of the deep-topped phase of the Bilbster series have been classified as Class 3c, there being no obvious limitation to arable agriculture other than that of climate. The podzols of the Bilbster and Ocklester series have been placed in Class 3s with the presence of an indurated horizon restricting rooting depth. The shallow phase of the Bilbster series is considered as Class 4s when rock restricts rooting depth and soil shallowness renders the soils liable to drought. The areas of Sordale complex are mapped as Class 3sg or Class 4g when moundiness of the complex and soil pattern are

extreme. Areas of rock-controlled complex have been mapped (Ulbster complex) and such areas ascribed to Class 4sg and Class 5g or Class 5gw.

The non-calcareous gleys of the Thurso, Tresdale and Midgarth series are placed in Class 3ws and where the surface horizon has a high organic matter content or where increased altitude and exposure takes effect into Class 4ws. Non-calcareous gley soils in which rooting depth is limited to some extent by the proximity of bed-rock are similarly mapped as Class 4ws.

Soils of the Fraserburgh series have been mapped as Class 4se and 5se—these soils having a high liability to erosion—and soils of the Whitelinks series as Class 4sw and 5sw. The peaty podzols, peaty gleys and saline gleys are usually placed in land use capability Classes 5 and 6 and the Trowieglen and Knitchen series into Class 7s.

Some areas of thin peat have been ascribed to Class 5w and to Class 6w with increased altitude and exposure hazard. Cut-over areas of thin peat are placed in Class 6gw. The deep peat is usually classified as Class 6w or 6wg where it is cut-over. Eroded peat is mapped as Class 6g and possibly 7g.

Soils of the Rackwick series are mapped as Class 6gs and soils of the Boyndie series as Class 4s.

Farming in the area is predominantly of the upland stock-rearing type with the production of beef cattle, sold traditionally as stores, the principal source of income. The dominance of the store industry has been sustained and strengthened by improvement in grass-land quality with the introduction of new grass varieties, by superior grass conservation with advances in silage and hay-making techniques and, arguably, by the introduction of the so-called exotic animal breeds. In 1973 the total area of grass-land approached some 40 000 ha or 40% of the land area, with sown grasses accounting for about a third of this sum. The past decade has seen a notable increase in the area of fodder barley; in 1973 approximately 1300 ha were planted out to fodder barley. The continuing increases in areas of grass-land and fodder barley has led inevitably to a decline in the area of the historical winter-feed supplements of swedes, turnips and oats, although oats have largely maintained their status in the north isles. A half-century ago some 14 000 ha were in root crop but by 1939 their extravagant labour demands had resulted in a decrease to around 4200 ha; since then the area has declined steadily and by 1973 a mere 250 ha were in root crop. The area of oats has declined from some 11 000 ha in 1939 to approximately 3000 ha in 1973 with much of this area consigned as arable silage.

Sheep numbered about 76 000 in 1973, of which some 30 000 represented the export lamb crop for the year. Most are North Country Cheviots, while Suffolk-Cheviot crosses are popular. North Ronaldsay has its unique seaweed-eating sheep but these are presently of scientific interest rather than economic value.

It is the egg-producing industry that has perhaps altered most radically over the past twenty-five years, the number of fowl decreasing from a peak of around 790 000 in 1950 to *ca* 48 000 in 1973. In the late 1960s some 80 million eggs were produced annually.

9. TECHNICAL SERVICES

A. W. STUART

The extension to the workshop complex has been completed and all three sub-sections are now fully operational. Several new items of equipment have been acquired, including a power operated guillotine, which has proved to be a great asset in the production of soil sample boxes and other sheet metal projects; a Printed Circuit Scriber unit to enhance the production of prototype printed circuit boards; and also 16 mm Ciné equipment to increase the facilities provided by the Photographic Section.

The past year has again been a very busy one and a summary of the work undertaken by the individual sections is given in the following paragraphs:

INSTRUMENTATION

As indicated below, this section has been involved in a wide variety of tasks, ranging from laboratory maintenance to development of scientific aids and instruments for different departments.

Spectrochemistry

A triple monochromatic mount for the spectroscopic determination of the major elements by atomic absorption spectroscopy has now been completed and is in experimental use. Other items supplied were: a Fabry-Perot Interferometer split X-Y mount constructed from a solid brass block, a heavy duty table with rails to carry the laser unit, a telescope filter/optical detector mount and an additional water cooled " 100 transistor " bank for the high current d.c. arc unit. Under construction also is an SO_2 gas sample cell for use with the laser remote sensing project. Further work is envisaged in connection with this project and on the radiofrequency inductively coupled plasma source unit.

Soil Survey

A Zeiss polariser slide bridge was constructed and $15\frac{1}{4}'' \times 6'' \times 2''$ vacuum chuck supplied for grinding thin sections; together with a perspex cover unit to cut down oil vapour dispersal during grinding operations.

Soil Organic Chemistry

A multiple magnetic stirrer was completed and a tubular bench with drawers constructed and installed to provide accommodation for a new microwave spectrometer.

Pedology

Digitiser coil mounts were designed and constructed for the stereo plotter, and also a special camera mount to enable aerial photographic work to be carried out. Modifications were carried out to the sample carriers and binocular system on the new Siemens Electron Transmission Microscope.

ELECTRONICS

During the past year, emphasis has had to be placed on routine repair and maintenance work, which accounted for some 80% of available time, but progress was also made in improving the section's facilities, to cater for future needs of the Institute.

A satisfactory method of producing double-sided printed circuit boards has been developed, permitting the construction of digital registers, and memories of fairly high component density.

Work on the Intel 8080A microprocessor project has progressed and a microprocessor-based data handling system is now in the course of preparation for the Multi-element analyser recently acquired by Soil Organic Chemistry. Other microprocessor systems are also under consideration because it is felt that they will be invaluable in processing experimental results for input to the Institute's computer.

Full use is being made of existing equipment and devices to facilitate programming, and the potential applications of a single chip microprocessor are being investigated. In view of the increased use of microprocessors in both commercial and purpose designed equipment, however, it is hoped that additional programming development aids will become available.

PHOTOGRAPHY

Over 1000 slides for projection in the form of colour, black and white, or coloured diazo transparencies were produced. The audiovisual facilities in the auditorium in Craigiebuckler House are nearing completion and it is hoped very shortly to have them all fully operational.

Photographs depicting laser interference rings, necessary in the measurement of output wavelength, were produced for the Department of Spectrochemistry's laser project.

Widespread field services have again been provided. Vertical stereo and colour photography of peat lands in the Isle of Lewis, in Shetland, and in the Cawdor area have been undertaken to facilitate the peat resource and vegetation surveys being carried out by the Peat and Forest Soils Section of the Department of Pedology. In addition, low level oblique photographs, in both true and infrared false colour, have been provided for a range of ground truth sites. Such photography also provides a valuable basis for monitoring peat erosion and land-use changes and for classifying the multispectral imagery obtained from earth satellites. Effects of copper toxicity on crops in the Glenlivet area were photographed for the Department of Soil Fertility.

10. LIBRARY

A. H. W. Dickie

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 directly or through the inter-library lending scheme. 719 items were borrowed of which 400 were from the British Library Lending Division. 151 items were lent out to other libraries in response to 257 requests. 320 books were added to stock, but no new journals, due to increased costs.

The two current awareness Bulletins have continued to be produced—the Periodicals Bulletin is weekly, and the Book Bulletin once every two months. Although primarily internal publications, copies are also distributed to the other Scottish Institutes and to local research establishments.

A List of Available Publications was mailed in September and there has been a good response. Anyone wishing to receive a copy of this list should apply to the Librarian.

APPENDIX

THIRD

T. B. MACAULAY LECTURE

23rd NOVEMBER, 1978

AMATOLA HOTEL, ABERDEEN

by

PROFESSOR J. C. BOWMAN

Chairman:

Professor T. C. Phemister, MSc, PhD, DSc, FRSE

THIRD T. B. MACAULAY LECTURE

Aberdeen, 23rd November, 1978

ILL FARES THE LAND

PROFESSOR J. C. BOWMAN, PhD, FIBiol,
Professor of Animal Production, and
Director, Centre for Agricultural Strategy,
University of Reading

In 1770 considerable changes were taking place in the rural life of the United Kingdom. It was the time of the agricultural revolution, when one rural economic and social system was replaced by a new one. To quote Trevelyan (1949) " Great compact estates cultivated in large farms by leasehold tenants employing landless labourers covered more and more of the acreage of England, at the expense of various forms of petty cultivation and ownership. Small squires and peasants with diminutive rights in the soil were bought out to make room for the new order. The open fields of the great Midland corn area were enclosed into the chess-board pattern of fenced fields which has ever since been the hallmark of the English landscape. . . . For everywhere the large owners were consolidating their estates by purchase; everywhere squires and farmers were busy with new methods. And everywhere better roads, canals and machines were diverting industry from cottage and village to factory and town, thereby cutting off the peasant family from spinning and other small manufacturing activities by which its meagre budget had been eked out."

The new methods included new crops, draining, liming, drilling, manuring, breeding and feeding, improved strains of livestock, new forest plantations, as well as the construction of new roads and farm steadings. This was the time of the development of the landlord-tenant system of a large proportion of farms today.

In Scotland the changes were equally far reaching, but with somewhat different consequences. To quote Trevelyan (loc. cit) again " . . . the number of people employed in Scottish agriculture increased rather than diminished, owing to the constant enlargement of the area of cultivated land. And the new acres won from the waste were often the best, being situated in the fertile valley bottom which only required artificial draining to be more valuable than the fields of older cultivation on the self-draining hillside above."

It was in this setting that Oliver Goldsmith in 1770 wrote his poem " The Deserted Village " from which the title of my talk is taken. Goldsmith dedicated the poem to Sir Joshua Reynolds and in the letter of dedication he comments " . . . I know you will object . . . that the depopulation it deplores is nowhere to be seen, and the disorders it laments are only to be found in the poet's own imagination. To this I can scarce make any other answer than that I sincerely believe what I have written; that I have taken all possible pains, in my country excursions, for these four or five years past, to be certain of what I alledge, and that all my views and enquiries

have led me to believe those miseries real, which I here attempt to display."

In many respects the changes, the conflicts and the depreciations reflected by these extracts are familiar still in the United Kingdom of the 1970s. Indeed the desires to develop new and improved farming methods, to open up new lines of transport, and to increase the forest area are still as strong, perhaps stronger than ever. It is common to hear people bemoan the depopulation as well as the loss of light industry and part-time employment in the rural areas, leading to the break-up of village life. Above all the concern about new forms of landownership and farm management has a very contemporary familiarity. Thereafter the similarity fades because the general context in which the problems of the 1970s arise is substantially different from the context of 1770. Let me turn your attention to concentrate on the present, whilst remembering that our present rural problems have their origins in that period in the past.

Today the world supports nearly 4 billion people and by the end of the century this may well have increased to between 7 and 8 billion. Many of these people are poorly fed and housed and likely to remain so for many years even though there is an expressed desire to eliminate hunger and poverty. The fortunate ones who live in comparative affluence and who fear no immediate shortage of food, wood and other materials depend for their lifestyle on an increasing use of fossil energy and other non-renewable resources which cannot be sustained indefinitely in its present form. The continued future for all peoples, for both rich and poor, depends on substantial changes in lifestyle involving the recycling of non-renewable minerals, the development of new methods of extracting and using energy from the environment, and greater reliance on contemporary solar radiation as an energy source. Whatever view one takes of the future the pressures on, and conflicts from, land use seem certain to become more intense at the world level.

At a more parochial level, the United Kingdom now has 56 million people and this figure is predicted to increase to about 60 million by the year 2000. About 55% of the food consumed and 8% of the wood used in the UK is produced domestically. It would not be possible to produce domestically all the food and wood currently consumed in the UK because there is insufficient land. Though for the next few decades there are adequate oil, gas and coal reserves for the UK to be energy self-sufficient, it is not too soon to be considering the possibilities for energy and chemical feedstock cropping which will take additional land. The lifestyle of people in the UK seems likely to contain more time devoted to leisure, needing more land for sport, for tourism and for conservation. At the political level the UK has joined the European Community and even if it remains a member and the Community develops into some form of closely combined federation, the pressures on land seem certain to intensify.

In these circumstances it is not at all surprising that several important land issues are the subject of active debate. Here I shall examine in more detail four of these issues, namely land ownership; the use and management of land; the availability of land for different purposes; and the institutional arrangements pertaining to land.

All these issues are inter-related and the acuteness of them in the UK arises from the population density here, which is greater than for most countries in the world. If we can find solutions to them, it may prove helpful to the rest of Europe and to the world.

Landownership

The ownership of land is an active political issue closely related to discussions about the distribution of wealth and power. Some of the changes of ownership, albeit still on a small scale, are giving cause for concern about their effect on farm and forest productivity, on food prices, on access to the general public and on the future flexibility of changing the use of land. It is astonishing that it is not possible to get a clear picture of landownership in the UK because, in order to assess the consequences of many fiscal and legislative measures and of ownership changes, it is essential information. The last complete survey in England and Wales was made in 1873 (HMSO, 1875) and a new ownership survey for the whole of the United Kingdom is long overdue. It is pleasing to note that in the Queen's Speech opening the present session of Parliament the Government have indicated their intention to compile a register of landownership in Scotland which it is anticipated will take ten years to complete. Differences in title deeds between Scotland and England and Wales are claimed to be the reason for the register not to apply to England and Wales.

There are three aspects of rural landownership which give rise to debate and which have partly been responsible for the establishment of the Committee of Inquiry into the ownership and occupancy of agricultural land under the chairmanship of Lord Northfield. These aspects are the purchase of farms by non-British citizens especially those who are also non-resident, the purchase of farms by corporate institutions such as pension funds and insurance companies, and suggestions to transfer land to State ownership either by direct acquisition or in lieu of payment of taxes. In each case the opponents of these changes complain that the new owners are increasing the price of all land. This they claim makes it more difficult for young Britons to buy farms and become farmers, it increases rents and thereby increases food prices, and it leads to a less personal form of management which may result in lower output per unit area of land and the destruction of the desirable paternalistic and self-reliant aspects of the individual owner in village life. It is difficult to find any hard facts to support any of these claims. Indeed in the absence of foreigners, institutions or the State in the land market it is possible that land prices would have risen just as fast in accord with the inflation of all property values and as the UK land market moves to be closer to values prevailing in continental Europe. Whether these new types of owners will use the land more effectively and be adequate members of rural communities remains to be seen for there are too few of them yet to reach valid conclusions about their habits. Nevertheless it is right to consider whether these ownership changes are desirable before they have gone too far.

Ownership by non-British citizens, particularly non-residents, may seem undesirable if only for the reason that the aspirations and ideals of such

people may not accord with those of the UK. However, the UK as a member of the European Community may find it politically impossible as well as undesirable to prevent foreign ownership of land. Any attempt at such prevention is likely to attract similar retaliatory action in other countries which would not be favoured by Britons who have purchased farms abroad.

Ownership by pension funds, insurance and other companies superficially may seem desirable to those who wish a more egalitarian distribution of wealth, power and the natural resources of the country owned for the benefit of the population as a whole. However, landownership by financial institutions may not lead to a more egalitarian or more acceptable distribution of power even if it leads to a more egalitarian distribution of wealth in the form of land. It is not at all clear whether financial institutions and their managers will use the power derived from landownership any more responsibly than an individual owner-occupier. Indeed it is often more difficult for an individual to persuade or require an institution and its agents to change their ways rather than another individual.

It is possible that land ownership by institutions may be associated with access to more working capital from the same sources as purchased the land and this might enable a more intense use of land than by present individual owners. However, the future attitude of such owners in this respect seems far from clear. The income which pension funds and insurance companies can expect from their investment in farmland only makes financial sense if it includes an assumed substantial element of capital appreciation. Historically the rent yield or the income from direct management of investment in farm land has been negative in real terms and only reaches a positive 1%-3% if captial appreciation of land values is included. If pension and insurance companies are intending to rely on capital appreciation to meet their commitments in the future, it is pertinent to enquire whether such appreciation will materialise and to whom they will sell the land to realise the appreciation. If a large proportion of farmland is purchased by such buyers in the next few years—and they certainly have very large sums to invest—it is difficult to see who the new buyers will be who will need to emerge in 20 and 30 years time. If no new buyers emerge then it seems inevitable that direct earnings from the land-use will have to increase so increasing the relative cost of food and other goods and services which depend on land for their provision.

It has been shown (CAS, 1978) that financial institutions own only a very small proportion (less than 1%) of the land of the UK. It is also the case that about 1½% of the land area of the UK is sold each year so that, though financial institutions are buying about a third of the land sold each year, it will take them a long time to accrue a substantial part of the UK at the present rate of acquisition. Such statements should not obscure the possibility of more land coming on the market each year as individual farmers are stimulated to sell by the attraction of higher land prices and by the effects of taxation which impinge disproportionately on private wealth and business. Pension funds and insurance companies could own a large proportion of UK land by the end of the century.

One potential buyer of land is the State. At least two political parties have land nationalisation as an objective to be attained by taking land in lieu of taxes. To date there has been no reasonable suggestion that land should be purchased by the State nor that landowners should be compensated for loss of ownership. The two parties envisage the State as a landlord and have not indicated any intent to develope State farming. However, there are those (e.g. Green, 1977) who are suspicious that such will be the end result and with disastrous consequences for food production. The reasons advanced in favour of the State ownership of land are to remove the adverse effects of absentee landowners, to allow the re-arrangement of land between production units to make more effective operation and to remove the inequality of power associated with the ownership of wealth including land. It has to be said that legislation already exists which enables the State to put pressure on landowners who do not make good use of their land though understandably there has been marked reluctance to use it in recent years. Also there is little evidence to suggest that major reorganisation and division of land holdings by the State would have much effect on food and timber output which could not be achieved by other less drastic means. It is significant that the Highlands and Islands Development Board (HIDB, 1978) has recently proposed changes in its powers so that it can compulsorily purchase land in order to achieve changes in land-use which will accord with the Board's regional development objectives and in the interests of society as a whole.

Another way of gradually removing inequalities of wealth represented by large private land holdings is to introduce legislation to control the maximum size of land holding by one individual or company, similar to that which now exists in Denmark. Under such legislation individuals who now own land in excess of the limit might be forced to sell the land in excess. This has not happened in Denmark where the legislation only applies to new owners.

A limit on the size of farms would have to take account of the land potential for different types of enterprise. Denmark does not face the same difficulty because the land potential is more homogeneous than in the UK. A size limit can also be criticised because it may fail to allow farmers to benefit from economies of scale. This potential criticism needs close examination. It is not clear whether very large farms in the UK do make more efficient use of resources. It may be that large farms are run by people who can manage large farms and it is not known if there are many more such people. Also, large farms may appear to make more efficient use of resources because the size of machinery and the trading terms from suppliers to and buyers from farmers favour large units. Smaller farms may need new and appropriate machinery and trading circumstances created for them.

It is not obvious that any of the new forms of landownership have any advantages over individual ownership when judged on their ability to benefit society as a whole. Certainly substantial individual wealth including landownership, particularly to the extent that it bestows individual power, is not generally favoured at present. However, the new forms of ownership

may also lead to associations of power and responsibility which are just as unacceptable to society as individual ownership. It will be prudent to allow only a slow change in forms of landownership until the consequences of changes have been examined thoroughly.

The use and management of land

The determination of good and bad landscapes depends on the eye of the beholder. It is not difficult to describe in qualitative terms the features and the changes in the landscape, but to ascertain whether the changes represent deterioration or enhancement is very difficult. A landscape which proves attractive or advantageous to the interests of some people turns out to be an eyesore or disadvantageous to others. Thus the farmer who drains a marsh to plant more cereals may be destroying the wildlife sanctuary of the conservationists, and the source of water supply of the water authority. Clearly the population as a whole seeks to maintain a variety of landscapes since variety itself is a source of pleasure. In recent years several changes in landscape have been judged to be deleterious to the enjoyment of onlookers, even though the effects of the changes may be advantageous both to those responsible for them and by another route to the onlookers. Such changes include the sprawl of disjointed urban buildings in the otherwise rural scene; the spread of large areas of blanket coniferous forest; the loss of hedgerows and small woodlands from much of lowland Britain; the intrusion in rural areas of mineral extraction, water conservation and treatment, and energy processing, and their associated buildings; the enclosure, drainage, cultivation and pasture improvement of marshes and open moorland for agriculture. Some of these changes are reversible, albeit with a considerable interval of time and much capital expenditure, others are irreversible. Is it possible to gain the advantages which arise from these changes without causing a deterioration in the landscape to the onlooker? Are all these changes really necessary either to those responsible or to the nation as a whole? A great many aspects of landscape change are subject to control under the Town and Country Planning legislation, but many aspects of agriculture and rural estate management are not. There are those who would like to see a much tighter control on all aspects of landscape change. However, let us not be overattracted by their arguments, there are dangers of rigidity in strict control.

Financial pressures are the main causes for change in the landscape. In the rural sector the financial context within which farmers, foresters and landowners operate leads them to make decisions which are to their own financial benefit, but lead to landscape changes the general population dislike. The landowner did not plant new woods containing several species of broad-leaved trees because the capital taxation system did not induce him to do so, the Forestry Commission have planted large blankets of conifers without contouring because the Treasury have established financial targets for Forestry Commission earnings which mean that other forms of tree planting do not meet the target. The farmer on Exmoor who ploughs the moorland or the farmer who drains a marsh does so partly as a result of the financial inducement in the form of a grant from government to carry out the farm-

ing improvement. The landowner, the Forestry Commission and the farmer should not be criticised for taking such action because they are trying to maximise the earnings from their own businesses. Rather those who determine the financial context, and who do not modify their influence on the context even when the adverse effects of their actions are pointed out to them, should be criticised and persuaded to change their actions. Surely it is desirable to provide a financial stimulus to encourage people to take actions which are in their own interests and in the interests of all who wish to benefit from an aesthetically pleasing landscape. However, such landscapes may be a cost to maintain and may not be consistent with maximising the profits in the business of the person engaged in the main land use activity. If the State, acting on behalf of a society which has concluded that it wishes to maintain and enhance certain types and areas of landscape and is prepared to meet the costs, finds that the land users will suffer a disbenefit as a result of being required to observe certain rules to maintain the landscape, the State has to decide whether the land user should be compensated for complying with the rules. This is a very difficult decision and depends on the view taken of the rights associated with landownership. If landownership is assumed to entitle the holder to use the land as he wishes, then the imposition by the State of constraints on its use may entitle the owner to be compensated for accepting the constraint. Alternatively if landownership is assumed to entitle the holder to use land subject to the constraints imposed by and for the benefit of the State then the holder may not be entitled to compensation. In those circumstances the purchase price should be expected to reflect the constraints to which the land is subject. A landowner cannot use the land for his own benefit without any regard for the needs that society has from that land. The title deeds are permission for the owner to use the land subject to the rules imposed by society.

One of society's requirements is that land is used in such a way that the use does not destroy the land's potential use in future. This is not always possible. The land from which minerals have been extracted may not be suitable for farming or forestry because the soil has gone or may not be suitable for urban use because of possible subsidence. However, there is no technical reason why land used for farming and forestry cannot be maintained over many years in a state which represents no irreversible deterioration in its potential for crop production.

There are some farm practices which on some farms can cause deterioration in soil structure and hence in crop yields on those soils. In the UK concern has been expressed amongst other factors about the consequences of monoculture systems, the use of heavy machinery, the lack of organic matter and the use of heavy dressings of chemical fertilizer. The report "Modern farming and the soil" (MAFF, 1970) and more recently Greenland (1977) indicated that there are still important gaps in knowledge on this subject and that some of the concern is justified. The conservation of soil quality may well attain greater significance in future. Not only is the rate of increase in crop yields declining from about 3% per year in the 1950s to 1% to 1½% now (Wise and Fell, 1978). It may be economically and technically less satisfactory to maintain yields using large dressings of

chemical fertilizers, pesticides, herbicides and large machinery. Energy saving may stimulate new arable techniques such as "no till" farming methods. Conserving soil quality whilst achieving high crop yields as part of the normal management routine and with lower inputs are likely to be the objectives in the years ahead.

In the last century the concern by landlords for maintaining soil fertility and farm potential was translated into effect by including conditions in some tenancy agreements, which represented the rules for good husbandry. Such conditions contained the sequence of crops which could be grown, the way in which FYM had to be returned to the land, the stocking rates which were allowed as well as rules for the maintenance of hedges, ditches and woods. It is argued that no farmer will use methods which will cause deterioration to his farm for he is too interested in maintaining if not improving his income in the future. Therefore, the farmer is the best judge of what constitutes good husbandry. I am sceptical of this argument and am not convinced that farmers always look to the long-term interest in spite of the attractions of short-term gain. I am also not convinced that all farmers are equally and fully competent to know and manage their land in the interests of future generations.

The idea of formulating a code of good farming practice which would be applicable to all farms and which could be used to judge the soundness of the management of individual farmers has a great deal to commend it. There are two obvious criticisms of the idea. One is that unless the code is subject to regular and frequent review there is the danger that it inhibits the adoption of new but appropriate methods and second the notion of having rules for British farmers is repugnant to a group of people who are naturally independent, self-reliant and individualistic. Nevertheless, it is probably worthwhile to attempt to get the representatives of British farmers with scientific and technical advice to draw up a code of good husbandry to be commended to all farmers and to seek to deter farmers from using methods and actions which are deleterious to the long-term potential of soil, land and landscape. If farmers do not instigate such action themselves then it is likely that they will be forced by the action of local and water authorities and by government, acting on behalf of pressure groups in society, to change their ways.

The availability of land

It is not surprising that in the UK, a country with one of the highest population densities, and still one of the more affluent, in the world, there should be a great deal of conflict over the availability of land. Not only is there argument about how much land can be devoted to all competing activities, but also about the location and the quality of the land. The difficulties are caused by changes in land-use particularly for those activities requiring more land at the expense of agriculture. Rational consideration of the problem is not aided by the lack of adequate statistics on the extent of land-use changes year by year. Those who have had cause to seek such data will know that whilst the rate of reduction in farmland area is known with a large error (representing 15% of the area transferred), the areas which

have been added to the activities which are increasing in area is something of a mystery. Even though the Department of the Environment attempted in 1974 (DOE Circular 7/74) to start a system of collecting information on land use changes it has not been successful. Some of the reasons for failure have been summarised by Dickinson and Shaw (1978) who also indicate that a form of spot sampling could give adequate data for monitoring purposes.

There are those (such as Best, 1976, 1977) who consider that the Town and Country Planning legislation has been effective in containing the encroachment of urban development on farmland and in preventing urban sprawl. However, there are others (particularly Coleman, 1977 a and b) who disagree and consider that both the level of urban development and the extent of urban sprawl have continued unabated if not increased and that planning procedures need to be changed (Centre for Agricultural Strategy, 1976; Advisory Council for Agriculture and Horticulture, 1978).

CAS made two major recommendations about the way in which changes in land-use should be determined. First, the onus of responsibility for decisions on transfer of land-use should be altered to give precedence to agriculture and forestry. It would then become necessary for those seeking a change of use of agricultural or afforested land, and for those deciding whether a change should be allowed, to show why any proposed urban development could not be accommodated within existing urban areas.

Second, a detailed statement of the effect of changes in land-use on the nation's future agricultural and forestry production should be prepared now and at three year intervals by MAFF, DAFS and DANI. Such a statement should be transmitted to Local Authorities by the DOE and the Secretary of State for Scotland. The compatibility of Local Authority proposals for changes in land-use with national needs for land for agriculture and forestry as determined by MAFF, DAFS and DANI should be monitored by the DOE and the Scottish Development Department and discussed with MAFF, DAFS and DANI.

The information, not only on land area, use and change of use, ownership and tenure, but also on land capability is fragmentary and, in general, inadequate for land allocation and planning purposes. A great deal of research has been and is being devoted to soil surveys and land capability surveys for several major activities such as agriculture, forestry, conservation, water catchment and storage, fuel cropping and mineral extraction. This effort is to be encouraged though in one respect it may prove to be seriously deficient. From my own recent experience it is clear that the extent of possible cross reference between the several land assessments may be negligible. Thus the suitability of the land for an activity may be well-defined on the assessment scheme designed for that activity, but the extent to which activities are likely to be competing for the same areas cannot be discerned easily by comparison of the several assessment schemes. I suggest that this problem of co-ordination merits urgent attention.

A major element in the conflict over land-use is the concern, originating from the experience of food rationing during the Second World War, that a

situation may arise again, not necessarily national, in which the UK has to feed itself from its own land area. There is, therefore, a strong desire to maintain as much land in agriculture as possible and to prevent encroachment by all forms of urban development, by forestry, by water conservation and by the extractive industries. The conflict is likely to intensify. It is clear that agriculture in the UK could not, if required to, supply all the food now consumed in the UK because there is too little land. Also it is clear that agriculture could supply sufficient food to keep the present population alive in the event of a complete curtailment of imports on a much smaller area than is now used for agriculture. National security cannot be used to support the retention of poorer quality land in agriculture. The case for not allowing urban development to take more farmland is based on the fact that the amount of land which lies derelict within existing urban areas and which is already lost to agriculture, appears to be large enough to meet urban purposes until the end of the century. However, there are uses such as forestry, water conservation, recreation, tourism and conservation of flora and fauna which may have a strong case for taking poorer quality land from agriculture. It is very difficult to judge where change of activity could take place and the consequences for agriculture in the absence, to which I have referred, of the necessary statistical information. To some extent the confllict between some activities can be resolved by multiple use of the same area and by integrated use of adjacent areas under the same management. Some excellent examples of what is possible have been recorded but they remain too few to have much effect. The reasons why more multiple and integrated use of agriculture do not develop need to be sought out. It may be that the reasons are not technical or economic so much as institutional.

Institutional arrangements and land use

The need for decisions to be made about many aspects of the use of land in the interests of those directly concerned in using the land and of those who make use of the products and services derived from the land has never been more urgent. There is a danger that if the institutional arrangements for making these decisions are not considered and some improvements made there will be a polarisation of views between competing interests.

Recently Coppock (1977) and Gilg (1978) have summarised the way in which rural land-use problems have been considered and dealt with in the past thirty years. Gilg points out that the Scott Report (HMSO, 1942) was successful in identifying the main contemporary rural planning issues and that most of them have been tackled effectively by government in the post-war years. One issue on which he considers there has not been effective action is in relation to overall planning control, particularly with the exclusion of agriculture and forestry. Gilg argues the need for a new Scott inquiry "to advise on the allocation of rural resources and the new machinery needed to assign priorities and resource allocations within a global and integrated context . . . At present, policies for each sector of rural life are being examined for the period of change without growth in a strategic vacuum, and this, if allowed to continue, will lead to a continuous

rejigging of policies and low efficiency in the integration of policies and the wise use of all countryside resources".

Most critics of the present institutional situation in relation to rural land-use and development point to two main deficiencies. These arise from the vertical compartmentalisation of responsibility of institutions for land-use activities between the national and the local, indeed the individual landuser, level. Thus agriculture, forestry, water, conservation, recreation, rural industry, countryside affairs, to name but a few activities, are dealt with by separate institutions with national responsibility. At the national and at the local level this separation of responsibility between activities is not conducive to the efficient co-ordination of policies. The result is that nationally there are policy instruments which clearly conflict. A good example is the conflict between the policies for countryside conservation on the one hand and for agricultural development and expansion on the other. At the local level, the poor landuser is bemused and irritated by the complexity of organisations, grants, regulations and advisors with which he has to deal.

Scotland is perhaps fortunate in that some action has been taken to solve these problems; England and Wales might benefit by following Scotland's example. In 1973, after the publication of the White Paper entitled " Land resource use in Scotland " (HMSO, 1973) the Standing Committee on Rural Land Use was established. It is helping to co-ordinate the several rural land use activities in Scotland. The fact that several of the principal land-use activities, handled by separate ministers in England and Wales, come within the responsibility of one minister, the Secretary of State for Scotland, should not be overlooked.

For England and Wales there have been several proposals to form new and enlarged Ministries in order to achieve the same objective. Thus for a short time in the 1960s there existed the Ministry of Land and Natural Resources and more recently the idea of a Ministry of Rural Affairs or of Rural Planning and Development has been made (Country Landowners' Association, 1976; Wibberley, 1976). It is not clear how practical such a proposal may be, but the conflicts which might arise from a major re-organisation of existing Departments such as Agriculture, Forestry and Food and Environment might make the change unrealistic. The Advisory Council for Agriculture and Horticulture in England and Wales in their report "Agriculture and the countryside " suggested that the responsibility of the Agricultural Development and Advisory Service should be widened to include aspects of conservation and tourism. At the same time the Countryside Review Committee established by the Department of the Environment is publishing a series of reports. The committee's terms of reference are:

> " To review, in relation to land outside urban areas, the state of the countryside and the pressures on it; to examine the effect of existing policies for, or having impact on, the countryside and the extent to which they are adequate to contain or modify or accept the pressures. Given the existence of other major policy objectives, including the maintenance or agricultural production, to consider whether changes of policy or of practice are necessary to reconcile these objectives where they conflict

with the conservation of the countryside, the enhancement of its natural beauty, and its enjoyment by the public; and to make recommendations ".

The need for co-ordination of rural land-use policies at the national level is undoubtedly realised, but it is apparent that an appropriate method for such co-ordination has not yet emerged for England and Wales.

Turning from the lack of co-ordination at national level to the problems at local-cum-regional level, the Highlands and Islands Development Board established in 1966 is the sole organisation of its type in the UK. The way in which this Board can supplement the national policies to suit local circumstances and can focus the many national policy instruments to solve the individual land-user's problems is the envy of other regions of the UK. The demise of the rural development board in England and Wales is to be regretted and something similar will need to be established.

Institutional arrangements at both national and regional level need to be modified to overcome the strong tendency to compartmentalise by activity. It may be, as Alexander (1978) has suggested in relation to the needs of the HIDB, that our educational system needs to be changed so that people learn naturally to consider subjects in a co-ordinated rather than a compartmentalised way.

Concluding remarks

I am conscious that much of my talk has been devoted to emphasising the problems of land use and to exposing the inadequacies of the way in which these problems are handled now. I do not wish to convey the impression that I am unaware that much has been achieved by those involved in tackling the difficulties and that the difficulties involve the livelihoods and the interests of people who have independent and strongly held opinions. Progress is bound to be gradual, but is likely to be faster if problems are clearly exposed and discussed.

Land is an important resource which once destroyed is almost impossible to replace. The pressure of population in the UK, the prospect of a shortage of fossil energy and the demands on land in other parts of the world will cause the demands on land in the UK to increase. Even if the population in the UK declined, for instance as a result of migration south into Europe, and if a still larger proportion of the population migrate into the urban conurbations, the problems of land use will grow. It is curious that at a time when there is increasing pressure on land use the population in the remoter areas is still declining. This is a most undesirable trend, and one which needs to be reversed for the proper management of the land depends on maintaining a viable community structure. If I may I will refer to 1770 and in conclusion quote Goldsmith again:

" Ill fares the land, to hastening ills a prey,
Where wealth accumulates, and men decay;
Princes and lords may flourish, or may fade;
A breath can make them, as a breath has made.
But a bold peasantry, their country's pride,
When once destroyed, can never be supplied."

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1. Release of potassium by acid extraction in relation to the mineralogy of selected soils from Southern Turkey. By N. Güzel (Cukurova University, Turkey) and M. J. Wilson, *Agrochimica*, **22**, 48-60, 1978.

   The non-exchangeable potassium of four profiles representative of widely occurring soil series in the Cukurova Plain of the Seyhan region of Southern Turkey has been investigated by making successive 1.0N HCl extractions on total soils and on the clay, silt and sand separates. In general, the clay fractions contain a major part of this form of potassium where it is associated mainly with a montmorillonitic mineral containing interstratified mica layers. Mica existing as a separate phase releases its potassium less readily. Mineralogical examination provided a basis for the interpretation of the general variation in total, non-exchangeable and exchangeable forms of potassium, both within and between the soils.

2. X-ray identification of clay materials in thin sections. By M. J. Wilson and D. R. Clark, *J. Sediment. Petrol.*, **48**, 656-660, 1978.

   A method is described enabling complementary optical and X-ray powder diffraction observations to be made on small areas of fine-grained material in soil thin sections.

3. The effect of Fe-for-Si substitution on the *b*-dimension of nontronite. By J. D. Russell and D. R. Clark, *Clay Minerals*, **13**, 133-137, 1978.

   Study by X-ray diffraction of a series of chemically analysed dioctahedral nontronites has shown that their 060 spacings are large and fall in an area generally assigned to trioctahedral minerals. It is proposed that the large values are due to appreciable iron-for-silicon substitution in tetrahedral sheets causing an increase in *b*-dimension. Factors which take account of this type of substitution in dioctahedral smectites have been calculated from the X-ray and compositional data and incorporated into existing formulae for calculating *b* from composition. These formulae are usually less successful in predicting *b*, however, than a proposed new one in which *b* is determined from ferric iron content only.

4. Occurrence of thaumasite in weathered furnace slag, Merthyr Tydfil. By M. J. Wilson, *Mineralog. Mag.*, **42**, 290-291, 1978.

   Thaumasite, an unusual hydrated calcium silicate containing sulphate and carbonate occurs in abundance in furnace slag at Merthyr Tydfil, South Wales. The mineral has a finely fibrous nature and was formed during the weathering of the slag.

5. Calculated X-ray diffraction curves for the interpretation of a three-component interstratified system. By P. D. Cradwick and M. J. Wilson, *Clay Minerals*, **13**, 53-65, 1978.

   Interstratified clay minerals are common in soils and frequently form during the pedogenic weathering of mica. It is often difficult to interpret the X-ray diffraction patterns of such material, especially when more than two components are involved. In this paper, a series of calculated curves are presented for interstratified mica-vermiculite-montmorillonite; these should be of practical use where interpretative problems are encountered.

6. The occurrence of imogolite in some Scottish soils. By J. M. Tait, N. Yoshinaga (Ehime University, Japan) and B. D. Mitchell, *Soil Sci. Pl. Nutr.*, **24**, 145-151, 1978.

   Imogolite, a hydrous aluminium silicate mineral, occurs in small amounts in the B horizon of several freely drained Scottish soils. Its occurrence may be of value in assessing soil-forming processes.

7. Alteration of allophane and imogolite by alkaline digestion. By V. C. Farmer, B. F. L. Smith and J. M. Tait, *Clay Minerals*, **12**, 195-198, 1977.

   Poorly ordered hydrated gels containing silica and alumina, which play an important role in adsorption of anions such as phosphate, sulphate and humate in soils, can be distinguished from more highly crystalline clay minerals by their greater solubility in alkaline solutions. It is shown, however, that hot sodium

carbonate solutions can convert imogolite and allophane gels into new products richer in silica and with infrared spectra similar to those of zeolites. Cold sodium carbonate treatment does not alter these materials, and can be used for extracting the most reactive gel components.

8. Some characteristics of the brown forest soils of Scotland. By J. M. Ragg, J. M. Bracewell, J. Logan and L. Robertson, *J. Soil Sci.*, **29**, 258-262, 1978.

   The term brown forest soil, which has been used in Europe for almost seventy years, embraces a range of soils too wide for classification purposes. 86 Scottish brown forest soil profiles have been divided into two groups, podzolic and non-podzolic, on the basis of various morphological and physical properties. Statistical analysis of analytical data and environmental properties have revealed differences between these groups, altitude, accumulated temperature, base status, pyrolysis ratio, C/N ratio and pyrophosphate- to dithionite-extractable iron ratio being the most significant variables. Of these, the pyrophosphate- to dithionite-extractable iron ratio is a more useful group discriminator than the widely accepted extractable sesquioxide to clay content ratio.

9. Water-table depth and oxygen content of deep peat in relation to root growth of *Pinus contorta*. By R. Boggie, *Pl. Soil*, **48**, 447-454, 1977.

   Oxygen concentrations were measured in plots in deep peat in which the water-table levels ranged from 11 cm to 33 cm below the surface. The amount of oxygen in the peat decreased with depth and was related to water-table depth. Root distribution of 12-year-old *Pinus contorta* on these plots was strongly correlated to the oxygen concentration in the peat.

10. Growth of Scots pine under nutritional and climatic stress. By H. G. Miller, J. D. Miller and W. O. Binns (Forestry Commission), *Pl. Soil*, **48**, 103-114, 1977.
    Poor growth of a Scots pine crop on a terrace of the river Dee was found to be due to both nitrogen deficiency and lack of rainfall, the latter working both directly through May drought and indirectly through an influence of June rainfall on nitrogen uptake. Response to applied nitrogen fertilizer was independent of and additive to climate-induced changes. The effect of the fertilizer on distribution of growth up the stem and on the ratio of early wood to late wood in each ring is discussed.

11. Ground vegetation and humus nitrogen levels as indicators of nitrogen status in an established sand-dune forest. By H. G. Miller, B. L. Williams, C. S. Millar (University of Aberdeen) and T. R. Warin (University of Aberdeen), *Forestry*, **50**, 94-101, 1977.

    Examination of the ground vegetation in two nitrogen fertilizer experiments in pole-stage pine growing on sand established a sequence of five categories associated with increasing rates of nitrogen. In the forest as a whole, these vegetation categories were found to indicate increasing tree growth and increasing concentration of nitrogen in the humus. In particular, the level of nitrogen in humus seems to be a good, and possibly useful, measure of the nitrogen status of a site.

12. Effect of afforestation with *Pinus contorta* on nutrient content, acidity and exchangeable cations in peat. By B. L. Williams, J. M. Cooper and D. G. Pyatt (Forestry Commission), *Forestry*, 51, 29-35, 1978.

    Nutrient contents, acidity and exchangeable cations in the upper 300 mm of peat planted with *Pinus contorta* Dougl. are compared with those in unplanted peat from contiguous areas at each of six sites in the north of Scotland. The drier peat beneath the tree crop contains less calcium and magnesium, higher amounts of sodium and is more acid than the unplanted peat. The increased acidity is attributed partly to losses of calcium and magnesium but mainly to a gain in the content of exchangeable hydrogen ions arising from additional exchange sites.

13. Metal contaminants in sewage sludges and some effects on soil and plant contents. By M. L. Berrow and J. C. Burridge, pp. 31-38 of *Tech. Note* 11, *Department of Environment Research Seminar on Effect of Metal Contaminants in Sewage Sludge*. Water Engineering, Research and Development Division, 1978.

    Trace elements in sewage sludges are reported and discussed in relation to normal soil contents. Analyses of soil and plant samples from a long-term field experiment being carried out in conjunction with ADAS at Luddington

Experimental Horticultural Station, Warwickshire, are briefly presented. Total and extractable soil contents and also plants sampled from this experiment in 1976, eight years after the start of the experiment, clearly reflected the high metal contents of the sludges applied in 1968.

14. A carbon-rod atomizer for the determination of cadmium and lead in plant materials and soil extracts. Part III. Simultaneous determination of cadmium by atomic fluorescence and lead by atomic absorption spectrometry. By A. M. Ure, M. P. Hernandez-Artiga and M. C. Mitchell, *Anal. Chim, Acta,* **96**, 37-43, 1978.

    An apparatus and technique for the simultaneous determination of cadmium by atomic fluorescence and lead by atomic absorption spectrometry are described. A common dithizone-in-chloroform extraction procedure is used for the analysis of plant material and soil extracts with the carbon-rod atomizer. Detection limits in solution of 0·002 ppm for cadmium and 0·035 ppm for lead are obtained with a precision of ±2-6% and minimal interference effects.

15. Differential pulse polarography of selenium IV in the presence of metal ions. By G. P. Bound and S. Forbes, *Analyst,* **103**, 176-179, 1978.

    The differential pulse polarographic analysis of selenium IV was investigated. In acid solutions copper was found to be a serious interferent. In a background electrolyte of 1·0 M NH_4OAc and 0·01 M E.D.T.A. no serious interferents were found. The detection limit of the technique was 5 ng cm^{-3}.

16. Comprehensive analysis of soils and rocks by spark source mass spectrometry. By A. M. Ure and J. R. Bacon, *Analyst,* **103**, 807-822, 1978.

    A description is given of the technique used for the quantitative analysis of soils and rocks by Spark Source Mass Spectrometry with aluminium as the conducting material. Details are given of photographic plate emulsion calibration and evaluation methods together with the interference correction procedures essential before measuring, and finally before applying, the Relative Sensitivity Coefficients used to standardize the analyses. Over fifty elements can be determined and a typical precision of ±10-15% is attained. The techniques are illustrated by application to the analysis of soils, concentrates of acetic acid extracts of soils, and U.S. Geological Survey Standard Rocks G-2 and AGV-1.

17. Scandium, yttrium and the rare earth contents of water lily (*Nuphar lutea*). By A. M. Ure and J. R. Bacon, *Geochim. Cosmochim. Acta,* **42**, 651-2, 1978.

    The contents of scandium, yttrium and the rare earth elements, determined by spark source mass spectrometry, for water lily (*Nuphar lutea*) from Dow Loch (Scotland) have been compared with those for the National Bureau of Standards Orchard Leaf SRM 1571 and Dow Loch sediment. In contrast to the conclusions from a recent North American study of aquatic plants no evidence of accumulation of any of these elements has been found.

18. Trace element analysis in biological materials by spark source mass spectrometry. By A. M. Ure and J. R. Bacon, *Euroanalysis III, Dublin, Ireland, 1978, Paper 184.*

    An outline of the methods being developed for the analysis of biological materials of plant and animal origin by spark source mass spectrometry is presented. These are adapted from quantitative multi-element methods already evolved for soils and rocks. The considerable problems of super-positional interference by molecular ions in the analysis of biological samples are discussed. The use of internal standard elements (a) added to the sample in known fixed amounts or (b) present naturally in amounts determined by a different method is described. Examples of applications to various samples including standard materials such as the NBS Orchard Leaf SRM 1571 and NBS Bovine Liver SRM 1577 are given.

19. Ammonia-treated vermiculite—a possible controlled-release N-fertilizer. By J. D. Russell and A. R. Fraser, *J. Sci. Fd Agric.,* **28**, 852-854, 1977.

    The preparation and properties of ammonia-treated vermiculite are described and discussed in terms of its potential as a controlled-release nitrogen fertilizer. This is likely to have relevance for those Scottish soils that contain hydrobiotite or vermiculite weathering products since it will be formed *in situ* on direct injection of anhydrous ammonia fertilizer.

20. Glauconite and celadonite: two separate mineral species. By H. A. Buckley (Dept. Mineral. Br. Mus. Nat. Hist.), J. C. Bevan (Dept. Mineral. Br. Mus. Nat. Hist.), K. M. Brown (Dept. Mineral. Br. Mus. Nat. Hist.), L. R. Johnson (Dept. Mineral. Br. Mus. Nat. Hist.) and V. C. Farmer, *Mineralog. Mag.*, **42**, 373-82, 1978.

    A distinction can be made between two series of ferruginous mica on the basis of chemical compositions, X-ray diffraction patterns, infrared spectra, and crystal morphology. The glauconite group is of low temperature origin, whereas the celadonite group is of hydrothermal origin.

21. Infrared spectroscopic evaluation of iron contents and excess calcium in minerals of the dolomite-ankerite series. By V. C. Farmer and S. St. J. Warne (Dept. Geol., Univ. Newcastle, Australia), *Am. Mineral.*, **63**, 779-781, 1978.

    Evaluation of the dolomite content of carbonate deposits and the placing of a ferroan dolomite within the dolomite-ankerite isomorphous series are of importance for the agricultural use of dolomite as a source of magnesium and as a soil pH regulator. Infrared spectroscopy is shown to be a convenient and rapid method for evaluating the proportion of dolomite end-member in minerals of the dolomite-ankerite series, and for estimating the amount of admixed calcite.

22. The identification of sulphide minerals by infrared spectroscopy. By R. Soong (N.Z. Geol. Surv., D.S.I.R., N.Z.) and V. C. Farmer, *Mineralog. Mag.*, **42**, 227, M17-20, 1978.

    The value of infrared spectra in identifying sulphide minerals has been assessed by surveying the spectra of some forty specimens. Except for minerals whose metallic conductivity obliterates vibrational features, the spectra permit rapid recognition of sulphide minerals either alone or in mixtures. Spectra of 25 pure or nearly pure specimens are presented. The iron sulphides can form in soils under anaerobic conditions, and others can give rise to heavy metal toxicities in the neighbourhood of sulphide outcrops.

23. Chemical and infrared spectroscopic studies of fulvic acid fractions from a podzol. By H. A. Anderson, A. R. Fraser, A. Hepburn and J. D. Russell, *J. Soil Sci.*, **28**, 623-633, 1977.

    This paper is the first part of a series dealing with podzolization. Infrared spectroscopic and chemical evidence have indicated that several fulvic acid fractions from an iron-humus podzol are capable of complexing and translocating metals. In particular, acid-extractable organic matter isolated from the illuvial humus and having a high content of carboxylic acid groups, is likely to play a major role in any translocation.

24. Comment on " Spectroscopie infra-rouge de quelques fractions d'acides humiques obtenues sur Sephadex ". By J. D. Russell and H. A. Anderson, *Pl. Soil*, **48**, 547-548, 1977.

    Faulty interpretation of infrared spectra and Sephadex chromatograms of soil organic matter fractions have led to a further instance of misleading conclusions about the structure of such fractions. A simpler, more realistic explanation in terms of a mixture of humate and clay mineral is proposed.

25. The Mössbauer spectra of nontronites: consideration of an alternative assignment. By B. A. Goodman, *Clays Clay Minerals*, **26**, 176-177, 1978.

    An alternative assignment of the Mössbauer spectra of nontronites, which does not require the presence of more than one phase, is considered with reference to new and previously published results.

26. Distribution of ^{14}C in soil humus and soil saccharides during the decomposition of [^{14}C] labelled ryegrass incubated in soil. By S. Murayama, M. V. Cheshire and C. M. Mundie, *Abs. Soc. Sci. Soil Manure*, **24**, 14, 1978.

    Grass labelled with ^{14}C has been allowed to decompose in soil and the rate of decompostion and distribution of the radioactivity in saccharides followed over the period of a year.

27. Effect of temperature and soil drying on the transformation of (^{14}C) glucose in soil. By M. V. Cheshire, G. P. Sparling, C. M. Mundie, H. Shepherd and S. Murayama (Nat. Inst. Agric. Sci., Tokyo), *J. Soil Sci.*, **29**, 360-366, 1978.

Previous studies at this Institute on the effect of temperature on the transformation of glucose in soil used predried soil. It has now been shown that the increased synthesis of xylose observed at 5°C over that at 20°C with predried soil is not observed when fresh soil is used. The xylose synthesis can be related to the metabolism of yeasts and their relative numbers in relation to bacteria. Bacteria appear to be inhibited at low temperature in predried soil.

28. Polycarboxylic acids extracted by water and by alkali from agricultural top soils of different drainage status. By D. J. Linehan, *J. Soil Sci.*, **29**, 373-377, 1978.

Humic substances present in solution in soils may be taken up by plants and alter their growth and metabolism. Such soluble humic substances have been isolated from soils having varying degrees of drainage impedence. The amounts were much higher in very poorly-drained soils with, in one Soil Association, a ten-fold difference between the well-drained and poorly-drained sites. In contrast, the proportion of total organic matter accounted for by the structurally similar polycarboxylic acid of fulvic acid was lower in the very poorly-drained soils. The amount of oxalate-extractable aluminium, thought to be involved in adsorbing these soluble polycarboxylic acids, decreases with increasing drainage impedance. Since soluble humic substances may influence plant growth under field conditions the factors influencing their amounts are being further investigated.

29. Fractionation of humic acid by gel permeation chromatography. By H. A. Anderson and A. Hepburn, *J. Soil Sci.*, **28**, 634-644, 1977.

Two humic acids from a podzol have been fractionated by gel permeation chromatography. This technique allows the separation of most of the organic nitrogen in the gel-filtered product, from an adsorbed fraction which may be mainly polycyclic aromatic in nature.

30. Phenolic hydrolysis products from gel chromatographic fractions of soil humic acids. By R. Tate (Soil Bureau, DSIR, Lower Hutt, New Zealand) and H. A. Anderson, *J. Soil Sci.*, **29**, 76-83, 1978.

Humic acids extracted from the B_h horizon of a Kauri (*Agathis australis*) podzol and the A horizon of a yellow-brown earth under hard beech (*Nothofagus truncata*), both New Zealand soils, have been fractionated by gel chromatography.

The relative contents of lignin-derived phenolic acids in acid hydrolysates of the resulting fractions have been compared by gas chromatography. The phenolic compounds from both humic acids are probably modern products derived from deciduous vegetation. In the Kauri podzol, these must be derived from the present-day scrub vegetation.

31. Ether-soluble hydrolysis products in humic and fulvic acids. By H. A. Anderson, A. Hepburn and A. Sim, *J. Soil Sci.*, **29**, 84-87, 1978.

The major ether-soluble products from the hydrolysis of humic and fulvic acids include levulinic, succinic and fumaric acids, accompanied by more variable amounts of 4-hydroxy- 3-methoxy-4-hydroxy-, and 3,4-dihydroxybenzoic acids. 3,5-Dihydroxybenzoic acid was not detected in the hydrolysates examined, indicating a lignin, rather than flavonoid, source of the phenolic acids.

32. Geo-stimulation of root growth and pigment synthesis in mustard seedlings. By I. R. MacDonald and D. C. Gordon, *Nature*, **272**, 48-49, 1978.

Experiments using mustard seeds have demonstrated a positive non-tropic effect of gravity both on the rate of root growth and the synthesis of anthocyanin and chlorophyll in the cotyledons. The results are of particular interest in showing that the perception of gravity occurs in the germinating seed before the emergence of the radicle and that the level of enzyme activity in the seedling is regulated by gravity.

33. Some microbial and chemical changes in soil near the roots of spring barley, *Hordeum vulgare* L., infected with take-all disease. By J. F. Darbyshire, M. S. Davidson, N. M. Scott and P. J. Shipton (North of Scotland College of Agriculture), *Ecol. Bull (Stockholm)*, **25**, 374-380, 1977.

Bacterial and active protozoan populations in the soil near barley roots gradually increased as the plants aged until harvest. The populations of these microbes, associated with the roots or barley stubble remaining in the soil after harvest, declined although eventually they recovered. The level of nitrate nitrogen increased in this soil immediately after harvest but the total amount of nitrogen did not change. Bioassays after harvest for the incidence in the soil of the fungal pathogen which causes take-all disease in cereals, showed an increase until mid-winter and then a sharp decline. Microbial antogonists to this fungus also reached their maxima in mid-winter.

34. Surface morphology of narcissus flowering stems as revealed by scanning electron microscopy. By D. Jones, *Micron*, **9**, 95-97, 1978.

Surface features of biological tissue examined in a scanning electron microscope can vary according to the preparative technique used to preserve and dry the material. This paper reports the finding of wax in the form of irregularly-shaped protrusions on freeze-dried flowering stems of narcissus whether or not they had been preserved chemically. This wax was not present on critical-point dried stems similarly treated.

35. Preservation of biological specimens for SEM examination. By D. Jones, *Proc. Roy. Micro. Soc.*, **13**, Part 4 Micro '78 Suppl., 33, 1978. No reprints.

The preparation of biological specimens needs special care if their external features are to be preserved. This was illustrated by comparing two standard techniques used to dehydrate specimens. The results showed that the preparative techniques to be chosen obviously depended on the ultra-structural features under investigation.

36. Scanning electron microscopy of cystosori of *Spongospora subterranea*. By D. Jones, *Trans. Br. Mycol. Soc.*, **70**, 292-293, 1978.

The powdery scab fungus *Spongospora subterranea* can cause severe damage to potato tubers. A scanning electron microscope has been used to examine the microscopic spore balls found in the lesions. Clusters of wart-like protuberances were seen on the individual cysts which are stuck together to form the sponge-like spore balls.

37. Crop losses due to the soil-borne fungus *Sclerotinia sclerotiorum*. By D. Jones and E. G. Gray (North Scotland Coll. Agric.), *ARC Research Review*, **3**, 79-81, 1977.

Plant losses due to the fungus, *Sclerotinia sclerotiorum*, can be quite considerable in certain areas of the world. It became a problem in parts of north-east Scotland after the introduction of vining peas as an agricultural crop. A brief account of the biology of the fungus is given, together with some information on the extent to which it occurs.

38. The morphology of a soil flagellate, *Spiromonas angusta* (Duj. Alexeieff Mastigophorea: Protozoa). By C. M. Macdonald and J. F. Darbyshire, *Protistologica*, **13**, 441-450, 1977.

The morphology of a common soil protozoan is described with the aid of the electron microscope. The ultrastructure of this protozoan has close affinities with other common flagellates of the genus *Bodo*. *Spiromonas angusta* can ingest large numbers of soil bacteria.

39. Soil fungi as food for giant amoebae. By K. M. Old (Dundee Univ.) and J. F. Darbyshire, *Soil Biol, Biochem.*, **10**, 93-100, 1978.

Twenty-four species of soil fungi were fed to an unidentified giant soil amoeba. Fifteen of these species were perforated in the same manner as was recently reported for the conidial spores of the soil fungus, *Cochliobolus sativus*. This giant amoeba can also feed on bacteria, algae, protozoa and nematodes. Seven other species of soil amoebae failed to attack conidia of *C. sativus*.

40. Fertiliser recommendations for the North College Advisory Area. By The North of Scotland College of Agriculture and the Macaulay Institute for Soil Research. *College Bulletin No. 15*, September, 1978.

41. Phosphate relationships of some phosphated Alberta soils. By J. A. Robertson and B. W. Bache, pp.208-209, *11th International Congress of Soil Science*, Volume 1, 1978.

    Phosphate supply from soil to plant depends on both the amount of phosphate present and its ease of withdrawal from the soil. A mathematical analysis of phosphate sorption curves has allowed the amounts of phosphate held at each of three different bonding energies to be calculated and the phosphate buffer capacity to be measured at different phosphate levels. Phosphate uptake by barley in the glasshouse can be predicted by combining a buffer capacity measurement with either the amount of isotopically-exchangeable phosphate, or the phosphate concentration in solution.

42. Long term culture methods for the production of isotopically labelled plant material. By A. H. Knight, *New Phytol.*, 79, 573-582, 1977.

    The preparation of radioactively-labelled plant material for use in subsequent experiments is an important problem in radiobiology. This paper describes the methods that have been used to prepare material labelled with ^{65}Zn, ^{36}Cl, ^{59}Fe, ^{45}Ca, ^{14}C and ^{3}H, and evaluates critically the factors to be considered in the production of such material.

43. The use of air photo interpretation for land evaluation in the Western Highlands of Scotland. By C. J. Lawrance (Soil Sci. Lab., Univ. Oxford), R. Webster Soil Sci. Lab., Univ. Oxford), P. H. T. Beckett (Soil Sci. Lab., Univ. Oxford), J. S. Bibby and G. Hudson, *Catena*, **4**, 341-357, 1977.

    Classifications of terrain, into land systems and land facets, relying largely on air photo interpretation are justified in two ways: (i) that recognition of the pattern of variation within a *land system*, and its description by means of diagrams and annotated air photos, facilities the identification of distinct sub-areas within it (*facets* or *elements*), particularly by staff with limited local experience; (ii) that the classes are useful for indexing existing information on natural resources, including soil, and as strata for economic sampling when obtaining new data. Such schemes have been widely used, for one or both reasons, but not so far in the intricately varying landscapes shaped by glacial and periglacial processes on hard rock. This paper reports a study in which attempt was made to classify such terrain in the Western Highlands of Scotland using the same philosophy and procedures, and the result checked.

    It proved reasonably easy to classify a trial area into distinct land systems, which are mapped. Division of the land systems was more problematic since each subdivision was itself a complex termed a "patterned facet", consisting of several elements of more or less contrasting land with different potentials for use. Elements were not consistently recognized correctly by air photo interpretation, though elements of the more specifically soil complexes could be recognized by surveyors with considerable local experience.

44. Soils. By J. H. Gauld, Chapter in *County Flora: Moray, Nairn and Inverness*, pp.20-34, Aberdeen University Press, 1978.

    The soils of Moray, Nairn and parts of Easterness are described and classified. The soil-forming factors, in particular the geological and glaciological history of the soil parent materials, are discussed, prior to an account of the distribution and character of the main soils in eight major landform units.

45. Geomorphology and soils. By J. S. Bibby, An introductory chapter for inclusion in a publication by the British Museum entitled "Flora of Mull". Requested by The Curator, Department of Botany, British Museum.

    A general account of the genesis and soils of each of the major landform units or land systems of the Isle of Mull, Argyll, is given. This is followed by a short explanation of the meaning of each of the major soil group terms used in the text. The paper is intended to provide a background to the evolution and distribution of the soils of Mull for the non-specialist.

46. The maps of the Soil Survey of Scotland. By W. S. Shirreffs, *Proc. 1977 Ann. Summer School Soc. Univ. Cartographers*, Aberdeen, pp.6-11, 1978.

    An account is given of the cartographic work of the Soil Survey Department, Macaulay Institute for Soil Research in this edited summary of an illustrated lecture given at the Society of University Cartographers Annual Summer School on 6th September, 1977.

47. Design and production of 1:25 000 multicolour land use capability maps. By W. S. Shirreffs, *Cartographic J.*, **14**, 99-102, 1977.

    A procedure is described for producing short runs of multicoloured land use capability maps using a combination of two printing methods, lithography and silk screen. The advantages and limitations of the process are discussed.

48. Soil survey of part Taieri Uplands, Otago, New Zealand. By J. M. Ragg and R. B. Miller (Soil Bureau, Lower Hutt, New Zealand), *N.Z. Soil Bureau Bulletin No. 39*, 1978.

    The soils of 40 000 ha (100 000 acres) of uplands between the Taieri River and the Outram-Middlemarch Road, eastern Otago are described in detail and classified. A soil map at a scale of 1:63 360 is appended, with an extended legend which summarises, for each soil unit, factors of the soil environment, soil properties, and agricultural characteristics.

    The topography is predominantly rolling (69%), hilly (20%), and steep (10%), and tors, tarns, and rock outcrops are extensive. The soils were formed on varying thicknesses of loess over schist rock under a vegetation of tussock grasses. Rainfall ranges from 500 to 750 mm/year and mean annual temperatures are probably between 7 and 10°C.

    Thirty-eight soil mapping units, including thirteen complexes, are distinguished, but half of these cover less than 1000 ha. Yellow-brown earths (69%), and yellow-grey earths (23%) are the most extensive soils, but complexes of these, and brown granular loams, gley soils, recent soils, and organic soils also occur. Particle size distribution, soil chemical properties, and mineralogical properties of representative samples of the main soils are tabulated and discussed in relation to soil classification and soil use. These properties support the conclusion that a considerable intensification of agriculture is possible in the uplands of eastern Otago.

(B) *Awaiting publication at 30th September, 1978*

49. Clay mineralology—whence and whither? By R. C. Mackenzie. To appear in *Proc. 6th Int. Clay Conference, Oxford, 1978.*

50. An examination of the variability of organic matter, exchangeable cations and other components within a given pedological feature. By J. M. Bracewell, G. W. Robertson and J. Logan. Submitted to *J. Soil Sci.*

51. *De Calore:* prelude to thermal analysis. By R. C. Mackenzie. Submitted to *Thermochimica Acta.*

52. Nomenclature in thermal analysis. By R. C. Mackenzie. To appear in *Treatise on analytical chemistry*—2nd ed., Pt. 1. Edited by I. M. Kolthoff, P. J. Elving and C. B. Murphy. New York: Wiley Interscience.

53. Complementary Techniques. By R. C. Mackenzie. To appear in *Thermogravimetry*. Edited by J. P. Redfern and C. J. Keattch. London: Butterworths.

54. Application of thermogravimetry to naturally occurring organic materials. By E. Paterson and B. D. Mitchell. To appear in *Thermogravimetry*. Edited by J. P. Redfern and C. J. Keattch. London: Butterworths.

55. Variable atmosphere DTA in identification and determination of anhydrous carbonate minerals in soils. By S. St J. Warne (Univ. Newcastle, Australia) and B. D. Mitchell. Submitted to *J. Soil Sci.*

56. Penecontemporaneous weathering of the Old Red Sandstone in the Midland valley of Scotland—discussion. By M. J. Wilson. Submitted to *Scott. J. Geol.*

57. Erosion deposits in tile-drained soils. By E. Paterson and B. D. Mitchell. Submitted to *Agric. Wat. Manage.*

58. Origin and significance of extractable titanium and vanadium in the A horizons of Scottish podzols. By M. L. Berrow, M. J. Wilson and G. A. Reaves. Submitted to *Geoderma.*

59. The mineralogy and heavy metal content of some serpentinite soils in north-east Scotland. By M. J. Wilson and M. L. Berrow. Submitted to *Chem. Erde.*

60. Mössbauer spectra of chlorites and their decomposition products. By B. A. Goodman and D. C. Bain. To appear in *Proc 6th Int. Clay Conference, Oxford, 1978.*

61. Interlayer and intercalation complexes of clay minerals. By D. M. C. MacEwan (Hythe, Kent) and M. J. Wilson. To appear in *X-ray Identification and Crystal Structures of Clay Minerals.* Edited by G. Brown and G. W. Brindley. 3rd ed London: Mineralogical Society.

62. General theory for the one-dimensional scattering of X-rays from interstratified clay minerals. By P. D. Cradwick. Submitted to *N.Z. J. Sci.*

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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.

ARC Institutes

Animal Breeding Research Organisation	King's Buildings, West Mains Road, Edinburgh, EH9 3JQ.
Institute of Animal Physiology	Babraham, Cambridge, CB2 4AT.
Institute for Research on Animal Diseases	Compton, Newbury, Berks, RG16 0NN.
Food Research Institute	Colney Lane, Norwich, NR4 7UA.
Meat Research Institute	Langford, Bristol, BS18 7DY.
Poultry Research Centre	King's Buildings, West Mains Road, Edinburgh, EH9 3JS.
Letcombe Laboratory	Letcombe Regis, Wantage, Oxfordshire, OX12 9JT.
Weed Research Organisation	Begbroke Hill, Sandy Lane, Yarnton, Oxford, OX5 1PF.

State-aided Institutes (Scotland)

Animal Diseases Research Association	Moredun Institute, 408 Gilmerton Road, Edinburgh, EH17 7JH.
Hannah Research Institute	Ayr, KH6 5HL.
Hill Farming Research Organisation	Bush Estate, Penicuik, Midlothian, EH26 0PH.
Macaulay Institute for Soil Research	Craigiebuckler, Aberdeen, AB9 2QJ.
Rowett Research Institute	Bucksburn, Aberdeen, AB2 9SB.
Scottish Institute for Agricultural Engineering	Bush Estate, Penicuik, Midlothian, EH26 0PH.
Scottish Horticultural Research Institute	Invergowrie, Dundee, DD2 5DA.
Scottish Plant Breeding Station	Pentlandfield, Roslin, Midlothian, EH25 9RF.

State-aided Institutes (England and Wales)

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