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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

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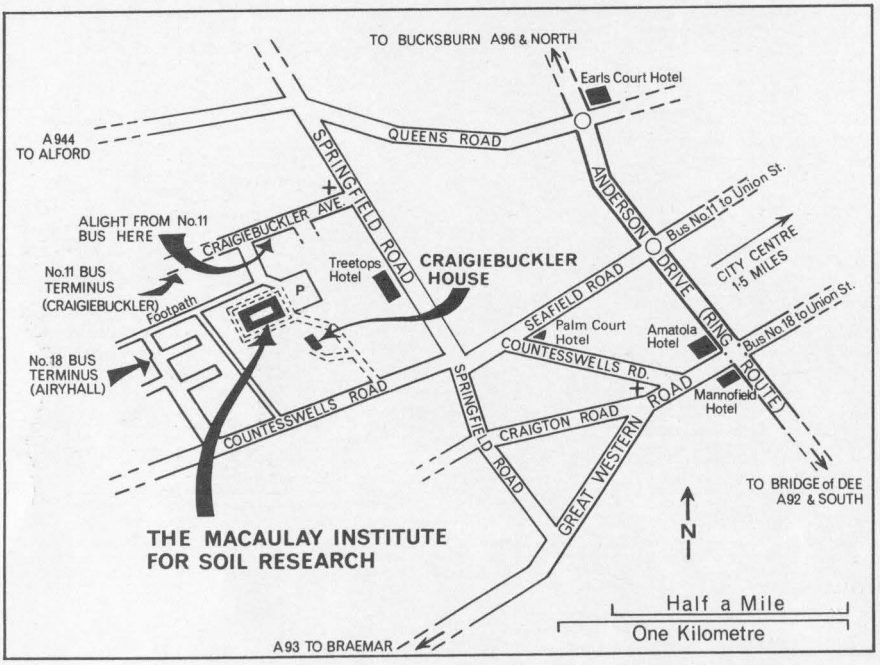

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The main part of this report covers the period from 1st January to 31st December, 1985. The staff list is that current in December, 1985 and the Introduction is similarly updated. The report was published in May

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

(Founded 1930)

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Presentation of the Scroll of Honour to the Macaulay Lecturer Sir John Mason (left-hand side) by the Director (right-hand side) and the Chairman, Professor H. M. Keir, on 20th November, 1985.

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1985

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Mrs.M.E. Reid — appointed 1.2.85
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P.F.S. Ritchie, B.Sc., B.A. — deceased 10.4.85
J.S. Anderson
G.G. Wright, B.Sc.
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Mrs. A.F. Nisbet(née Leech), B.Sc., Ph.D., D.I.C. (DOE Term Contract)
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Miss L.A. Clark — resigned 20.6.85
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Miss S.M. Bissett — transferred to Statistics 2.9.85
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B.G. Ord
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Miss R.M. Paterson
Miss S.M. Crooke — transferred to Peat & Forest Soils 1.8.85
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Mrs. A.M.Ross — resigned 3.5.85
Miss S.A. Cope — resigned 2.8.85
Miss A.E. Thomson
Miss J.A. Almeida — appointed 1.8.85
Miss S. Campbell — appointed 19.8.85
Miss K.A. Wood — appointed 24.9.85

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R.G. Baker, B.Sc. (HIDB Term Contract)
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Miss K.D. Webster
Miss A.M. Smith — appointed 3.6.85
Mrs. M.M. Justice

SOIL FERTILITY

Head of Department: N.M. Scott, Ph.D., C. Chem., F.R.S.C. — Acting Head of Department — retired 28.2.85
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Mrs. M.E. Reid — transferred to Mineral Soils 1.2.85
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Mrs. L. Murray — resigned 28.2.85
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Miss S. Main
Miss P.J. Anderson
Miss C.M. Stott
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A.P. Stewart — appointed 23.4.85
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J.S. Morrison
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Miss H.E.A. Brand — appointed 21.10.85

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C. Halliday

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W.S. Shirreffs - appointed 1.11.85

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G. Sim
D.W. Clark
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Mrs. A.F. Stewart, M.A.
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J.W.S. Reith, B.Sc., Ph.D., C. Chem., F.R.S.C.

HONORARY RESEARCH ASSOCIATE

Profesor H.G. Miller, B.Sc., Ph.D., D.Sc., F.I.(For)

VISITING RESEARCH WORKERS

Dr J.A. Adams, Department of Peat and Forest Soils, (University College of Agriculture, Lincoln College, Canterbury, New Zealand.)

Dr F. Ajmone Marsan, Department of Mineral Soils, (Istituto di Chimica Agraria Universita di Torino, Italy.)

*Miss J.A. Armstrong, Department of Plant Physiology, (Department of Forestry, University of Aberdeen.)

*C.D. Campbell, Department of Microbiology, A.R.C. Research Student.

Mr J.P.J. Dicks, Department of Soil Organic Chemistry, MSc Student (with possibility of extension to Ph.D degree) on Scotch Whisky Research Studentship, October 1985 for 2 years.

*Miss C. Flower, Department of Peat and Forest Soils, A.R.C. Research Student.

Dr D.G. Lewis, Department of Spectrochemistry, (Waite Agricultural Research Institute, University of Adelaide, South Australia.)

Dr R.L. McLeod, Department of Mineral Soils, (Darling Downs Institute of Advanced Education, Australia.)

*Mr R. McMahon, Department of Spectrochemistry, Ph.D Student on SWAP Studentship, October 1985 for 3 years.

Dr P. Nadeau, Department of Mineral Soils, (Dartmouth College, Hanover, New Hampshire, U.S.A.)

Dr T. Nomura, Department of Spectrochemistry, (Senshu University, Japan.)

*Miss F. Proctor, Department of Plant Physiology, DAFS Research Student.

Dr R. Tippkötter, Departments of Microbiology and Soil Survey, (Institut fur Bodenkunde, University of Hanover, Federal Republic of Germany.)

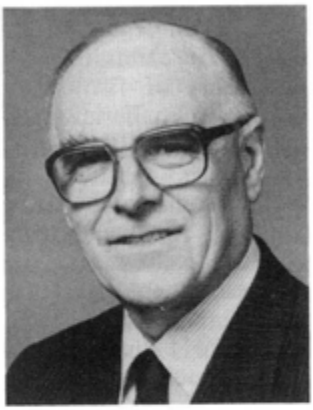
Mrs A. Yahalom, Department of Soil Organic Chemistry, (University of Tel Aviv, Israel.)

*Ph.D. Student.

CONTENTS

INTRODUCTION

T.S. West



The concern expressed in recent Annual Reports about uncertainties for the future of agricultural research has intensified this year to a very considerable extent culminating near the end of December, just before the arrival of the 1985 AFRC Visiting Group, with the appearance of the DAFS paper on its strategy for agricultural research and development. The announcement therein of DAFS intention to amalgamate the Macaulay Institute for Soil Research and the Hill Farming Research Organisation to form an Institute to be concerned with land use on the hills, uplands and marginal lands came as a complete surprise. DAFS' announcement that it favoured the HFRO Bush Estate south of Edinburgh has naturally caused very considerable concern and uncertainty. All of this came on top of DAFS' known need to cut back on agricultural research work following the appearance of the Priorities Board recommendations.

However, despite these uncertainties and the background of unease and insecurity they have engendered, the staff of the Institute have, as always, responded well and established new achievements in several areas. One hundred and six papers were published in 1985.

Surface Water Acidification, Acid Rain and Soil Interactions

The Departments of Mineral Soils, Spectrochemistry, Peat and Forest Soils and Soil Organic Chemistry's involvement in work related to the impact of acid deposition on the composition of soil, stream and loch waters has developed significantly during the year. Soil and stream waters from four separate catchments are now being monitored on a regular basis, these being at Allt a' Mharcaidh, near Glen Feshie in the Cairngorms, an unforested site which is thought to be transitional in respect of fish death, Loch Chon and Kelty Water near Loch Ard in the south-west Highlands, which are partly-to-heavily forested and fishless. The first three catchments have been chosen for the SWAP study, referred to in the 1984 Annual Report. About 80 soil moisture probes have been installed in various horizons of all the major soil types both on a catchment-wide basis and in the more detailed experimental plots set up by the Department of Peat and Forest Soils. Soil, stream and spring waters are being collected on a monthly basis and analyzed for all the major cations, including aluminium, and anions. Soil profile samples have also been collected from sites directly adjacent to the porous cup lysimeters and the chemical and mineralogical characteristics of the soils, particularly the nature of their exchange complexes, are currently being assessed. The SWAP work is being done in

collaboration with the Institute of Hydrology, the DAFS Freshwater Fisheries Laboratory and the Environmental Group of Imperial College, London.

The Loch Fleet experiment is being organized and partly funded by the CEGB and involves a large number of interested research organisations. The overall objective of the work is to investigate the conditions and processes that have led to the acidification and loss of fish stocks particularly in the Loch and to seek cost-effective ways of ameliorating this situation. As part of this programme, and with the object of assessing the role of soil seepage waters as a contributor to the input of the Loch, the Institute has installed 12 soil moisture probes at the soil/rock interface around the perimeter of the Loch. Preliminary results for the first three month period of measurement suggest that the soil waters have not substantially influenced the composition of the Loch waters, although it has to be said that this period was one of exceptionally heavy rainfall.

The SWAP work of the Department of Mineral Soils has been further expanded by the award of an additional grant of £55,000 over the next four years to study mineral weathering in the soils of the catchments, and a small additional grant has been requested from the Royal Society to allow work to be done on an unacidified site in Norway in conjunction with the SWAP Scandinavian group. Particular points for investigation include the elucidation of the processes and products of mineral weathering, the role of mineralogy in determining the acid neutralizing capacity of the soils and the determination of the rates of long-term and present-day mineral weathering. Background information for this work has been assembled and reviewed and a conceptual model proposed to show how mineral weathering processes in podzol soils could be modified under the influence of acid deposition. A key point of this model is that there is evidence to suggest that the partial replacement of natural soil organic acids by mineral acids introduced through precipitation could deplete the exchangeable bases in the soil more rapidly and at the same time slow down the rate of weathering of primary minerals. The consequence of this would be that the soils would become more acid and that the amounts of dissolved ionic aluminium in soil and stream waters would increase. Experiments are being set up to test the validity of this concept.

Part-time studies by a research student in the Department of Plant Physiology, funded by a DoE grant to the Department of Forestry, University of Aberdeen, have allowed quantification of calcium fluxes across cell membranes in spruce needles, and the mobility of calcium present in the twigs. Such information is fundamental to an understanding of the effects of acid rain on crown leaching in forest trees, thus adding further to the acid-rain work of the Institute and earlier and still ongoing work on tree nutrition and forest soils.

New Techniques Shed Light on Properties of Clays and Suggest New Uses in Industry and Technology

Fundamental studies of the finely divided clay fractions which, because of their large surface area, strongly and disproportionately influence the

chemical and physical properties of soils, have led to some exciting new developments that could be of direct industrial and commercial interest. This prospect results from the development of techniques enabling clay materials to be dispersed to their ultimate structural units in aqueous suspensions and to combine different suspensions in a controlled way so that clay products can be synthesized and their unique properties, such as high surface area and ion exchange, utilized in a more effective manner. The products of such combinations are synthetic randomly interstratified clays whose adsorption/desorption characteristics, microporosity, permeability and chemistry can be modified to optimize their performance as chemical supports and heterogeneous catalysts. Thin films of these materials may find applications as release agents and coatings in agriculture and pharmaceuticals, in bacterial immobilization and enzyme supports in biotechnology and as protective coatings and bonding intermediates in the materials sciences. This work arising out of the DAFS commissioned programme of the Institute has been supported by a grant from the British Technology Group.

Soil Aggregates and Soil Physical Conditions

Increasing emphasis upon the desirability of making more extensive soil physical measurements as expressed in the meetings of the MISR/COSAC Working Group on Soil Physical Conditions, has led to the development of a new method for measuring the stability of soil aggregates. The method is based on rapid wetting and sieving of soils and quite importantly, unlike some others, does not involve stresses that are unlikely to occur in the natural environment. Aggregate stabilities are expressed over a range of possible values from 0 to 100, with 0 representing a single grained soil completely lacking structural development and 100 representing a soil where the aggregates are completely stable. First results on a range of soil types from north-east Scotland show broad agreement between field and laboratory assessment of aggregate stability.

Vital Role of Organic Matter in Soil

However slowly or rapidly it may occur, organic matter in soil is continuously undergoing oxidation to CO_2, H_2O, and other oxides. This is a necessary process for it to exercise some of its functions such as the gradual release of nitrogen and phosphorus in plant-available form, whereas other functions such as the maintenance of soil aggregation, depend on the presence of a minimum concentration of well-decomposed organic matter in the soil. Most of this organic matter originates from the decay of plant remains.

Current thinking on the disposal of straw and stubble is against burning, mainly on the grounds of avoiding pollution and the loss of organic matter input, but burning does help to prevent the persistence of disease and the release of toxic chemicals during decomposition. The rate of decomposition is very dependent on temperature, and knowledge of the rate of

decomposition of straw under field condition in a northern climate is, therefore, being sought from field as well as laboratory experiments in the Department of Soil Organic Chemistry.

Many other factors, both physical and chemical, determine the rate of decay. Soil microorganisms are the main agents of decomposition, but the contribution of macrofauna tends to be disregarded in laboratory experiments. Recent work in the Department of Soil Organic Chemistry in conjunction with the Department of Microbiology has, therefore, been concerned with measuring the enhanced rate of decomposition of plant material caused by soil invertebrates such as earthworms and leather jackets. The rate of decomposition of whole plant tissue under laboratory conditions appears to be most precisely described by two or three part functions and that is also true for the major component sugars. The reasons for there being a difference between the rate for two fractions which have chemically identical components is not yet understood. Decomposition rate models divide the organic matter into compartments, but few studies have been made where it has been possible to characterize the chemical structure of the organic matter in these compartments. The presence of sugars in similar polysaccharide structures in both rapidly and slowly decaying material supports arguments for a physical mechanism of protection.

The value of peat for various purposes can usually be related to its degree of decomposition. Peats are frequently classified according to the von Post humification index. Recent work in the Department of Soil Organic Chemistry shows that the degree of humification in well decomposed peats is quite low in comparison with that of the humic substances in many mineral soils. Thus a distinction must be made between the degree of decomposition as indicated by the von Post index and the degree of humification.

New Studies of Interactions between Soil Microbes at Root Surfaces

The technique of preparing thin sections of soil embedded in polyester resin has been used routinely by soil mineralogists for a long time, but it has been relatively neglected by soil microbiologists. Using a new procedure, which involves fixing the soil in buffered glutaraldehyde, dehydration in a graded series of acetone: water mixtures and finally impregnation with a low viscosity polyester resin, the Department of Microbiology has shown that it is now possible to study microbial interactions in soil near plant roots much more effectively.

Rapid Microbial Composting of Tree Bark Removes Phytotoxins

Studies of the phytotoxins and phytosanitary compounds in tree bark have continued in the same Department. The optimal conditions for rapid decomposition of the bark and removal of phytotoxins have been determined. The moisture content of the bark and the aeration rate proved to be the most important environmental factors. The possibility now exists of being able to ferment tree bark rapidly to remove the phytotoxins and

provide a suitable horticultural compost, which could replace or supplement existing but diminishing supplies of peat.

Trace Element Movement and Speciation in Plants

Recent work on cobalt transport in the Department of Plant Physiology has concentrated on some unusual features of the time-course of uptake. The observed diurnal cycle of uptake rate is an unsuitable circumstance in which to pursue compartmentation experiments. Conditions yielding a linear uptake pattern are being sought.

With appointment to one of the Department's vacancies, work on copper uptake, transport and speciation in ryegrass has started. The Scottish Universities' Research and Reactor Centre has proved to be an inexpensive source of radioactive copper for transport experiments. Speciation studies have started with attempts to isolate, from leaves, the copper protein plastocyanin, which is of particular interest in relation to trace element deficiency studies in ruminants, since it is thought to survive the sulphur-rich environment of the rumen, to be absorbed further along the alimentary tract.

Studies of Growth of Sphagnum Moss for Medical Applications

Work on optimising conditions for growth of *Sphagnum* funded by the HIDB has progressed with the production of sterile plants from spores, thus avoiding the undesirable proliferation of algae, naturally present on field-collected plants. Sphagnum is traditionally involved in wound dressings and is being re-investigated for similar purposes in some hospitals in Britain.

Sulphur Nutrition on Field Crops

Work on sulphur has continued in the Department of Soil Fertility during the past year. An application of micronized elemental sulphur to the soil, at a rate similar to that which would be used as a foliar application, 10 kg ha^{-1}, increased the yield of grass at the first cut and was as effective as a foliar spray when assessed over the four cuts taken during the season. This is important because it indicates that a foliar application of micronised sulphur may be partly absorbed through the root system, that material given early in the season when crop cover, e.g. for oilseed rape, is poor may not be wasted and the yield of first cut grass can be increased.

Effects of Nitrogen Fertiliser on Barley and Potatoes

Collaborative studies with the Rowett Research Institute have suggested that spring barley can be harvested as a "green crop" and the whole plant fed to stock. Harvesting in this way saves nitrogen, as smaller nitrogen rates are needed for the short growing season, avoids the problem of straw disposal as no straw is left as a residue and allows early harvesting so giving maximum flexibility in respect of land preparation for the succeeding crop.

A number of experiments have now shown that nitrogen additions increase tuber yields by increasing light interception, especially by accelerating the rate of canopy expansion. The relative amino-acid composition of potato tubers was unaffected by the rate of nitrogen applied. Protein yields were increased by applications of nitrogen up to 250 kg ha^{-1}, beyond the point at which yield continued to respond. This suggests the possibility of producing high quality potato protein, rich in lysine which is deficient in cereal protein, as a protein feed.

A method has been developed to allow a "pulse" of ^{15}N-labelled material to be applied to a portion of the potato root system so as to allow measurement of rates of nitrogen uptake at different growth stages. Initial measurements, during periods of active growth, have indicated rates that are high, 3×10^{-11}mol cm^{-1} sec^{-1}, even when compared with measurements made under laboratory conditions.

Trace Element Mobilization in Soils and Winter Barley

Comparisons of nutrient mobilization in winter and spring barley have shown that the crop species influences the extent and timing of micronutrient mobilization from the soil adjacent to the crop root system. Copper was mobilized in May with winter barley and in July with spring barley.

Progress in Spectrochemical Investigations

Exciting new areas of research are opening up as a result of the recent acquisition of a VG 354 Thermal Ionisation Mass Spectrometer (TIMS). This provides a capability for the very accurate measurement of elemental isotopic composition and isotopic ratios. Its principal applications are envisaged in the use of stable isotope tracer studies for the elucidation of the transport, forms and sites of trace element action in soils, plant, animal and human experiments. The use of stable isotope tracer studies becomes an essential technique for elements such as Cu or Pb where suitable radioactive isotopes are not available or where, as in human nutritional research, use of radioactive tracers is impossible on ethical grounds. Geochronological dating of minerals or rocks, measurements of rates of mineral weathering by strontium isotope ratio determination and very accurate trace element analysis by isotope dilution methods all become accessible by the use of TIMS. Much of the work will be carried out in collaboration with the Rowett Research Institute and the Medical School of Aberdeen University. The instrument is illustrated in Fig. 3.2. of section 3 of this report.

A compliment was paid to the Institute's reputation in the provision of trace element analytical and advisory services to farmers by the invitation to Drs. A.M. Ure and J.W.S. Reith from Dr. H. Bergseth of the Agricultural University of Norway in Ås to assist in the development of their service to farmers. After an initial visit to Ås where lectures on these topics were given by Drs. Ure and Reith, Dr. Reith spent 1 month in the Agricultural

University of Norway working with Norwegian colleagues to this end. We hope these visits will inaugurate increasing collaboration between the two establishments whose soils and trace element problems have much in common.

Total trace element concentrations in the B-horizons of some 1200 profiles are now being used to assess the status of all the soil associations mapped in Scotland. The data are being used to prepare soil association trace element maps of Scotland on a 1:250,000 scale. Such information is invaluable to those working in the fields of animal nutrition, agriculture, environmental and geomedical studies to identify areas which may merit more detailed investigations; few other countries have such a comprehensive body of trace element soil data. This work is largely based on data accumulated since 1948 from analysis of soil profiles selected to represent the soil associations and series mapped by the Soil Survey of Scotland. An example of an experimental copper map is presented in Fig. 3.1., section 3.

The fresh insights into podzolization processes and the mechanisms of aluminium, iron and silicon transport in soils given by the work in the Institute on imogolite and proto-imogolite provide a continued impetus to new research. Infrared specroscopy and transmission electron microscopy have identified the formation of rings and short tubes with the imogolite structure during the development in the laboratory of the full tubular morphology of well-crystallized imogolite. These early forms of imogolite may help to explain the morphology observed in some natural allophanes produced during podzolization.

In studies of skeletal components of soil invertebrates, infrared spectroscopy has identified the presence of amorphous calcium carbonate which on maturity and final shredding of the exoskeleton crystallizes to calcite. This mechanism is associated with depletion of nitrogenous components e.g. protein and N-acetyl groups in chitin, and might partly explain the origin of soil calcite.

Free radicals related to oxygen metabolism have been observed, using electron paramagnetic resonance (EPR) techniques, in both plant and animal tissues. With live wheat roots, the spectrum was consistent with an organic peroxide and in heart tissue from rats deficient in selenium provided by the Rowett Institute, the spectrum was similar to that from $0._2^-$

Progress in Soil Survey and Remote Sensing

Progress is being made in the 1:50 000 land capability map series; the publication date of 1987 can be achieved. There is obviously great interest in the information ranging from agricultural and commercial surveyors and valuers to political parties.

During the previous year, several technical difficulties in analytical cartography have been overcome and it is now becoming increasingly possible to exploit the Soil Database to the full and to show the

environmental relationships which form the framework of land-use in Scotland.

Agreement has been reached by the Colleges of Agriculture in Scotland, the Agricultural Development and Advisory Service in England and Wales and the Agrochemicals Industry on standardization of methods of measurement and description of soil texture. From 1 January 1986 all soil survey descriptions will use the agreed system, allowing the information to be more useful to farmers and growers.

Considerable progress has been made in the development and application of remote sensing techniques. Research continues on a broad front in line with the philosophy that it is important to match problems with the appropriate technology. Thus satellite imagery is being used for large area resource mapping operations, aerial photography for regional studies on rates of bracken encroachment on hill land, and hand-held radiometers for the detailed monitoring of crop trials. This approach is reflected in the configuration of the remote sensing laboratory facilities. These now represent a unique combination of image processing, photogrammetric and map digitising equipment all linked to a single host computer. This system has permitted major advances to be made in the fields of digital image processing, digital mapping and geographic information technology, to the extent that the Macaulay Institute is now one of the leading centres for such research in the United Kingdom. This fact was recognised by the visit to the Institute in December of the D.O.E. Committee of Enquiry into the Handling of Geographic Information under the Chairmanship of Lord Chorley.

Statistics and Computing

An assessment has been made in terms of performance, suitability and price of three 32-bit computer systems to replace or upgrade the present 16-bit Data General Eclipse. A decision on the matter and a capital grant to implement it are awaited.

Communications with other computers have been established *via* the JANET and AGRENET networks.

The recent survey of computing equipment in the Institute showed that there are 69 micro and mini computers, "Apples" being the most numerous.

EVENTS AND PEOPLE

Tenth T.B. Macaulay Lecture

The Tenth T.B. Macaulay Lecture entitled "Recent Improvements in Weather Forecasting" was delivered by Sir John Mason, Director-General of the Meteorological Office from 1965-83. This took place in the Marine Suite of the Amatola Hotel on 20 November 1985 before an audience of 200. Sir John's lecture is presented as Appendix I of this Report. Sir John's account of global weather forecasting was a lively and informative one and was greatly appreciated by an attentive audience. The members of the

Council of Management entertained the Lecturer and the Fellows of the Institute to lunch before the lecture. Professor Keir took the chair and the Director presented the Macaulay Scroll to Sir John at the end of the Proceedings.

Retirements

There have again been a number of retirements during the year as follows:

Mr R.A.R. Clark, a gardener/groundsman at the Institute since August 1975, retired on 31st December 1984.

Dr N.M. Scott, PSO in the Department of Soil Fertility, retired on 28 February 1985. Dr Scott came to the Institute in 1949 after having worked in the Aberdeen area for a number of years as a chemist. The title of his Ph.D. Thesis was "Studies on the sulphur relationships of selected Scottish soils" and his research work in the Department was mainly concerned with sulphur studies. It was most fitting that Dr Scott's career ended on a high note with widespread recognition of the value of his work on deficiency. Sulphur has once more been recognised as an essential fertilizer for many soils in pollution-free areas of the UK particularly on sandy soils.

Dr George Anderson, Deputy Director and Head of the Department of Soil Organic Chemistry, retired on 31 March. Dr Anderson graduated with an Honours BSc in Chemistry from Edinburgh University where he also gained his PhD degree. After spending three years as a research assistant at the Edinburgh and East of Scotland College of Agriculture, he joined the Institute staff in 1952 as a Scientific Officer in the Department of Soil Fertility where initially his work was concerned with investigating organic phosphorus in soil. His work on phosphorus compounds in soils has been widely acclaimed and he has written monographic contributions in several standard books that are regarded as definitive by soil scientists the world over. In 1974 Dr Anderson was appointed Head of the Department of Soil Organic Chemistry and Deputy Director in 1980. An appreciation of Dr Anderson's many talents appears in the Institute magazine Profile.[1]

Mrs. I.L. Brown, who came to the Institute as a part-time cleaner in 1961, retired on 31 May 1985 as Head Cleaner.

Mr W.L.W. Ross, a member of the grounds and maintenance staff since 1974, retired on 31 July 1985.

It is with great regret that we record the sudden death on 10 April 1985 of Mr Peter F.S. Ritchie at age 40. Mr Ritchie came to the Institute in 1969 to assist with the investigations on clay minerals in the Department of Pedology. He had obtained his BSc degree in Chemistry and Geology at St Andrew's University in 1965 and followed this by working for BP Chemicals (UK) for four years, prior to joining the MISR staff. In 1974 he gained his BA from the Open University, majoring in computing, telecommunications, electronics and instrumentation, which led him in 1980 to transfer to the Department of Peat and Forest Soils where he made a substantial contribution to the Remote Sensing Unit in many ways during

the last five years, including his talents as a pilot of small aircraft. Peter's quiet and unassuming personality was greatly appreciated by all his colleagues and friends. He is survived by his wife Christine, his son Keith, and daughter Jacqueline. A tribute to him appears in the Institute magazine Profile.[2]

New Appointments

Dr David Atkinson's appointment as Head of Soil Fertility in succession to Dr B.W. Bache was mentioned in the introduction to the 1984 annual report. Dr Atkinson, who has written this year's Section 7, took up his appointment in February 1985.

Dr M.V. Cheshire was appointed Temporary Head of the Department of Soil Organic Chemistry from 1 May 1985. Dr Cheshire has worked in the Department since coming to the Institute in 1964 after gaining both his Honours BSc in Agricultural Chemistry, followed by the degree of PhD, from the University College of North Wales.

Dr B. Thornton was appointed a Higher Scientific Officer in the Department of Plant Physiology on 1 April 1985. Dr Thornton, an Honours BSc in Biochemistry of the University College of North Wales, was also an AFRC Student at the Institute and gained his PhD degree from Aberdeen University in 1983.

Dr A. Mellor joined the staff of the Department of Mineral Soils as a Higher Scientific Officer on 7 January 1985.

Mr W.S. Shirreffs, formerly Senior Cartographic Draughtsman in the Department of Soil Survey, was appointed Information Officer on 1 November 1985, in succession to Miss Watson. His former post has now been taken up by Mr A.D. Moir.

Two Higher Scientific Officer appointments have been made during the year under the SWAP contract that was placed with the Institute by the Royal Society. These are Mr R.C. Ferrier in the Department of Peat and Forest Soils and Mr T.A.B. Walker in the Department of Mineral Soils; both took up their appointments on 16 September 1985.

Resignations

Dr S. Cooke, Higher Scientific Officer in the Department of Soil Fertility, resigned on 30 April 1985 to become a Microcomputer Application Programmer with Glaxo Group Research Ltd. in Middlesex. Dr Cooke worked at the Institute from 1979, having gained his PhD degree at Aberdeen University after carrying out his research work in the Institute from 1975 on a Ministry of Defence Scholarship.

Mr J.R. Christie, Higher Scientific Officer in the Department of Peat and Forest Soils resigned on 30 April 1985 after 5 years in the Institute, having accepted an appointment as Computing Lecturer at Aberdeen College of Commerce.

Dr Peter Wilson, Higher Scientific Officer in the Department of Soil Fertility resigned on 2 August 1985 to take up a post with the Electro-optics

Department of Ferranti in Edinburgh. Dr Wilson also undertook his PhD studies on an AFRC Studentship at the Macaulay Institute and gained his degree from the University of Aberdeen in 1984.

Miss E.M. Watson, Information Officer in the Institute since 1973, who married in September, resigned on 31 October 1985. Acting as Editor of Profile since 1976 she was largely responsible for organizing and planning the many exhibits made at agricultural shows by staff of the Institute in Scotland and outwith it. She also played a large part in running the 1980 Jubilee Celebrations and the 1983 Subject Day. As Mrs Alan Young we wish her success and happiness in the future.[3]

Visitors to the Institute

Lord Chorley, Chairman, and members of the Committee of Enquiry into the Handling of Geographic Information, London, visited the Institute on 9 December 1985. During the year the Institute also received visits from various members of staff of the Agricultural and Food Research Council and the Department of Agriculture and Fisheries for Scotland.

Other visitors to the Institute who delivered lectures were:
Professor H.M. Seip, Central Institute for Industrial Research, Oslo, Norway, on "Acid Precipitation Research In Norway: Soil Water Interactions and Aspects of Modelling"; Dr J.H. Johnston, Chemistry Department, Victoria University of Wellington, New Zealand on "A Mossbauer Spectroscopic study of the formation and growth of ferric hydrolysis polymers in the weathering of iron"; Dr D. Jenkins, Institute of Terrestrial Ecology, Hill of Brathens, Banchory on "What goes on at Brathens?"; Dr Wilan Inhat, Head of Analytical Chemistry Services, Chemistry and Biological Research Institute, Ottawa, Ontario, Canada, on "Agricultural - Biological Reference Materials - The Challenge of Development"; Professor Alan R. Putnam, Department of Horticulture, Michigan State University, Michigan, USA, on "Impacts of Allelopathy in Agroecosystems".

Short-term visitors came to the Institute from twenty countries during the year and group visits included delegates from the European Association for Potato Research and North East Farmers, students from the Botany, Chemistry and Geography Departments of Aberdeen University, Department of Geography, University of Strathclyde, and Topographic Science students from the University of Glasgow, as well as from the North of Scotland College of Agriculture and Clinterty College, Aberdeen.

Long-term visitors were received from Australia, Israel, Italy, Japan, New Zealand, USA and West Germany.

Honours and Appointments

Mr A.C. Birnie, a Senior Scientific Officer in the Department of Mineral Soils, was awarded the degree of MSc of the University of Aberdeen, for a Thesis entitled "Morphological, physical and chemical changes within a hydrosequence of soils of the Strichen Association".

Mr A. Mellor, a Higher Scientific Officer in the Department of Mineral Soils, was awarded the degree of Ph.D. of the University of Hull for a thesis entitled "An investigation of pedogenesis in selected neoglacial moraine ridge sequences in southern Norway".

Dr R.V. Birnie, Principal Scientific Officer in the Department of Peat and Forest Soils has been appointed to an Honorary Lectureship in the Department of Physics, University of Dundee for 1984-85.

Mr J.M. Ogilvie, Senior Scientific Officer in the Department of Spectrochemistry and Institute Safety Officer, has been awarded membership of the Institute of University Safety Officers.

Mr R.A. Robertson, Head of the Department of Peat and Forest Soils, has been appointed Chairman of the Editorial Board of the International Peat Society and Editor of its new International Peat Journal.

Professor J.S. Bibby, Head of the Department of Soil Survey accepted an invitation from Strathclyde University to extend his visiting professorship in Soils and Land Use for a further year.

W.S. Shirreffs was again invited to judge the John Bartholomew award for excellence in the field of small scale thematic mapping by the British Cartographic Society.

Professor T.S. West was appointed by the Royal Society as a member of the British National Committee for the International Council of Scientific Unions. As representative of the International Union of Pure and Applied Chemistry he was also made a member of the General Committee for ISCU. He was also appointed to the Independent Advisory Group on Gruinard Island set up by the Minsistry of Defence to look into decontamination (from anthrax) of the Island that was used in experiments in the 1939-45 war and which is still contaminated forty years later.

Visits Overseas by Staff and Lectures Given in Britain

Details of visits overseas by staff and of UK meetings where lectures were given are presented in Appendices 2 and 3.

Post-graduate Students

Miss Charlotte A. Flower has now completed her experimental work for the degree of PhD and is currently writing up her Thesis for submission to the University of Aberdeen.

Mr M.J. Hepher, who studied in the Department of Soil Fertility, has been awarded the degree of PhD of the University of Aberdeen, for work on piezoelectric crystal detectors. He is now employed in the analytical laboratories of the West of Scotland College of Agriculture.

Institute Events

The Council of Management met twice on 31st May and 20th November 1985 and SWAP Meetings were held at MISR on three seperate occasions.

Institute Caravan

During the year the Institute caravan was taken to the Royal Highland & Agricultural Show at Ingliston, Edinburgh, the Muir of Ord Show, the Ayr Agricultural Show and to an Open Day held at Craibstone Farm, Bucksburn, which was sponsored by the North of Scotland College of Agriculture and the North of Scotland Grassland Society. The Institute was also represented and set up exhibits at the Orkney Agricultural Show, the Royal Show at Stoneleigh and also at a Cereal '85 demonstration at Stoneleigh.

Fellowship of the Institute

In recognition of his service as Deputy Director and Head of the Department of Soil Organic Chemistry, the Council of Management conferred the title of Honary Research Fellow of the Institute on Dr G. Anderson on his retirement.

Programme Units and Research Objectives

Only a few changes have been made to the Institute's overall Programme during 1985. The principal one is the appearance of PU 11 which relates to environmental factors funded at the Institute by the joint 'SWAP' Programme of the Royal Society - Norwegian Academy of Sciences and Letters - Royal Swedish Academy of Sciences and by the Department of the Environment.

The departmental responsibilities for individual Research Objectives in the Report are as follows:

1000	Mineral Soils	6000	Microbiology
2000	Peat and Forest Soils	7000	Soil Fertility
3000	Spectrochemistry	8000	Statistics
4000	Soil Organic Chemistry	9000	Soil Survey
5000	Plant Physiology		

Interdepartmental projects are listed as 0800. Thus PU 1801 represents interdepartmental project 001 in Mineral Soils; the number 4801 and 6801 listed alongside show that the RO is also part of the programme of Soil Organic Chemistry and Microbiology. Service Objectives will be listed as 0900. RO numbers are allocated serially across the Institute. Interdepartmental and Service Objectives will also be listed serially within the 0800 and 0900 series, *i.e.* 0801, 0802, etc.; 0901, 0902, etc. Objective numbers will be discarded once the Objective has been discontinued.

References

1. M.V. Cheshire, Profile 1985, **90**, 8
2. R.A. Robertson, Profile 1985, **91**, 8
3. T.S. West, Profile 1985, **94**, 1

PROGRAMME OF WORK
(1985)

PROGRAMME UNITS AND RESEARCH OBJECTIVES

PU 1: MINERAL SOILS: THEIR DEVELOPMENT, COMPOSITION AND PROPERTIES

RO

1001 Determine chemical and physical characteristics of Scottish soils, relevant to soil development and use.

1006 Characterize the composition of soil solution, soil atmosphere and stream water in relation to soil development, use and type.

1060 Determine the nature, origin and properties of the inorganic and organo-mineral constituents of Scottish soils.

1003 Determine surface and colloidal characteristics of soil particles in relation to soil chemical and physical properties.

3005 Characterize soil mineral structures, surface properties and weathering by IR, UV, Mossbauer, EPR and other spectroscopies.

1061 Determine relationships between weathering of minerals in Scottish soils and the availability of nutrient elements.

1062 Understand differences of properties and behaviour in various soil series and associations in Scotland.

1067 Relate mineral weathering to soil and freshwater acidification.

PU 2: TRACE ELEMENTS: ORIGIN, DISTRIBUTION AND SPECIATION IN SOILS AND PLANTS IN RELATION TO EFFECTS IN AGRICULTURE

RO

3007 Establish geochemical and environmental origins, distribution, and mobility of trace elements in Scottish soils.

3008 Determine effects of soil conditions on the uptake and distribution of trace elements in plant parts and species.

3803/ 4803 Determine forms of trace elements in soils, their interaction with organic substances and their transport mechanisms to the plant.

4068 Devise practical methods to remove pollutants from agricultural and industrial wastes.

3010 Develop multi-element analytical techniques using dc arc optical emission and spark source mass spectrometry for solids.

3011 Develop spectrochemical methods using atomic absorption and inductively coupled plasma emission spectrometry for solutions.

3069 Develop chemical and instrumental methods for trace-element speciation in soils and plants.

PU 3: SOIL SURVEY OF SCOTLAND

RO

9012 Survey and map the soils of Scotland and produce soil maps and accompanying descriptive literature.

9013 Produce interpretative maps.

9804/1804 Characterize the structure-forming processes of Scottish soils.

9063 Monitor the soil moisture status of a number of the principal soils of Scotland.

9015 Establish a fundamental classification of plant communities by recording and mapping.

9016 Assess grazing quality of plant communities and changes caused by pressures of land use.

9070 Devise methods of national soil survey data management and modelling.

PU 4: NATURE AND PROPERTIES OF SOIL ORGANIC MATTER

RO

3017 Characterize soil organic matter by infrared and ultraviolet spectroscopy.

1018 Assess organic matter composition and development in natural and agricultural soils by analytical pyrolysis.

4019 Identify and measure organic nitrogen compounds in soil and establish the factors affecting their transformations.

4020 Determine the origins, nature and behaviour of polysaccharides in soil and their effects on soil physical properties.

4021 Identify soil humic substances and examine their distribution and properties within soils and soil solutions.

3808/4808 Determine the function of organic matter in ameliorating trace element problems in soil.

4064 Extract organic constituents from soils and assess their effects on plant and microbial metabolism.

PU 5: ROLE OF MICROORGANISMS IN SOILS, ESPECIALLY IN SOIL/PLANT RELATIONSHIPS

RO

6025 Determine interrelationships between soil actinomycetes, bacteria, protozoa and plant roots.

6026 Determine the interrelationships between fungi and plant roots.

6027 Relate soil fertility and structure to microbial transformation of soil organic matter.

6028 Establish an understanding of the survival of fungi in soil and their transformation into soil organic matter.

6031 Determine the nature, distribution and metabolic activity of protozoa in soils.

PU 6: THE SURVEY, CHARACTERISATION AND MONITORING OF PEAT, LAND RESOURCES AND TERRAIN FEATURES

RO

2032 Apply environmental remote sensing techniques for resource survey and agricultural monitoring operations.

2033 Develop computer-aided methods for the integration and manipulation of spatial data.

2034 Provide an advisory and application centre for remote sensing within the AFRS and facilities for contractual research.

2035 Survey, classify and evaluate peat resources using ground-based, remote sensing and photogrammetric techniques.

2036 Characterize the physical and chemical nature of peat and peat products.

2065 Survey, map and monitor the distribution of bracken in Scotland.

2071 Develop portable radiometers for monitoring crop cover, biomass and stress parameters.

PU 7: SOIL FACTORS AFFECTING CROP PRODUCTION

RO

7037 Quantify the availability of soil and fertiliser phosphorus to crops by chemical methods and field trials.

7038 Measure the ability of soils to provide sulphur to crops, and assess atmospheric sulphur inputs.

7039 Estimate mobility of soil native and applied nitrogen relative to water movements and crop uptake.

7041 Optimise crop yields by efficient control of fertilisers and soil nutrient reserves.

7042 Determine the trace element balance in soils and crops and environmental conditions which affect availability.

7044 Measure mechanical stability of structure of contrasting soils and importance to crop growth.

7045 Develop automated electrochemical techniques for analysis of soil extracts and solutions.

7046 Determine physicochemical factors which control availability of trace elements from soils to plants.

4801/ 9801 Determine mechanisms involved in ochre formation and devise methods of minimising its production.

PU 8: FACTORS AFFECTING CROP AND PLANT COMPOSITION

RO

7047 Relate the organic and inorganic constituents of crops to age and yield.

7048 Study the growth, development, nutrient accumulation and yield of field crops.

7049 Develop and apply radioactive isotope methods to soil-plant investigations.

5050 Characterize trace element uptake by roots and transport to shoots in electrochemical and metabolic terms.

5051 Characterize and compare the efficiency of uptake and transport of ammonium and nitrate ions.

5052 Determine nutrient interactions in trace element uptake by plants; implications for selection of pasture species.

5806/ 3806 Determine the forms of trace elements in plants with particular reference to dietary availability in animals and man.

4053 Determine the influence of environmental forces on plant growth and the physiological mechanisms involved.

5072 Determine the factors that affect the growth, productivity and morphology of Sphagnum.

PU 9: NUTRITION AND DISTRIBUTION OF PLANTS AND PLANT COMMUNITIES ON ORGANIC AND OTHER MARGINAL SOILS IN SCOTLAND

RO

2054 Determine the effects of different management practices on biogeochemical cycling of elements in upland ecosystems.

2055 Determine the processes controlling nutrient mineralisation and availability in highly organic soils.

2056 Forecast nutritional requirements on marginal lands and prescribe remedial treatments for diagnosed deficiencies.

2807/ 6807 Identify the processes by which mixtures of different tree species enhance nitrogen availability in poor forest soils.

2066 Determine factors contributing to the passage of rainwater acidity into streams and suggest appropriate control measures.

PU10: STATISTICAL METHODS FOR SOIL-CROP RESEARCH AND DEVELOPMENT AND MANAGEMENT OF COMPUTER TECHNIQUES AND EQUIPMENT

RO

8057 Extend the range of experimental designs and methods of statistical analysis appropriate to soil research.

8058 Establish relationships which will show a closer dependence of crop responses on soil properties.

8059 Provide the computing facilities, both hardware and software, required in soil research.

1802/ 3802/ 8802/ 9802 Establish an information system for Scottish soils by means of data-base and statistical techniques.

PU11: THE IMPACT OF SOIL FACTORS AND VEGETATION ON THE ACIDIFICATION OF STREAM WATER

RO

2073 Determine changes in water composition on passage through forested and unforested sites and effects of K, Ca, Mg.

1809/ 2809/ 3809/ 4809/ 9809 Determine effects of soil/water chemistry and vegetation type on acidification of streams

MISR Research Objectives 1985 —

The correspondence between the numeration of the DAFS RO costing system used throughout this Report and the AFRC (ARCIS) code is shown in this table. The numeric code is used in this Report because it provides an unequivocal guide, whereas the ARCIS code can be confusing due to re-use of alphabetic letters from discontinued research objectives.

ARCIS code	DAFS code
PU 1 a	001001
b	001006
c	001060
d	001003
e	003005
f	001061
g	001062
h	001067
PU 2 a	003007
b	003008
c	003803/ 004803
d	004068
e	003010
f	003011
g	003069
PU 3 a	009012
b	009013
c	001804/ 009804
d	009063
e	009015
f	009016
g	009070
PU 4 a	003017
b	001018
c	004019
d	004020
e	004021
f	003808/ 004808
g	004064
PU 5 a	006025
b	006026
c	006027
d	006028
e	006031
PU 6 a	002032
b	002033
c	002034
d	002035
e	002036
f	002065
g	002071
PU 7 a	007037
b	007038
c	007039
d	007041
e	007042
f	007044
g	007045
h	007046
i	004801/ 009801
PU 8 a	007047
b	007048
c	007049
d	005050
e	005051
f	005052
g	003806/ 005806
h	004053
i	005072
PU 9 a	002054
b	002055
c	002056
d	002807/ 006807
e	002066
PU 10 a	008057
b	008058
c	008059
001802/	003802/ 008802/ 009802
PU 11 a	002073
b	001809/ 002809/ 003809/ 004809/ 009809

1. MINERAL SOILS

M.J. WILSON

The work of the Department is concerned mainly with the investigation of the fundamental factors controlling the physical and chemical characteristics of mineral soils, in order to provide a basis for rationalizing and predicting the varied behaviour of such soils in Scotland largely, but not entirely, from an agricultural point of view. This work involves, therefore, study of the formation, composition, structure and properties of Scottish mineral soils and encompasses research objectives on the chemical analysis of soils, plants and waters, the characterization of inorganic, organic and organo-mineral constituents of soils, the determination of the nature and chemical reactivity of the surfaces of soil colloids, the elucidation of the geochemical processes involved in the release and sorption of plant nutrients and other elements, and the study of soil structure and texture as affected by natural processes and management practices. In addition, under the auspices of SWAP (Surface Water Acidification Programme) work has recently begun on the relationship between mineral soils and the composition of surface waters in certain upland catchments affected by acid precipitation. This work is largely financed by funds administered by the Royal Society, the Norwegian Academy of Science and Letters and the Royal Swedish Academy of Sciences.

As in previous years staff have collaborated with, and made available the specialized equipment and technical expertise within the Department to, a variety of outside organizations. These include other SARIs (Scottish Institute of Agricultural Engineering, Scottish Crop Research Institute, Rowett Research Institute), the Scottish Colleges of Agriculture - particularly through the MISR/COSAC Liaison Committee - and various Universities including the University of Aberdeen, the University of Salford, the University College of North Wales, Bangor and the University College of Wales, Aberystwyth. In connection with SWAP, collaborative work has also commenced with the Centre for Environmental Technology at Imperial College, the Institute of Hydrology and the Fresh Water Fisheries Laboratory at Pitlochry. It seems likely that cooperative arrangements with Scandinavian scientists will be entered into as this work develops. A variety of work has also been done for locally-based oil companies including, for example, Redwood Corex, Gearhart Geodata, Occidental, Conoco, Shell, N.L. Baroid etc.

Members of staff are serving on various national committees, editorial boards and working groups. These include the Editorial Boards of Clay Minerals and Applied Clay Science, the Council of the British Society of

Soil Science and the MISR/COSAC Working Group on Soil Physical Conditions (M.J. Wilson); the U.K. Organizing Committee of the 7th International Symposium on Analytical and Applied Pyrolysis (J.M. Bracewell); the Committee of the Clay Minerals Group (W.J. McHardy); and the Committee of the Aberdeen Institute of Ecology (B.F.L. Smith). Other posts include Assistant Editor of the Journal of Analytical and Applied Pyrolysis (J.M. Bracewell); and Secretary of the Clay Minerals Group and Assistant Editor of Clay Minerals (D.C. Bain).

During the year the Department was fortunate to recruit some new members of staff and a sincere welcome is extended to them. These include Dr. A. Mellor who is working on mineral weathering in upland and forest soils and Mrs M. Reid who was transferred from the Department of Soil Fertility and is responsible for the day-to-day running of the ^{15}N stable isotope service. Mr T.A.B. Walker has also been appointed under SWAP on a fixed contract to investigate the exchange and sorption characteristics of mineral soils in determining surface water composition in catchments on granitic and metamorphic rock terrains. The SWAP work has also enabled the purchase of a Dionex ion chromatograph and an automatic sample changer for the recently acquired X-ray fluorescence spectrometer. The Department was also happy to welcome two new visiting research workers during the year, namely Dr F. Ajmone Marsan (Istituto di Chimica Agraria, Universita di Torino, Italy) and Dr R.L. McLeod (Darling Downs Institute of Higher Education, Queensland, Australia).

Soil, Plant and Water Analysis

Soil Analysis

The systematic chemical and physical analyses of soil profiles collected by the Soil Survey of Scotland during the 1984 field season have now been completed. Soil samples have also been analyzed for other departments in the Institute and for outside bodies, such as the Scottish Crop Research Institute (SCRI), the Scottish Institute of Agricultural Engineering (SIAE) and others. Input of data into the Institute's Soil database has continued, almost 70 percent of all profiles received in the period 1978 to 1983 and over 70 percent of the National Inventory profile samples having now been entered. In collaboration with the Departments of Statistics, Soil Survey and Spectrochemistry, a paper on the design of the Soil Database has now been accepted for publication[1]. Increasing demands for more determinations of the physical properties of soils, as well as the realization that there are few data available on such properties for Scottish soils, have led to the setting up of a new physical laboratory which is now operational. The physical properties that can now be analyzed include liquid/plastic limits, index of shrinkage, water release characteristics, bulk density, aggregate stability and particle size distribution. In the first instance a pilot study is being undertaken on six different soil types with contrasting physical characteristics, from the north-east of Scotland. This study is being organized in conjunction with the working group on Soil Physical Conditions set up by the MISR/COSAC Liaison Committee.

1001, 9012, 1802, 1003

Work has continued on the extraction by selective chemical techniques of X-ray amorphous material in Scottish soils. Even small amounts of such material may strongly influence bulk soil properties and it seems that chemical methods provide the most satisfactory means of assessment. The techniques involved, which include dissolution by alkali, dithionite, acid oxalate and pyrophosphate, trimethylsilylation and fluoride exchange, have recently been illustrated with respect to the inorganic gel in a Scottish brown forest soil[2]. A more detailed application of the trimethylsilylation technique to a sequence of genetic soil groups developed on two contrasting glacial till parent materials (lavas of basic and intermediate composition on the one hand and sandstones and conglomerates on the other) has also been described[3]. In general, the importance of X-ray amorphous materials of soils is now becoming more widely appreciated, not only because of their influence on soil properties, but also because they could well have a significant role in determining amounts of dissolved aluminium in surface waters. 1001, 1060, 1003, 1062

Plant Analysis

A service in ^{15}N analysis for the requirements of several Institute departments performing ^{15}N stable isotope experiments has now been set up using a VG SIRA 9 triple collector mass spectrometer. Unfortunately, the first year of operation has been beset with instrumental difficulties but despite this a total of about 3000 samples has been run for the Departments of Soil Fertility and Plant Physiology. Teething problems have also been experienced with a new X-ray fluorescence analyzer leading to lost analysis time. Sulphur determinations in particular have continued to be in demand, some 590 being performed on various types of herbage for the Department of Soil Fertility and 390 on extracts from fumigated and unfumigated soils from the Department of Microbiology. Sulphur analyses of crops have also been supplied to Rothamsted Experimental Station and to the Rowett Research Institute. Collaboration continues with the Rowett Research Institute on the composition of barley and wheat straw. XRF and X-ray photo-electron spectroscopy results have shown that the chemical labelling of lignin by bromination is not as selective as previously thought and future work will be directed towards obtaining information on the composition and nature of the inner and outer surfaces of straws before and after digestion. 7038, 6027, 7039

Soil and Stream Water Analysis

Catchment studies, previously confined to small areas situated on the main soil associations of north east Scotland, have now been extended to other areas of Scotland which are thought to be influenced by acid deposition. As part of a wide-ranging, multi-disciplinary project on the Loch Fleet catchment in Galloway, which is being organized by the Central Electricity Research Laboratory, a programme for measuring the major

cation and anion compositions of soil seepage waters, as well as the compositions of loch, embayment, stream input and outflow waters has now commenced. Preliminary results for a 3 month summer period indicate that the pH and silicon, aluminium, iron, sodium, potassium and chloride contents of the soil waters are all markedly higher than those of stream and loch waters. The loch and outflow waters tend to have a similar composition to that of the input streams, except that the latter are lower in sodium, sulphate and chloride. First results suggest, therefore, that waters passing through soil have not substantially influenced the composition of the loch waters during the first three month period of measurement, although in view of the exceptionally heavy rainfall during this time, this is perhaps to be expected.

An extensive programme of soil and stream water analysis has also commenced in connection with SWAP (Surface Water Acidification Programme). A major part of the Department's involvement in this work is to assess the role of the exchange, sorption and dissolution reactions in mineral soils in determining the surface water composition in catchments developed on granitic and metamorphic terrains. This involves determination on a monthly basis of all the major cations and anions in water from various soil horizons and from nearby streams. About 80 porous cup lysimeter probes have now been installed, both at point sites and in experimental plots, in all the major soil types (mostly podzols, gleys and peaty soils) in each of the three SWAP catchments, located at Allt a'Mharcaidh near Glen Feshie and at Kelty Water and Loch Chon near Loch Ard. Sampling sites for stream and spring waters have also been identified and analysis of the waters collected will continue for the next 3 years. 1006, 1067, 1809

Thermoanalytical Studies

Thermoanalytical techniques are particularly suitable for evaluating poorly ordered soil materials and can often yield information of a quantitative nature. Review articles describing various thermal techniques[4] and the application of thermogravimetry to organic materials[5] still await publication. 1060, 1003

Inorganic Soil Constituents

The inherent fertility of soils depends to a considerable extent on the nature of the minerals making up the soil and the way in which they are associated into aggregates and other structural units. Thus, minerals represent what may be termed the nutrient capital of the soil, strongly influence soil texture and structure and bear on a number of important soil properties such as water availability, nutrient fixation etc. The clay fraction is particularly significant in this respect because of its large area of reactive surface and much attention has been devoted to characterizing the nature and properties of the different kinds of crystalline and highly disordered soil clay minerals. An understanding of the chemical and physical nature of

the minerals in soils is essential to an understanding of the properties of the soils themselves.

Clay Minerals

Before studying soil clays, it is worth remembering that sampling and separating procedures may induce significant changes in surface properties, and sometimes in mineralogy, of soil clay particles. The possibility of such changes is greatest in surface soils and in these circumstances it may be advisable to use samples in as near field conditions as possible[6]. Work has continued on the development of a new conceptual model for the so-called interstratified clay minerals which was described in last year's report. Transmission electron microscope (TEM) and X-ray diffraction (XRD) evidence has been presented to show that these types of clays may be composed of exceedingly thin individual or free particles whose interfaces are capable of expanding by the adsorption of water or organic molecules. The interstratified XRD character thus results from an interparticle diffraction effect[7]. This model, which postulates the existence of only three types of clay particles of varying thickness, was used to explain the XRD and other characteristics of virtually the whole family of interstratified clays that are found in nature, and has important implications for the chemistry, behaviour and genesis of these minerals in soils and sediments as will be described later. The quantitative TEM techniques used in this study have also been applied to the investigation of the physical dimensions of fundamental particles of other clay materials[8]. The results have provided new insights into the nature of these materials and explain their large surface areas in terms of the dimensions of dispersed clay particles. The data have been used to calculate volume, total surface area, cation exchange capacity and charge density of the clay materials and the results agree reasonably well with independent determinations. Such data should be useful in assessing soil properties such as adsorption, desorption, microporosity and permeability. Work has also continued on the chemical characterization of interstratified illite-smectite clays by X-ray fluorescence analysis. The results document the variable chemistry of these clays, reflected in isomorphous substitution of aluminium for silicon, magnesium for aluminium and ammonium for potassium within the mineral structure[9]. Such detailed characterization is proving of value in elucidating the infrared absorption spectra of illitic clays, a study being undertaken in collaboration with the Department of Spectrochemistry.

A full understanding of the nature of clay minerals in soils can only be attained by careful investigation of pure minerals using modern analytical techniques. In collaboration with the Department of Spectrochemistry a paper has been published on the compositional variation of beidellite, a swelling clay mineral, involving the complementary use of XRD, XRF, infrared spectroscopy (IR), electron microscopy and the relatively new technique (at least as applied to clay materials) of nuclear magnetic resonance (NMR)[10]. The results show the utility of the NMR technique in the detailed characterization of clays. 1060, 3005

It is also important to bear in mind, however, that there may well be major differences between minerals found in soils and those found in geological deposits, which are usually considered as standard minerals. It seems that for smectites in particular, this is likely to be the case. Thus, soil smectites often have a composition intermediate between those of well-characterized, standard, smectite species, and one example, ferriferous beidellite, appears to be rather widespread. Furthermore, interstratified soil smectites are different because they most often form from relatively large crystals of mica and chlorite, in contrast to interstratified smectites from other sources which usually consist of aggregates of very fine particles. Again, soil smectites may be interlayered with non-exchangeable aluminous, organic or inorganic species, a phenomenon that does not appear to be widespread in other environments. It is important that such differences are characterized fully if the properties and behaviour of smectitic soils are to be fully understood[11]. 1060, 1061

A paper on the nature of the soil clays in all the major soil associations of Scotland has now been published[12]. Most of the information presented was acquired during the course of the systematic mineralogical examination of soils sampled by the Department of Soil Survey during mapping and as part of the Institute's research programme into the properties and behaviour of soil constituents. The results show that there are marked variations in the clay mineralogy of Scottish soils, mainly because the soils are strongly related to the geological parent material from which they derive. In general, the results reinforce the validity of the soil association concept in Scotland. 1060, 1061, 9012

Iron and Manganese Oxides

These constituents are important in soils because they influence a variety of soil properties including water adsorption, ion adsorption and soil aggregation. Their conditions of formation also give some indication of the prevailing pedogenetic processes within a soil profile. A paper on the iron oxide phases present within a poorly drained alluvial soil at Linross, Perthshire has been accepted for publication[13]. The results suggest that the source of the iron is in ground water and that oxidation of ferrous iron at various sites within the profile is controlled mainly by chemical rather by than microbiological processes. Many poorly drained soils have a distinct green hue, a colour that quickly fades after short exposure to the atmosphere. At present, the reason for this phenomenon is not clear although it has been suggested that it could be accounted for by the oxidation of the so-called "green-rusts" which are mixed Fe(II)/Fe(III) hydroxycarbonates. An effort was made to confirm the existence of these compounds in some poorly drained soils, and although the results obtained were somewhat ambiguous, the work did at least bring into sharper focus the problems related to isolation and identification procedures[14]. This work was done in collaboration with Dr R.M. Taylor, Division of Soils, CSIRO, Australia. 1003

Work has continued on the detailed mineralogical characterization of manganese oxides in Scottish soils, and a study has been made of a particularly well-developed pan at Tiretigan, Mull of Kintyre. At this site manganese deposits were also observed in a drainage ditch and have been shown to consist of the mineral vernadite, a poorly ordered, hydrous manganese oxide. Electron microscopy shows that the mineral consists of extremely thin flakes, and is free from contamination by other manganese minerals. Although the properties of vernadite have not been studied intensively, it seems likely that the thin flake morphology will lead to considerable surface reactivity. No reliable method exists for synthesizing vernadite in sufficient quantities for study of its sorption properties, but a product similar to vernadite has been synthesized by oxidizing Mn(II) at a slightly acid pH in the presence of nitrate and atmospheric oxygen. This phase may prove useful as a model compound and as an indicator of the redox conditions necessary for the oxidation of Mn(II) in solution. The site at Tiretigan will provide a natural reference point for synthetic studies.
1003, 1062

Other Minerals

In collaboration with the Department of Microbiology, a review has been made of the biominerals associated with crustose lichens[15]. These types of biominerals are characterized by extracellular and/or intracellular formation, without associated organic matrices and typically result from interaction between the lichen and its substrate, mainly because of the organic acid secreting activity of the fungal partner. A variety of oxalate minerals has been found including the monohydrate and dihydrate of calcium oxalate (the minerals whewellite and weddellite, respectively) magnesium oxalate (glushkinskite), manganese oxalate and copper oxalate. The type of oxalate formed depends directly on the composition of the substrate and, in principle, it seems likely that the dihydrates of nickel, zinc and cobalt oxalates could also occur where crustose lichens have colonized appropriate substrates. Lichen activity can also lead to the formation of iron oxide minerals, such as ferrihydrite and goethite, and according to some authors, aluminous clay minerals.

A paper describing a new phosphate mineral occurring in a soil profile in an area of nesting penguins on Elephant Island, British Antarctic Territory has been accepted for publication[16]. The mineral is the ammonium dominant form of leucophosphite $(NH_4,K)\ (Fe^{3+},Al)_2\ (PO_4)_2\ (OH).2H_2O$ and its X-ray characteristics, and chemical, optical, thermal and physical properties are described. The mineral is thought to have formed by the interaction of ammonium phosphate solutions from penguin guano with micaceous and chloritic minerals in the soil and is called spheniscidite after Sphenisciformes, the order name for penguins. Since the preliminary description of this mineral appeared, an extensive range of phosphate minerals has been recorded by other workers in ornithogenic soils in Antarctica.
1060

Organic and Biological Materials

Work has continued to progress on the characterization of soil organic matter using a combination of advanced pyrolysis, mass spectrometry and computerized multivariate analysis (Py-MS). This has proved to be a viable approach for the analysis of complex soil organic materials[17,18,19,20] and has the advantage of a large sample throughput of whole soils with minimal sample preparation.

In natural soils, podzolization is accompanied by the build up of organic-rich surface horizons and Py-MS was used to demonstrate variations in organic matter composition within those layers. Principal components analysis of the mass spectra of products showed this variation to be dominated by structural polysaccharide, yielding a first component which represented 50% of total variance. This displayed a sample distribution related to the accepted designations of L (litter), F (ferment) and H1, H2 (humified) as shown by eight of the samples in Fig. 1.1. A discriminant based on these products could thus classify these horizons on the basis of chemistry as well as external morphology.

Py-MS is now giving a more coherent picture of organic types and transformations within the major soil groups of Scotland leading to

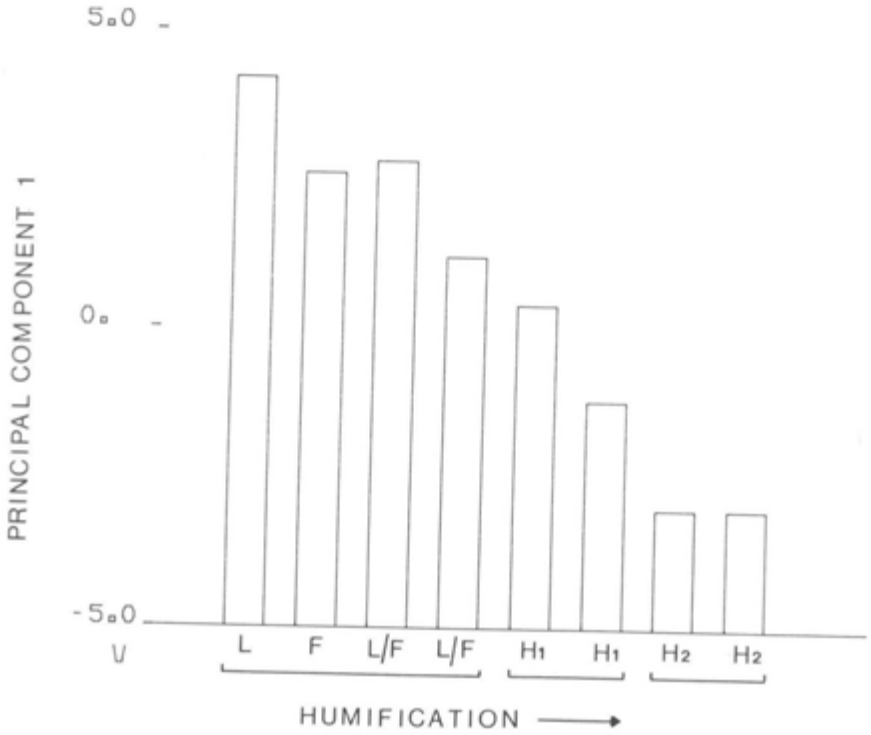


Fig. 1.1. Humification in organic surface horizons as assessed from pyrolysis-mass spectra and showing decrease with depth of the first principal component corresponding to structural polysaccharide.

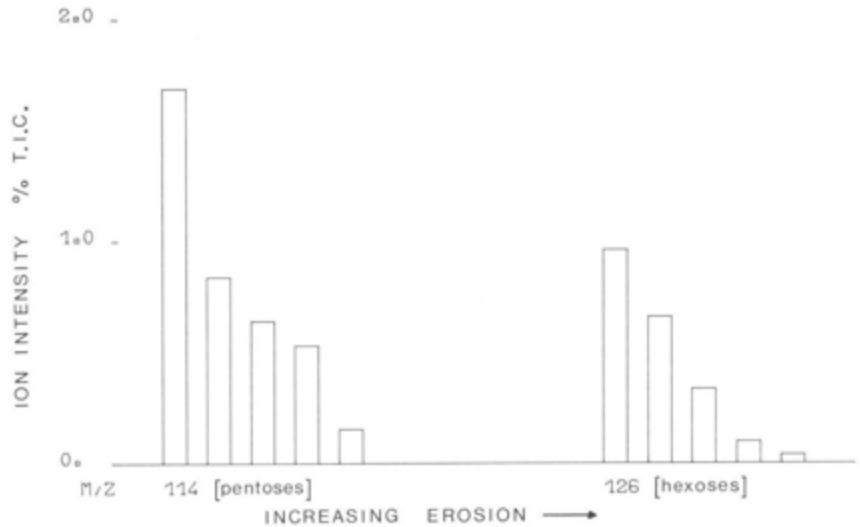


Fig. 1.2. Variation of pyrolysis-mass spectrometry ions characteristic of polysaccharide in five similar soils suffering varying degrees of erosion.

diagnostic criteria based on discriminant analysis. Examination of a few samples from world soil groups has indicated a more comprehensive picture of soil organic matter variations and a cooperative agreement has been made with the International Soil Reference and Information Centre, Wageningen to examine representative suites of major soil groups.

A previously identified organic component, common to all soils but more prevalent in highly hydromorphic soils, is characterized by a homologous series of certain aromatic hydrocarbon products (benzenes, styrenes, indenes) and was thought to be a residuum of older organic matter. This idea is currently supported by Py-MS analysis of a series of organic extracts from Cretaceous chalks, reconstructed factor spectra from soils and chalks showing a striking similarity. Some of this work was carried out in conjunction with the Chemistry Department, University of Aberdeen.

As well as basic work on fundamental organic factors, attempts have been made to relate organic constitution, as revealed by Py-MS, to physical and environmental soil properties. A sequence of soils from an area suffering from varying degrees of water erosion showed, in addition to different organic contents, a related change in organic composition (Fig. 1.2). Stability is associated with greater polysaccharide levels and this work is being continued in conjunction with the East of Scotland College of Agriculture. 1018

A series of soils used in a departmental study of aggregate stability has also been examined. Multivariate analysis of the mass spectra of products gave a first principal component related to aggregate stability ($r = 0.784$ at $P<0.01$) and the corresponding factor spectrum clearly indicated a polysaccharide and lignin origin, characteristic of raw plant material. This

was consistent with a fine root mat binding the aggregates for which there was visual evidence. Similar work is continuing with other Scottish soil series. 1018, 1003, 4020

The versatility of the Py-Ms technique has been illustrated during the year by some collaborative studies. In one such study with the Department of Microbiology, difference spectra between the product spectra of food and faeces showed, for example, that with a wood-eating termite *Zootermopsis nevadensis* there was an increase in lignin products and a decrease of polysaccharide products, due to selective absorption of the latter. On the other hand, a soil-eating termite, *Cubitermes ugandensis*, showed absorption of protein but rejection of structural polysaccharide. Again, a group of marine and estuarine sediments from the Institute of Marine and Environmental Research, Plymouth was examined for marine or terrigenous contributions to its organic composition. The Py-Ms method showed this distinction in many of the characteristic biopolymer pyrolysis products, the best being those related to sulphur containing amino acids (greater in marine) and pentose polysaccharide, presumably from plant xylans etc (greater in freshwater). 1018, 6027

Surface and Physical Characteristics of Soils

XPS (X-ray Photoelectron Spectroscopy) Studies

Qualitative aspects of XPS have been explored during an investigation on the influence of lattice structure, isomorphous substitution, ion occlusion and adsorption, and structural disorder on the spectral characteristics of Fe in iron oxides. The changes caused by these effects are relatively small, and although it seems that XPS cannot be classed as a primary investigative technique for probing iron oxide structures, nevertheless it does yield information not available by other techniques. In collaboration with the Department of Spectrochemistry, work has been started on the surface composition of Al-containing goethite, many of the results having been incorporated into a poster presented at the NATO Advanced Studies Workshop on "Iron in soils and clay minerals" held at Bad Windesheim, West Germany. 1003, 3005

Aggregate Stability

The work reported last year on the aggregate stability of soils of the Laurencekirk and Foudland Series has continued and the methodology developed used in a preliminary study of other Scottish soils being investigated in conjunction with the MISR/COSAC Working Group on Soil Physical Conditions. Aggregates were isolated from genetic horizons of six soil profiles and examined by low temperature nitrogen adsorption and mercury intrusion porosimetry. Comparison of the clay contents for the 2-5 mm aggregates with their specific surface areas showed that A horizon aggregates are quite different from aggregates from the B and C horizons.

In particular, the first have lower surface areas (as assessed by nitrogen adsorption), than might have been anticipated from their clay content but contain much coarser pores in the 3.5 nm – 7.5 μm range, probably because of a predominance of inter-aggregate pores formed between stable microaggregates within the macroaggregates. Such aggregates are currently being examined by SEM in order to obtain direct evidence of their structure. First results show that macroaggregates tend to break down along concave surfaces formed from oriented clay (Fig. 1.3.) and that such surfaces may well be an important factor in the internal structure of the aggregates.

1003, 1804

Further investigations have been made on the pore-size distribution and specific surface areas of sand fractions isolated from the the C horizons of a variety of soils, selected so as to represent a range of geological parent materials, including igneous, metamorphic and sedimentary rocks. The results show that conventional dispersion procedures and exhaustive

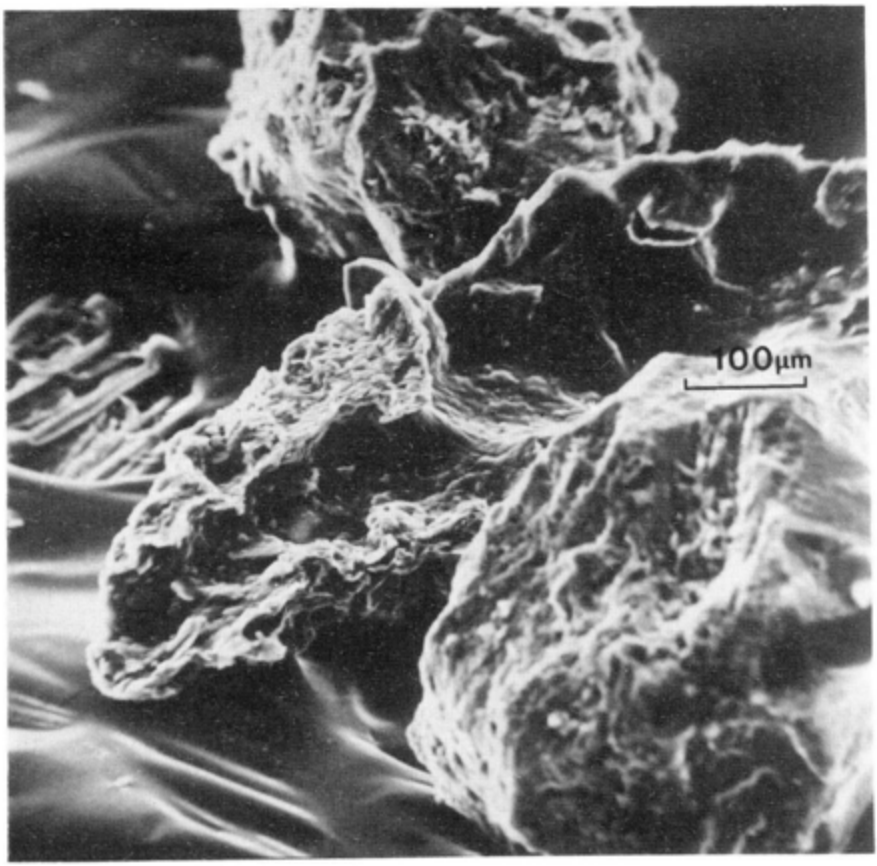


Fig. 1.3. Scanning electron micrograph of soil aggregate showing concave faces with orientated layers of clay.

separations do not always yield a low surface area sand fraction. Indeed, some of the coarse sand fractions separated from lava-derived soils have specific surface area values as large as the whole soil. As these fractions have been separated from C horizons, where there is minimal organic matter, it seems that aggregation must arise from inorganic cementation or could perhaps represent weathered primary materials or inherited porous aggregates of clay minerals. Further work is being carried out to distinguish these possibilities. 1003, 1804

Physical Properties of Soils

In collaboration with the Department of Soil Survey, work has continued on the characterization of the structure of compacted soils as assessed by scanning electron microscopy (SEM). The soils involved are from the Winton Series and have been used in field trials by the Scottish Institute of Agricultural Engineering (SIAE) to study the effect of compaction on crop yields. Although it is difficult to quantify SEM images, some interesting observations have been made. For example, Fig. 1.4 shows vertical and horizontal fracture surfaces after artificial compression at 20 lb/in^2 at three magnifications. It can be seen that the horizontal fracture surfaces have a smoother aspect than the vertical fracture surfaces, indicating some reorientation of the platy clay mineral (kaolinite) particles, perpendicular to the direction of compaction. It is difficult to say, however, that this effect is a general one, because the roughness of both vertical and horizontal fracture surfaces is such that the rather small areas examined by SEM may actually be at any orientation.

Other soil structural features are also being examined by SEM. In particular, some ped faces are being examined to determine if they show evidence of being more or less permanent soil features or whether, on the contrary, they close up during wet periods to be replaced by new faces. Generally, the ped faces have coatings of fine material which is more highly oxidized than the centre of the ped. These observations seem to suggest that ped faces may be semi-permanent points of weakness in the overall soil structure, opening and closing during dry and wet periods and perhaps being responsible for the drainage of a significant proportion of the soil solution. 1804

In collaboration with SIAE, work has continued on a set of 26 surface soils from south east Scotland to determine whether their physical properties could be correlated with soil mineralogy and other factors. As mentioned last year, total layer silicate content (as assessed by XRD) correlated much better with properties such as liquid limit, plastic limit, total porosity and drop cone penetrometer index than did total clay content, as determined either by the hydrometer or pipette method. These results implied that there were significant quantities of layer silicate minerals in the coarser particle size fractions and for six selected soils it was found that kaolinite was common or even dominant in the silt (2-20 μm) fractions. Electron microscopy showed that the kaolinite was not necessarily in an

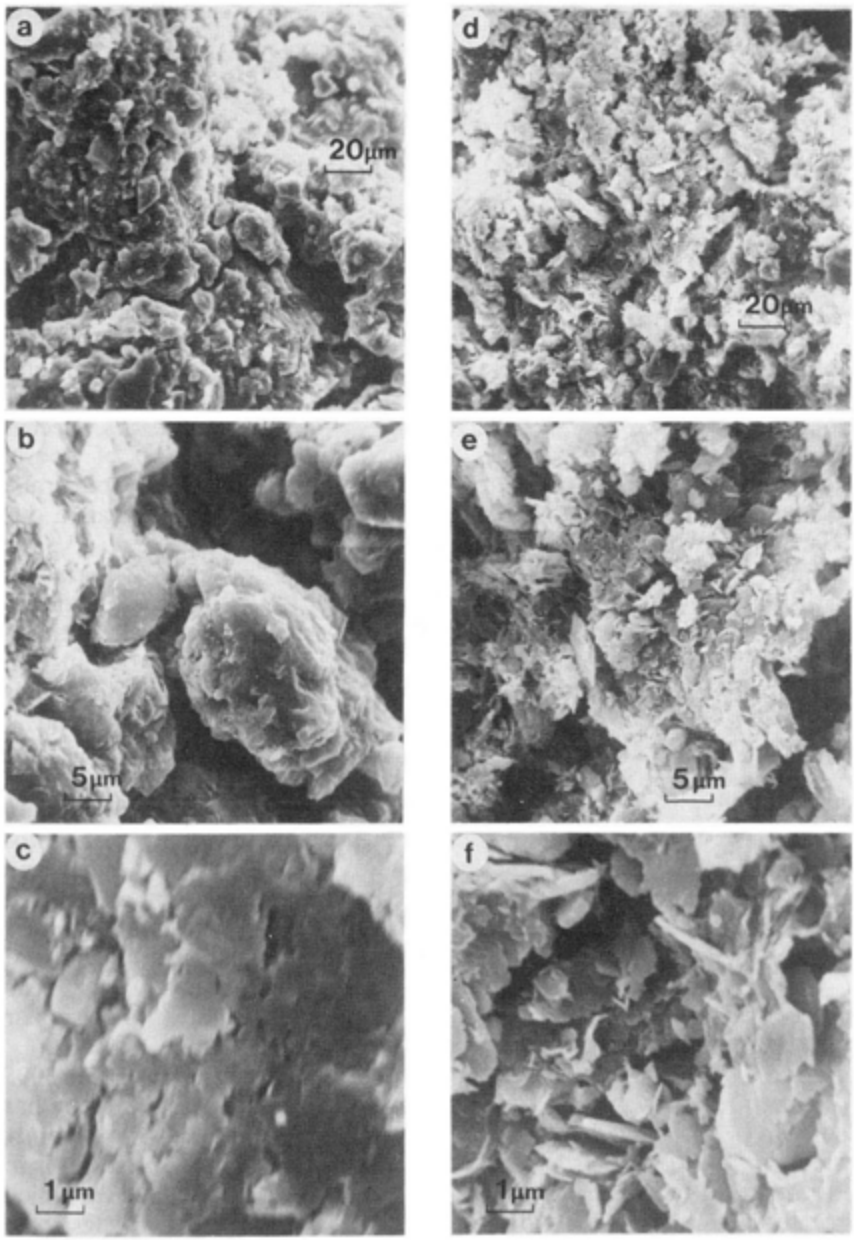


Fig. 1.4. Scanning electron micrographs of horizontal (a, b, c) and vertical (d, e, f) fracture surfaces of Winton Series soil compacted at 20 lb/in^2. The horizontal surface has a smoother aspect indicating some reorientation of the platy kaolinite, perpendicular to the direction of compaction.

aggregated form but could occur in large discrete particles. Further detailed characterization of the mineralogy of these soils continues.

1060, 1062, 1804

Studies Involving Soil Processes

Weathering and Soil Mineralogy

A paper describing the mineralogy and weathering history of a Scottish soil has now been published[21]. From a consideration of geological, geomorphological and mineralogical factors, it is shown that the composition of soils in Scotland can be readily interpreted in terms of the combined effects of parent material, Preglacial/Interglacial weathering and recent pedogenesis. Inheritance effects are usually dominant, because of the youthfulness of the soils but Preglacial weathering may have a profound influence in some areas, and is typically shown by the occurrence of kaolinite, halloysite and gibbsite in soils af all drainage classes. Recent pedogenic weathering is usually confined to the formation of poorly ordered clays and to the formation of interstratified vermiculitic minerals. Substantial progress has been made during the course of the year in our understanding of the formation of these weathering products.

One of the most commonly occurring poorly ordered clay materials in Scottish soils is proto-imogolite allophane and, in collaboration with the Department of Spectrochemistry, the different stages in the development of the imogolite structure have been illustrated by high resolution transmission electron microscopy and electron diffraction (Fig. 1.5). Synthesis experiments carried out at 25, 60, 80, and 96°C show that the globular 3-5nm particles of proto-imogolite allophane formed after six years at 25°C are produced in less than one hour at 96°C. At the latter temperature well-developed tubular imogolite is synthesized within a few hours. Electron diffraction of these phases shows a very diffuse three ring pattern of proto-imogolite allophane which sharpens up and develops with time and temperature to the sharp multi-ring pattern unique to well-crystallized imogolite tubes. The data suggest that imogolite should form in a soil environment in only a few hundred years, although a search for the mineral in young podzolized soils developed on sand dunes has so far been unsuccessful. The fibrous phases that have been found appear to be similar to the fibrous goethite previously reported by Japanese workers.

1060, 1061, 3005

The nature of interstratified clay minerals formed during weathering has also been clarified[22] and it has been shown that these minerals form mainly by reactions involving relatively large crystals of mica or chlorite. This is in contrast to interstratified clays generally associated with diagenesis, which typically consist of extremely fine-grained particles some tens of Angstroms in thickness.

1060, 1061

A paper describing the weathering of chlorite in the silt and clay fractions of Scottish soils has now been published, in which it is shown that the physical breakdown of this mineral from silt to clay size particles could lead

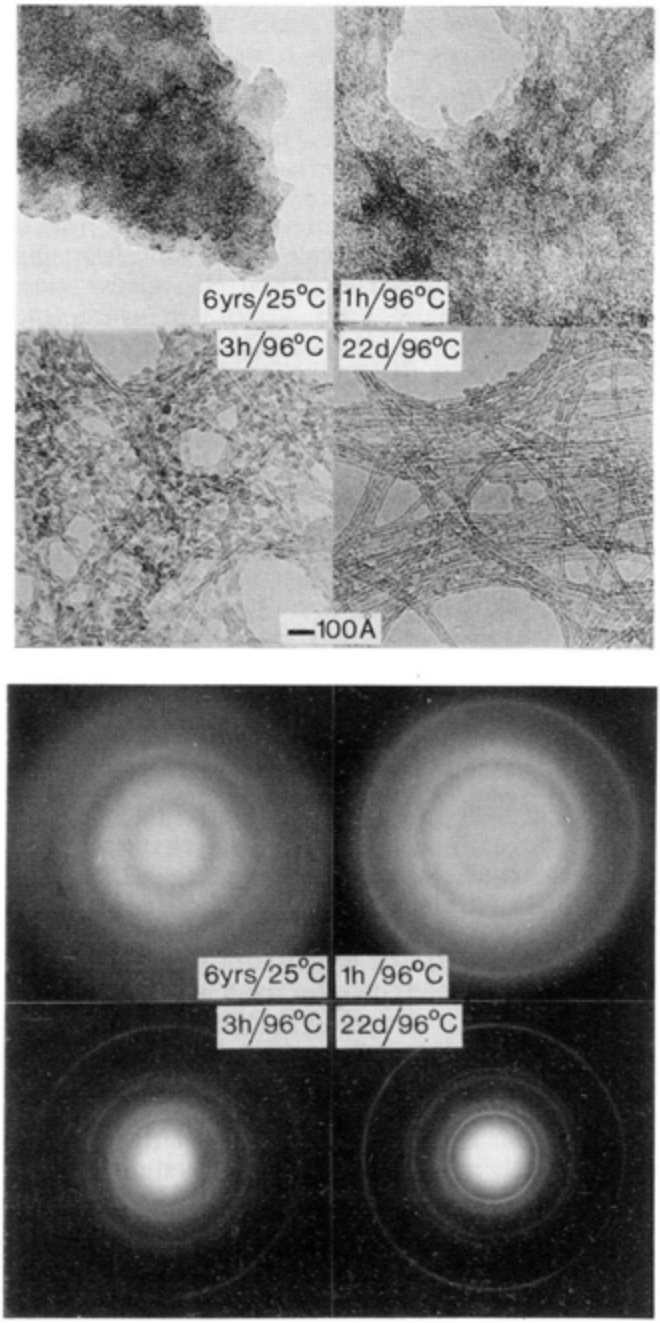


Fig. 1.5. Transmission electron micrographs and corresponding diffraction patterns showing stages in the synthesis of imogolite (lower right) from proto-imogolite allophane (upper left).

one to the erroneous conclusion that chlorite may remain stable in the fine fractions[23]. 1061

Pedogenesis and Trace Element Status

Studies of the weathering patterns and pedogenic processes in soils where the levels of extractable trace elements have been found to vary with drainage status have been extended from a hydrologic sequence from the Strichen Association to soils of varying drainage status from the Thurso and Ettrick Associations. Clay mineralogy has been determined and the coarser fractions are also being examined, in collaboration with the Department of Spectrochemistry, to establish in which fractions and components the trace elements are located and to clarify mechanisms of release. 1061, 3007

Surface Water Acidification (SWAP)

The Department is involved in two separate aspects of SWAP, concerned with soil chemistry and mineral weathering. Plans for the water sample collection and analysis programme have already been described and soils have been sampled immediately adjacent to the soil moisture probes. The chemical and physical characteristics of these soils are currently being determined and once this work has been completed it is intended to investigate the exchange characteristics of the soils and their fractions, and in particular, to determine cation-exchange capacity, buffer capacity, sulphate sorption capacity and amounts and rates of aluminium release under varying conditions of acidity. The second aspect of the Department's involvement in SWAP is concerned with processes and products of mineral weathering in the soils of the experimental catchments, with the determination of the acid neutralizing capacity of the soils and with the estimation of weathering rates so that these can be used in modelling studies. To facilitate an integrated approach, the soils currently being studied are the same soils as those collected for the soil chemistry study. A review of the mineral weathering processes in podzol soils developed on granitic material and the implications of these processes for surface water acidification has now been accepted for publication[24]. This paper outlines some concepts which are important to evaluate, in particular the possibility that acid deposition may induce modifications in natural weathering processes. This could occur if organic acid mediated weathering processes - which are usually dominant in podzol soils - were partly replaced by mineral acid weathering, and there is evidence from the literature that such a change could lead to more rapid soil acidification and possibly to an increase in ionized aluminium in solution. It is intended to set up experiments to test this hypothesis. In collaboration with the Department of Spectrochemistry, a paper describing the relationship between the acidic weathering of feldspar and biotite in the A horizon, and the precipitation of poorly ordered allophanic components of the Bs horizon of a podzol has now been published[25]. 1067, 1808, 3005

Mountain and Forest Soils

The work on surface water acidification has meant that more effort has had to be devoted towards understanding the processes that occur in these types of soils, particularly in view of the locations of the selected experimental catchments. The Department's capacity for this type of work has been substantially strengthened by the recruitment of staff with experience of arctic alpine soil processes in Norway[26,27,28], obtained during studies at the University of Hull. With regard to mountain soils in Scotland, a survey of the mineralogy of twenty five C horizon samples showed that there were significant amounts of the aluminium hydroxide mineral gibbsite in ten instances. This observation is of interest because it has been suggested that aluminium in surface waters draining podzolized soils is controlled primarily by equilibrium with a gibbsite-like mineral in the soil, despite the fact that the mineral has rarely been detected. The origin of the gibbsite in the mountain soils is problematical. It could conceivably be forming at the present time, although micromorphological and mineralogical evidence is more consistent with inheritance from a previous weathering cycle and formed under humid, subtropical conditions. A similar conclusion was reached following work on weathered rock containing halloysite from the Gaick plateau in the Cairngorms not far from the Allt a' Mharcaidh, SWAP catchment. Preliminary work on the alpine and sub-alpine soils of this catchment shows that there is an appreciable amount of gibbsite and kaolinite in the soil clay fractions and it will be of interest to determine whether these minerals influence the soil water chemistry. 1060, 1061, 1067

Mineralogical work has also been carried out on the clay fractions of four podzolized soils from Fetteresso, Aberdeenshire, a site chosen by the Department of Peat and Forest Soils, for the monitoring of changes in rainwater chemistry during passage through vegetation and soil horizons. Each of the soils is characterized by the same clay mineral trend, with hydroxy-aluminium interlayered vermiculite becoming prominent in the B horizon, and a hydrobiotite-like mineral (which could form relatively quickly[29]) occurring in the E horizons. All the soil clays contain kaolinite and one contains 5% gibbsite, as determined by differential thermal analysis. Similar clay mineral trends were also observed in two podzolic soil profiles at Cairn-o-Mounth and Glen Dye, developed on parent materials similar to those at Fetteresso. Again, the relationship with soil water chemistry remains to be determined. 1067, 2073

Soil Chronosequence Studies

The determination of long-term mineral weathering rates, a measurement that is of some importance in catchment studies, depends on the characterization of securely dated soils. In Glen Feshie, near the Allt a' Mharcaidh SWAP catchment, there is a sequence of soils developed on river terraces and outwash for which dates of 13,000, 10,000, 3,500 and 80 BP have been obtained by Miss M. Robertson-Rintoul (Department of Geography, University of St Andrews). These soils have now been collected

and are currently being analyzed by X-ray diffraction and fluorescence methods. Although the results of this study may not be directly applicable to the SWAP catchment itself, they will at least provide invaluable background information regarding rates of weathering of the main soil mineral species. Previous chronosequence studies have also been carried out on accurately dated till deposits in southern Norway[30,31]. 1067, 1809

An essential element in comparative chronosequence studies is to be certain of the uniformity of the soil parent material. In collaboration with Dr F. Ajmone-Marsan (Universita di Torino, Italy) an investigation was made into this aspect of three deep soil profiles from the Valsesia district in northern Italy developed on fluvial outwash. The method used was based upon the XRF analysis for major and minor elements, in addition to the trace elements Zr, Y, Sr and Rb, in the heavy minerals of the fine sand fractions. Despite large variations in some elements with profile depth, the ratios of some elements (e.g. expressed as Y_2O_3/ZrO_2, ZrO_2/TiO_2, P_2O_5/TiO_2) showed insignificant changes which, in conjunction with supporting mineralogical data, suggested that the soil parent material was indeed uniform. 1061

Biological Weathering

In collaboration with the Department of Microbiology, an investigation of the chemical action of lichens on mineral surfaces, which involves the effects of chelating organic acids produced by the lichen fungus, has now been published[32] and a further paper describing the decomposition of various rock types, including basalt, serpentinite and granite, has been accepted for publication[33]. This work has now been re-orientated to investigate the decomposing effects of soil mycorrhizal systems, which are, in many respects, analogous to lichens. 1061, 6028

Studies Involving Foreign Soils

As in previous years studies have been made of various aspects of foreign soils in order to deepen and to extend the technical and research experience of appropriate staff. For example, the Department is now participating in LABEX, an inter-lab comparison exercise organized by the International Soil Reference and Information Centre, Wageningen. Soil analytical data have been determined on a range of different soil types developed under various climatic conditions. The experience is proving to be an invaluable (and salutary) exercise and has certainly brought home the point that the appropriate methodologies for temperate climates, may be quite inappropriate for soils of arid or tropical regions. In collaboration with the Department of Soil Fertility a paper has now been published describing the influence of clay mineralogy on the cation exchange characteristics, particularly aluminium release, of some New Zealand podzols[34]. A paper has also been published on an unusual assemblage of high-magnesium clay minerals, which included sepiolite and palygorskite, in some Turkish alluvial soils developed on an inter-montane plain under a semi-arid

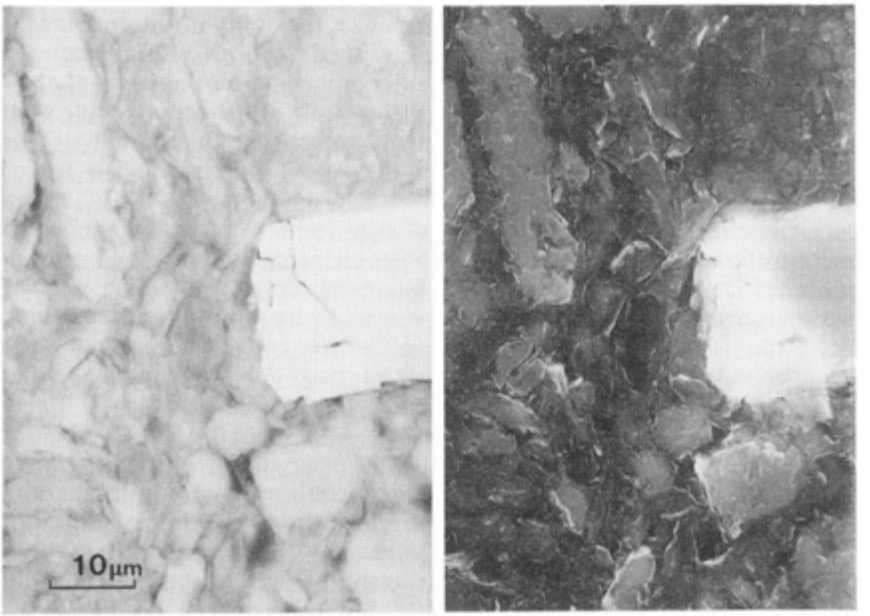


Fig. 1.6. Comparison of secondary electron image (left) and back-scattered electron image (right) of polished soil thin section.

climate[35]. In collaboration with the University of Nsukka, work has continued on the relationship between the mineralogy and fertility status of various Nigerian soils. 1001, 1060

Development of Methods

The year has been characterized by the development of refinements and improved applications of virtually all the primary analytical techniques used in the Department. The ability of X-ray diffraction to cope with poorly ordered soil materials has been extended by using a differential technique, although the available software is still rather clumsy, and a method has been developed based on acetone suspension for preparing randomly orientated clay mounts on glass slides using one tenth of the material required for the conventional aluminium holder[36]. The acquisition of a Philips PW 1404 automated, sequential, wavelength-dispersive, X-ray fluorescence spectrometer (combined with a twelve position sample changer) and a Dionex ion chromatograph greatly increases the Department's capacity for soil, mineral and water analysis.

1003, 1060

Progress involving electron microscope and microprobe techniques has been remarkably good. In collaboration with the Department of Microbiology two papers have been published illustrating the use of the cryofixing and critical point drying techniques on sensitive biological material[37,38]. The acquisition of a back scattered electron detector for the

scanning electron microscope greatly enhances the utility of this instrument for examining soils, particularly in polished sections. Back scattered electron imaging differentiates between components on the basis of their atomic number and reveals details scarcely visible using secondary electron imaging (Fig. 1.6). Quantitative electron microprobe micro-analysis has now been routinely established with the recent purchase of a set of standards for use with the data reduction programme FRAMEC and a paper describing how multivariate statistical techniques can be applied to microprobe analyses to demonstrate inter-element relationships has been published[39]. A semi-micro method has been developed which enables heterogeneously distributed soil components to be sampled and examined by transmissiom electron microscopy[40]. In collaboration with the Department of Spectrochemistry a paper has been published on the use of a high gradient magnetic separation system to separate iron-rich soil clay minerals[41]. 1003, 1060, 1804, 3995, 6026

Improvements have also been made to the pyrolysis-gas chromatography equipment, initially for more specific characterization of polysaccharides from their larger molecular fragments and for the further identification of the aromatic hydrocarbons. Modifications to the pyrolyser have been effected with the co-operation of the manufacturer (Fisher). Finally, in collaboration with the Department of Spectrochemistry and with the Director, a paper describing the application of optical, electron and X-ray spectrometry methods to problems in soil analysis has been written and accepted for publication[42]. 1018, 1003, 1061, 1804, 3010, 3011

Other Work and Work of Commercial Interest

The international reputation of the Department, particularly for the analysis of clay minerals, has led to a steady stream of requests for advice from commercial organizations, especially those involved in the oil industry. The opportunity to examine a wider range of samples is often beneficial to the Department's own programme of work, as is the opportunity to participate in discussions concerning problems arising from clay materials. For example, electron microscope and X-ray diffraction examination of diagenetic illite clays from the Magnus Field, made at the request of BP, not only yielded results of direct value in the assessment of the quality of reservoir sandstones[43], but also led directly to the development of a new conceptual model for interstratified clays which, as shown earlier, clarified the nature of these materials in soils, as well as rocks. Further work led to the proposal of a new mechanism to account for the smectite to illite diagenetic conversion, a reaction of great relevance to the origin and migration of petroleum in the geological sequence[44]. Building on this work and on the discovery that randomly interstratified clays could be readily synthesized, an investigation has commenced into the catalytic properties of these clays in collaboration with the Edward Davies Chemical Laboratories, University College of Wales, Aberystwyth. This work is funded by the British Technology Group and first results are encouraging. Thus, synthetic randomly interstratified illite-smectite (90% smectite) can

attain 73 percent of the activity of standard commercial catalyst (hydrogen ion exchange resin) for the synthesis of methyl tertiary butyl ether, representing a 49 percent improvement over pure smectite clay. The improved activity is attributed to better desorption of the reaction product. A similar approach is being applied to develop a cracking clay catalyst for hexane with favourable gas phase adsorption/desorption characteristics. Other industrial/commercial applications of highly dispersed clay materials have been investigated in an exploratory way, including thin films, coatings and microceramic products[45]. In collaboration with the Department of Soil Organic Chemistry, work has commenced on the formation, characteristics and degradation of clay/enzyme complexes, montmorillonite-cellulase being the first such system investigated. 1060, 4064

In conjunction with Ove Arup and Partners, the influence of clays on the stability of abandoned limestone mine workings in the West Midlands has been studied[46], and, in a more hypothetical vein, a contribution has been made to the possible role of clays in the origin of life[47]. Finally for the last two months of the year Dr R.L. McLeod (Darling Downs Institute of Higher Education, Queensland, Australia) has been investigating the occurrence and significance of various types of clay minerals associated with ore bodies in Scotland and Ireland. Initial results are most encouraging.

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2. PEAT AND FOREST SOILS

R.A. ROBERTSON

The work of the Department is primarily concerned with the survey and evaluation of Scottish peat resources; the development and application of remote sensing, photogrammetric and digital mapping techniques for terrain analysis, crop assessment and environmental monitoring operations; and the establishment of both field and laboratory experiments designed to elucidate the biogeochemistry of nutrient cycles in different soil/plant systems, the effects of atmospheric inputs, including pollutants, on plant growth, soil development and surface water chemistry and the consequences of changes in management practices on hill and marginal land.

During the year increasing demands have been made on the Department's expertise and facilities to provide information on the nature and extent of peat resources and their suitability for the production of horticultural and energy-related products. Survey operations and map output continue to benefit considerably from the ongoing development of photogrammetric and digital mapping techniques which enable a more rapid response to requests for resource assessment from external agencies. Much of this work is carried out in close association with the Highlands and Islands Development Board, the Scottish Development Agency, the Scottish Development Department, the UK Peat Producers Association, the Forestry Commission, the Nature Conservancy Council and other organisations in both the public and private sectors.

Good progress has also been made in the development and deployment of remote sensing strategies and the integration of photogrammetric, digitising, image processing and cartographic facilities to accelerate the capture, display, enhancement, interpretation and editing of spatial data and the output of geoscientific maps. The mixing of image and map information and the construction of local geographic information systems are major areas of current and future research. The Institute is now recognised as a Regional Centre of the National Remote Sensing Centre, RAE, Farnborough. Close collaboration is also maintained with the European Space Agency, the Department of Industry (Space Division), the Royal Signal's Research Establishment, Malvern, the Scottish Development Department (Air Photo Library), Cranfield Institute of Technology and the Universities of Aberdeen (Geography), Dundee (Physics) and Glasgow (Geography).

Significant advances have also been achieved in studies designed to investigate the pathways and mechanisms controlling the size and rate of nutrient fluxes in different soil/plant systems, the construction of

simulation models to predict nutrient requirements of forest trees, the effect of environmental factors, tree species and microbial activity on the rate and pattern of nitrogen mineralization in highly organic soils and the interactive role of soils and vegetation in modifying rainwater chemistry and surface water acidification. Here again an important element in these wide ranging studies has been the excellent co-operation and support received from external organisations including the Forestry Commission (Research and Development Division), the Irish Forest and Wildlife Service in association with the EEC, the Forth and Clyde River Purification Boards, the Departments of Forestry and Soil Science, University of Aberdeen, the Department of the Environment, the Central Electricity Generating Board, the DAFS Freshwater Fisheries Laboratory, Pitlochry, Imperial College, London, the Institute of Hydrology and the Royal Society.

Members of staff have continued to serve on a number of national and international committees and working groups. These include the Executive Committee and Council of the International Peat Society, the Executive of the Scottish Peat and Land Development Association and the British Standards Institution's Technical Committee FAC/2 (R.A. Robertson): the Remote Sensing Applications Committee and the Land Applications Working Group of the National Remote Sensing Centre, Royal Aircraft Establishment, Farnborough (R.V. Birnie): and the Mires Research Group and Meetings Committee of the British Ecological Society (P.D. Hulme).

A sincere welcome is extended to Mr R. Ferrier who joined the staff in October 1985 on a term contract under the Surface Water Acidification Project supported by the Royal Society.

It is with deep regret that we record the loss of a highly esteemed colleague Mr P.F.S. Ritchie who died in April 1985. During his few years in the Department, Peter Ritchie made an outstanding contribution to the development and application of remote sensing and image processing techniques. His special expertise, cheerful disposition and sincere friendship will be sadly missed.

Terrain Resource Survey and Monitoring Operations

Peat Survey and Evaluation

The field component of the Shetland peat survey, based primarily on land use, vegetation and peat characteristics, has been completed; observations on upland peat erosion are still ongoing. A map showing the main peatland classes has been produced in draft form at 1:50,000 scale. For reporting purposes it is intended to reduce the map to 1:100,000 and superimpose it upon a geometrically transformed space image. This project is the first where geometric transformation of a Landsat image has been done within the Department and the results have proved comparable to those from the National Remote Sensing Centre, Farnborough. Recognising the relatively coarse resolution of Landsat MSS (Multispectral Scanner) imagery, it is also intended to explore the possibility of using Landsat Thematic Mapper (TM) imagery as a base. At least one TM image is known to exist for Shetland. This imagery not only has increased spatial resolution but can be produced

in a pseudo-true colour form which makes it particularly suitable as a map base for publication. A provisional peatland vegetation classification for Shetland and an account of some erosion processes have been published[1,2]. 2032, 2035

During the year detailed topographic and stratigraphic surveys have been completed at Dale Moss (Caithness), Creca Moss (Dumfries) and Gardrum Moss (Stirlingshire). Both the Dale and Creca Moss surveys were carried out using Wild T1 and DI4 electronic measuring equipment to establish a 50m close grid over the bog surface. The survey data were then reduced using ground survey computation programs (Annual Report No. 54) and both site plans and cross-sections were generated on a Wild TA plotter at 1:2,500 scale. The plan of Gardrum Moss was produced photogrammetrically at 1:2,500 scale. Both survey data and the results of sample analyses have been used to assess the potential of these resources for peat production or further development. 2032, 2035, 2036

At the request of the National Coal Board, a report[3] has been prepared on the quantity and quality of the peat overlying an area scheduled for opencast mining. The peat is to be retained and used for the subsequent rehabilitation of the site. 2035, 2036

Further surveys have been undertaken on a regional and local basis to provide information on peat resources and peat soils for inclusion in Memoirs of the Soil Survey of Scotland[4,5,6]. Work currently in progress is concentrated on the Midland Valley and north-east areas of the country. Further progress has been made with studies designed to elucidate the processes of peat formation and development[7,8]. A peat-soil classification system has been developed for Scotland based on the inter-related factors of peat type, land use and horizon development. 2035, 2036

Palaeobotanical Investigations

Collaborative work with the Central Excavation Unit of the Scottish Development Department has continued at Strathallan, Perthshire[9]. Stratigraphical and palaeobotanical studies of mineral soil and peat deposits have provided information on the effect of Man on soil and vegetation development. These studies, supported by radiocarbon dates together with soil micromorphological studies undertaken by the Soil Survey Department, indicate that cultivation, including the growth of cereals, started at Strathallan at least 5600 radiocarbon years ago and has continued, possibly without major interruption, until the present day. The results of a study of the pollen content of soil from a medieval site in Deeside, near Aberdeen, have been published[10].

Bracken Survey

The mapping programme to establish the extent of bracken infestation in Scottish hill land, and the rate of bracken spread in the post war period has continued along the lines previously reported[11]. Determination of the rates of spread is based on a combination of historical air photo interpretation

Table 2.1 Change in bracken coverage 1947 to 1967 at Poltalloch site (Kilmartin, Argyll)

Section	1947 (m^2)	1967 (m^2)	Total area of section (m^2)	Increase (m^2)	Gross Annual Increase %	Decrease (m^2)	Net Annual Increase %
South	120,074	120,218	302,525	24,036	1.1	23,892	0.0
Centre	92,854	131,345	280,525	53,114	3.0	14,623	2.2
North	220,542	254,275	343,253	50,199	1.2	6,466	1.0
Total	433,470	515,838	926,303	127,349	1.5	44,981	1.0

and ground survey. A number of sites around Scotland have been selected as being broadly representative of different bio-climatic regions. During 1984, the field survey of the Kilmartin (Argyll) site was completed and over the winter the relevant air photo interpretation was performed. This utilised 1947 RAF fan photography at c. 1:9,900 scale and 1967 OS vertical photography at 1:25,000 scale. By comparison of the 1947 and 1967 distribution maps it was possible to identify areas where bracken had either increased or decreased. In order to reveal relative changes in different ecological settings, the Kilmartin site (Poltalloch) was divided into north, central and southern sections. The north section comprises steep slopes with rocky outcrops and shallow soils supporting an unimproved grassland sward. Here, bracken increase has averaged 1.0% per annum, only a relatively small area losing its bracken cover during the period (Table 2.1). The central section is less steep, with deeper soil and an improved grassland sward. In this area the pattern of bracken infestation during the period 1947-67 has been complex with both increase and decrease, but the overall effect has been for the bracken-infested area to increase rapidly at c. 2.2% per annum. In the southern section bracken is competing with a semi-natural vegetation community dominated by heather. Here, although there has been little change in the absolute levels of bracken infestation, there have been significant transfers (Table 2.1). 2065

The Kilmartin data are reported in detail elsewhere[12] but the indications are that, in this area, bracken spread has been most rapid on the better quality land. It remains to be seen whether this pattern is typical. During 1985, the ground survey component of the programme was completed at the Glensaugh, Sourhope and Gatehouse-of-Fleet sites and the relevant air photo analysis is currently in progress. Work on the generation of regional bracken cover estimates still awaits a cloud-free Thematic Mapper image. 2065

Snow Surveys

Analysis of springtime Landsat MSS imagery has been performed to determine whether it is possible to distinguish wet snow from dry snow. The transition from wet snow at lower altitudes to dry snow at higher altitudes should be apparent from a decrease in the ratio of green radiance to infrared radiance (waveband 4/waveband 7). The analysis for the Cairngorm Mountain area indicated that the ratio of 4/7 actually increases.

Since it is unlikely that the snow does become wetter at higher altitudes, an alternative hypothesis is presented, that of mixed pixel effects. At lower altitudes the snow cover is patchy and each pixel includes areas of snow-free ground. This has the effect of depressing the ratio 4/7. Radiance values for snow-free ground provide 4/7 ratios of 0.60 and for snow-covered ground 1.27. Results for 4 transects at two image dates show that there is a systematic increase in 4/7 values with altitude, which is explained in terms of the general increase in snow-cover with altitude rather than a progression from wet snow to dry snow as previously supposed[13]. 2034

The contract with the University of Aberdeen to investigate the reflectance characteristics of snow at mm wavelengths is ongoing. A second field season in the Bavarian Alps during February-March 1985 was curtailed due to lack of snow and the project has been extended for a further year. Further analytical results have been published[14]. 2034

Aerial Surveys

The major aerial surveys in 1985 were carried out in connection with the bracken survey. Over two flights in July and September, false colour infrared and panchromatic photography was obtained of sites in the west of Scotland and over Sourhope in the Borders. Additional sorties were done on behalf of the Department of Soil Survey (Fochabers drainage scheme) and the Scottish Institute of Agricultural Engineering (coverage of the Bush Estate). Individual fields identified as erosion trial sites by the East of Scotland College of Agriculture were also covered with false colour infrared photography. Liaison with the Scottish Crop Research Institute resulted in the provision of photography of relevant potato fields in the Angus area. Similar liaison with the Geography Department, University of Aberdeen provided photographic coverage of gas pipelines in connection with a research project on the effectiveness of reinstatement procedures. 2032, 2034, 2065

In late September, airborne multi-spectral scanner data and panchromatic photography were obtained, on the Department's behalf, by the Natural Environment Research Council's aircraft. The coverage of Sourhope and an area west of Dundee is intended to further the bracken and crop mapping projects but has yet to be assessed. 2032, 2034, 2065

Crop Investigations

Winter Oilseed Rape (WOSR) Survey

Further distribution studies on this crop have been hindered by non-availability of suitable cloud-free satellite imagery[15]. An image of central and south east Scotland has, however, been obtained for the 1981/82 growing season from which it will be possible to extend the classification to cover this area. WOSR fields classified and mapped so far are indicated on Fig. 2.1. Methods used in this study have now been adopted by the National Remote Sensing Centre, Farnborough and by Silsoe College to monitor the WOSR crop in England and Wales. The acquisition of "SPOT" satellite

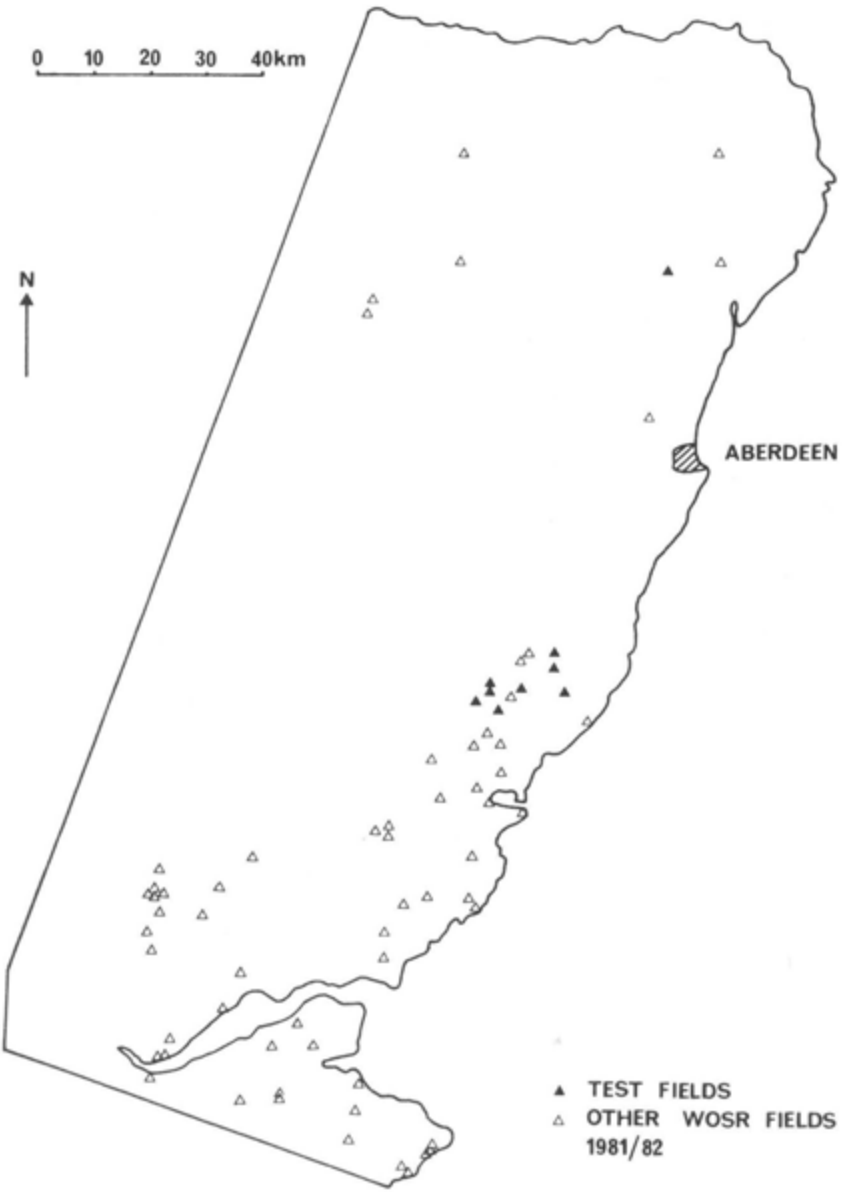

Fig. 2.1. Distribution of winter oilseed rape fields in Eastern Scotland 1981/82, based on Landsat multispectral data.

simulation data (Annual Report No. 54) has enabled studies into within-field crop variations to be carried out and assessments of the accuracy of crop area measurements to be made in anticipation of such high resolution data becoming available in 1986. 2032

Potato Crop Survey

The distribution of the 1982 potato crop within Kincardineshire and Deeside has now been obtained using multitemporal Landsat imagery (Fig. 2.2). Some 2628 hectares (ha) of potatoes were classified using imagery from 30th May 1982 and 3rd October 1982. Confused classification did not generally occur in areas greater than 2ha. When these errors were removed using a minimum area filter, the total area of potatoes grown in Kincardine and Deeside was given as 2131ha. This compares with the Department of Agriculture and Fisheries for Scotland (DAFS) and Potato Marketing Board (PMB) figure of 1889ha. The difference between the Agricultural census data and the Landsat classification may be due to fields not registered at census, fields of turnips harvested before 3rd October 1982 or over classification of certain fields. 2032

Fig. 2.2. Potato fields within Kincardine and Deeside, 1982, identified using multitemporal classification of Landsat data. Fields have been categorised according to area.

The second phase of the study relating the classified fields to environmental characteristics is now in progress. The following maps (in raster digital form) have now been prepared.

(i) Agroclimatic Areas (Met. Office data, 1:625,000)
(ii) Urban Areas (O.S. 1:250,000 Routemaster)
(iii) Region and District boundaries (O.S. 1:250,000 Admin. map)
(iv) Woodland and Moorland (Classified from 30/5/82 Landsat 3 image)
(v) Potential Water Deficit (Macaulay Institute - Soil Survey Climatic maps)
(vi) Rainfall (Met. Office data)

These maps are available in vector digitised format (E.C.U.) and cover Eastern Scotland (O.S. sheet 5). 2032

A 1:250,000 Soil Association map has yet to be obtained in suitable digital form. The Department of Soil Survey have contracted the Laser-Scan Laboratories to digitise all seven 1:250,000 soil maps of Scotland but preliminary investigations into the use of these files is still being undertaken within that Department. The 1:625,000 digital O.S. contour file has also been obtained (for research use only) and successfully converted to E.C.U. format for inclusion in the small-scale geographic data base. The non-availability of suitable digital maps to be used in the second phase has extended completion of the project into 1986. 2032

Crop Reflectance Studies

Winter Barley

In collaboration with the Department of Spectrochemistry and the North of Scotland College of Agriculture, the crop reflectance of winter barley under different fertiliser and crop husbandry systems is being investigated. Using the correlations between Infrared/Red waveband values and crop efficiency, a non-destructive indicator (the IR/R ratio) is being tested as a measure of the treatment performance sequence of a crop trial[16]. 2032

Using the radiometer developed for potato nitrogen uptake trials[17], the IR/R value for 160 winter barley plots was taken at approximately 14 day intervals throughout the growing season. The treatments monitored included 4 different sowing dates, 2 levels of autumn nitrogen, 2 levels of growth regulator and 5 levels of spring nitrogen application. The mean IR/R value between spring and pre-harvest ripening was found to be highly correlated to grain yield (at 85% dry matter). Preliminary analysis of conventional yield data and the treatment performance sequence indicates a high correlation with that obtained using non-destructive remotely sensed data. If this analysis proves reliable, then the possibility of monitoring trials with only minimal destructive sampling may be contemplated. 2032

Environmental Effects on the IR/R Ratio

A common problem in using radiometers for vegetation studies is that readings are often view-angle dependent. This is due to the fact that vegetation canopies, and particularly those of row crops, are non-Lambertian reflectors. Whilst this effect is generally well-recognised, less so are the effects of wind turbulence on radiometric readings. Observations on

the winter barley crop revealed that, during the period of inflorescence, wind effects could alter the IR/R ratio by as much as 10.8%. This is an important observation since the greatest correlations between IR/R ratio and grain yield are obtained during the period of stem elongation, inflorescence emergence and flower development. Wind effects were found to be important only at the inflorescence stage and therefore radiometric measurements at this time should only be undertaken under still conditions if these correlations are to be exploited[16].

Potatoes

During 1985, a programme of weekly measurements of crop cover and crop reflectance was undertaken in collaboration with the Department of Soil Fertility on two potato trials designed to investigate nitrogen-application and soil compaction effects, respectively. The object of this programme was to test the strength of the relationship between per cent ground cover (GC) and the IR/R ratio (R). Percent ground cover data was obtained using a vertical camera rig providing 35mm colour slide coverage of each plot. From these, ground cover was determined using a manual digitising technique. Radiometric measurements were obtained using the two-band radiometer developed in 1984[17]. Analysis of the data indicate that GC is highly correlated with R up to the time of canopy closure and where a suitable calibration curve has been obtained it should be possible to obtain percent ground cover estimates directly from radiometric readings. Further, the relationship between GC and R appears to be robust and for all cases where the crop was growing in conditions of N-sufficiency the same relationship was obtained. Further work on the use of radiometric measurements to monitor crop efficiency is planned for 1986, including the development of a new reflectance radiometer in collaboration with the Department of Spectrochemistry. 2032

United Kingdom SPOT-Simulation Investigation

In 1986, the first satellite of the French SPOT (System Pour l'Observation de la Terre) series is to be launched. The VIR (Visible/Infrared) scanning system aboard will provide spectral data in the range 0.5-0.9 μm with a spatial resolution of either 10m (panchromatic) or 20m (multispectral). In order to prepare for both the handling and the interpretation of SPOT data, the National Remote Sensing Centre (NRSC), Farnborough initiated a United Kingdom SPOT-simulation investigation in 1984 in which the Macaulay Institute participated. 2032

Using data obtained from the Tayside test area (Annual Report No. 54), a detailed field investigation was conducted at a site where considerable soil variations were known to occur (Fig. 2.3a). The dominant soil groups were identified and surface samples of these soils obtained. The VIR reflectance characteristics of these soils were measured in the laboratory and correlated with the radiance values obtained from the 'satellite' data (Coefficient of Correlation = 0.78 for 50 samples, 10 sites) to provide a measure of the

KEY

a = Carey Series (high silt %)
b = Carey Series
c = Carpow Series
d = Alluvium (poorly drained)
e = Forfar Series
(separated on sub-surface features only)
f = Doune Series

- - - = Northern limit of reclaimed land

A1 to G1 = Soil sample sites

Fig. 2.3a. Soil mapping units as identified by conventional ground survey and air-photograph interpretation (subsurface and surface parameters).

SLICE VALUES			ORGANIC			
LOW	HIGH	SYMBOL	MATTER %	SLICE	PIXELS	AREA %
47	53	■	unclassified	1	66	7.1
54	62	●	8-6	2	547	58.9
63	70	△	6-4	3	264	28.4
71	79	▽	4-2	4	52	5.6
80	88	+	2-0	5	0	0.0

Fig. 2.3b. Surface soil variation (soil organic matter) classified using airborne multispectral scanner data.

potential for detecting, and quantifying, variations in surface soil properties. 2032

Problems in using satellite imagery for surface soil analysis are largely related to:

(a) Soil often covered by vegetation
(b) Cloud cover limits image availability
(c) Spatial resolution is insufficient to provide adequate within-field data in north-west Europe.

The first two points do mean that use of VIR data has to be on an opportunity basis. With regard to the third point, given an average field size of 6ha, data coverage will increase from 14 pixels for Landsat MSS (80 metre resolution) to 150 pixels with SPOT (20 metre) MSS and 600 pixels at 10 metres panchromatic. From evidence obtained in this investigation[18], it is clear that there will be considerable potential for using SPOT data to detect surface soil variation on a field by field basis (Fig. 2.3b). 2032

Soil Reflectance Studies

Using the radiometer developed for the crop reflectance studies[17], the red and infrared reflectance values of all 50 soils sampled for the SPOT-simulation investigation have been obtained. All soils were analysed for organic matter, moisture, clay, silt and sand percentages. Soil reflectance values were obtained at field moist and air dry conditions. Multilinear regression (MLR) analysis of all samples has been performed using red reflectance as a dependent variable and organic matter, moisture, clay, silt and sand as independent variables. Iron oxide was not measured as its effect on reflectance in the visible and near infrared wavebands is only significant for soils with less than 1.5 to 2.0 percent organic matter. 2032

From the MLR, red reflectance was found to have a highly significant correlation with organic matter, T value 8.81 ($p < 0.001$), 44 D.F., whereas clay, silt and sand were only slightly correlated, T value 2.67, 2.64, 2.62, respectively ($p < 0.05$), 44 D.F. Soil moisture was found to have no significant correlation with reflectance for these samples. The linear prediction model for percentage red reflectance (R) is

$$\%R = -359.7 - 0.995\,(O.M.\%) + 0.011\,(\text{Moisture }\%) + 3.826\,(\text{Clay }\%) + 3.732\,(\text{Silt }\%) + 3.695\,(\text{Sand }\%)$$

There appears to be a useful potential for using discrete waveband reflectance studies in quantifying some soil properties[18]. Further investigation into the soil and reflectance interrelationship continues. 2032

Automated Photogrammetry, Image Processing and Digital Mapping

The computing facilities within the Remote Sensing Unit have been significantly improved in 1985. A second hard disk, an extra terminal and an updated version of the operating system have all been added to the Prime 250 minicomputer. The extra storage capacity (315m bytes) giving a total of 450 mbytes of accessible disk space allows more flexible data handling of large satellite images, together with more rapid data input/output from

disk. The new operating system (Primos 19.2) has permitted implementation of a new version of the GEMSTONE image processing software package (version 1.1). 2033

In addition, the Ferranti Cetec System 4 digitiser, the Wild B8S stereoplotter and TA flatbed plotter are all now linked to, and operational from, the Prime 250. With these hardware links achieved, considerable effort on software development is now being directed towards capturing, editing, manipulating and output of digital map data. Software for vector to raster data conversion has been implemented and further work is in progress. Significant progress has also been made towards the use of the GEMS image processing system for displaying, editing and interrogating map data. This has led to experimentation on the use of GEMS as host to a geographic information system in, for example, the potato crop project previously mentioned. 2033

Image processing facilities have been improved via the update of GEMSTONE and the implementation of a package for geometrically correcting Landsat MSS imagery. Progress has also been made in the development and testing of algorithms for image classification. The latter is a joint project with the Department of Statistics and Robert Gordon's Institute of Technology. Through close collaboration with the Department of Statistics it is now possible to transfer digital map and other data between the Prime 250 and the DG Eclipse central computing facility. Using the link, the soil databank map base of Scotland has recently been updated.

Due to the increasing requirement for digitising facilities, the Department has recently purchased a second Ferranti digitising system from the DAFS Marine Laboratory. This is a pencil following system and will initially be linked to a BBC microcomputer to form a stand-alone digitising facility. Investigations into the possibilities of raster digitising via a video camera/frame-grabbing configuration have also been carried out in collaboration with GEMS of Cambridge and Robert Gordon's Institute of Technology. The initial results suggest that this may provide a cheap and rapid means of digitising with significant advantages over the existing manual methods. 2033

Nutrient Cycling in Forests

Investigations have continued into the cycling of nutrients in young plantations of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) established on poor peats and upland heaths. This work was initiated to elucidate the mechanisms by which nurse species of pine or larch enable Sitka spruce to avoid the check to growth usually associated with nitrogen deficiency on such sites. The study has been financed, in part, by the Commission of the European Communities and has been run in collaboration with the Forestry Commission, the Irish Forest and Wildlife Service and the Universities of Aberdeen and Edinburgh. Two sites were instrumented to collect bulk rainwater, "filter gauge" water, throughfall and stemflow. One of the sites was at Inchnacardoch Forest, near Fort Augustus and the other at Culloden Forest near Inverness. Comparable data for one complete year have been

obtained for the various treatments on both sites and the analyses of material collected during the whole tree sampling carried out in the summer of 1984 are now complete. Humus and soil water samples have also been collected using ion exchange resin bags together with porous cup samplers. The accumulated data together with that obtained by our collaborators in their studies of fine root and microbial dynamics and rates of nitrogen mineralisation will be used to construct detailed nutrient budgets for each system studied so that inferences can be made regarding the past development of the mixed and pure stands. Supplementary studies have also been conducted in the glasshouse to examine possible interactions between tree species, soils, litter and ground vegetation and to assess the nitrogen available for uptake in soils taken from each system and sown with ryegrass (*Lolium perenne* L.). 2054, 2055, 2056, 2807

During the year whole tree sampling was carried out in the Kirkton Glen of Strathyre forest near Balquhidder. This study was designed to determine the input, retention and loss of nutrients from a forested catchment that is gauged at its outflow by the Institute of Hydrology. These investigations form part of a wider catchment study to assess the affects of afforestation and deforestation on water quality. Stream water samples have been collected from adjacent forested (Kirkton) and unforested (Monachyle) glens at weekly intervals and sampling will continue during the progressive clearfelling of Kirkton Glen and afforestation of the Monachyle. Inputs to the forested catchment have also been monitored by bulk precipitation samplers and "filter gauges" together with throughfall and stemflow measurements. Immobilization of nutrients into the standing crop will be calculated using results from the whole tree sampling, and nutrient budgets for the catchment as a whole will be deduced. 2054

The large number of organisations participating in this study has enabled an Analytical Quality Control Scheme for harmonised water monitoring to be established. So far tests have been conducted for precision and bias in the analyses of pH, nitrate, phosphate, calcium and aluminium; further tests for sulphate and chloride are planned for the near future. 2054

The large body of data collected during nutrient cycling investigations within the Department provides a sound basis from which to develop nutrient flow simulation models for a variety of forest ecosystems[19]. One such model (FENDS) simulates growth and nitrogen cycling in pine and is currently being used to assess the nutritional consequences of the various management options open to the forest manager. 2054, 2056

Collaborative studies with Dr J. Miles, of the Institute of Terrestrial Ecology, continue in an attempt to explain the apparent reputation of birch as a "soil improver". The object was to obtain, over one year, sufficient information to model nutrient cycling in birch of different ages at sites where either birch invasion had led to soil changes (Craggans, Speyside) or where it had not (Silpho, North Yorkshire). All samples collected during this investigation have now been analysed and the results are currently being processed. 2054

The large body of data that has accumulated from a series of fertiliser experiments laid out in six pole-stage stands of Sitka spruce continues to be

processed. Samples from vegetation and soil organic layers were taken from replicated NPK-fertilised and unfertilised plots prior to fertiliser application and again after five years. In addition, incident rainfall, throughfall, stemflow and litterfall have been measured and samples of each collected at fortnightly intervals for chemical analyses. All sampling has now ceased and it is envisaged that the results, once analysed, will further enhance our understanding of the relationship between element cycling and tree growth. The data on water chemistry within each system continues to provide valuable information pertinent to both nutrient cycling studies and investigations into processes affecting acid deposition within the environment[20]. 2054, 2066

Investigations continue into the potential for forest plantations to serve as areas for sewage disposal. This work aims to investigate the effect of liquid sewage sludge on the development of a pole-stage stand of Scots pine (*Pinus sylvestris* L.) in Angus forest and also a newly established plantation of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) in Ardross forest. In addition, each system will be monitored for any potentially harmful environmental effects arising from sewage sludge applications. Intensive sampling of soils and surface organic layers, together with tree foliage analysis at Angus, has been carried out by the Departments of Peat and Forest Soils and Spectrochemistry prior to sewage application. Samples of foliage and soil will continue to be taken at regular intervals throughout these experiments so that nutrient and heavy metal contents can be determined. Collaborators on this project include the Tayside and Highland Regional Councils, the Forestry Commission and the Water Research Centre who are responsible for providing and distributing the sewage, monitoring tree development and checking for possible contamination of neighbouring waterways. 2056

Forest Nursery Nutrition

As in previous years the Department continues to provide a nutrition advisory service to forest nurseries based on soil analyses carried out by the Department of Soil Fertility. A review of the format and nature of presentation of this advice is still underway and it is hoped that improvements will be made in the near future, perhaps taking advantage of the Department of Soil Fertility's computer based Soil Fertility Information System. 2056

Studies on Acid Rain

The Department continues to build upon the experience gained in acid rain research over recent years. The standardised instrumentation used for monitoring forest systems in nutrient cycling studies serves equally well for determining the changes that occur to incident precipitation as it passes through tree canopies, ground vegetation and soils although modifications continue to be made, primarily in the soil water collection systems. Work sponsored by the Department of the Environment is now well underway

Table 2.2 Systems selected for plot studies

	Loch Ard Forested High SO_4^{2-} deposition	Allt-a'-Mharcaidh Unforested Moderate SO_4^{2-} deposition
Alpine podsol	-	*
Humus iron podsol	*	-
Peaty podsol	-	*
Peaty gley	*	-
Peat	-	*

with one season's data ready for processing. The overall objective is to elucidate how acidity, both pollution derived and natural, passes through upland ecosystems and into streams without being neutralised within the soil and to establish the role, if any, of trees in this process. Two sites have been instrumented, one at Fetteresso, Aberdeenshire and one at Loch Fleet, Galloway. The site at Loch Fleet lies within a collaborative catchment study and has received additional funding, through the Central Electricity Research Laboratories, for instrumentation although this study remains independent of the catchment study as a whole. Measurements already made will be supplemented by flow data for streams draining the two sites and automated stream sampling equipment will soon be installed for time series analyses of stream water chemistry during individual storm events. The consequences of applying supplementary cations to the forested sites is also being assessed as an option for ameliorating incoming acidity in forested, riparian zones. Close collaboration is being maintained with the Department of Forestry, at the University of Aberdeen, where related biochemical and physiological studies are being carried out. 2066, 2073

The importance of a multi-disciplinary approach to understanding the mechanisms responsible for the acidification of surface waters and the potential environmental consequences of such acidification has been recognised in a major new study, the Surface Water Acidification Programme, financed through the Royal Society. In addition to the Departments of Mineral Soils, Peat and Forest Soils, Soil Organic Chemistry, Soil Survey and Spectrochemistry within the Macaulay Institute a number of other organisations are involved including the Freshwater Fisheries Laboratory at Pitlochry, Imperial College and the Institute of Hydrology. Complementary studies under the same funding and management are also being conducted in Norway and Sweden. 2066, 2809

Five sites have been selected for study covering a range of soil types and vegetation cover (Table 2.2). Each site will be instrumented to monitor both wet and dry forms of atmospheric deposition and to measure changes in the chemistry of water as it passes through different parts of the plant-soil system and into adjacent streams. Background monitoring will be carried out at fortnightly intervals, weather permitting, and the results obtained will serve as a base-line against which changes in flow pathways and water chemistry will be assessed during individual storm events and throughout periods of snowmelt. Such information should allow the processes by which soils and vegetation modify the chemistry of surface waters to be deduced, and the factors contributing to the passage of acidity into streams during

prolonged periods of heavy rainfall or snowmelt to be identified. The design and construction of suitable sampling systems is now complete and equipment has been installed at two of the five sites. 2066, 2809

The input of nutrients and pollutants from the atmosphere to upland ecosystems may be enhanced by impingement and trapping of particulate matter onto vegetation surfaces. The contribution of such inputs to nutrient cycles on marginal soils forms the basis of an AFRC studentship now nearing completion. The effects of canopy architecture and elevation on throughfall chemistry have been measured continuously for two years and the performance of a variety of artificial filter gauges has been assessed in a series of short term experiments both in the field and in the laboratory. Results from this investigation should enable the significance of atmospheric inputs of nutrients and pollutants to be assessed in terms of plant growth and soil development in upland areas. 2054, 2056

Nutrient Availability in Highly Organic Soils

The preliminary work carried out in 1984 on the poor response of a grass sward on reseeded deep peat to applications of fertilizer-N has been developed further. A small field experiment has been laid out at Sletill Hill, Sutherland in conjunction with the Department of Grassland Husbandry of the North of Scotland College of Agriculture. The objectives of the study include the identification of the mechanisms influencing the fate of fertilizer-N applied to grassland on deep blanket peat. These mechanisms include losses in run-off, uptake by grass, denitrification and immobilization of mineral-N by organic matter and the microbial biomass. The experiment comprises 2 sets of 6 plots, 2m × 2m, laid out on a sloping area of reseeded blanket peat. One set of plots has been equipped to collect surface run-off and the other is a source of peat samples for analysis. Two treatments, O and +N, were randomized within each set of 6 plots and, in late April, +N plots received 112kg N ha^{-1} as NH_4NO_3 and all plots were given 30kg P ha^{-1} as granular superphosphate and 30kg K ha^{-1} as KCl. Atmospheric inputs of N to the site are being estimated by collection and analysis of rainwater. Samples of peat, rainwater and run-off water have been sampled regularly and analyzed for different forms of N. The results so far confirm those obtained during the previous year, viz. that fertilizer-N, in particular NO_3-N, is either transformed or lost very soon after application. The water-table at the site is close to the surface and the peat is poorly aerated. Consequently there is a strong possibility that fertilizer NO_3-N is lost through denitrification processes and these are being studied jointly with the Department of Microbiology. Mineralization of the native organic nitrogen is also being measured at this site by incubating undisturbed cores *in situ*. 2055, 6027, 8057, 8059

The investigation into the apparent ability of mixed crops of spruce and pine to exploit soil nitrogen that is, seemingly, unavailable to pure spruce has continued at the experimental site at Culloden forest where Sitka spruce (SS) is planted singly and in mixture with Scots pine (SP). Sampling of the L + F + H horizon and the soil to a depth of 10cm was carried out at monthly intervals in collaboration with the Department of Microbiology as

part of the EEC-funded project on nitrogen cycling in mixed stands. Nitrogen mineralization in humus and in soil has been estimated both in laboratory-and in field-incubated material and in each case mineral N production during spring tended to be greater in samples from beneath the mixed species. This is consistent with the greater amounts of metabolically active fungal biomass observed in humus from SS + SP compared with those in SS plots. The possibility that decomposing litters of SS and SP interact to accelerate the cycling of nutrients, particularly N, has continued to be studied employing leaching columns containing pure and mixed litters. In a second experiment of this type, using hand sorted litters from the mixture plots at Culloden, release of soluble N in water was extremely small compared with the first which used SS and SP litters from different sites. On harvesting, and extracting the material in the columns with 1M KCl, however, more mineral-N was produced by SS than by SP litters and SS + SP released 26% more mineral-N than calculated for a 1:1 mixture. This result was similar to that obtained during the first experiment except that nitrification of NH_4-N in the spruce litter did not occur to any great extent. 2055, 2807, 8057, 8059

In a collaborative study with the Department of Soil Organic Chemistry, peat samples amended with ^{14}C labelled substrates, such as glucose and glycine, were subjected to particle size fractionation by wet sieving techniques to determine the location of microbially derived material. A paper on the possible abiotic interactions between ^{15}N labelled glycine and sterilized peat has been submitted for publication[21]. 2055, 4020, 6027

A joint study with the Department of Microbiology on the effects of water-table height on mineral nitrogen and the bacterial populations in a deep oligotrophic peat has also been completed[22]. 2055, 6027, 8057, 8059

A paper on the effects of reseeding and grazing on the physical and chemical properties of blanket peat in Lewis has been accepted for publication[23]. 2055, 8057, 8059

The soil microbial biomass is considered to represent a pool of readily available nutrients and in highly organic soils the nitrogen and phosphorus contents of microbial material could be particularly important factors, influencing the availability of these elements to plants. Additions of carbon as glucose and cellulose, and nitrogen and phosphorus as mineral salts to humus (F + H horizons) from beneath larch and Scots pine raised the levels of biomass carbon, determined by direct microscopy and the Anderson and Domsch test. When samples were fumigated with chloroform to kill the microbial biomass there was no concomitant increase in the release of nitrogen and phosphorus. This anomalous behaviour suggested that microbial nitrogen and phosphorus in amended samples were stored in forms resistant to fumigation and extraction or that release after fumigation was influenced by variations in C:N:P ratios of the biomass[24]. 2055, 6027

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15. Distribution and area of winter oilseed rape within eastern Scotland : a survey based on LANDSAT data. By G.G. Wright. *Research and Development in Agriculture*, **2** (1), 41-45, 1985.
16. Some observations of the effect of wind turbulence on the infrared/red ratio. By G.G. Wright. *Int. J. Remote Sensing* (in press).
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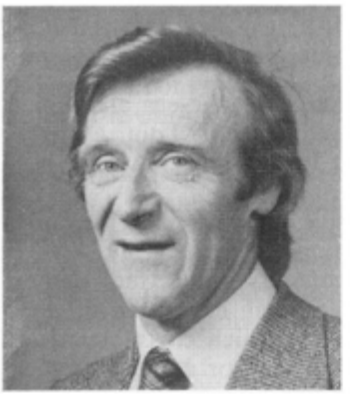
3. SPECTROCHEMISTRY

A.M. URE



The work of the Department of Spectrochemistry continues to embrace the main themes of recent years. These are (1) studies of the distribution of trace elements in soils, plants and biological materials, (2) the investigation of soil-plant trace element relationships in the field, (3) the elucidation of the structure, composition and forms of soil components, (4) the provision of an analytical service for trace and major elements to the Institute and to the North of Scotland College of Agriculture for their advisory service to farmers and (5) the development of spectrochemical methods to implement these programmes.

Attendance at national and international conferences and papers presented at them by departmental staff are detailed elsewhere in this report. The Department has been represented on various national and international committees and working parties. These include DAFS Consultative Committee on Spectrochemical Work (T.S. West, Chairman; A.M. Ure, Technical Secretary; M.L. Berrow), IUPAC Commission V-4 on Spectrochemical Methods (A.M. Ure), FAO European Co-operative Network on Trace Elements (A.M. Ure), Department of the Environment/ National Water Council Standing Committee of Analysts (Main Committee, A.M. Ure; Working Group 4, M.L. Berrow), MISR/COSAC Liaison Group (A.M. Ure), MISR/COSAC Working Party on Advisory Soil Analysis and Interpretation (M.L. Berrow), the Scottish Association of Industrial Analysts (J.C. Burridge) and the Royal Society of Chemistry - Council (A.M. Ure), - Analytical Editorial Board (A.M. Ure, B.L. Sharp), - Analytical Spectrometry Updates (B.L. Sharp, Chairman; A.M. Ure, Secretary; J.C. Burridge) - Editorial Board Journal of Analytical Atomic Spectrometry (A.M. Ure) - Scottish Region Committee (Asst. Secy., M.J. Adams). A.M. Ure has also served on the Steering Group for the setting up of an Agriculture Group of the Industrial Division of the Royal Society of Chemistry. B.A. Goodman was co-director of a NATO Advanced Studies Institute on Iron in Soils and Clay Minerals at Bad Windsheim, W. Germany. B.A. Goodman also served on the MAFF sub-group on the speciation of trace elements in food and on the AFRS Group on the aetiology and control of nutritional disorders. A.M. Ure and B.A. Goodman also took part in meetings of a discussion group of the Rowett and Macaulay Institutes on Speciation (DRAMS) studies. J.W.S. Reith and A.M. Ure visited the Agricultural University of Norway in Ås to assist in the development of the Norwegian trace element advisory service. J.W.S. Reith spent a further month in Ås working with Norwegian colleagues in

pursuit of this objective. That this invitation was made can only be regarded as a compliment to the Institute's reputation in this field.

Trace Elements in Soils, Plants and Biological Materials

Soils and Soil Parent Materials

Analyses of soil profiles from the Ardnamurchan-Morvern area (Sheet 52) for total and extractable trace elements have been carried out. A further twelve profiles from the area covered by Sheet 30, Glasgow, have also been analysed for extractable trace elements.

Soil profiles from some of the more extensive associations in the north-west of Scotland including the Arkaig, Lochinver, Torridon and Kintyre have been analysed for total trace element contents. Little trace element information had been available for these soils which have been surveyed relatively recently. Soils from other associations which cover significant areas in other parts of Scotland and for which little or no trace element information is available have also been analysed. This information, together with that acquired over a period of some 30 years, will allow soil trace element maps for, currently, some 10 elements, based upon total trace element contents in soil profile B-horizons of the different soil associations, to be produced in collaboration with the Scottish Soil Survey covering the whole of Scotland on a 1:250,000 scale. These will broadly indicate areas where the soils are inherently high or low in their contents of elements such as cobalt and copper, and give a first indication of the likelihood of trace element-related disorders arising. In this capability for providing national trace element soil maps Scotland is almost unique. An example of an experimental soil association map of this type with 3 categories of total copper content in B horizons is illustrated in Fig. 3.1.

A report on trace elements has been published in the Memoir of the Soil Survey of Scotland entitled, "The Soils of the Black Isle". A trace element report for 35 representative profiles from the Orkney Islands has also been prepared for the Memoir in prospect.

A poster discussing data for the trace element mapping of Scottish soils was presented at the First International Symposium on Geochemistry and Health held at the Royal Society in London[1] and illustrated with a map showing areas with low, medium and high concentrations of cobalt in soils in the Aberdeen area. A paper on the distribution and mobilization of trace elements in Scottish soils was presented at the Third European Meeting of the Society for Environmental Geochemistry and Health held in Birmingham[2].

In collaboration with the British Geological Survey and the Departments of Soil Survey and Mineral Soils, a study of the relationships between trace element concentrations in soils and in their underlying parent rocks has been carried out. Fifty-four B-horizon soil samples have been analysed for their total contents of nine trace elements. Spark source mass spectrometry is being used to determine other elements such as the rare earths in the same samples. A paper describing the distribution of extractable copper in 725

soil profiles detailed in Annual Report No. 54, 1984, has now been published[3].

Adding to the reports already published on the distribution of total and extractable lead and copper in Scottish soils, a further paper reports the frequency distribution of chromium and nickel in Scottish soils and the relation of the concentrations of these elements to other soil variables[4]. The derived mean or typical value for chromium in some 3000 samples is 62 mg/kg and the normal range 5 to 710 mg/kg. The corresponding values for nickel in some 4000 samples are 27 and 3.4 to 210 mg/kg, respectively. The concentrations of chromium and nickel are highly correlated ($r = 0.83$) and the forms of the relationships between element contents and other soil variables are very similar. Concentrations of chromium and nickel are greater in soils derived from basic and intermediate igneous than in those derived from acid igneous rocks, are greater in argillaceous than in arenaceous sediments, decrease with increasing sand and organic matter

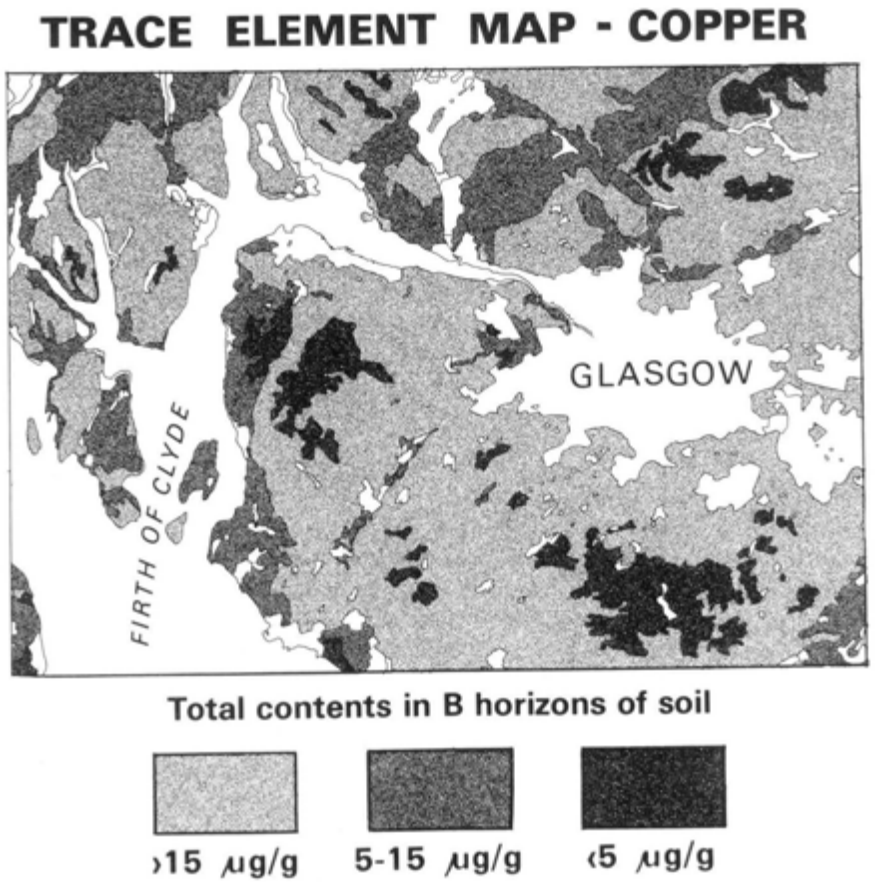


Fig. 3.1 Experimental trace element map for copper produced by the Department of Soil Survey in collaboration with the Department of Spectrochemistry and based on B-horizon trace element data for the soil associations of Scotland.

contents and show relatively little variation with increase in depth below about 10 cm. 1001, 3007

A chapter entitled, "Occurrence and distribution of selenium in geological materials and soils" has been prepared for a book on the occurrence and distribution of selenium edited by M. Ihnat for CRC Press Inc.[5]. The amounts of selenium in meteorites, minerals, rocks and sediments are tabulated and the contents, sources, forms and distribution of selenium in soils are reviewed, covering the literature up to 1983. 3007

A detailed study of the weathering and release of copper and other trace elements due to impeded drainage conditions in a hydrologic sequence of profiles of the Strichen Association has continued. Analysis of the 120 particle-size separates has been completed. This investigation, in collaboration with the Department of Mineral Soils, is being extended to soils of other associations derived from sedimentary rocks. Particle size separates from two profiles on soils of the Thurso Association developed on till derived from Middle Old Red Sandstone, Caithness Flagstone Series strata have been analysed. Ratios of cobalt concentrations in clay and coarse sand of about 3 are found, whereas in soils developed from metamorphic rocks they are often around 8 and in soils derived from granite can be as great as 30. Particle size fractions separated from soil profiles of the Ettrick Association derived from Silurian and Ordovician greywackes and shales are being prepared for analysis. 1061, 3007

Acetic acid extractable trace elements have been determined in soil particle-size fractions separated from profiles developed on granitic and basic igneous parent rocks. Extractable amounts of Al, Cu, Fe, Mn and Zn generally increase with decrease in particle size. 3007

Papers discussing the role of soil data in the assessment of geochemical and environmental influences on trace element supply[6] and relationships between trace element availability and the soils and geology of the Aberdeen area,[7] presented at TEMA 5 Conference last year, still await publication. 3007, 3008

A paper describing the design of the soil database has been submitted for publication[8]. 3007, 1001, 8802, 9802

Analysis of soils from the Scottish Soil Inventory has begun on a selective basis with peaty topsoils at a depth of about 5-20 cm from two SW-NE transects across Scotland, one from Islay passing north of Glasgow to Fraserburgh and the other from Mull to Dornoch. *Aqua regia* digestion and analysis by atomic absorption and ICP emission spectrometry for the elements Cu, Zn, Cd, Pb, Ni, Cr, Mn, and B have been carried out together with more comprehensive analysis by spark source mass spectrometry of the ignited soils. Preliminary results indicate, as might be expected, that the atmospheric pollutant elements cadmium, lead and zinc, which readily bind to organic matter in soils, show elevated soil contents in coastal areas, especially those with high rainfall. 3007, 3010

Trace Element Availability and Soil Plant Relationships

The results obtained from numerous long-term field experiments with trace elements, together with advisory experience gathered over many years

at the three Scottish Colleges of Agriculture, have been drawn together in a MISR/COSAC Bulletin No. 1 entitled Advisory Soil Analysis and Interpretation[9]. This details the agreed methods to be used for the analysis of soils for trace and major nutrients throughout Scotland.

3007, 3008, 7042

Results of pot experiments carried out in collaboration with the Department of Soil Organic Chemistry and reported in Annual Report No. 54, 1984 have been presented at the International Conference on Heavy Metals in the Environment[10]. Treatment of a contaminated soil with peat, combined with sufficient liming to offset the acidification effects of the peat, can be used to ameliorate the effects of copper toxicity in soils.

3007, 3008, 4022

A paper reporting a comparison of long-term effects of similar sewage sludge treatments on two different soils at the Luddington and Lee Valley Experimental Horticulture Stations has been published[11]. The considerable soil and plant content data obtained so far show remarkably consistent effects at the two sites. The changes in extractable metal content with time are small and the percentage extractability of copper, nickel and zinc remains high 13 years after sludge application. Metal concentrations in timothy grass at one site are closely related to the contents of the same elements in ryegrass at the other. Soil and clover samples from the Luddington site were again taken in 1985 for analysis.

A database is being planned to hold the extensive results of plant analysis that have been accumulating in the Spectrochemistry Department for over 40 years. This will enable information on elements such as nickel to be made more readily available. Associated with these plans, a major effort is in progress to examine the condition of samples that have been held in plant stores, many of them for over 30 years. Samples to be retained are being repacked in polythene bags. The acquisition of thermal ionisation mass spectrometric equipment will permit some useful new measurements of the isotopic composition of some of these 'historic' materials.

An investigation into the effects of treating straw with NH_3, to improve its feeding quality, has begun in collaboration with the Rowett Research Institute. Of particular interest is the possibility that the NH_3 treatment may make trace elements in the straw more available to the animals' digestive system. 3007, 3008

Miscellaneous samples analysed for trace elements included soils from the Institute of Hydrology, Oxford, the Agricultural Development and Advisory Service, the Animal and Grassland Research Institute, and conifer needles for the Forestry Commission in connection with nursery problems and with the long term effects of applying sewage sludge to forests. 3008

Spectrochemical Methods of Analysis

Arc emission

The paper describing the use of sodium sulphide as a substitute for thionalide in an established procedure for concentrating trace elements (see Annual Report Nos. 53 and 54) has now been published[12]. Among several

reagents synthesized in the Soil Organic Chemistry Department for that investigation, 2-mercapto-4-*n*-propylacetanilide was found to be more effective than thionalide for precipitating lead from acetate-buffered solutions at pH 5.2. This reagent does not appear to have been previously reported. A note describing its application to the precipitation of lead has been prepared[13].

Two methods have been developed for determining Al by coprecipitation with iron as carrier, using 8-hydroxyquinoline in acetate-buffered solution at pH 5.2. For the range 5-200 μg Al, the precipitate is ignited and determined in a cathode-layer carbon arc by atomic emission spectrometry. This method has been described in detail[14]. A simpler procedure, suitable for the range 50-1000 μg Al, makes use of the infrared absorption spectrum of the dried, but not ignited, precipitate after incorporation in a KBr disc. Details of the procedure are being prepared for publication. During the development of the method, the spectra of other metal-oxinates e.g. Cu and Mn were investigated to study possible inter-element interferences. The methods are applicable to the determination of Al in waters, soil extracts and acid-solutions of plants, soils or rocks.

A procedure has been developed which could substantially reduce the analytical effort needed to assess soil cobalt [see also *Atomic Absorption Spectrometry - Cobalt*] and molybdenum status for advisory purposes. The acetic acid and ammonium acetate extractions are carried out separately as usual, but are then mixed for analysis without the prior destruction of extracted organic matter. The trace elements are coprecipitated with aluminium using 8-hydroxyquinoline. Cobalt and molybdenum are then both determined simultaneously in the ignited precipitate by carbon arc emission spectrometry, in the same way that is at present used for molybdenum on its own. The principal saving is the elimination of the separate analysis for cobalt that is made at present when information about both elements is required. Results with the new procedure for over 150 soils agreed very well with the original advisory analyses, and a full report has been prepared[15].

A 3-metre grating spectrograph was acquired at a nominal price from the Forensic Laboratories of the Metropolitan Police in London. Although made in 1955 and originally set up at AERE Harwell, the instrument was in good condition and provides the Spectrochemistry Department with a high-resolution spectrographic facility. It will probably be used with the high-current arc source, developed some years ago (Annual Report Nos. 49 and 50), and with the automated microdensitometer at present under construction. 3010

Atomic Absorption Spectrometry

The Pye-Unicam SP-9 video furnace atomic absorption spectrometer purchased in 1984 has proved to be an exceptionally valuable instrument. The graphite furnace with its auto-sampler is reliable in operation and has allowed analyses to be carried out with little operator attention. The video display of the sample absorption profile with time has allowed more

efficient development of temperature/time programs. Investigations of the use of totally pyrolytic graphite cuvettes, at present only available for the SP-9, have shown these to have much longer useful lives when compared with pyrolytically-coated, graphite cuvettes and have demonstrated remarkable freedom from drift in sensitivity with cuvette life. A number of temperature/time programs already developed for use on the IL-751 atomic absorption spectrometer have been transferred to the Pye-Unicam SP-9 with only small modifications.

Cobalt. Acetic-acid extraction is commonly used to assess the plant-available cobalt in soils in order to give advice on the prevention of cobalt deficiency in animals. In this laboratory the concentration of cobalt in acetic acid extracts of soils used for advisory purposes is routinely determined by flame atomic absorption spectrometry following time-consuming stages of filtration, evaporation and preconcentration. The sensitivity of graphite furnace atomic absorption spectrometric (GFAAS) determination has proved to be high enough for the determination of cobalt directly in the acetic acid extract without preconcentration and this technique has been investigated, particularly with regard to the effects of concomitantly extracted and potentially major interfering species such as Ca, Mg, Si and Fe. Results obtained for approximately 100 soils sampled for advisory analysis and ten bulk soils analysed by the routine procedures and by GFAAS with the SP-9 and the IL751 on a 4 ml aliquot drawn from 400 ml of acetic acid extract, have shown excellent agreement. The new procedure once fully verified will result in a major saving in laboratory and operator time in the determination of cobalt for advisory purposes.

Selenium. In this department determination of selenium in plant materials is usually accomplished using a fluorimetric procedure with diaminonaphthalene following either wet oxidative digestion of the sample with $HNO_3/H_2SO_4/KMnO_4$ or combustion of the sample in a closed oxygen flask. Alternative methods have been developed in which the sample (0.4 g) is burned in a stream of oxygen in a special quartz combustion apparatus (VAE Trace-O-Mat, Paar Scientific) and collecting the volatilised selenium in 2-4 ml of acid medium (Annual Report, Nos. 52 and 53). The selenium content of the extract is determined either by graphite furnace atomic absorption spectrometry or by hydride generation/atomic absorption spectrometry. If the determinations are to be made by the former procedure the liberated selenium is collected in 2M acetic acid and the selenium determined using a L'vov platform and copper at 1000 ppm as matrix modifier. If the latter procedure is used the selenium is collected in 6M hydrochloric acid and the selenium hydride generated using a laboratory constructed auto-analysis system. The development of the hydride procedure was carried out by a visiting research worker, Dr. T. Nomura from Japan, who also investigated the effects of hydrochloric acid concentration, temperature and time on the conversion of Se(VI) to Se(IV). His conclusions were exploited in the use of 6M hydrochloric acid and a heated coil at 95°C in the autoanalyser flow system with a residence time in

the coil of 2 mins to carry out this conversion. With similar conditions As(V) could be converted to As(III) prior to hydride generation.

Since the sample ash is discarded after combustion and only volatile components collected, matrix effects in both the GFAAS and hydride methods are minimal. These methods have been assessed on several standard reference materials and show good agreement. Analysis of several samples of fungi collected in the N.E. of Scotland have been made. Some of these, already known to be accumulators of Se, have shown high levels e.g. freeze dried *Boletus edulis* had a Se concentration of 26 ppm/DM, and *Amanita muscari* 7 ppm/DM. The Trace-O-Mat combustion apparatus also facilitates the combustion of oils and waxes.

The application of atom-trapping atomic absorption spectrometry to the determination of cadmium in calcium chloride extracts of soils, used as a diagnostic technique for the assessment of cadmium uptake by some plants has been described[16]. A review of the capabilities of atom trapping atomic absorption spectrometry awaits publication[17] and its use for the examination of domestic water supplies has been discussed.

Co, Cu, Mn, and Zn in Soil Solutions Obtained by Centrifugation. Approximately 800 samples of soil solutions collected by the Departments of Soil Organic Chemistry and Soil Fertility have been analysed for Cu, Zn and Mn, mainly by GFAAS, as part of a collaborative project on the mobilization of trace elements in the rhizosphere of growing crops. Selected samples have also been analysed for Co. This work has involved a considerable effort and skill on the part of the analyst as the concentrations of these elements in the sample have been extremely low. As pointed out in last year's Annual Report (No. 54) contamination by airborne dust, particularly zinc, continues to be a problem. A paper on the mobilization of Cu, Mn and Zn in the soil solution of barley rhizospheres has been published[18].

Comparative Analyses of Extractable Trace Elements in Treated Straw. Samples of straw, treated and not-treated with ammonia, have been extracted by a series of dilute acid extractants and the concentrations of Co, Cu, Zn etc. determined in the extracts and residues to assess differences in trace element solubility. This is part of a joint project with the Rowett Research Institute on straw digestibility. The feasibility of using flame and furnace atomic absorption methods for the analysis of rumen- or enzyme-digested straw from this study is being assessed.

Aqua Regia Digestion Procedures for Soils. In collaboration with ADAS and the Rothamsted Experimental Station, the *aqua regia* extractable trace element contents of 22 topsoils from uncontaminated and contaminated localities in England and Wales have been determined. Analyses by atomic absorption spectrometry using reflux digestion in *aqua regia*, (1) with electrothermal heaters and water-cooled condensers and (2) block digestion with air-cooled condensers incorporating a stage involving taking the digest to dryness, are being compared.

Although cobalt is not an element which causes pollution problems due to sewage sludge disposal, a deficiency of this element causes widespread problems in the health of ruminant stock in Scotland. The use of *aqua regia* extraction to determine the total content of this element in Scottish soils has therefore been tested. The *aqua regia* extractable cobalt concentrations in 216 soil profile samples were compared with the total cobalt determined by direct current arc analysis and the mean percentage of the total content extractable by the strong acid was 88 per cent. This agrees well with the proportion of the total iron extracted from such soils.

In a comparison of the *aqua regia* extractable concentrations of 8 trace metals in 16 Scottish topsoils, determined at the Macaulay Institute, with the perchloric acid/nitric acid extractable contents, determined in the same soils at two different ADAS laboratories, good overall agreement was obtained. It appears that for topsoils, an extraction with an HCl-HNO_3 mixture removes the same amounts of Cr, Cu, Fe, Pb, Mn, Ni and Zn as an $HClO_4$ -HNO_3 mixture. The results for Cd were inconclusive. In collaboration with the Department of Soil Science, University of Aberdeen, a comparison between HCl-HNO_3 digestion and $HClO_4$ -HNO_3 digestion for metal concentrations in sewage sludge-treated soils has been carried out. There were again very close relationships between the amounts of seven metals removed by the two strong acid extractants.

Routine analysis of the major cations Ca, K, Mg and Na for advisory and other purposes continued at about last year's level of some 110,000 element determinations. The number of trace element determinations increased considerably this year with more than twice the number of Co and 50% more Cu determinations being performed. In all some 10,000 trace element analyses were carried out over the year.

1001, 2056, 3007, 3011, 5050, 7038, 7041, 7043, 7047, 7048

Specialised analyses have been carried out for various trace elements in basic foodstuffs and reference materials for a continuing study by the FAO European Cooperative Network on Trace Elements. Lead has been determined in a range of water samples for the Department of Peat and Forest Soils and lead and cadmium in synthetic foodstuffs for the MAFF AQA analytical quality control exercise. Herbages have been analysed for selenium for the West of Scotland College of Agriculture in connection with an animal trace element dose/response trial. 3011

Trace Element Speciation - Hybrid HPLC/GFAAS. High performance liquid chromatographic separation equipment (LKB Instruments Ltd.) has been installed to fractionate soil extracts and soil solutions obtained by centrifugation and, in combination with trace analysis of the fraction by GFAAS, will serve to investigate the forms of trace elements in solution. The LKB system is well-suited for trace element speciation studies as it employs titanium pumps and piping in place of the more usual stainless steel. Studies of transition elements such as cobalt are therefore feasible with this equipment as it avoids the inherent contamination problems associated with the use of stainless steel. This will be employed not only for speciation of agriculturally important trace elements such as cobalt and

copper but for elucidating the forms of aluminium in surface, soil and stream waters under the action of acid rain (see Surface Water Acidification Programme, SWAP, section below).

Reflectance Spectroscopy

The construction and operating details of a new, two-band portable radiometer (Annual Report No. 54) have been published[19]. In a collaborative study with the Remote Sensing Unit and the Department of Soil Fertility, this instrument has been fitted with red and near-infrared optical filters and used to monitor the growth of potato crops subjected to a variety of stress conditions. The instrument has also been employed, in collaboration with the Remote Sensing Unit and the Department of Crop Husbandry, NOSCA, to study a winter barley crop. The results show a high correlation between the infrared-to-red reflectance ratio and plant biomass and reports are currently being prepared for publication. A similar radiometer was constructed and sold to the National Vegetable Research Station and other instruments are under construction for field trials.

By ratioing the sample reflectance at two wavelength regions, the effect of changes in ambient light conditions are greatly reduced but not eliminated. To overcome the problem and facilitate the application of portable radiometers, a double-beam, two-band instrument has been constructed. This radiometer monitors not only the target reflectance at two wavelengths but also the illuminating radiation *via* an opal glass diffusing filter. Preliminary results with this instrument indicate that excellent correction for changing illumination conditions can be achieved and field trials are planned.

A new double-beam wavelength scanning, portable spectrometer, capable of operating in the range 400 nm to 1800 nm, is currently being constructed. This instrument will employ a portable computerised data-logging system. Results from this instrument in field trials will allow the selection of optimum optical filters for future radiometers. A lecture on optical methods in remote sensing has been presented to the Scottish region of the Royal Society of Chemistry. 2071

Radiofrequency Plasma Emission

Analytical service work with the inductively coupled plasma (ICP) emission spectrometer has continued unchanged with the instrument running at near capacity. Attempts to determine Mo directly in ammonium acetate soil extracts were unsuccessful because of the high levels of co-extracted cations that raise the level of the background emission from the plasma and result in a loss of sensitivity. Preliminary results indicate that dry ashing the residue from the evaporated extract, after partial oxidation with HNO_3, followed by redissolution and stripping of the cations on a cation exchange column may be a suitable preconcentration/separation procedure. More experience with various soil types is required before such a method could be adopted for routine use.

Following the filing of a patent[20] for the "Conespray" nebulizer, research has concentrated on the mechanism of operation and design of spray chambers used in atomic spectrometric analysis. Various designs have been tested and a mechanism proposed to explain the poor efficiency achieved by these devices. Inertial impaction is the principal source of aerosol loss and is used deliberately to filter out the large droplets. The high level of turbulence, however, results in substantial additional losses of particles in the usable range below 8 μm in diameter.

A review for the *Analyst* on nebulizers and spray chambers is in preparation and a review detailing recent developments in ICP spectrometry has been submitted to *Chemistry in Britain*[21]. A review of optical, electron and X-ray spectrometry in soil analysis dealing with ICP optical emission as well as dc arc emission and atomic absorption spectrometry has been accepted for publication[22]. Analytical plasma spectrometry has been reviewed in Annual Reports on Analytical Atomic Spectroscopy[23]. 3011

Laser Spectroscopy

Progress in using infrared laser long-path absorption spectrometry to study field emissions of N_2O has been delayed by staff changes in the Department of Soil Fertility. A feasibility study on this project will be completed when a new soil physicist is appointed to the post vacated by P. Wilson.

A paper detailing the work previously carried out on a laser remote sensing system for the determination of atmospheric SO_2 has been submitted to Analytical Chemistry[24]. 3011

Spark Source Mass Spectrometry

The spark source mass spectrometer has been used throughout the year for the multi-element survey analysis of various types of sample. A wide range of sample types can be analysed by the technique and most of the procedures used are now fully standardised. The methods used have remained unchanged this year but the development of a new densitometer system is nearing completion and this will greatly facilitate the data acquisition from photographic plates.

Samples analysed have included a further batch of soils taken from the vicinity of a chemical waste-disposal plant to investigate the possible role of toxic elements as the cause of animal health problems on farms close to the plant. While no significantly elevated levels were found, the technique served to eliminate the possibility. Similar use has been made of spark source mass spectrometric analysis for the investigation of other obscure animal health problems on farms. Analyses of peat samples taken from two transects across Scotland have been completed and the results are being assessed. Some preliminary conclusions are given in the section on *Soils and Soil Parent Materials* elsewhere in this report.

Soil profiles selected, on the basis of existing trace element knowledge, as representative of the major Scottish soil associations are being analysed by

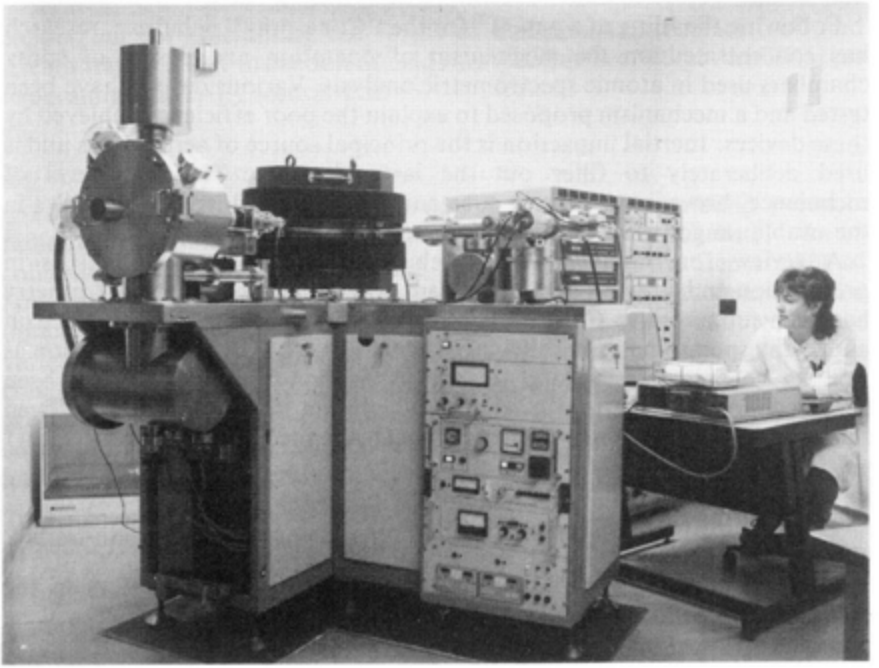


Fig. 3.2 VG-354 Thermal Ionisation Mass Spectrometer (V.G. Isotopes Ltd).element data for the soil associations of Scotland.

this comprehensive technique to extend the range of elements for which data is available. The results may serve also to confirm or otherwise the identity of these soil associations. A group of podzol profiles with well developed iron pans are being analysed to investigate the possible accumulation of other elements along with the iron.

Humic acid fractions extracted from mud and plant samples have been analysed for the Department of Soil Organic Chemistry to investigate the possible enrichment of trace metals in the humic acid fractions. Results of the analysis of a set of human foetal kidney samples were presented at the 10th International Mass Spectrometry Conference in Swansea[25] and the study has been continued by the analysis of the corresponding human foetal lung samples. 3010

Thermal Ionisation Mass Spectrometry

A VG Isotopes 354 thermal ionisation mass spectrometer was installed at the beginning of October and is now operational. This is an instrument for the very precise determination of isotope ratios in samples of pure metal salts. A sample weight of about 1 μg is dried on to a thin metal filament, usually tantalum or rhenium, and raised in the instrument source to a high temperature (1500-2000°C) when a very steady beam of metal ions is produced. A magnetic field disperses the ion beam into separate beams for

each of the element isotopes which are measured simultaneously on up to five separate collectors set at the required positions and the calculated isotope ratios are printed out immediately. The instrument is illustrated in Fig. 3.2.

The instrument can be operated either semi-automatically or completely under the control of the computer. In the former mode the operator sets up the sample and raises and focusses the ion beam before instructing the computer to measure the isotope ratios according to a predetermined procedure. In automatic operation up to 16 samples can be analysed without any operator involvement following the initial input of relevant data. The analysis of 16 samples may take up to 64 hours.

The precision of the instrument (<0.001% for the $^{86}Sr/^{87}Sr$ ratio) is such that very small differences in isotopic composition from one sample to another can be detected and this can give information on the history and origin of the particular samples.

Clean laboratory conditions are essential for sample handling and preparation to avoid contamination and it is hoped to have these available in the early part of 1986. Three initial applications are foreseen:- (1) the measurement of strontium isotope ratios in rainwater and in surface and soil waters to determine rates of weathering of rock and soil materials, with particular reference to leaching of base cations such as calcium of particular importance in the amelioration of the acidification of surface waters by acid rain and the release of fish-toxic aluminium into them; (2) the measurement of lead isotope ratios in plant samples to give information on the proportion of lead taken up through the roots and from aerial deposition; (3) the use of stable isotope tracers in soil, plant, animal and human studies where suitable radio isotopes are not available or where, as in human zinc balance studies for example, radio isotopes cannot ethically be employed. Mass spectrometric procedures for the analysis of strontium and lead isotopic composition are already available, whereas procedures for the analysis of zinc and other elements will need to be developed. This technique will also make possible very accurate measurement of elemental contents by the use of isotope dilution procedures.

Surface Water Acidification Programme (SWAP)

Two appointments have now been made in the department, one ASO and one PhD student, Mr. R. MacMahon, for the Surface Water Acidification Programme under the auspices of the Royal Society, the Norwegian Academy of Science and Letters and the Royal Swedish Academy of Science.

Following the soil survey of the three SWAP sites, ten soil profiles from each of the sites are being analysed for total and extractable trace elements. To date the 0.05M EDTA extractable contents have been determined. The upper horizons of the profiles at all three sites contain relatively high levels of 0.05M EDTA extractable lead and zinc. The mean extractable lead and zinc contents of the two upper horizons of the ten profiles at each site decrease in the order Kelty Water, Loch Chon and Glen Mharcaidh. These

differences may well be due to differences in the amounts of these elements contributed by atmospheric deposition.

Various plastics for possible use in the construction of water sampling devices have been tested for trace element content. Light and dark grey PVC, sheet, rod, pipe and pipe-junction pieces tended to contain large amounts of lead and zinc. The amounts of lead and occasionally cadmium removed by acid washing were also high. Grey polypropylene tube contained zinc, chromium and barium but as the amounts of acid soluble cadmium, copper, chromium, lead, nickel and zinc were very small, or not detectable, this material was adopted for use in the SWAP experiments.

A used, ceramic, porous-cup lysimeter was also tested for trace elements. The black synthetic rubber used in the construction of porous cup lysimeters contained acid-soluble zinc, iron and aluminium while the ceramic pot itself appeared to release aluminium and small traces of Cu, Ni, Pb and Zn. A new ceramic pot was cleaned and tested by standing in water at pH 4.0. Small amounts of aluminium and silicon were released during a period of standing in distilled water (approx. 1.5 mg/l). A fritted glass porous disc released much smaller amounts of aluminium (approx. 0.15 mg/l) when left to stand in 2M nitric acid.

Methods for the speciation of aluminium in surface and soil waters are being developed. This work is being carried out by Mr. R. MacMahon under a SWAP funded Ph.D. studentship. An automatic colorimetric system using pyrocatechol violet reagent, based on a Technicon pumping system and a Cecil Instruments spectrophotometer, has been established for the determination of total monomeric aluminium. Modification to this system, to include an Amberlite IR-120H ion exchange column are being made at present. This will allow both monomeric and organically bound monomeric aluminium to be determined individually.

A Varian 1275 flame atomic absorption spectrometer, funded by SWAP, has been installed and commissioned in the Department. This instrument is being used for the determination of major and minor elements in *aqua regia* extracts of soils collected from the SWAP sites. 3809

Molecular Spectrometry of Soil Components

Despite the now wide acceptance of the crucial role played by protoimogolite in the translocation of Al, Fe and Si during podzolization (Annual Report Nos. 53 and 54) little is known about the rate of formation of this amorphous phase, its relationship to allophane, and the rate of its subsequent crystallization to imogolite. Such information may be of significance in characterizing the early development of podzolization and, to this end, laboratory studies of synthetic systems have established from IR spectroscopic and electron-optical investigations (in collaboration with the Department of Mineral Soils) that protoimogolite forms virtually instantaneously at room temperature. It crystallizes to the fibrous imogolite through several morphological stages involving curved sheets, rings and short tubes, some of which closely resemble those already observed for

natural allophanes. The rate of crystallization to imogolite varies directly with temperature, and it is estimated that, at the average temperature of a temperate soil, imogolite would be expected to appear after a period of podzolization of the order of a few hundred years. These results were presented at the 8th International Clay Conference in Denver, U.S.A., and a manuscript is in preparation. A paper on the appearance of allophane and imogolite in the micropores of a podzol Bs horizon has now been published[26], and a review on the sources and speciation of aluminium and silicon in natural waters is in press[27]. Papers on the ^{27}Al and ^{29}Si NMR spectra of allophane and imogolite[28] and the structure and genesis of allophane and imogolite[29], still await publication.

The intrinsic ability of infrared spectroscopy to indicate structural and compositional changes in minerals has proved invaluable in soil clay research. A series of smectites and illites of varying geological origins have been investigated in collaboration with the department of Mineral Soils and early results are suggesting that the IR spectrum may provide direct evidence for the type of occupancy of the octahedral cation sites, information only previously obtainable by quite time-consuming X-ray powder and electron diffraction methods. A paper is in preparation on this topic, and one on a related theme using IR to distinguish compositional variation in a beidellite has now been published[30]. Papers on a magnetic separation technique[31], and the X-ray distinction between susannite and its polymorph, have also now been published.[32] A paper on the general applicability of IR to soil studies has been prepared[22], and a detailed chapter on the use of IR in organic systems still awaits publication[33]. Studies by IR of the influence of foreign ions on the surface OH groups of synthetic goethite are continuing with particular emphasis on silicate and aluminium.
1060, 3005

Collaborative work with the Department of Soil Organic Chemistry has continued along well-established lines. The use of infrared and ultraviolet absorption spectroscopy to assist in the characterization of soil fulvic acid and a synthetic model compound, polymaleic anhydride (PMA), (Annual Report No. 46) have allowed a definitive statement to be made concerning the relevance of PMA as a model for fulvic acid[34]. This work has also shown that, contrary to a widely held view, fulvic acid contains insignificant amounts of aromatic compounds which are thought to be non-essential to the fulvic acid structure. A response in support of this contention has also been accepted for publication[35]. 3017, 4019, 4020, 4021

Infrared spectroscopy continues to play an important role in support of collaborative work with the Department of Microbiology. It is being used to identify digestible components in the food supplied to various insects, by comparing spectra of food and faecal samples. This approach looks promising and should supplement results obtained by pyrolysis mass spectrometry. In a study of the skeletal components of the wood louse, and millipede, IR has established the presence of amorphous calcium carbonate as a major component in a fresh exoskeleton in addition to protein and chitin. Nitrogen is conserved during the moulting of this skeleton. A paper on this topic has been accepted for publication[36]. 3005, 3017, 6027

The identification of fungal metabolic products relies heavily on IR and UV and current collaborative effort is being directed towards an antibiotic produced by *Penicillium echinulatum*. A paper describing the production of the antibiotic vermiculine by *Talaromyces wortmannii* has now been published[37]. 3017, 6026

Current work also involves a collaborative study with the Rowett Research Institute on the identification by IR reflectance methods of the changes produced in cereal straw during rumen digestion. 3017

Mössbauer Spectroscopy

The paper on the use of Mossbauer spectroscopy in the study of colloidal materials referred to in Annual Report No. 54 is still awaiting publication[38]. Several new projects have been commenced during the year involving both single and multi-mineral systems. Work on a series of illites in collaboration with the Department of Mineral Soils has shown that all were contaminated with iron oxides, which could not be detected by other methods used at the MISR. In one case it was shown that a significant fraction of the Fe(III) was in tetrahedral coordination, this being one of the few cases of Fe populating tetrahedral sites in an aluminosilicate mineral when there is more than sufficient Al present to account for the Si deficiency in the tetrahedral layers. In addition, different specimens showed one or other of two different quadrupole splittings for the octahedral Fe(III), and work is still underway with the aim of satisfactorily explaining these results.

In similar work on a series of montmorillonites, Mössbauer spectroscopy at 77K has been used to identify those specimens with small amounts of oxide impurity phases. In several cases hyperfine structure has been observed which originates from magnetically-dilute Fe(III) ions. Such structure has only been reported previously at 77K for kaolinite minerals.

Several standard asbestos samples have been investigated in collaboration with the MRC Pneumoconiosis Unit. Information has been obtained on the distribution of Fe(II) and Fe(III) ions and the presence and identity of associated iron oxide phases. The presence of small amounts of magnetite in some specimens may explain the ability of some asbestos fibres to orient in external magnetic fields.

The mineral Macaulayite has been investigated over a range of temperatures in collaboration with the Department of Physics, Liverpool University. The magnetic properties of the hematite-like layer differ from those of pure hematite in that there is no Morin transition and the Neel temperature is lowered by approximately 300 degrees. This behaviour indicates that there is no magnetic interaction between adjacent hematite layers.

Several clay/shale samples have been investigated in a project with Mobil Research and Development Corporation and the variation in Fe(II) and Fe(III) contents can be correlated with changes in mineralogical composition. In similar work with dolomites it was possible to distinguish clearly the contributions to the Mössbauer spectra from carbonate, sulphide and oxide environments, thus demonstrating the power of the technique for

identifying broad types of iron-containing mineral present in low amounts in mineral samples. 3005

In order to characterize small amounts of iron oxide minerals in soil samples by conventional techniques, a concentration method is often used that involves boiling with alkali. Recently a paper appeared which showed that synthetic ferrihydrite could be converted to hematite by this method but the transformation was prevented if kaolinite was added. We have used a number of iron pans that had already been studied (Annual Report No. 47) to investigate the effects of the published concentration procedures. In all but one case the alkali treatment led to the formation of significant amounts of goethite, in contrast to the hematite reported for the synthetic sample, and in these cases there was a reduction in the amount of goethite produced when kaolinite was added at a level equal to 50% of the weight of the pan material. In the sample where no conversion to goethite occurred with the alkali treatment, addition of kaolinite led to a significant goethite production. Addition of humic acid to the reaction mixture had little effect on the subsequent goethite production. Traditional concentration procedures for iron oxides in soils can, therefore, result in conversion from poorly-defined minerals, such as ferrihydrite, to goethite or hematite and should therefore be used with extreme caution. 3005, 3803

The work on the reaction of iron with fulvic acid referred to in Annual Report No. 54 has now been published[39] and has been extended significantly in the current year. The extent of iron reduction has been found to depend critically on the fulvic acid:Fe ratio. Rather surprisingly at high fulvic acid:Fe ratios (>100:1) there is a decrease in the fraction of Fe reduced at a particular pH, and this has been shown to be due to a favoured formation of a mononuclear complex that is not readily reduced. This complex exhibits hyperfine structure at 77K and is stable over the pH range from >1 to <9. The remainder of the Fe(III) appears to be in a polymerized form that is associated with the organic matter and reduction leads, at least initially, to the production of some Fe(II) that remains associated with the cluster, a conclusion that is supported by EPR results on the same system. 3803, 3808

Nuclear Magnetic Resonance (NMR) Spectroscopy

The paper on the structures of imogolite and allophane using ^{29}Si and ^{27}Al NMR referred to in Annual Report No. 54 is still awaiting publication[28]. New experiments on rectorite have been initiated in collaboration with the Department of Mineral Soils, MISR, and the Department of Chemistry, University of Illinois, U.S.A. Preliminary results indicate a discrepancy between the tetrahedral Al contents from the ^{27}Al and ^{29}Si spectra, the latter agreeing with figures obtained from elemental analyses. The ^{29}Si results also show that two different levels of tetrahedral Al populations exist within the mineral. 3005

Electron Paramagnetic Resonance (EPR) Spectroscopy)

In work with model systems of relevance to soils and plants, papers referred to in Annual Report No. 54 on copper(II) diglycine complexes[40]

and on the use of individual copper isotopes for deriving complete spectroscopic parameters for amino acid complexes[41] have been published. Extensive measurements have been made on oxovanadium (IV) complexes with amino acids, dicarboxylic organic acids, amines and simple peptides. In several cases the natures of the complexes can be deduced with a high degree of confidence, but in other cases, particularly those involving amino acids with additional functional groups, the presence of several complexes can be seen and identification is less certain. Preliminary results were presented at the Royal Society for Chemistry Meeting on ESR of transition metal ions in inorganic and biological systems and manuscripts are in the course of preparation. 3803

A number of the complexes referred to above have been used in an investigation of the interaction of simple organic complexes of copper and vanadium with the mineral montmorillonite. Such a reaction may be of relevance to the chemistry of the rhizosphere where such organic molecules may have a significant abundance. Very varied behaviour was found and the adsorbed species resembled those observed with uncomplexed metal ions in some cases, whereas in other cases ligands remained bound to the metals after adsorption. The adsorbed species, however, differed significantly from those in solution. Results of this work were presented at the American Chemical Society Symposium on chemical reactions at the mineral/water interface and a review paper on the adsorption of metal ions and complexes on aluminosilicate minerals is in the final stages of preparation for a book based on this meeting. 3005, 3803

The iron-fulvic acid system referred to in the section on Mössbauer spectroscopy has also been the subject of EPR experiments. These show the presence of a signal with g 4.3, which corresponds to the mononuclear Fe(III) complex whose presence was deduced from the Mössbauer spectra. The Fe(III) clusters produce a weak broad signal with g 2.0, but this sharpens and increases in amplitude when reduction occurs. Thus the Fe(II) must remain, at least partly, associated with the cluster and the spectral behaviour can be understood if there is antiferromagnetic exchange between adjacent Fe(III) ions and ferromagnetic exchange between Fe(II) and Fe(III) ions.

Papers on the occurrence of copper and iron complexes in humic acids extracted from municipal refuse decomposed in model landfills (Annual Report No. 54) have now been published[42,43] as has the paper on the nature of copper complexes with soil humic acids[44]. 3803, 3808

Preliminary experiments on soil solutions have demonstrated that the uncomplexed Mn(II) ion can be readily determined at natural levels. Total Mn(II) can also be measured by acidifying to destroy any complexes present. Plans are underway to combine EPR and analytical measurements for characterizing the manganese in soil solutions. 3803

In collaboration with the Danish Pharmaceutical School, Chemistry Institute, Copenhagen, experiments have been performed with copper-rich lake sediments in order to see if EPR spectroscopy could be of value in identifying any copper species present. However, no spectrum originating from any copper species was seen, except possibly after persulphate

oxidation, thus indicating that any copper was in an EPR-silent form, either as Cu(I) or as Cu(II) forms undergoing rapid relaxation or magnetic exchange. 3005

Of the papers referred to in Annual Report No. 54 on free radicals in humic materials of soil or fungal origins, three have now been published[45,46,47] and the fourth is still awaiting publication[48]. No further progress has been made in the past year on attempts to identify the sources of these free radical signals. 3808

Work on free radicals in plant materials has been extended during the past year and the O_2 -produced radical in wheat roots is now thought to be due to short-lived organic peroxides. The study of free radicals in seeds has now been concluded and papers are in the final stages of preparation for both of these projects. In collaboration with the Rowett Research Institute, experiments have been performed on the hearts of rats with selenium, copper and vitamin E deficiencies. A signal which we believe originates from the O_2^- ion has been seen, but as yet it has not been possible to relate its strength to the previous dietary status of the animal, possibly because of the lack of long-term stability of the radical on tissue storage. 3806

Computerisation and Automation

The microcomputer link to the EPR and Mössbauer spectrometers (Annual Report No. 54) has been completed and an account of the work published[49]. Computer interfacing of the E789 49-channel polychromator has been extensively modified to eliminate the use of the punched paper tape recording system. The present arrangement employs an Apple II microcomputer interfaced directly to the analogue output of the polychromator amplifier units. Timing signals are obtained from the uni-selector and the voltage signals are digitised using a high-speed, 12-bit analogue-to-digital converter circuit designed and constructed within the department[50]. A twin disk-drive unit is used to store the analytical data prior to its transmission to the Institute mainframe computer. A general account of microcomputer interfacing in spectroscopy laboratories has been published[51].

The construction and development of the rapid-scanning microdensitometer is nearing completion. Some preliminary results of the use of multivariate numeral techniques applied to the multi-element analytical data obtained from spark source mass spectrometry were presented at the Colloquium Spectroscopicum Internationale meeting held in West Germany[52].

There is an increasing interest in the use of automatic sample handling (robotic) techniques in analytical laboratories. In the department a tri-axis autosampler unit has been constructed that can be easily controlled by means of a personal microcomputer. The instrument will be evaluated in the laboratory and may provide a simple and inexpensive alternative to the more limited and costly commercial autosampler units.

The increasing use of microcomputers to acquire and store spectral data has led to a study of error-free, data compression techniques for the storage

of binary data. Excellent results have been achieved using Huffman shift coding and a report has been submitted for publication[53].

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4. SOIL ORGANIC CHEMISTRY

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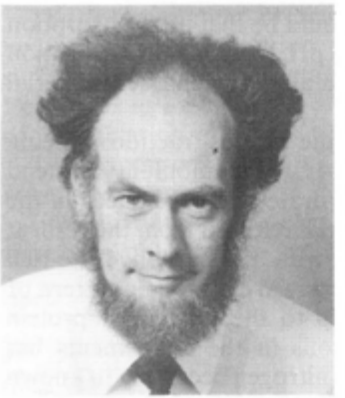

The work of the Department continues to be concerned with the nature and origin of the organic constituents of soil, particularly in relation to their influence on soil fertility. Studies on the direct effects of organic constituents on plants concern the supply of the major nutrient N, effects on enzyme activities, ion uptake and growth stimulation, whereas those dealing with indirect effects involve trace element solubilities and soil physical conditions.

The Department staff continues to maintain a high level of collaboration with other departments within the Institute and with researchers in the University of Aberdeen, the North of Scotland College of Agriculture and overseas in Canada, Germany and Denmark.

In October, Mr John Dicks, a graduate of the University of Reading, took up a studentship in the Department to work on the removal of copper from industrial wastes.

A major new item of equipment, an elemental analyser, has been installed and commissioned this year for work in conjunction with the Surface Water Acidification Programme (SWAP). This programme of work forms a natural progression from the Department's previous studies on the soil podzolization process.

During the year a book has been published[1] entitled Soil Organic Matter and Biological Activity, edited by two members of the Department. The subject matter is mainly concerned with the influence of organic matter on soil fertility and several chapters have been contributed by members of the Department[2–7].

Nitrogen

Investigations are continuing on the nature and transformation of organic forms of nitrogen in soil with the development of satisfactory methods of fractionation. The method of fractionation of soil fulvic acids using *poly*-methylmethacrylate and *poly*-vinylpyrrolidone resins in sequence, described in last year's Annual Report (No. 54, 1984), has been applied to three arable soils from the Countesswells, Insch and Tarves Associations. Air-dried samples were restored to field condition by remoistening and incubating for fourteen days, prior to extraction with dilute alkali. About half the carbon and two thirds of the nitrogen were brought into solution by this means. A very large proportion of each of these was present in the humic acid fraction and a substantial proportion of the extracted nitrogen was associated with a dispersed clay fraction. Part of

the nitrogen in the remaining fulvic acid fraction could be adsorbed on *poly*-methylmethacrylate with very little further adsorption of the unadsorbed substances occurring on *poly*-vinylpyrrolidone. A part of the material adsorbed on *poly*-methylmethacrylate is released by eluting the column with water. One explanation for this could be that after adsorption of the hydrophobic polycarboxylic acids at low pH, a secondary adsorption of protonated fulvic polyelectrolytes onto the already adsorbed material takes place.

The distribution of the forms of nitrogen in the various fractions is being examined. Amino acids, purines and pyrimidines and ammonium ions tend to be associated with the unadsorbed carbohydrate-rich substances in the fulvic acid or the more strongly adsorbed material released from the resin at high pH. Amino sugars are also associated with the carbohydrate-rich fractions as well as with the humic acid and dispersed clay. Their pattern of distribution does not indicate any relationship to the peptide or protein components. The use of freshly incubated soils in the experiments has resulted in a large increase in the proportion of nitrogen occurring in known form in comparison with air-dried soils and the reason for this is the subject of further study.

A review of nitrogen in humic substances presented at the Second International Meeting of the Humic Substances Society has been prepared for publication.[8] 4019

Humic Substances

Further samples of soils from sites of archaeological interest have been examined on behalf of the Scottish Development Department. Material from suspected Iron-age and Neolithic dwelling place post-holes has been found to have a higher organic phosphorus content than the surrounding soil. High levels of organic phosphorus are usually taken as evidence of decomposed animal remains. Its origin in this instance is conceived as the result of the filling of old holes with detritus. On the other hand, the organic matter from the samples appears to have a higher degree of humification, as measured by the E_4/E_6 index of the pyrophosphate extract, than the surrounding soil, which implies that it is older. This is difficult to reconcile with the previous observation. However, the relationship of the index value to the degree of humification has been established only for peats: its validity for the organic matter in mineral soils has yet to be tested. Attempts to determine the lignin residue content of samples using acid hydrolysis and gas chromatography have given inconclusive results. 4021

A study has been made of the variation shown by humic substances in peat profile horizons.[9] Acid hydrolysis of peat humic acids releases low molecular weight ether-soluble phenols in amounts which can be related to the proportions present in the lignins of the predominant plant species from which the peat is derived. The relative proportions of the various phenols also change with humification. The amounts of 3, 4-dihydroxybenzoic acid relative to those of 4-hydroxy and 3-methoxy- 4-hydroxybenzoic acid are, however, lower than would be expected from the von Post humification

index of the peats considering the ratios found for humic acids from well-humified horizons in mineral soils. Similarly the amounts of monosaccharides and levulinic acid found in the hydrolysates indicate a relatively low degree of humification.

The interpretation of the data is complicated by the possibility that hydrophilic decomposition products may be leached from the peats by surface water. Nevertheless, it seems more appropriate to regard the von Post index as an indicator of the degree of decomposition, rather than one of humification. 4021

Two papers concerned with the properties of *poly*-maleic acid have been submitted for publication.[10,11] 4021

Investigations of the electron spin resonance of humic substances have now been published or are accepted for publication.[12–15] 3009, 4029, 4805, 6027

Soil Carbohydrate

The complexity of the mixture of mono, oligo and polysaccharides comprising the soil carbohydrate presents great difficulties for the interpretation of the polymer structure from the commonly applied permethylation analysis procedure, but some valuable information about the types of bonds linking the sugars and the degree of branching should, in theory, be obtainable. Such parameters might be particularly important in determining the strength of adsorption on soil mineral components which may be the basis of the involvement of polysaccharide in the aggregation of soil particles. Further studies have therefore been made to investigate more efficient ways of methylating soil carbohydrate. There are considerable losses of carbohydrate during its isolation from soil in an unmethylated state, and so the work has concentrated on the direct methylation of material *in situ* in soil. Repeated methylation appears to be necessary to obtain good yields, but there are attendant risks of elimination reactions with uronic acid-rich materials. A number of preliminary treatments, both physical and chemical, have therefore been tried to test whether the yields on initial methylation can be significantly increased and whether prior reduction by sodium borohydride, which would prevent ß elimination, has any influence on the products. Chemical treatments such as acetylation did increase the initial yield of methylated product, but physical comminution of the soil was more effective. In all treatments tested, multistage methylation was still necessary. The reduction process led to lower yields with no apparent effects on the composition of the products. 4020

The results of two studies on the relative contribution of plants and microbial polymers to the aggregation process have now been published,[16,17] as well as a paper describing a simple, inexpensive turbidimeter for measuring soil dispersion.[18]

Many studies have been made of the aggregating effects of microbial polysaccharides on soils by the simple addition of the polymers. There are fewer instances where the products of a specific organism growing in the soil have been shown to be effective. Experiments are therefore being

conducted in conjunction with the Department of Microbiology to examine the aggregation caused by the growth of microorganisms which synthesize well-characterized extracellular polysaccharides. Eventually it is hoped to be able to relate aggregate stability to carbohydrate structure, taking into account possible natural processes. 4020, 6028

In general, it is recognized that high levels of organic matter in soil are beneficial to agriculture and indeed that in some soils a minimal level is essential to maintain a workable structure. In most soils the level depends on the regular addition of organic matter in the form of plant residues or animal waste because a very large proportion of any added material is rapidly lost from the soil as carbon dioxide. All the added material undergoes oxidation, however gradual, and a knowledge of the rates of decomposition and the factors which control them can be of great importance. For example, problems might be expected to arise from the disposal of sewage sludge on agricultural land through the release of toxic trace elements. Initially these elements are in an unavailable form, complexed by the organic matter, but may become available as the organic matter is oxidized. A complication here is that the presence of the metals can itself influence the rate of decomposition of the organic matter in which they are present.

A re-examination of the rate at which carbohydrate in plant material decomposes is being made in a laboratory study using cereal rye straw and young green ryegrass leaf as substrates. The overall rate of decomposition determined by measuring the total ^{14}C content of the soil over periods of time up to 5 years may be best expressed by multiple exponential functions as has been observed in many similar experiments reported from other laboratories. In our experiments we have also measured the rate of loss of ^{14}C for the individual labelled sugars composing the plant material. Some of these sugars (mannose, galactose, glucose) become, with time, mixtures of the original labelled sugar and sugar synthesized by microorganisms, whereas others (arabinose, xylose) are considered to have their source only in the plant material. The rate of decomposition of those latter sugars and of the cellulose-like material in the soil is each best expressed by double or triple exponential functions. This means that a part of the sugar is decomposing at one rate whereas other parts are doing so at slower rates. The finding implies that the overall pattern of decomposition of the whole material need not be explained as the result of differential rates of decomposition of different components such as, for instance, carbohydrate and lignin, even though such a difference would be expected. The reason for the stabilization of parts of the material, at present chemically indistinguishable from the whole, are not known.

These laboratory studies on straw decomposition are being run in parallel with field studies in collaboration with the Department of Soil Fertility and the effect of straw-stubble incorporation on soil physical conditions, including aggregation, are also being examined. 4020, 7044, 8057

The rate of decomposition of plant residues may be affected by the macrofauna of soils. Organisms within this size range are usually excluded from decomposition studies in soils in laboratory conditions for various

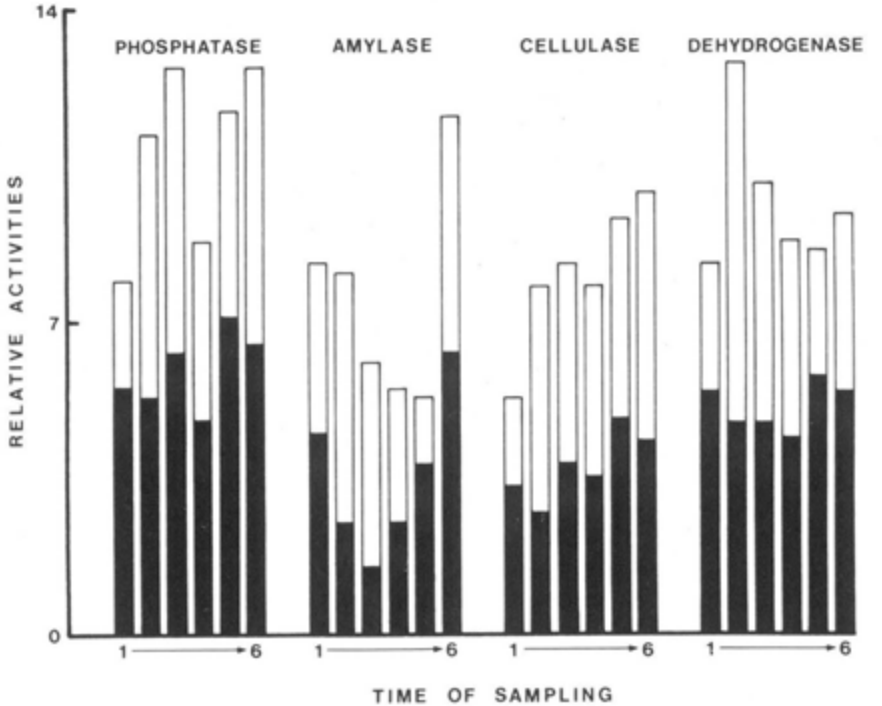

Fig. 4.1 Relative activities of phosphatase, amylase, cellulase and dehydrogenase in fallow soils, represented by black bars, or in soils planted with barley, represented by total bar heights. Soils were sampled every 21 days (numbers 1-6) commencing 1 May 1985 and ending 4 September 1985.

reasons: soil treatment such as drying or sieving is probably disastrous for many, whilst sample size may exclude the more mobile, or provide too small a habitat for survival. In collaboration with the Department of Microbiology an attempt is being made to study the influence of two types of organisms, earthworms (*Allobophora* and *Lumbricus* species) and crane-fly larvae *Tipula paludosa*. Both increase the rate of decomposition of plant tissue substrate in the initial stages in soil, and analyses are being made to test to what extent differential decomposition of the tissue components occurs. When crane-fly larvae are fed with grass leaves a large proportion, about 90% or more of the protein and hemicellulose, is digested compared with only about half the cellulose.[19] 4020, 6028

Soil Enzymes

Enzymes present in soil may originate from plant, animal or microbial sources. The influence of plants may be discerned to some extent by following the changes that occur under different crops during the growing season. Using soil from field plots it has been established that the activities of enzymes such as cellulase, amylase, dehydrogenase and phosphatase

change substantially, though variously, throughout the growing season (Fig. 4.1). The lowest enzyme activities were always found in soil from the fallow plots with the greatest changes occurring in amylase. The enzyme activities were almost twice as high in soil taken from plots growing barley. A sharp increase in dehydrogenase activity in late May in the barley plots corresponds to an increase in the microbial biomass. The data obtained provide conclusive evidence that the previous cropping history of a plot also influences the level of enzyme activity. 4064

Metal Organic Matter Interactions

Further studies using Mossbauer spectroscopy have been made, in collaboration with the Department of Spectrochemistry, on the influence of pH and inorganic ionic species present on the reduction of Iron Fe(III) to Fe(II) by fulvic acid. It has been observed that the extent of reduction depends on the proportions of iron and fulvic acid present. With ratios of organic matter : iron of the order of 20:1 or 50:1 in a system buffered by Li and NO_3 ions, ferrous iron is formed at pH 3 and 4 and a small proportion even occurs at pH 5. With a larger ratio of organic matter to iron, 200:1, there is little formation of ferrous iron above pH 3, and the difference is accounted for by the complexing of the iron by the organic matter. These findings indicate that organic matter in soils plays a role in controlling the oxidation state of iron.

A component with paramagnetic hyperfine structure is present in amounts which increase with increasing proportions of organic matter and arises from mononuclear ferric complexes. This is the first positive identification of such a species amongst the complexes found between iron and soil organic matter. A preliminary report on this work has now been published.[20] 3805, 4808

Papers have also been published on the forms of complexing of iron and copper by the humic substances in composted refuse.[21,22] 3805, 4808

Micronutrients in Soil Solutions

Work on the mobilisation of micronutrients Cu, Zn, Mn and Co into the soil solution in the rooting zone of barley plants has continued in collaboration with the Department of Soil Fertility. 1985 proved to be the wettest season for many years. This contrasted with the 1983 and 1984 seasons which were dryer than average. Despite this difference the patterns of mobilisation of micronutrients in the rooting zones of spring barley were similar though not identical in the three growing seasons. In addition to the continuing investigation of spring barley a comparison has been made with mobilisation under winter barley. Mobilisation under spring barley remained low until mid June and reached a maximum in the first week in July. In contrast, mobilisation under winter barley was already substantial by early April, when growth was accelerating, and reached a maximum in early June (Fig. 4.2). This is a clear demonstration of the importance of the growing crop in influencing its rooting environment. An experiment with

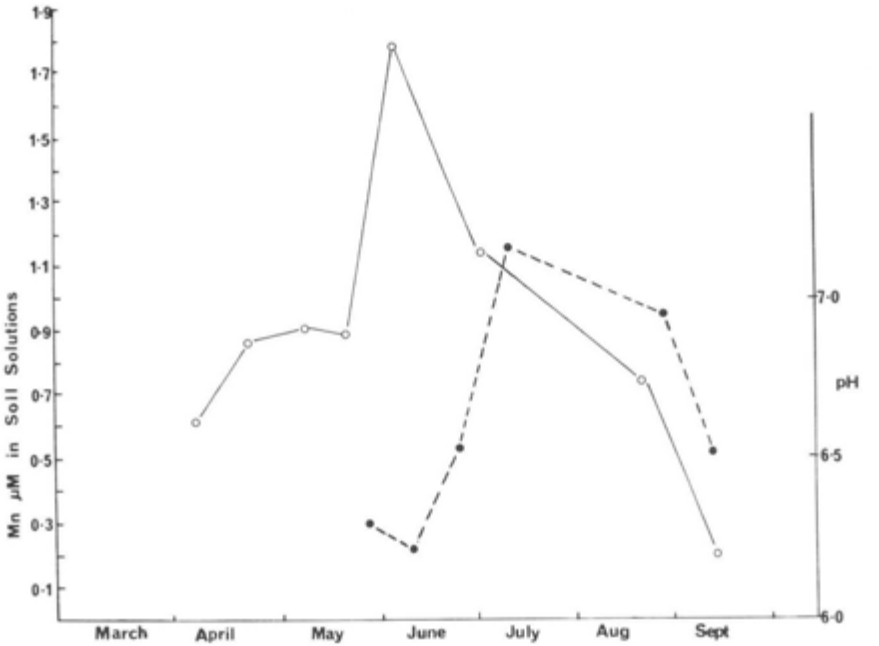

Fig. 4.2 Manganese mobilisation in soil under winter o—o and spring barley ●—●.

winter barley was carried out on a copper deficient site. Copper oxychloride was applied after ploughing but prior to seed sowing, to some plots but not to others. Significant differences in the copper concentrations were not observed during the winter and early spring period. Maximum mobilisation occurred in early May. The maximum in the non-treated plots was of brief duration (Fig. 4.3) whilst soils treated with copper oxychloride maintained high concentrations of copper in the soil solution until early July. This period of enhanced copper mobilisation corresponded to the period of maximum growth and thus, maximum demand by the plant. Preliminary reports of some of this work have been published[23] and also presented to a meeting of the Agriculture Group of the Society of Chemical Industry[24] . The studies on manganese mobilization form the basis of an Institute Technical Note.[25]. 4803, 7041

A paper has been presented on the ameliorating effects of adding peat to two soils which contain toxic levels of plant-available copper.[26] The effects are considered to be the result of complex formation by the peat. 3007, 4808

Enzyme - Clay Interactions

In collaboration with the Department of Mineral Soils, an investigation has been initiated to study the effects of clays on the various enzymes taking part in the catabolic processes which occur in soil. The activities of cellulase

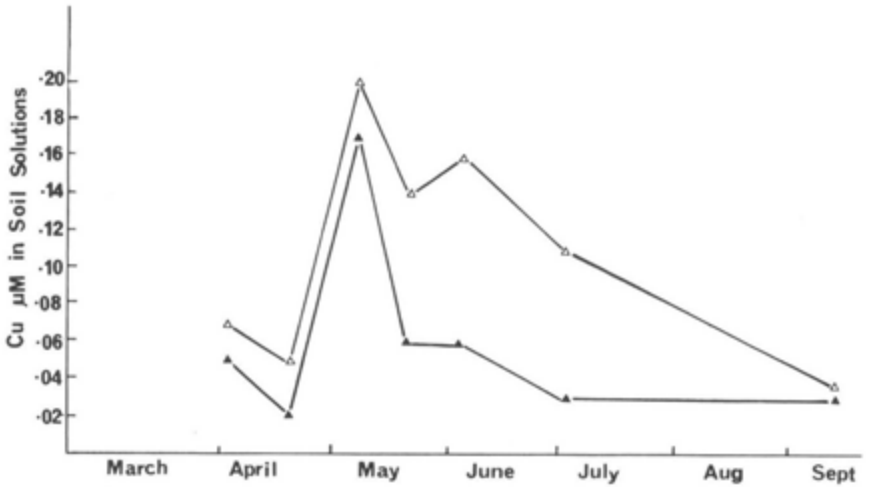

Fig. 4.3 Copper mobilisation under winter barley in soil treated with copper oxychloride or untreated.

and invertase are inhibited by montmorillonite, the extent of the inhibition being dependent on the pH of the medium. For example, in buffered suspensions at pH 3.5 cellulase and invertase were inhibited by 88 and 77%, respectively, whereas at pH 5.5, neither enzyme was affected. Kinetic measurements revealed that montmorillonite affected the V(max) of the reaction, but not the Km, thus displaying a non-competitive inhibition with both enzymes.

An explanation of these effects may concern interlamellar adsorption; cellulase is adsorbed only at low pH. In contrast to montmorillonite, kaolinite had no effect on the activity of cellulase or invertase at any pH.

4064

Ochre in Field Drains

Collaboration with the Department of Soil Survey has continued on investigations into the iron ochre problem in field drains and several articles on this subject have been published.[27–29] The bark infill experiment set up in collaboration with the North of Scotland College of Agriculture at a site near Elgin (Annual Report No. 54, 1984) has continued to give satisfactory results in terms of limiting ochre formation. Lines treated with a 1:1 v/v mixture of bark and gravel continue to give lower Fe(II) concentrations in the water leaving the drainage lines than those observed in the untreated lines. Drainage problems at the site have arisen from silt, but the efficiency of the drains does not appear to have been adversely affected by the bark treatment. A similar infill experiment has been installed at a site in Kintyre near to two other experiments in which the bark can be renewed. 480l, 980l

The regular monitoring of drainage water from a local field drainage system badly affected with ochre has commenced. It is hoped to explain

differences in ochre formation between six drainage lines by an examination of the chemical composition of the drainage waters and various physical factors such as flow rate and pH. There appears to be considerable variation of Fe(II), over a range of 2 to 75mg/l, between different drainage lines and time in any one line. Levels of soluble silica also vary both spatially and temporally but do not correlate with changes in Fe(II), and neither do pH or flow rate. The water from three lines contained appreciable quantities of humic substances, especially during the summer months of August and September, with a maximum of over 200 mg/l. Humic substances complex Fe(II) and so reduce the concentration of the ionic form. The relationship between the quantity of humic substances and bound iron is not, however, a simple one. 4801

The amounts of soluble tannins present in bark vary considerably between tree species, and between different batches from the same species. Most of these tannins, which are a potential environmental hazard in drainage water, are lost when the bark is composted. Furthermore the composted bark is found to be much more efficient in removing Fe(II) from drainage water. Most of the remaining water soluble tannins are quickly released from the composted bark before it has absorbed more than 10% of its capacity for Fe(II). 4801

Labelling of Plant Material

Work has continued on the radioactive labelling of the hydrophyte *Lemna gibba* L. by growth in axenic conditions in ^{14}C glucose solutions. Use of *Lemna* in long term incubation experiments in soil has shown that the labelled tissue is transformed in a similar manner to that of mesophytes which are labelled in axenic conditions only by a more complex and costly procedure. The method being developed has the advantage that it can also be used to make ^{13}C labelled material efficiently. In collaboration with the Department of Plant Physiology, a critical assessment is being made of the nutrient and glucose concentrations required to give optimal growth of the *Lemna* fronds. Sub-optimal culture conditions, used previously, produced plants with brittle roots and physiological characteristics similar to those of the other common duckweed species, *Lemna minor* L. A paper describing these effects is now being prepared for publication. 4020, 4064

Environmental Effects on Seedling Growth

Various modifications and improvements have been carried out in the course of the past year on the video image analysis equipment in order to increase its usefulness. The miniature growth chamber, in which seedling growth is observed and recorded, has undergone modifications, the effect of which has been to improve the external manipulation of the seedlings permitting their relocation without recourse to partial dismantling of the growth chamber as was previously necessary. An additional facility which has been incorporated is the ability to irradiate seedlings *in situ* with light of narrow-band wavelength. This facility was used in an investigation of

phytochrome control of mesocotyl cell elongation in maize seedlings which was carried out in collaboration with Mrs Avital Yahalom, a British Council visiting researcher from the University of Tel Aviv.

Light is a major factor controlling stem elongation and it is a well established feature of grass stems that mesocotyl elongation is suppressed by red light. In the case of maize mesocotyls white or red light inhibition is reversible by a short irradiation with far-red light and in turn this effect is itself reversed by red light, indicative of phytochrome involvement. The kinetics of the red/far-red reversible inhibition of mesocotyl elongation was studied in maize seedlings and from the image analysis data it was concluded that far-red growth stimulation was detectable after 2 hours, or even earlier. The image analysis data also revealed that the recovery from light inhibition was most pronounced in the upper zones of the mesocotyl. It is hoped eventually that the growth data will be found to correlate with phytochrome levels.

For the characterisation of the growth kinetics it was necessary to write additional computer programs, a task in which Dr A.R. Berg of the Department of Plant Science, University of Aberdeen, materially assisted. Collaboration has continued with the Department of Plant Science on relative elemental elongation rates of normal and tropic growth of sunflower hypocotyls and it has been established that the promotion of growth consequent to the application of a geostimulus, commences after approximately 20 minutes. A distinct polarity was observable in the progression of growth stimulation along the hypocotyl and the data also bring out the pulsating nature of growth. A paper reporting this work has been submitted for publication.[30]

Papers referred to in last year's report dealing with geogrowth responses of horizontal hypocotyls and the role of the apex in geostimulated growth have been published in the course of the year [31,32]and further studies have been carried out in an attempt to characterise growth regulation in seedlings. These studies have been concerned with the function of the epidermis in effecting directional movement of the hypocotyl and the significance of axial polarity in autotropic growth. 4053

Surface Water Acidification Programme

Soil collected from profiles at two of the selected stream catchments at Allt a'Mharcaidh and Kelty Water are being studied to elucidate the nature and degree of humification of the soil organic matter and the ways in which iron and aluminium associate with it. 4809

Other Studies

In collaboration with the Department of Microbiology, a study is being made of the nature of an antibiotic substance produced by the organism *Penicillium echinulatum*. A paper describing the isolation and characterization of the antibiotic vermiculine from the soil fungus *Talaromyces wortmannii* has appeared. [33] 4021, 6028

A paper describing the influence of the amino acid analogues *p*-fluorophenylalanine and azetidine-2-carboxylic acid on continuous protein synthesis and ion uptake in wheat roots and mung bean seedlings has now been published. [34] 4064, 5050

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5. PLANT PHYSIOLOGY

A.E.S. MACKLON

Studies on uptake and transport of trace elements, of dietary importance to grazing animals, continue to be the Department's main concern. Characterisation of cobalt uptake in wheat seedlings has progressed, and with appointment to one of the Department's outstanding vacancies, work on copper uptake, transport and speciation in ryegrass has started. These studies on individual trace elements, in axenic conditions, are yielding knowledge which forms the basis for interpreting experiments designed to differentiate between interactions which affect the availability of elements for uptake (soil solution effects) and interactions occurring at the uptake step (across root cell membranes). This information is required to allow progress towards an understanding of the mechanisms which limit transport of trace elements to the shoot, following absorption by the roots. However, extension of the work to interaction studies has not been possible thus far, due to continuing limitations to the filling of staff vacancies.

The Department has recently taken delivery of two controlled environment growth cabinets which will allow much improved reproducibility of experimental conditions and regulation, by control of relative humidity, of transpirational through-put of water, which can be an important factor in ion uptake, both for trace elements and for the continuing work with nitrate and ammonium transport.

Trace Element Studies

Cobalt. Work on cobalt uptake and transport in wheat seedlings has continued, using ^{58}Co to examine the extent and effects of cobalt depletion in the nutrient solution, and the unusual features of the time-course for Co uptake into the root.

Trace element uptake studies are ideally performed in a system where the nutrient solution can be kept close to its nominal concentration by continual renewal. However, when radioisotopes are involved such a system is not feasible, on grounds of both expense and safe disposal of "spent" solution. In the past year, we have achieved a compromise by using larger vessels (containing 1000 cm^3 solution) than formerly employed (200 cm^3 solution), and when depletion of cobalt exceeds 15 per cent, the solution is renewed. Effects of cobalt concentration on uptake rates were found to be essentially as reported last year, although limiting depletion in the nutrient solution naturally resulted in increased levels of accumulation for solutions of nominally the same Co concentration.

Because valid use of efflux data in compartmentation studies relies upon a constant uptake rate before and during elution, attention has been turned to the detail of cobalt uptake time-courses, which, as reported last year, show increasing uptake with time. The example illustrated in Fig. 5.1 is typical of the relationship obtained. Over the first 17 hours the pattern is reminiscent of that found for calcium, in which the initial rapid uptake relates to the relatively fast exchange of radioisotope with the stable isotope in the free space and cytoplasm. When this is complete, the slow exchange with, or uptake by, the vacuole is revealed, and would be expected to progress steadily for many hours. However, after 17 hours, the rate of ^{58}Co uptake increases again and becomes exponential, exceeding the uptake rate in the early hours of the time-course. This behaviour is consistent with the

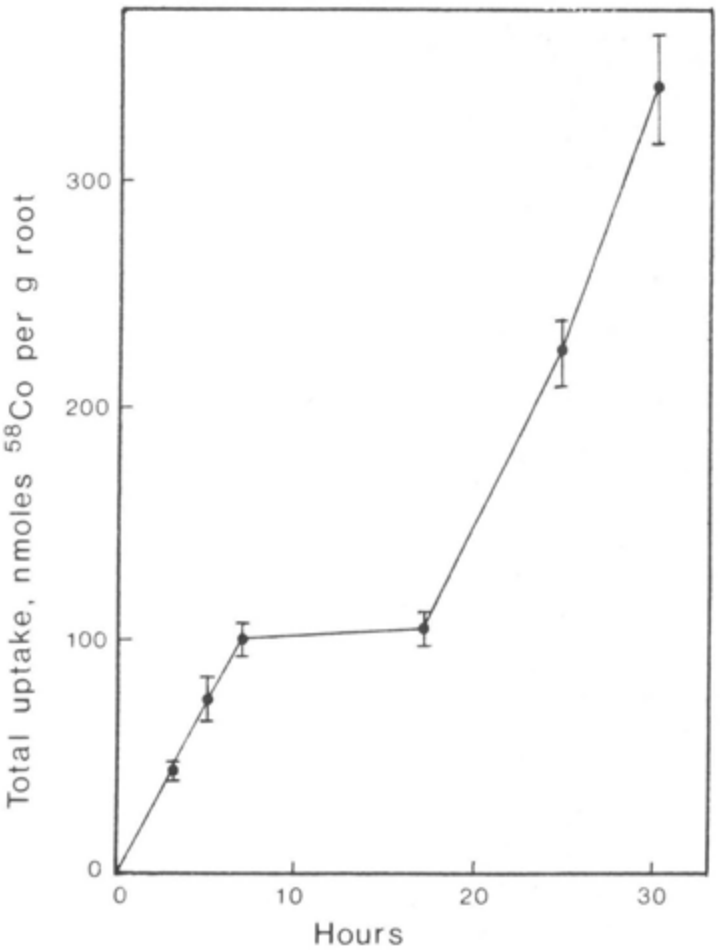

Fig. 5.1 Time course of total uptake of cobalt into wheat seedlings, expressed per g fresh weight of root + or - s.e.m. Uptake was from a normal nutrient solution, containing 2 μM radiolabelled Co, as the only micro-nutrient, at pH 5.5.

development of a cobalt uptake mechanism over several hours after the introduction of ^{58}Co to the root medium, but this pattern is observed in plants which have been supplied with unlabelled Co since germination a week previously, and in which a cobalt uptake capacity might be expected to be already fully developed. Such an effect suggests that isotope discrimination between ^{59}Co and ^{58}Co is occurring. Alternatively, cobalt uptake, unlike uptake of major nutrients, might exhibit diurnal periodicity. Work is in hand to resolve this problem and to determine conditions in which cobalt uptake occurs in a linear manner.

Full quantitative conclusions from compartmental analysis of efflux experiments require sound data for root cobalt content by analysis. A method for estimating cobalt in small plant samples is now reaching its final development stages in the Department of Spectrochemistry. Meanwhile, cobalt efflux measurements on plants of which the root systems were rapidly killed by exposure to liquid nitrogen, have confirmed the earlier finding with root segments (Annual Report No. 53, 1983) that the slowest exchanging compartment was eliminated. This indicates that most of the cobalt in normal roots is accumulated in cell vacuoles rather than held on exchange sites in the cell walls. 5050

Copper. Work has started on copper uptake and transport in perennial ryegrass (*Lolium perenne* L. cv. Premo). Preliminary efflux experiments have been undertaken using ^{64}Cu obtained, at adequate specific activity and acceptable cost, from the Scottish Universities Research and Reactor Centre. The plants are grown for about two weeks from germination in a nutrient solution containing 1 μM copper. As with cobalt, depletion of Cu in the nutrient solution during an experiment is a problem and early results suggest that the plants may require several changes of ^{64}Cu labelled solution in the radioisotope loading period prior to elution, to avoid inflexion in the efflux curves possibly caused by a depletion effect on the Donnan free space in the roots. If the inflexions can be overcome by reducing depletion, it will allow clearer resolution of Cu compartmentation in vacuole, cytoplasm and free space. Uptake time-course experiments suggest that a much larger proportion of root copper content is held in the faster exchanging (free space) compartments, compared with cobalt. It remains to be seen whether vacuolar accumulation of copper is significant. 5050

Attempts have been made to isolate the copper protein plastocyanin from ryegrass as part of a larger study of the speciation of copper forms in plants in relation to animal trace element deficiency studies, in collaboration with the Department of Spectrochemistry. Plastocyanin was chosen for study first as it has been suggested that this may be a form of copper present in the diet of ruminants which can survive the S-rich environment of the rumen. Although progress has been made in eliminating some problems associated with the isolation, successful isolation remains to be achieved. 5806

Preliminary work on the isolation of protoplasts from root and leaf material of ryegrass (by enzymatically digesting away the cell wall) has been started. Isolated protoplasts should provide a useful tool in many aspects of

the speciation and compartmentation of copper and other trace elements in plants. 5050, 5806

Nitrogen Flux Studies

Analyses. Estimations of ^{15}N enrichment in elution samples from efflux experiments with onion root segments are now becoming available following the resolution of staffing and technical difficulties experienced by the Department of Mineral Soils which provides the service for nitrogen isotope assay by mass spectrometer. Plant samples highly enriched with ^{15}N are analysed using an optical emission spectrometer, with the co-operation of the Department of Spectrochemistry. Recent modification of this equipment to allow a faster through-put of samples has considerably helped to expedite this work. 5051

Onion Roots. Early experiments were conducted on large samples of root segments washed in funnels so that the elution data represented the sum of root surface efflux and transported nitrate or ammonium ions leaking from segment cut ends. Efflux curves for NH_4 , based on this kind of data are often irregular in form and difficult to resolve, possibly because of the unquantified transport component in the elution samples. However, with the acquisition of analytical equipment capable of measuring small enrichments and requiring smaller amounts of nitrogen in samples, we have more recently attempted experiments with small enough numbers of segments to make it feasible to set them up in a three-compartment chamber, designed to isolate transported ^{15}N from that eluted from the root surface. Results now coming to hand indicate that ^{15}N levels in elution samples, from experiments using small numbers of root segments (c. 10×4 cm), are distinguishable from the natural abundance. It has been established, meanwhile, that onion roots, in the conditions used here, show no nitrate reductase activity. This will make assessment of nitrate fluxes simpler, since no ^{15}N absorbed during the experiment will have been removed from the ion transport milieu by assimilation. 5051

Barley Seedlings. Plants are grown axenically in the dark, with aeration of the nutrient solution. After five days, the seedlings (cv. Golden Promise) are brought into a light (16 h) - dark (8 h) regime, and two days later used for uptake experiments. Once exposed to light, root growth typically slows down or stops, but both $^{15}NH_4$ and $^{15}NO_3$ uptake proceed in a linear manner for 30 hours. Commonly, half of the absorbed N is found, at any time during the uptake period, in the shoot, although water transport in the closed containers must be at a minimum. Now that controlled environment facilities are available, the effects of water transport, as modified by relative humidity, and of light intensity on ^{15}N efflux, uptake and transport will be examined. 5051

Ion Fluxes in Tree Leaves.

This study is in collaboration with the Department of Forestry, Aberdeen University, and undertaken by a research student working part-time at the

Institute. The work here is directed towards estimating the mobility of cations across the cell membranes in spruce and birch leaves as part of a wider study of the effects of acid rain on crown leaching in forests. Compartmental analysis and estimation of transmembrane fluxes for calcium in spruce needles, bathed in a solution of calcium chloride, has been started. However, it was found that such large and variable amounts of calcium accumulate in the needles over the course of their 2 to 3 year life that attempts to find the external concentration of Ca, in which the needles showed a net calcium flux of zero, were frustrated. Work with needles still attached to twigs, to avoid leakage of Ca from needle cut ends, indicated that some calcium in the twigs was mobile. Some work with new shoots, collected in early summer before Ca accumulation became appreciable, promised an opportunity to complete the Ca study satisfactorily and it is planned to finish this early in the coming summer. Meanwhile, work will continue with other ions of interest. 5050

Growth and Morphology of Sphagnum

This pilot study, funded by a grant from HIDB, aims to explore methods of growing *Sphagnum* species rapidly and in large amounts, free from plant and microbiological contaminants, and to define optimum growing conditions for selected species. It was soon apparent from small scale studies that starting from shoots collected in the field was not ideal. The algae naturally associated with *Sphagnum* flourished rather better in warm, nutrient-rich conditions than did the moss, which usually became smothered with the algae. However, after some weeks, the capitula of those moss species naturally emergent in habit did manage to "grow away" from the worst of the algal contamination and were used to test conditions in large tanks containing trays of shoots, subject to spraying and recirculation of nutrient solution. It was then found that contamination, identified as high levels of copper and zinc originating from the pump and fittings used for nutrient circulation, was killing the plants. Replacement of the pump and piping with plastic components has overcome this problem.

More recently, sterile *Sphagnum* protonemata have been grown in axenic culture from spores which are produced in the field only in late summer. Within a few weeks, shoots of adult form are produced by the protonemata, and these have been collected from the agar culture plates, for growing on as supplies of sterile shoots for further growth studies.

Financial support for travel costs, associated with this project, from Courtaulds p.l.c., is acknowledged. 5072

Other Investigations

Axenic cultures of *Lemna gibba*, radiolabelled with ^{14}C-glucose, are used by the Department of Soil Organic Chemistry to examine incorporation and subsequent transformation of organic carbon in soils. Collaborative experiments are in progress to define the optimum growing conditions for normal development of these plants. 4064

Work on the effects of some amino acid analogues on uptake and transport of potassium and calcium in seedlings has now been published [1,2]. In conjunction with this work, and in collaboration with the Department of Soil Organic Chemistry, a study of the effects of amino acid analogues on enzyme activity and amino acid incorporation has also been published [3]. This work confirms, for wheat and mung bean seedlings, that analogues become incorporated during protein synthesis, into enzymes and carriers which then fail to function properly. The analogues are thus useful tools in investigating the role of proteins in ion absorption and transport to the shoot, and it is planned to use them in the trace element transport studies.

5050

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2. Effects of some amino acid analogues on the uptake and transport of K^+ and Ca^{2+} in wheat and mung bean seedlings. II. Uptake and translocation in whole seedling plants. By B. Thornton and A.E.S. Macklon, *J. Exp. Bot.*, **36**, 930-936, 1985.
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6. MICROBIOLOGY

J.F. DARBYSHIRE

The majority of the research in the Department of Microbiology is concerned with microbial transformations of soil organic matter and the subsequent release of nutrients for plant roots. Particular attention is paid to the reserve of nutrients in the microbial community in both organic and mineral soils. Many studies are concerned with interactions between the microflora and microfauna and some research is concerned with microbial weathering of parent rocks and soil minerals. When several disciplines are involved it is only natural that a great deal of collaboration exists amongst members of the Department and with other scientists elsewhere in the Institute and outside.

Interrelationships Between Plant Roots and Microbes

The preservation of roots and microbes in soil thin sections has recently been improved. Soil samples are now fixed in buffered glutaraldehyde, dehydrated in a graded series of acetone: water mixtures and finally impregnated with a polyester resin of low viscosity. Using this procedure, it is now possible to prepare soil thin sections containing plant roots and delicate protozoa without any discernible artefact in approximately 14 days (Fig. 6.1). Previous methods usually required much longer curing periods for the resin. A paper describing the new procedure has been submitted for publication.[1] Root decomposition of some common local crops (barley, grasses, peas and rape) as well as the spatial relationships between roots, microbes and the pore network are being studied with the soil thin section technique. The particular influence of actinomycetes on the decomposition process has been studied with pea and barley roots. During the first 17 weeks of decomposition no significant change in the meso or thermophilic flora of actinomycetes was noticed, although the following genera were isolated; *Streptomyces*, *Micromonospora*, *Nocardia*, *Actinoplanes*, *Streptoverticillium*, *Microbispora*, *Microtetraspora* and *Thermoactinomyces*. 6025, 6027, 6028

Studies of the microbial activity in soil beneath Sitka spruce planted in pure stands or mixed with Scots pine are being concluded after collecting samples every month for two years. This is part of a joint research project with the Department of Peat and Forest Soils and the University of Edinburgh; it is partly financed by a European Community contract. The main conclusions from these field studies are that there is usually a larger

microbial biomass, greater microbial activity and greater rates of nitrogen mineralization in the organic horizons (0-5 cm) when Sitka spruce is planted with Scots pine than in pure stands of Sitka spruce. In the deeper horizons (5-10 cm), the microbial biomass is similar in size in the mixed and pure stands, although there is an accumulation of dead fungal hyphae in the pure stands. Any nitrogen in these undecomposed hyphae is probably not readily available to the tree roots. The results of these investigations and the litter leaching experiments described in the last Annual Report are being prepared for publication. The role of mycorrhizas in the mixed stands is being investigated in several experiments in the glasshouse. The new method of cultivating enchytraeid worms in coniferous litter, described in the last Annual Report is in press.[2] 2055, 2807/6807, 6027

Studies of the phytotoxins and phytosanitary compounds in tree bark composts have continued. Several small fermentors have been constructed and the optimal conditions for rapid decomposition and the development of

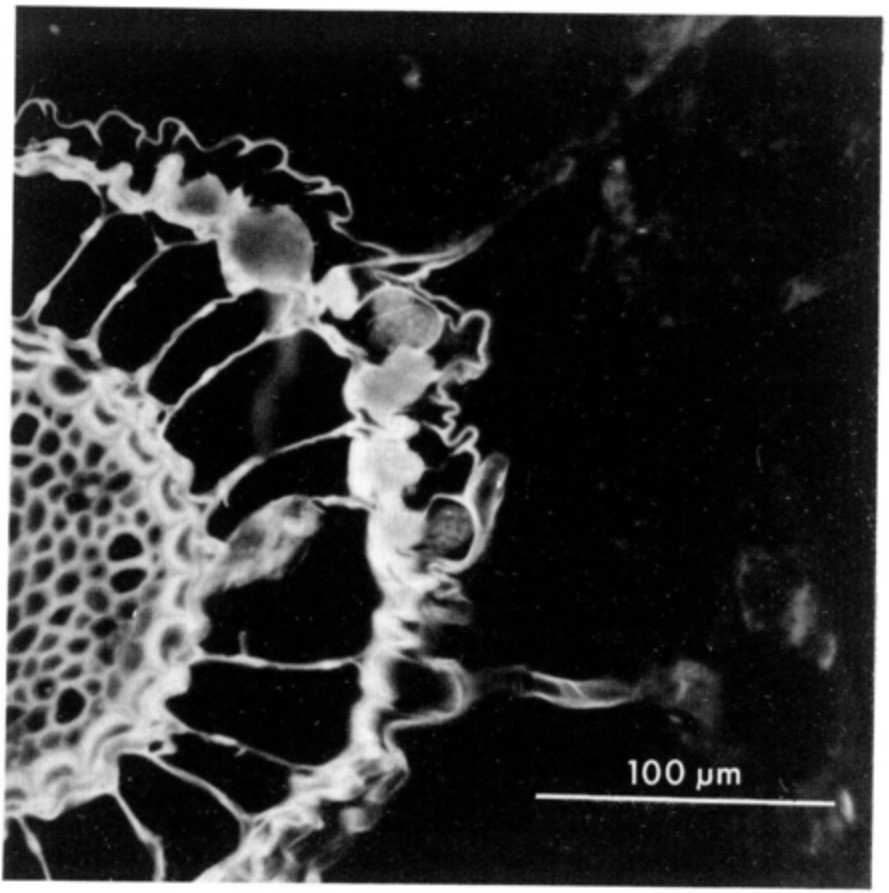

Fig. 6.1. Transverse section of root of perennial ryegrass (*Lolium perenne*) in soil thin section. Note root hairs in contact with soil. Autofluorescence of unstained roots.

thermophilic fungi have been determined. The moisture content of the bark and the aeration rate proved to be the most critical environmental factors. Apart from fungi, many bacteria, actinomycetes and yeasts colonise the bark in the fermentors. Many of the chemical changes have been investigated, particularly with regard to the phytotoxic phenolic compounds. Water-soluble phenolic compounds decomposed within 9 days, but seed germination tests showed that some phytotoxicity persisted after this time and further decomposition of the bark appears to be required. Six month old composted bark in a 4:1 bark/peat mixture compared favourably with peat/sand mixtures and commercial bark composts for the growth of tomato plants. In the future, the same mature bark will be tested for phytosanitary compounds. 6025, 6026, 6027

Fungi

Preliminary results suggest that cryofixation with liquid nitrogen at -190°C preserves the ultrastructure of ectomycorrhizas of Sitka spruce in a better fashion than either critical point or freeze-drying (Fig 6.2). The results of a similar comparison between critical point-drying and cryofixation using the gills of the soil basidiomycete, *Coprinus cinereus*,[3] and an invited review of cryofixation techniques have been published.[4] 6026, 6028

Actinomycetes

The potential use of a polyol gel, Lutrol FC 127, as a growth medium for actinomycetes has been discussed in a recent paper.[5] As this gel liquifies at low temperatures, it can readily be washed away from the mycelia and entire colonies of actinomycetes can be recovered for a variety of uses, e.g. in studies of growth kinetics of colonies or of nutrient transport between the medium and the microbial colony. 6025

Protozoa

A comparison of two methods of estimating the network of pores available to protozoa in soil has been published.[6] A redescription of the soil ciliate, *Engelmaniella halseyi* (Fig 6.3) used as a test organism in the soil thin section studies mentioned earlier, is being prepared for publication in collaboration with the Department of Zoology, British Museum (Natural History). 6031

Organic Matter

Microbial Synthesis. The ability of many soil fungi to produce antibiotics against other microorganisms is an important attribute in soil and may ensure survival on many occasions. A description of the isolation of the antibiotic, vermiculine, from the soil fungus, *Penicillium wortmannii* has been published.[7] This antibiotic was shown to be strongly antagonistic to the root pathogen and soil saprophyte, *Rhizoctonia solani*.

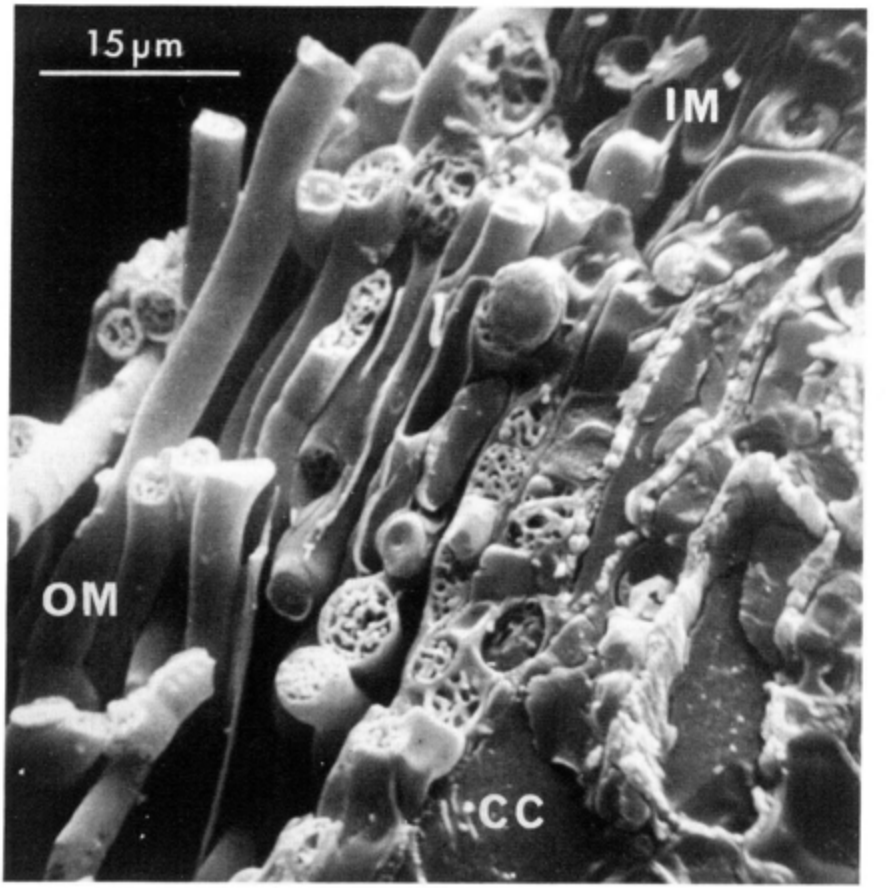

Fig. 6.2. Ectomycorrhiza of Sitka spruce (*Picea sitchensis*). Specimen cryofixed in liquid nitrogen and fractured in frozen state. CC = root cortex; IM = inner mantle of mycorrhizal hyphae; OM = outer mantle of mycorrhizal hyphae.

Czechoslovakian workers have shown vermiculine to be antagonistic to many bacteria and protozoa. Ten species of *Penicillium* from soil were tested for their antagonism to various saprophytic and pathogenic fungi. *Penicillium echinulatum* proved to be antagonistic to the saprophytes *Mucor subtilissimus*, *Mucor rammannianus* and to the root pathogens *Pythium debaryanum* and *Rhizoctonia solani*. In contrast, *P. echinulatum* was not antagonistic to *M. cercinelloides*. A crystalline material has been purified from the ethyl acetate extracts of the culture filtrates and its structure is being determined using infra-red and mass spectroscopy. Another soil fungus, *Penicillium thomii*, proved to be markedly antagonistic to *P. debaryanum* and *R. solani*. 3017, 4029, 6026

Melanin pigments in soil fungi may also hinder decomposition and help melanin - containing fungi to survive in soil. The black pigmented stipes of the fungus, *Xylaria hypoxylon* (Fig. 6.4), and the dark pigmented culture

media of *Penicillium janczewskii* are two examples of such pigmented material under current investigation. 3017, 4029, 6028

Polysaccharides. A study of how microbial polysaccharides are synthesised in soil and how they contribute to the aggregation of soil particles has started in collaboration with the Department of Soil Organic Chemistry. Many previous studies have investigated the effects of chemicals or microbial metabolic products on soil particles. Specific bacteria that can produce a range of extracellular polysaccharides are being cultured with the C horizons of 5 local soils, which represent a range of soil texture. 4020, 6027

Biomass. The size of the microbial biomass present in experimental plots of soil at Cross of Jackston (Foudland Series) sown with spring barley has been estimated at intervals throughout the growing season using the Jenkinson fumigation technique. Several different levels of nitrogen

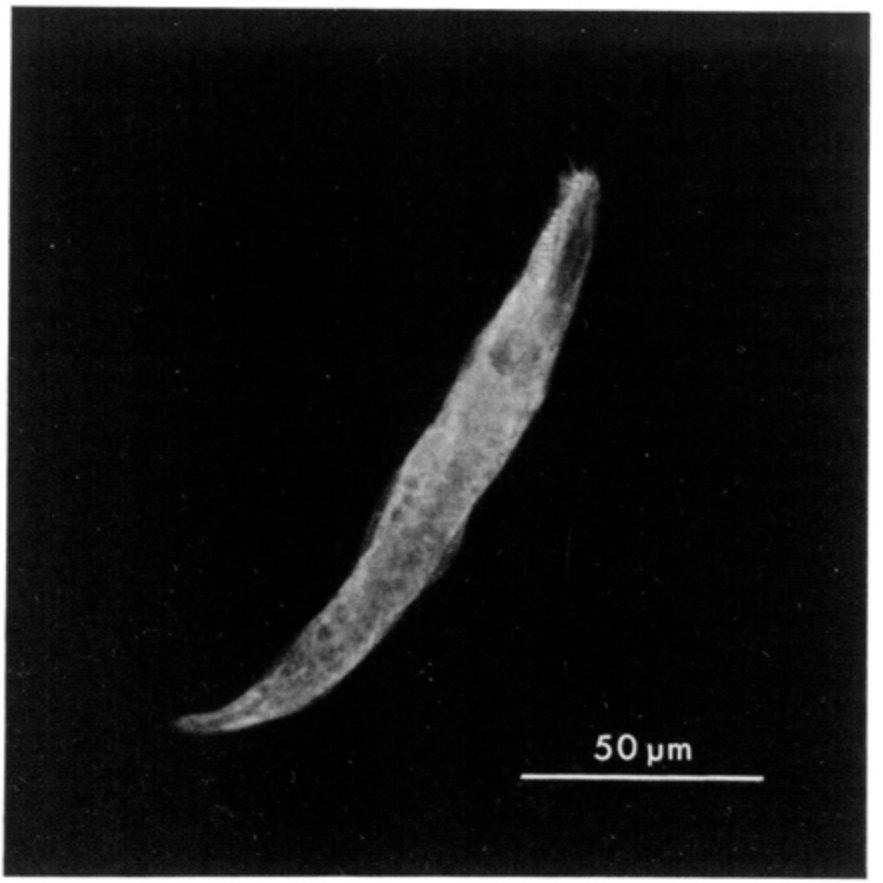

Fig. 6.3. Trophozoite of the soil ciliate, *Engelmaniella halseyi*, fixed in glutaraldehyde and stained with a fluorochrome, the magnesium salt of 8-anilino-1-naphthalene sulfonic acid.

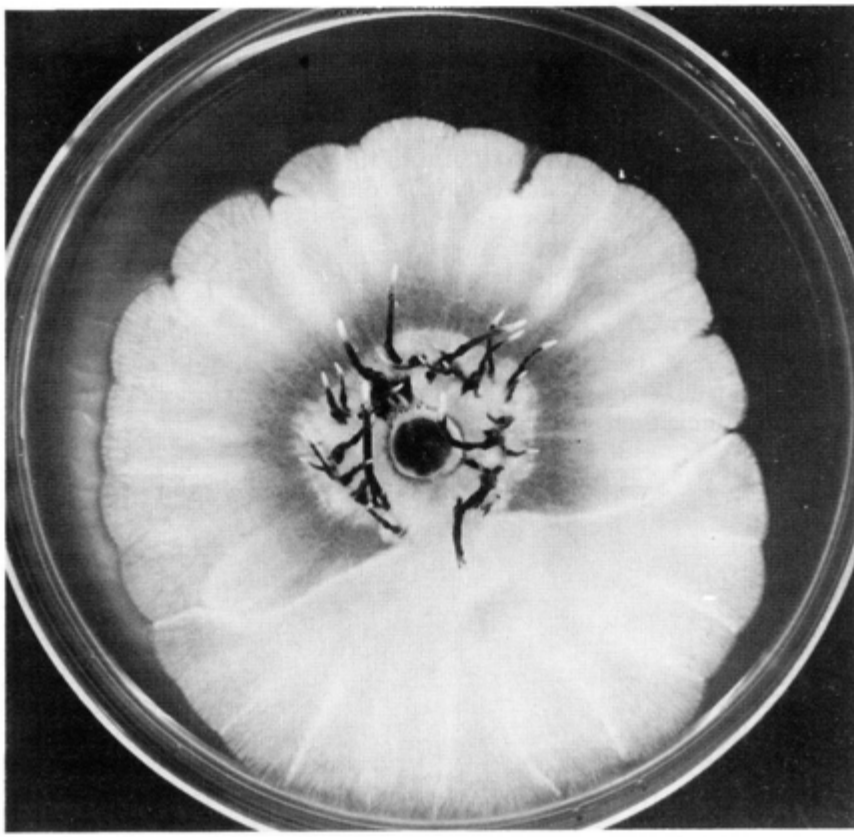

Fig. 6.4. Pure culture of *Xylaria hypoxylon* with darkly pigmented stipes. Diameter of Petri dish = 9 cm.

fertilizer have been applied to the plots and the amounts of nitrogen present in the biomass have been measured. As the fertilizer was enriched with ^{15}N, the biomass nitrogen derived from this source can be estimated. Preliminary results indicate that an increase in biomass carbon occurs during the early growth of the crop with a decline after 40 days from sowing. Biomass nitrogen increased for the first 70 days and then declined. The amount of nitrogen fertiliser applied had no apparent effect on the amounts of biomass carbon or biomass nitrogen during the early growth of the barley. Detailed analyses of all the experimental results have not yet been completed. These studies are in collaboration with the Department of Soil Fertility. 6027, 7039

Biomass sulphur is also being considered as a source of sulphur for crop growth. The levels of biomass sulphur present in some local soils are shown in Table 6.1 and it can be seen that sulphur extracted by phosphate and biomass sulphur are of a similar magnitude. Free sulphate, adsorbed sulphate and a small amount of organic sulphur are extracted by phosphate

Table 6.1 Total sulphur extracted with 0.016M NaH_2PO_4 compared with biomass sulphur in some local soils

Site	Soil Series	Sulphur extracted with Phosphate ppm	Biomass S ppm
Bailiesland	Boyndie	1.0	1.6
Conveth Mains	Laurencekirk	2.2	4.5
Fordoun Mains	Auchenblae	3.1	7.0
Upthank	Boyndie	4.7	3.8
Countesswells	Countesswells	12.2	6.4
Mosside	Tarves	13.1	10.5
Cross of Jackston	Foudland	19.0	9.3
Hill of Blair	Tarves	26.5	6.7

and soils are liable to be sulphur deficient when the concentration falls below 12 ppm. Sulphur in the biomass is probably more important in the first four soils in Table 6.1 than in the rest. Sulphur deficiency appears to have little effect on the ratio between biomass carbon and biomass sulphur. The mean biomass C:S ratio is 55 for the soils examined so far. Immobilization of sulphur has been studied following the addition of carbonaceous substrates to several of the soils listed in table 6.1. The microbial biomass was found to be sulphur-limited in Bailiesland, Conveth Mains and Unthank soils, but not in Countesswells soil.

The mineralization of sulphur from plant residues has been followed using ^{35}S labelled ryegrass shoots in a pot experiment. Labelled sulphur extracted with bicarbonate increased with time in the unplanted plots, but in the pots with ryegrass plants it decreased to almost undetectable levels. As the concentrations of labelled biomass sulphur were very similar in the planted and unplanted pots, the microbial biomass can probably compete successfully with the ryegrass plants for the mineralized sulphur. Further experiments on the mineralization of organic sulphur are in progress with the Department of Soil Fertility. No autotrophic thiobacilli have been isolated from local soils, but several heterotrophic sulphur oxidisers have been obtained from Countesswells soil. These isolates are mainly actinomycetes. 6027,7038

The role of the microbial biomass in the cycling of trace elements is largely unknown. The flush of trace elements, particularly manganese, after fumigation reported for Greenhall soil in the previous Annual Report has been detected in two other soils. With some elements (e.g. calcium) the size of the flush could not be equated with the anticipated concentrations in the biomass. 3007, 6027

Suitable methods are being developed for extracting a large proportion of the microbial population present in soil. The first stage of the extraction involves a gentle dispersion of the soil aggregates with the release of microbes from the soil surfaces. A wide range of surfactants are being tested for their effectiveness in releasing microbes from soil particles and for their toxicity to different groups of soil microorganisms. 6027

Soil Invertebrates. Further analyses of the food and faeces of the larvae of the common leatherjacket, *Tipula paludosa*, using infra-red

spectroscopy and ^{14}C labelled grass indicated that 50% of the cellulose and 90% of the hemicellulose ingested were digested by these insects. In addition, the crystallinity of the remaining cellulose was altered and most of the proteins were digested. These studies, which are in collaboration with the Departments of Mineral Soils, Soil Organic Chemistry and Spectrochemistry, are being prepared for publication.

1018, 3017, 4020, 6027

The commonest soil bacterium colonising the cuticle of the hind-gut of the wood louse (*Oniscus asellus*) was identified as *Enterobacter agglomerans* (see last Annual Report, p. 113). *Plesiomonas sp.* and *Pseudomonas* sp. were also present, but in smaller numbers. It is believed, however, that none of these bacteria were present in sufficient numbers to affect the metabolism of the hindgut. In short term experiments, a soil isolate, *Pseudomonas fluorescens*, grew less profusely on excised hindgut of *O. asellus* and it is suggested that this reflects the more effective adaptation of the resident microflora to the environment of the hindgut.[8] In contrast, the woodlice, *O. asellus* and *Porcellia scaber*, contain large numbers of bacteria in the hepatopancreas and these bacteria probably do influence the digestive processes. These bacteria are gram-positive non acid-fast rods ranging in length from 0.5 to 37.5 μm. In all the specimens examined, bacteria were present in the hepatopancreas of 47% *O. asellus* and 34% *P. scaber*. Further attempts are being made to identify these bacteria. Other preliminary studies with the woodlice suggest that their presence stimulates the number of bacteria, particularly the ammonifiers, and protozoa in the surrounding soil. These effects will be investigated in more detail in the future. 6027

In collaboration with the Departments of Mineral Soils and Spectrochemistry, the exoskeleton of *O. asellus* was found to consist of 45% calcium carbonate, 42% protein and 13% chitin. Some of the calcium carbonate was present in an amorphous form and the stability of this amorphous fraction was due to its association with protein and not to phosphates or silicates. Many chemical treatments of the exoskeleton, ecdysis or microbial decomposition resulted in the formation of calcite from the amorphous calcium carbonate. The results of these chemical investigations of the exoskeleton have been submitted for publication.[9] Infra-red spectra of the partly decomposed exoskeleton show weak absorption bands for protein and strong bands for calcite. Other chemical analyses by the Department of Soil Organic Chemistry indicated a loss of protein and an increase in galactosamine, probably due to components of bacterial cell walls. The significance of the protein and carbonate constituents for microbial decomposition was studied in soil samples amended with exoskeletons of *O. asellus* by comparing the effect of previously acidified exoskeletons with untreated samples. The exoskeletons were acidified with either hydrochloric acid or carbon dioxide. Over 14 days the total microbial respiration was reduced from 15.8 to 10.2 mg C when no carbonate was present in the exoskeletons and to 6.3 mg C when the protein was removed. The actinomycete population increased from 7.2×10^4 to 3.6×10^6 g^{-1} of soil when the soil was amended with exoskeletons of *O.*

asellus, but there were also large numbers of bacteria and fungi in the early stages of decomposition. Amendments of soil with powdered chitin from crustacea (Kodak P2064) did not stimulate microbial respiration in the first few days as is the case with exoskeletons of *O. asellus*. 6027

The relative effects of two bacteriovores, the ciliate *Colpoda steinii* and the nematode *Rhabditis* sp., on the flux of nitrogen and phosphorus from bacteria in soil are being investigated in the presence and absence of plants. In the presence of either white clover or perennial ryegrass, the numbers of ciliates increased far more rapidly than in unplanted soil and this effect may be due to root exudation stimulating the bacterial prey of the ciliates. Reproduction of the rhabditid nematode was inhibited by the ciliates in the presence and absence of plants. These preliminary results suggest that rapidly increasing populations of the ciliate increase the rate of nitrogen mineralization. Perennial ryegrass appears to be able to assimilate this extra nitrogen more readily than white clover. It has also been found that additions of glucose to soil can significantly reduce the losses of nitrate due to leaching. The glucose amendments stimulate the microbial population to multiply and assimilate any available nitrate in the soil. The optimal C:N ratio was found to be 10 and nitrate losses from pots of sandy soil, leached three days after the amendments, were reduced from 75% to 20% of the added amounts of potassium nitrate when glucose was added with the nitrate. Perennial ryegrass plants also assimilated more nitrate nitrogen when glucose was added with the nitrate amendments before leaching the soil than when nitrate was added alone before leaching. 6027

Peat Microbiology. In collaboration with the Department of Peat and Forest Soils, a paper dealing with the controlled water-table experiment at Lon Mor near Fort Augustus has been submitted for publication[10] and an abstract of a lecture on the same subject is in the press.[11] The fate of nitrogen fertilizer applied to grass leys on deep peat in Caithness is being studied in collaboration with the Department of Peat and Forest Soils. Preliminary observations on these leys suggested that the growth of grass early in the season showed little response to nitrogen fertilizers and no nitrate nitrogen was detected in the soil soon after the application of the fertilizer. Part of the area has been fenced off to prevent any grazing and all the area has received applications of phosphate and potassium fertilizers. Half of the plots have received applications of ammonium nitrate. Apart from monitoring the nitrogen gains and losses in the plots, cores have been removed from the plots for chemical and bacterial analyses. A large proportion of the bacterial population were ammonifiers, but no nitrifying bacteria have been found. There were also large numbers of nitrate reducing and denitrifying bacteria in the cores. The acetylene inhibition assay has been used to estimate the potential level of denitrification in these cores. As expected, the rate of denitrification was related to the water content of the soil. 2055, 6027

Microbiological Weathering. An invited lecture on 'biomineralization in crustose lichens' was given at a symposium on biomineralization in lower

plants and animals and a paper incorporating the data from this lecture is in the press.[13] Another review of the chemical activity of lichens on mineral substances has been published.[14] This second paper discussed the excretion of organic acid chelatants by lichen mycobionts. Both papers relate experimental results to the weathering of soil minerals and the subsequent release of important plant nutrients. 1061, 3005, 6028

Several other papers have been published. [12,15–21]The results were discussed in the previous Annual Report and in the current report for the Department of Soil Organic Chemistry.

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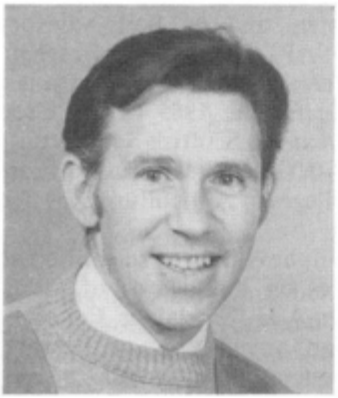
7. SOIL FERTILITY

D. ATKINSON



The overall objective of the Department is to increase understanding of the range of soil factors, chemical, physical and biological which influence the performance of crops. During the past year the balance of the Department's research programme has changed so as to interpret soil-nutrient-plant interrelationships in terms of the exploitation of soil by roots and the supply of nutrients and water to the root (or mycorrhizal) surface at the rate needed for either optimum crop growth or the development of quality produce, fodder or food. The practical aims of this approach are to improve the efficiency of fertilizer use, soil exploitation and soil management and to minimize any undesirable environmental impact. To maximize flexibility within the research programme and to allow for future research opportunities the Department is organised to progress both specific disciplines, e.g. soil chemistry, and more ephemeral multidisciplinary programmes; currently there are studies of the fate and effects of nitrogen, the growth of crops in rotations and the performance of crop root systems being progressed in this way. Achieving these objectives requires field, pot and laboratory investigations with a range of contrasting soils and the range of crops which are important to the agriculture of north Britain.

Advisory soil testing in collaboration with the North of Scotland College of Agriculture (NOSCA) continues to be a major activity for the department while during the year the number of cooperative trials with NOSCA have increased so that there are now active links with many departments in both the Crops and Agricultural Chemistry Groups. Increasing importance is placed on the attendance by departmental staff at both agricultural shows and agricultural and horticultural meetings. These are important channels for the dissemination of departmental research findings and are just as important in gaining information on practical problems needing research. The Department was represented at Cereal 85 and the Royal Show (both at the National Agricultural Centre, Stoneleigh, Warwickshire) with a technical note "Soil manganese and manganese deficiency in barley" prepared and distributed at both events[1]. This summarized for an agricultural audience information on the importance of regulating the manganese supply to crops.

Collaborative programmes of work with the Rowett Research Institute (RRI), currently on effects of feeding sulphur deficient and sufficient grass, the use of whole barley plants as an animal feed and the feeding of ammonia treated and untreated straw, have been extended. Both the scale and degree of cooperation with the Scottish Crop Research Institute (SCRI)

on the potato crop and its nutrient requirements have been increased.

Members of the Department are involved with the work of a number of committees, especially those linked to the MISR/COSAC Liaison Committee. Dr A.H. Sinclair is Chairman of the group's working parties on the Scottish Soil Fertility Information System and on Soil Advisory Analyses. Dr P.W. Dyson is Chairman of the SARI/COSAC committee on Maximum Yields and Yield Constraints of Cereals. Dr D. Atkinson was a Vice-Chairman of the programme committee for the 1985 British Crop Protection Conference - Weeds. During the year the Scottish Soil Fertility Information System was developed further with the first sets of data from the East of Scotland and West of Scotland Colleges of Agriculture expected in December 1985.

Department staff are increasingly involved in the editing of scientific and agricultural journals. Dr D. Atkinson serves on the boards of "Tree Physiology" and "Plant and Soil" while Dr A.H. Sinclair is Editor of "Norgrass". A book based on the proceedings of a symposium on the water relations of fruit crops edited by Dr D. Atkinson and Dr H.G. Jones of East Malling Research Station, was published during the year[2].

The turnover of younger staff and non-replacement of senior staff on retirement continues to be a matter for very serious concern and is a major restraint to research progress. During the year under review, Dr N.M. Scott, acting Head of Department April 1984 - January 1985, retired. Dr Scott was reponsible for showing the extent and significance of sulphur deficiency in Scotland and for devising methods for its control. Dr P. Wilson left to join Ferranti in Edinburgh and Dr S. Cooke to join Glaxo in Middlesex.

Crop Physiology and Nutrient Supply

Studies in crop physiology aim to understand the ways in which important mineral nutrients, which are usually added as fertilisers e.g. nitrogen and sulphur, influence crop growth and the quality of food or fodder produced.

Sulphur

Sulphur deficiency is a problem in the north of Scotland, because of low atmospheric and fertilizer inputs of sulphur and the small amounts of available sulphate in some soils. To obtain further information on the scale of the problem, the efficiency of potential treatments, the effect of deficiency on the quality of grain and fodder and the relationships between soil type/texture and response to added sulphur, field trials involving the application of sulphur to a range of crops have been continued in 1984/85. The results from a number of previous experiments have been published[3].

Effects on Peas. A pot experiment to examine the response of peas (Stegholt) grown on a low sulphur Boyndie Series soil gave an unexpected result. The lowest addition of sulphur (50 mg S/pot as K_2SO_4) sustained adequate growth and produced a 23% increase in the dry weight of peas. Sulphur deficiency caused premature maturation in the control plants

TABLE 7.1 The effect of the method of application of micronised elemental sulphur on the yield of rye grass (Mg (tonnes) ha^{-1}) grown at Conveth Mains, Laurencekirk

	1st cut	2nd cut	3rd cut	4th cut	TOTAL
Control (NIL S)	2.12	5.99	3.68	0.99	12.8
10 kg S ha^{-1} as thiovit (foliar at 1st cut)	2.17	7.03	4.28	1.02	14.5
10 kg S ha^{-1} as thiovit (soil applied in early spring)	2.60	6.45	4.14	0.95	14.1
10 kg S ha^{-1} $(NH_4)_2 SO_4$	2.15	6.67	3.98	0.95	13.8

resulting in a smaller number of pods. This behaviour is dissimilar to that of other crops, e.g. cereals and oilseed rape where sulphur deficiency resulted in delayed maturity and ripening of the seed. 7038

Effects on Grass. A pot study in 1984 with grass on a low sulphur soil demonstrated that micronised elemental sulphur (recommended as a foliar spray) could be effective as a nutrient source when applied directly to soil. This was tested under field conditions on grass grown on a Laurencekirk Series soil ('available' S = 4 ppm). Elemental sulphur, soil-applied in early spring when growth was minimal, gave a 22% increase in dry matter yield at the first cut. In contrast, a foliar application given as soon as growth was sufficient had no effect until the 2nd and later cuts. Averaged over the four cuts the two treatments were equally effective (Table 7.1). This suggests that even when used as a foliar spray, elemental sulphur may either be taken up by the plant through the leaves or by the roots following oxidation in the soil to plant-available sulphate. The results obtained in trials with grass suggest that root uptake may be important and elemental sulphur not absorbed by the leaves may still be recovered by the plant. The mechanism whereby elemental sulphur in a micronised form is assimilated through the plant leaf and by the roots is to be studied in 1986.

At the first harvest the application of thiovit increased the % dry matter from 13.9 to 14.9%. There was no effect of the foliar application or of an application of ammonium sulphate. At subsequent harvests effects were small. At the second and subsequent harvest an application of 20 kg ha^{-1} of thiovit gave higher yields than 10 kg ha^{-1}. 7038

Effect on Winter Barley. Two series of field experiments on soils of low sulphur status (Auchenblae and Boyndie Series) compared the effects of sulphur applied either as potassium sulphate or thiovit at 20 kg ha^{-1} at sowing or thiovit given half at sowing and half in spring. Treatment effects on both yields and % dry matter were small. 7038

Nitrogen/Sulphur Interactions. Studies carried out with oats in pots in 1983 suggested that the response to nitrogen could be limited in the absence of sulphur applications. During 1985, field trials were carried out at four low sulphur sites with winter wheat and at a further two sites with winter barley. At all sites combinations of eight rates of nitrogen (30 - 240 kg ha^{-1}) and two rates of sulphur (0 and 20 kg ha^{-1}) were compared. In the atypical

TABLE 7.2 The effect of the application of sulphur (kg ha^{-1}) on the response (Mg (tonnes) ha^{-1}) of winter barley grown at Fordoun to nitrogen (kg ha^{-1})

Sulphur	Nitrogen rate							
	30	60	90	120	150	180	210	240
0	4.3	5.9	5.7	6.0	4.9	4.4	4.8	5.1
20	4.1	5.7	6.0	5.9	6.0	4.8	4.3	4.4

conditions of 1985 effects of sulphur were small, e.g. at Rothienorman averaged across all the nitrogen treatments 20 kg ha^{-1} S increased yield from 3.15 to 3.40 Mg (tonnes) ha^{-1}. Although there was no clear evidence of high nitrogen reducing yields in the absence of sulphur, at one of the winter barley sites a decrease in yields associated with nitrogen rates above 150 kg ha^{-1} was more pronounced where sulphur was also being added (Table 7.2). 7038

Effects on Grass Quality. An experiment was initiated on an Auchenblae soil, a red fluvioglacial sand and gravel, to assess the effect of thiovit and ammonium sulphate on grass quality. On this site both forms of sulphur increased yields, thiovit before each cut from 13.0 Mg (tonnes) ha^{-1} to 14.6. Herbage from the third cut was used to study the effect of this level of sulphur deficiency on the proportions of the different nitrogenous constituents. There was a decrease in the proportion of nitrogen recovered as amino acids and an increase in the concentration of asparagine. Amino acid analysis showed that the concentrations of the sulphur-containing amino acids cystine and methionine were depressed by sulphur deficiency, as well as those of arginine, histidine, lysine, glycine, leucine, serine and threonine[3,4]. Sulphur deficiency, therefore, decreased the nutritional quality of the crude protein in the grass. The effect of the sulphur treatments on the quality of the grass as a forage was further investigated by studying its digestibility in collaboration with RRI. Changes in digestibility resulting from sulphur deficiency can be due either to changes in plant composition or to the ability of the rumen to degrade fibre when sulphur is limited. To distinguish between these effects, nylon bag digestibilities were measured using sheep previously fed either sulphur deficient or sufficient grass. Initial results (Table 7.3) show that sulphur-deficiency increases the digestibility of

TABLE 7.3 The effect of sulphur deficiency on the digestibility of grass measured in the rumen of sheep previously fed sulphur sufficient or deficient grass

	Digestibility (% DM) of:	
	S-sufficient grass	S-deficient grass
Sheep feed:		
S-sufficient grass	67.8	77.7
S-deficient grass	65.2	69.4

the grass, irrespective of the sulphur status of the rumen. This most probably results from a change in the relative proportions of leaf and stem material. However, sulphur limitation also reduced the capacity of the rumen to digest grass. The net effect of this being that the resulting digestibility of sulphur sufficient grass in a sulphur sufficient rumen was very similar to that in the corresponding deficient situation. This relationship is currently being confirmed, and the digestibility of individual

amino acids measured in order to assess effects of sulphur limitation on amino acid availability. 7047

Nitrogen

Effects on Potato Yield and Quality. Nitrogen fertiliser application can potentially affect the yield of potatoes through influencing any of four processes. These are: light interception, conversion of intercepted light to dry matter, partitioning of dry matter to tubers, and regulation of the dry matter content of tubers. In collaboration with SCRI, data from two years field experiments, in which crops were grown with nitrogen applications ranging from 0-250 kg N ha^{-1}, have been modelled. The results show that the primary effect of nitrogen in increasing tuber yields is by increasing light interception (particularly by accelerating the rate of canopy expansion). There were no measurable effects of nitrogen on photosynthetic performance. Mean values of 1.25 and 1.37 g MJ^{-1} in 1983 and 1984, respectively, were recorded. Similarly, nitrogen had no effect upon the dry matter content of tubers. It decreased the proportion of dry matter partitioned to the tubers during the initial phase of tuber bulking.

Potato plants can take up more nitrogen than is needed to satisfy their immediate requirements for growth. This 'luxury' nitrogen is partitioned between the canopy and the tubers. The nitrogen concentration found in the tubers decreased during the first four weeks of tuber growth then remained constant, at a level determined by the rate of nitrogen applied[5]. Analysis of the concentrations of the different amino acids in tubers showed that the increases in tuber nitrogen concentrations, in response to nitrogen application, had no effect on the partition of total nitrogen between the different amino acids. This is important because tuber protein is of a very high nutritional quality. It is rich in lysine, the nutritionally limiting essential amino acid in cereals. Nitrogen application up to 250 kg ha^{-1}, greater than that required for maximum tuber yields, increased protein yields without adverse effects on nutritional quality[5].

Unless very large dressings of nitrogen are applied (>200 kg N ha^{-1}) 'luxury' nitrogen is partitioned equally between the tubers and the canopy. Thereafter, proportionally more of the total nitrogen taken up by the crop is recovered in the canopy. This "luxury" nitrogen occurs as nitrate in the lower, shaded, leaves and reduced nitrogen in the upper leaves[6]. 7047

Radiometry. Potato crops grown with a full range of nitrogen treatments have continued to be used in collaboration with the Department of Peat and Forest Soils to assess the potential of radiometry in monitoring crop growth and development. Although there are very high correlations between ground cover and reflectance measurements with the radiometers used, there is an interaction between nitrogen nutrition and reflectance. This seems to be due to the increase in leaf chlorophyll concentration, found with increasing nitrogen supply. A method for the automation of colorimetric chlorophyll measurements, using photon-attenuation in a liquid scintillation counter, has been developed[7] to make practical the large number of measurements needed to relate chlorophyll and reflectance. 7047

Use of ^{15}N-Materials. In order to better understand nitrogen partitioning in the crop, a method of applying ^{15}N labelled nitrogen as a 'pulse' to field grown plants has been developed. This method allows the capacity of plants to use both stored nitrate and protein to sustain growth when under diminished soil nitrate supply to be determined. Very high (3×10^{-11} mol cm^{-1} s^{-1}) inflow rates have been measured, even when compared with published values obtained under 'ideal' laboratory conditions[8]. This method will be used again in an experiment in 1986 to allow the effects of different fertilizer N applications upon local, short-term inflow rates to be examined. The measurements made to date have allowed an initial assessment of the partitioning of nitrogen taken up at two stages of crop growth. 7047,7039

^{15}N labelled nutrients have also been used in an investigation of the efficiency of the use of fertiliser nitrogen. Two rates of nitrogen (80 and 120 kg ha^{-1}) were applied in four different ways: a) all at planting, b) all at tuber initiation, c) half at planting and the rest either at tuber initiation or d) half at planting and the remainder as foliar sprays of urea throughout the season. The use of ^{15}N enriched fertiliser will allow measurement of the amount and fate of the fertiliser nitrogen used by the crop. 7047

Whole Crop Harvesting of Spring Barley. Collaborative work with RRI has assessed the potential for whole crop harvesting of spring barley for use as animal feed. Digestible dry matter production by the whole crop has been measured from the time of maximum crop biomass to final harvest. Nitrogen applications increase crop biomass but reduce the concentration of non-structural carbohydrates in the straw. Crops grown with four rates of nitrogen application were assessed. Nitrogen application decreased the straw dry matter digestibility at each harvest. Comparison of straw soluble carbohydrate concentration (C) and dry matter digestibility (D) gave a linear relationship with a line equation of $D = 0.988C + 37.53$, and a correlation coefficient of 0.926 which confirmed that changes in straw digestibility in response to N were primarily due to changes in soluble carbohydrate concentrations. The dry matter digestibility of the ears was unaffected by date of harvest or nitrogen. The total crop digestible dry matter production was therefore calculated for successive harvests of crops grown in three years. The results showed that the total content of digestible dry matter did not increase during the five or six weeks preceding "maturity". In addition, comparison of total digestible dry matter production obtained at the start of the grain filling period, when straw soluble carbohydrate concentrations were maximal, with those of the ears alone at final harvest, showed that substantial increases in digestible dry matter production could be achieved by feeding the whole crop to stock. This would also allow less N to be applied[9]. This approach could reduce both the potential pollution problem resulting from high N applications to cereals and the problems related to the disposal of cereal straw. 7047

Rate Responses in Winter Barley. The cost of nitrogen fertilizers is such a major component of the total variable costs of cereal production that it remains essential to understand factors influencing cereal responses to different rates and timings of applications. The response to nitrogen by

TABLE 7.4 The effect of rate of nitrogen application on the yield of winter wheat in 1985

Fertiliser, N kg ha^{-1}	30	60	90	120	150	180	210	240
Grain yield, Mg (tonnes) ha^{-1}	2.0	2.4	2.3	2.6	4.2	5.9	6.3	5.0

winter barley was examined in a series of 26 experiments carried out in the period 1981-1984. The mean optimum for soils of moderate/low N status was 180 kg N ha^{-1}. This conclusion has been incorporated into current NOSCA/MISR fertiliser recommendations although some concern remains as this conclusion related to results from 4 relatively dry, storm-free years when lodging was not a major problem. Trials continued at a reduced level in 1984-85 with the abnormally wet 1985 season providing a more than adequate test of crop response under adverse weather conditions. Yields were poor, ranging from 5.4 to 7.0 Mg (tonnes) ha^{-1} at optimal N inputs. The form of the yield/N input relationship was consistent with the "split-line" function previously described. Two trials which tested 8 N levels from 30-240 kg N ha^{-1} gave maximum yields with 120 and 240 kg N ha^{-1}; neither trial suffered severe lodging except the former at 210-240 kg N ha^{-1}. 'Brackling' (stem break) was very severe, resulting in considerable cutter bar losses at combining. Similar effects occurred in a trial which compared 4 rates of N with 4 application dates for the growth regulator cycocel. "Brackling" was severe in this trial although cycocel produced a marked improvement in straw strength with consequent increases in combined grain yield. With cyclocel the highest yield was attained with 120 kg N ha^{-1} but with 80 kg in its absence. A paper describing the results of earlier trials in this series has been published[10]. 7041, 7048

Rate Responses in Winter Wheat. Five trials in 1985 examined the response of winter wheat to fertiliser N although the adverse weather conditions resulted in serious problems with disease control, lodging and harvesting. Yields were poor, 5.5 to 7.5 Mg (tonnes) ha^{-1} for optimum N inputs from 150-240 kg N ha^{-1} and a mean optimum N requirement of 180 kg N ha^{-1}. Two of the trials were subject to severe attacks of *Septoria nodorum* which was well established before ear emergence. Persistent rain hindered satisfactory control. In one of these trials infertility, resulting in very low grain numbers per ear, was a problem. This may have been related to the *Septoria* and was very markedly affected by fertiliser N. At low N levels yields were poor (Table 7.4) and showed little response to N up to 120 kg ha^{-1}. There was a remarkable improvement in grain set and yield as N inputs increased from 150 to 240 kg ha^{-1} although substantial losses were associated with the early lodging which occurred at 240 kg N ha^{-1} (Table 7.4).

A multifactorial trial compared six N levels (90 to 240 kg N ha^{-1}) of urea and ammonium nitrate and single compared to split applications of N. Maximum yield was attained with 240 kg N. There were no significant effects of either the form or timing of the N application. This is of particular interest in view of urea's substantial price advantage although this has been offset by fears of crop damage and denitrification.

Observations on these trials and on other crops in the area suggest that yields of at least 7 to 8 Mg (tonnes) ha^{-1} are attainable even under adverse conditions, provided suitable varieties are used and there is effective disease and lodging control. None of these trials showed a yield/N input relationship of the split-line type which had consistently been found for both spring and winter barley. Preliminary tests suggest third order polynomials as giving a reasonably satisfactory fit. This form will be compared with other models. 7041,7048

Timing of Nitrogen Uptake. Studies of crop growth and nutrient uptake carried out on the major arable species grown in Scotland have enabled comparisons between crops. Figure 7.1 illustrates the changes with time in total plant dry matter (DM) and total nitrogen uptake (N) expressed as percentage of their values at maturity. The examples used are a winter barley crop producing 18.5 Mg (tonnes) DM ha^{-1} and taking up 250 kg N

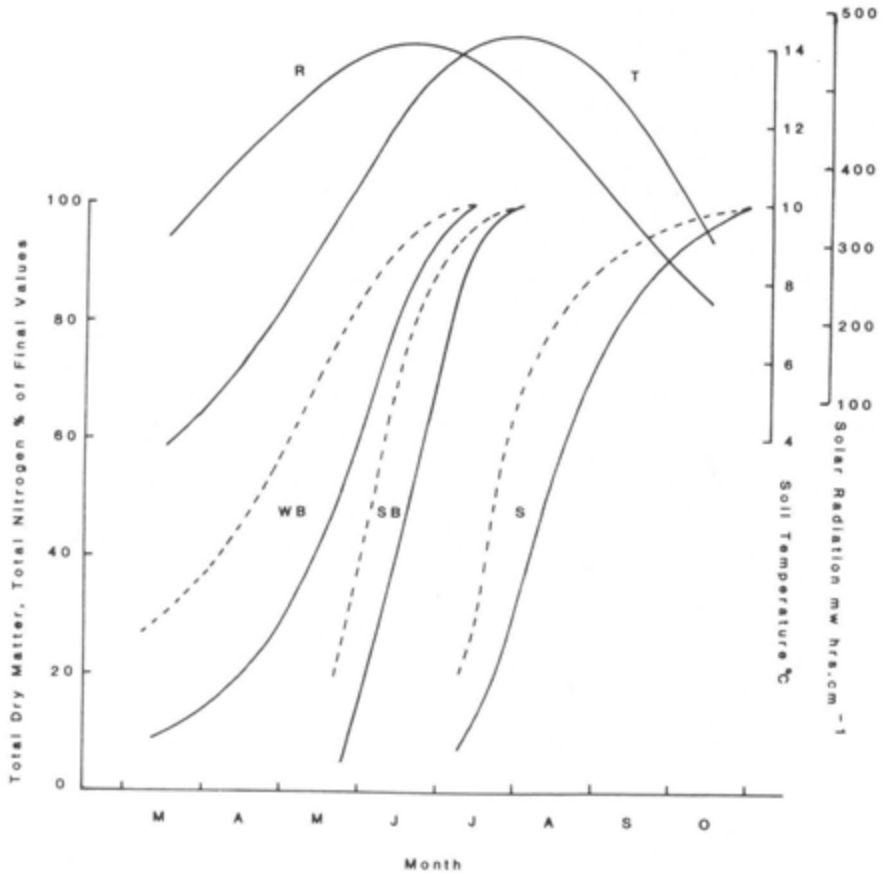


Figure 7.1. Changes with time in: soil temperature (T), °C, 30 cm depth under short grass; solar radiation (R), mw hrs. cm^{-1}; total dry matter (full lines) and total nitrogen uptake (broken lines), expressed as % of final harvest values, for winter barley (WB), spring barley (SB) and swedes (S).

ha^{-1} compared with spring barley, 13.7 Mg (tonnes) DM ha^{-1} and 170 kg N ha^{-1}; and swedes, 11.0 Mg (tonnes) DM ha^{-1} and 200 kg N ha^{-1}. Nitrogen content, as a proportion of total dry matter invariably decreases with age. This leads to a relatively high demand for N in the early stages of growth and maximum rates of N uptake preceding the attainment of maximum growth rates. In the examples shown, each species had taken up 45-50% of their final N uptake by the time they had attained 10% of final dry matter yield.

The mineralisation of organic soil nitrogen reserves is temperature dependent and very limited in March and April when the soil temperature is below 6°. Later sown crops have a much greater opportunity to utilise this resource and are less dependent on artificial supplements. As a result, without fertiliser N, winter barley produces only 40% of its maximum yield compared to 66% for spring barley and 92% for swedes. In addition cereal development is closely related to temperature. Winter sown cultivars develop more slowly in the lower spring temperatures to which they are exposed and have a longer growth period. Winter barley for example takes 70-90 days to accumulate 80% of its total dry weight (from 10% to 90%), while for spring barley this interval is only 45-50 days. Spring barley accumulates most of its dry matter during the period of maximum incoming solar radiation, late May to early July, and growth rates in excess of 250 kg ha^{-1} day^{-1} have frequently been recorded. The periods of most rapid potential growth in winter barley (late March to late June) and swedes (mid July to October) are before and after the peak of solar radiation inputs, respectively, and so their growth rates seldom exceed 200 kg^{-1} day^{-1}.

The Use of Ammonia-Treated Vermiculite. The field experiment in collaboration with the Department of Spectrochemistry to compare the relative effectiveness of nitrogen supplied to grass from ammonium nitrate and ammonia treated vermiculite has continued. In 1985 the first cut of grass showed no effects on yields or per cent dry matter as a consequence of treatment.

Models of Uptake. Increasingly, mathematical models are being used in the interpretation of soil and crop interactions. A simple model has been developed which relates plant growth rate and dry matter partitioning between roots and shoots to rates of N uptake and carbon assimilation[11]. The model indicated that there is an optimum root-shoot ratio at which relative growth rate is maximal, but that this optimum varies with the average N uptake rate and, hence, soil N availability. Attempts to model factors that regulate soil N availability are to be made in 1986, in relation to N use by a potato crop. 7039

Calcium

Calcium deficiency can cause apical necrosis of potato sprouts during chitting. Collaborative work with SCRI developing methods of labelling tubers with ^{45}Ca, followed by autoradiography and chemical fractionation experiments to study the mobilization of calcium have now been completed. The results have been prepared for publication[12]. 7047

Soil Chemistry

The aim of this programme is to understand the soil chemical factors which influence the supply of both native and applied (fertilizer) nutrients to the soil solution around the crop root system and their equilibration with the soil mineral content.

Nitrogen

Nitrogen is the only major nutrient element whose need cannot be predicted by soil analysis. This is partly a consequence of our poor understanding of the relative importance of fertiliser nitrogen and nitrogen mineralized from organic nitrogen sources which themselves depend on previous cropping patterns and nitrogen fertilizer applications.

Transformations in Soils. The number of ^{15}N samples analyzed in 1985 was limited by several major faults on the Institute's ^{15}N mass spectrometer and to date, no samples from the 1985 season have been processed.

Preliminary data are available for the levels of fertilizer ($^{15}NH_4$ $^{15}NO_3$) and soil N in the 1984 season of the long-term spring barley/grass rotation experiment at Cross of Jackston (Annual Reports No. 53, p.105; No. 54, p.118). In 1984, a dry year: (a) levels of available N (nitrate and exchangeable ammonium) declined to approximately the same values 5-6 weeks after application, and remained low thereafter, irrespective of the rate of fertilizer application; and, (b) the rate of incorporation of fertilizer N into the 'unavailable' pool (organic N and non-exchangeable ammonium) seemed to be related to the rate of fertilizer application. As crop samples are still being analyzed, a complete balance sheet for N in this system is not yet available. This experiment was continued in 1985, and attempts were made to estimate the incorporation of ^{15}N into the soil microbial biomass (with project 6027). 7039

Selenium

Selenium deficiency in livestock, resulting from its poor absorption into herbage, continues to be a problem of some economic importance. In the acid soils common in north Britain the dominance of the selenite form and its tight binding to the soil mineral fraction mean that no good soil test for selenium status exists. Current experiments aim to understand its dynamics in the soil and develop means of increasing uptake by fodder crops.

Effects of Additions. Studies on the use of sodium selenate immobilised on pumice granules to give a slow release form of Se have continued. The experiment begun in 1984 (report for 1984 p.122) using a Countesswells soil (granite and granitic gneiss) has been continued with the nitrogen applications of 0 and 100 kg N ha^{-1} as nitrochalk repeated but the 0.01 and 0.03 kg ha^{-1} Se treatments omitted in 1985. This should allow the residual effects of the application of the pumice granules on the soil status and grass crop uptake of Se to be assessed.

Interactions between selenium application, as sodium selenate immobilized on pumice, and soil type are being investigated in three trials begun in 1985 on contrasting soil types; Countesswells (granite and granitic gneiss), Foudland (slate and argillaceous schists) and Shields (Lower Old Red Sandstone sediment, mainly conglomerate with some lava). The results from these sites should show whether there is a variation in uptake of Se due to soil type. 7046

Phosphate and Potassium

The effects of additions of these major nutrients on crop growth and soil dynamics is being investigated (in addition to nitrogen) at the long term field site at Cross of Jackston (Report for 1984 p. 118) although staff shortages following the resignation of Dr B.W. Bache have limited the level of activity. The field experiment on Craigiebuckler field begun in 1965 to study the effects of combinations of rates of N, P and K on grass has been continued. Interactions between the elements continue to be found.

Trace Elements

Deficiencies of trace elements continue to affect the growth of both major crops, e.g. cereals, oilseed rape, and, as a consequence of low concentrations in fodder, livestock. The current programme aims to improve the diagnosis of deficiency by using soil analysis to investigate the responses of crops to additions and to understand soil factors affecting mobilisation into the soil solution.

Concentrations in Oilseed Rape. There is very little information for the U.K. on micronutrient concentrations in, and the removal of nutrients by, oilseed rape. The effects of soil pH on the micronutrient concentration in oilseed rape at different stages of growth are given in Table 7.5.

TABLE 7.5 The concentrations of micronutrients found in oilseed rape

		g Mg (tonne)$^{-1}$			
		Growth stage		Harvest	
pH at sowing		1.05	3.3	Straw	Seed
4.8	Mn	46.3	71.0	50.4	36.9
	B	11.2	32.9	7.4	7.0
	Cu	9.3	8.3	-	3.8
	Zn	80.5	74.0	74.3	44.8
5.5	Mn	14.0	50.0	22.9	35.1
	B	12.6	38.7	8.1	7.0
	Cu	9.4	7.3	-	3.8
	Zn	49.4	54.2	15.0	35.7
6.2	Mn	10.0	40.1	17.2	32.7
	B	17.4	28.0	7.7	6.8
	Cu	9.8	7.3	-	4.3
	Zn	44.3	45.8	11.7	36.7

With the exception of the seed, manganese and zinc tissue concentrations decreased with increasing pH at sowing. The tissue concentration of manganese at GS 1.05 and the amount of manganese extractable from soil

TABLE 7.6 The amounts of micronutrients removed by oilseed rape at harvest (Mean values for seven sites, g Mg (tonne)$^{-1}$

		Mn	B	Cu	Zn	Fe
Straw	Mean	22.3	11.5	3.2	7.2	45.7
	Range	15.8-35.4	6.7-15.3	2.8-3.7	5.3-13.7	39.5-51.7
Seed	Mean	42.7	9.4	4.2	28.8	72.7
	Range	32.2-51.6	7.3-11.0	3.8-4.5	25.3-37.0	62.8-80.5

with 0.01M $CaCl_2$ were closely correlated ($r = 0.93$; $P < 0.001$). Manganese concentrations were higher at GS 3.3 compared to 1.05. This may have resulted from the transient decrease in soil pH which occurs after ammonium nitrate fertilisation, giving a corresponding increase in soil manganese solubility. Similar changes in zinc tissue concentrations did not occur probably as a reflection of the more stable oxidation state of zinc compared to manganese. Tissue concentrations of boron and copper were not related to the soil pH at sowing. Boron concentrations at GS 1.05 were correlated with the boron which could be extracted with boiling water from dry soils ($r = 0.74$; $P < 0.01$). Boron concentrations at GS 3.3 were higher than at 1.05, again probably due to transient acidification. A soil value of 0.5 mg B kg^{-1} was associated with boron tissue concentrations of 15 mg kg^{-1} at GS 1.05 and 30 mg kg^{-1} at GS 3.3. Where soil boron is less than 0.5 mg kg^{-1} an insurance application of boron seems to be advisable.

Seven oilseed rape crops were monitored during the 1984/85 season, and the amounts of micronutrient removed by the crop at harvest estimated (Table 7.6).

Mobilisation of Micronutrients. The accuracy of prediction of the availability of micronutrients to plants on the basis of chemical extraction from soil samples taken prior to sowing may be poor. Factors responsible are being investigated in collaboration with the Department of Soil Organic Chemistry. Data showing changes in the concentrations of manganese, zinc and copper in soil solutions from the rooting zone of spring barley have been published[13,14]. This work has now been extended to include winter barley and to assess the mobilisation of copper following cultivation into the seedbed of 10 kg ha^{-1} of copper oxychloride. Copper concentrations in the soil solution of root exploited soil remained low in both treated and untreated plots throughout the winter and into April. The concentrations reached a maximum in May, during rapid growth of the crop. Copper concentrations in the soil solution following soil copper treatment were greater and persisted at this increased level for longer. At harvest concentrations in the two treatments were similar and low. The grain yield was 5.68 Mg (tonnes) ha^{-1} following soil treatment and 5.44 Mg (tonnes) ha^{-1} following a foliar application of 1 litre of liquid copper oxychloride (25% Cu w/v). This different seasonal pattern of nutrient mobilisation in spring barley (in winter barley mobilisation of copper and manganese occurred in early July) shows the major role played by the crop in solubilising micronutrients. This programme of work has now been extended to oilseed rape, grass and clover. A fine powder containing 5% manganese and 1.2% copper in the form of oxide and metal particles was cultivated into the seedbed of a manganese deficient site. In this case

mobilisation of manganese and copper in the rooting zone of spring barley was not increased above the control, and grain yield was unaffected.
7041,4803

Effect of Straw Incorporation. A project to study the effect of straw incorporation on nutrient release, root system development and soil structure has been initiated in conjunction with the Soil Science Department of Aberdeen University and Department of Soil Organic Chemistry. A combination of laboratory and field studies will be employed to model straw decomposition in soil under the conditions which pertain in north Britain so as to predict short- and long-term consequences of incorporation, and to identify management practices which may alleviate adverse consequences of incorporation. 7044,7041,4803

Soil Physical Properties and Crop Root Distribution

Effects of Irrigation and Nitrogen on Potato. The effect of irrigation on root growth and distribution in potato was examined in collaboration with SCRI. Two rates of irrigation were specified and the soil water content was monitored throughout the 1985 growing season using a neutron probe. As a consequence of the wet 1985 season water availability did not differ between treatments. Data was accumulated, however, on rates of root growth and the basic pattern of distribution. It is intended to repeat this experiment in 1986, but using portable rain shelters to ensure contrasting soil moisture conditions. A preliminary investigation was made in 1985 of the effects of different nitrogen applications on root growth which will be extended to record effects on both root extension and nitrogen uptake as part of the Department's interdisciplinary nitrogen programme.

Effects of Cultivation on Winter Barley. The effects of normal ploughing, shallow ploughing, discing and rotaspiking on both root development for winter barley and on soil strength and bulk density were measured. Early in the season root and shoot growth were greatest under normal ploughing although at the end of the season yields were similar under the 4 treatments. The differences in root growth observed early in the season were related to the resistance to a soil penetrometer. Normal ploughing showed the lowest resistance to the penetrometer and the most prolific root distribution. There is clearly a need to relate root system development to crop yield and to define the cereal root system in functional terms.

Root Distribution and Water Table Depth. In collaboration with the Department of Soil Survey the effect on crop performance of a proposed lowering of the depth of the water table in the valley of the River Spey has been assessed. The basic approach has been to 1) assess the potential of the water table to contribute to crop water use, comparing the distance between the base of the effective root system and the water table, now and following the proposed extraction, with data on the distances over which upward capillary water movement can occur, 2) relate estimated crop water needs (allowing for rainfall) to the amount of plant available stored water in the profile as a means of assessing the need for a capillary water supply and 3) where available soil moisture/potential transpiration data suggest a need, to

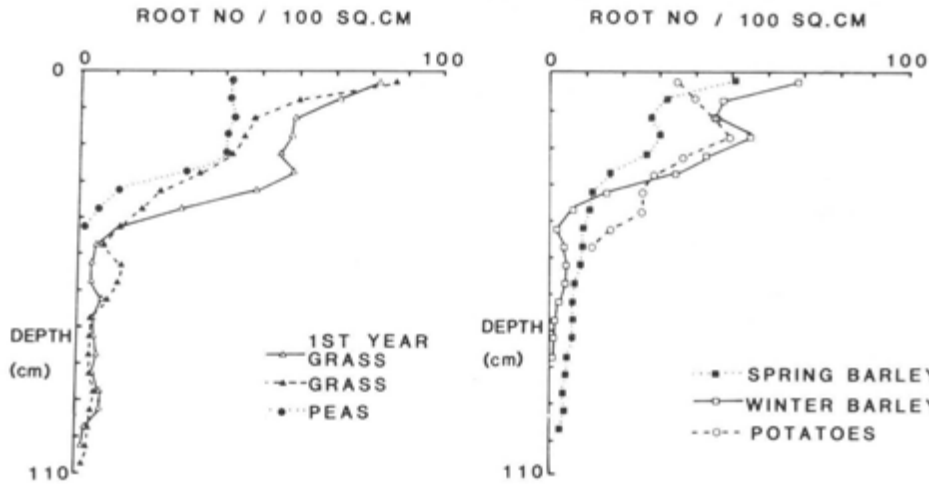


Figure 7.2. Root distributions of several crops in 1984

assess whether the plant root system/soil texture/water table combination which occurs makes a supply possible now and whether this situation will be changed following extraction.

Root distribution, for a wide range of crops was studied in the Spey Valley floodplain. During the two years, 1984 and 1985, grass roots were both prolific at the surface and grew more deeply than any of the other crops studied (100-120 cm). Winter barley and spring barley both grew to

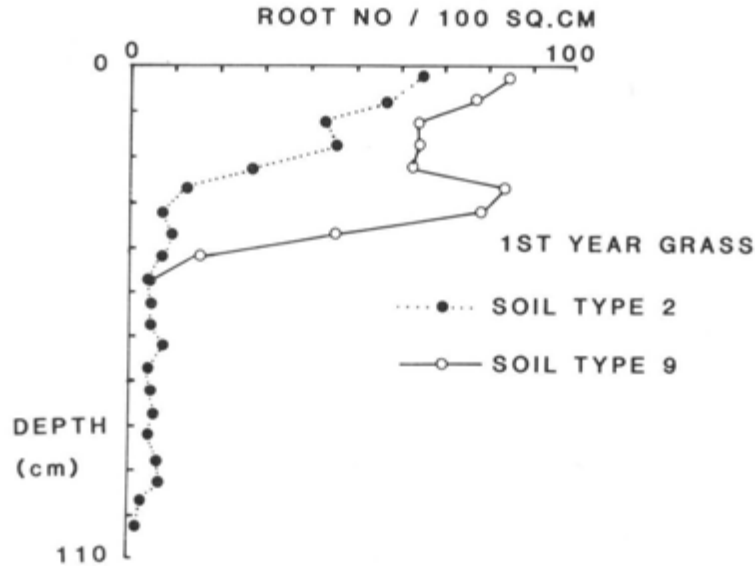


Figure 7.3 Effect of soil type on crop root distribution

80-100 cm and potatoes and peas to only 50 cm (Figure 7.2). All the pits which were used to assess root distribution, using the profile wall method, were also classified for soil texture. Root depth was related to soil type, e.g. root penetration was deeper on fine sandy loam soil (soil type 2) than on the sand and gravel soils (soil type 9) (Figure 7.3). Water use was measured using the neutron probe for the range of crops. In 1985 the soil remained close to field capacity during the whole growing season. It was therefore not possible in this year to relate crop water use to root distribution. Under grass and cereals water supply from the water table seemed possible on some of the soils but only in dry years did this supply seem necessary. 7044

Effects of Compaction. Using pea as a model crop a study on the effects of compaction on crop emergence and root growth has been initiated. Soil cores varying in unconfined compressive strength (0.1-0.8 kN) and water potential were compared. Emergence and root growth on a sandy soil of the Boyndie Association was little affected by compaction but on a fine textured soil of the Laurencekirk Association emergence was considerably reduced, and root growth stunted, even at low levels of compaction. Percentage seedling emergence was related to soil strength as determined with a needle penetrometer. It is aimed to extend the study to include the effects of aeration, soil moisture content, stone content and a wider range of soil types. Two papers describing methods for assessing soil structure have been published[15,16]. 7044

Effects of Growth Regulators. Plant growth retardants, especially triazole based materials affect the extent and distribution of the plant root system and the needs of the plant for water and mineral nutrients. A paper reviewing the consequences of these effects for root system functioning has been published[17]. These studies are being extended to assess longer term consequences. 7044

Soil Condition and Disease. The development of soil-borne plant diseases can be influenced by soil physical condition especially as a consequence of structural and management effects on soil water potential. 7044

Powdery Scab of Potatoes. The effects of deep loosening and normal ploughing on the incidence of powdery scab and on root distribution were studied in 1985 in collaboration with NOSCA. The experiment was replicated on two contrasting soil types, an imperfectly drained fine sandy clay loam of the Ordley Association, and a freely drained fine sandy loam of the Foudland Association. Considerable differences in crop performance were found between these common and important soil types; on the latter there was more rapid ground cover, a higher yield and a deeper root distribution. There was little difference between the soils in the incidence of disease which was low on both soils.

The method of assessing root distribution under the two soil types is shown in Figure 7.4. 7044

Development and Advisory Work

Advisory Analysis. An agreed common system for advisory soil analyses and for the interpretation of results for both macro and micro nutrients has

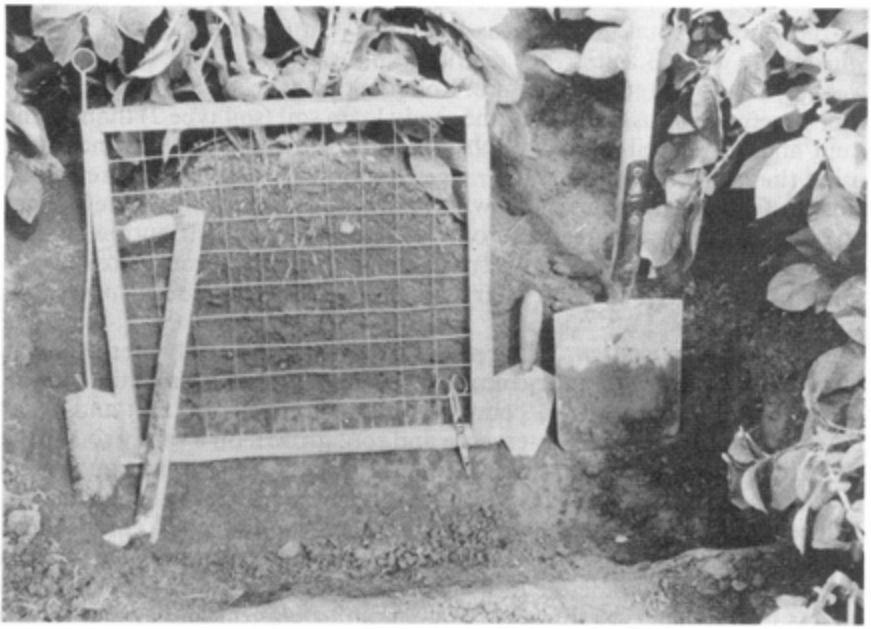


Figure 7.4. Potato root system and equipment used for the trench profile method of root counting

been introduced in the Institute and at the three Scottish Agricultural Colleges[18]. Soil pH will be determined in 0.01M calcium chloride solution, P, K and Mg extracted in 0.43M acetic acid, B in boiling water, Co in 0.43M acetic acid, Cu in 0.05M EDTA (adjusted to pH 7 with NH_4 OAc), and Mo in 1M neutral ammonium acetate.

In 1985 8750 advisory soil samples were processed for NOSCA. Sulphur was determined in 1600 of these samples, boron on 360 and over 1300 samples required the determination of combinations of manganese, copper, cobalt and molybdenum. Forest soil samples, from throughout the U.K., sewage sludge samples from Grampian Regional Council and herbage samples associated with poor crop growth or animal problems were also analysed.

Demand for Analyses. More than 360 fields have been analysed during the year for soil B content; previously the demand for B analysis had been very low. The increase is due to the increase in the hectarage of oilseed rape between 1983 and 1985. Analytical determinations are greatly aided by the use of ICP. A greater awareness in the farming industry of potential micronutrient deficiencies has been reflected in an increasing demand for Cu, Co and Mo. Currently a separate soil extract is used for each element but a method assessing Co and Mo in a combined extract has been developed. This places soils into similar status categories to the current method[19] but reduces laboratory time when both elements are needed. A report on practical aspects of maintaining a balance of trace elements in arable farming has been published[20].

Soil Fertility Information System. The computerised Soil Fertility Information System (SFIS) for Scotland (Annual Report Nos. 53 and 54) based at the Institute was introduced at the beginning of 1985. At the end of 1985 core data from the East and West Colleges will be sent to the Institute for processing on a Scottish basis. Summary tables of soil acidity and nutrient levels under different farming systems and geographical locations will be produced. The system is based on analytical results of soil testing and associated field data and at the Institute computerisation began in 1980. Using this data bank, and results on micronutrient levels obtained over a 25 year period, a report on the fertility of the soils of Orkney has been prepared[21]. A report using SFIS has been published[22]. 7043

Fertilizer Recommendations. A Scottish bulletin detailing fertiliser recommendations has been prepared by the Institute and staff from the three Scottish Colleges[23]. This is the first bulletin to cover the range of arable crops grown throughout Scotland, and was made possible by the harmonisation of advisory soil testing methods and interpretation. Reports have been produced on the efficient use of soil and fertiliser phosphate[24] and the need for sulphur fertilisation based on soil S levels[25,26]. 7041

Use of Mixed Anion/Cation Resins. A mixed cation-anion exchange resin has been tested for its ability to extract "available" P from soils and predict P fertilizer needs. Soils from five soil series, Tarves (mixed acid igneous, acid metamorphic and basic igneous), Insch (basic igneous), Laurencekirk (Old Red Sandstone), Countesswells (granite and granitic gneiss) and Foudland (slate and argillaceous schists) were assessed. The results with this resin for these soils is being compared with the amounts removed with other soil extractants, i.e. 0.5M acetic acid and 0.5M sodium bicarbonate and the response of a swede crops to added phosphate. 7041

Radioisotope and Other Services

Radioisotope Use. Radioactive isotopes continue to be used extensively throughout the Institute. ^{75}Se is being used as a tracer to develop an analytical method for selenium. ^{54}Mn is used with various labelled chelating agents to investigate the uptake of manganese while uptake and transport studies with ^{58}Co and with the short lived isotope ^{54}Cu (12.8 hours) continue as part of the Department of Plant Physiology's trace element programme. The use of ^{45}Ca labelled nutrient for study of calcium related disorders in brussels sprouts, the growth of ^{14}C labelled ryegrass for incorporation into soil organic matter under natural conditions and studies of the transformation of ^{14}C labelled fulvic and humic acids and sugars continue. The decomposition of ^{14}C cellulose and other polysaccharides are being studied using tipulids fed on ^{14}C cellulose and wood lice fed on ^{14}C labelled lemna. ^{35}S continues to be used in studies of the uptake and transformation of sulphur applied to the soil or sprayed on to plant leaves either as a solution of ^{35}S sulphate or ^{35}S labelled thiovit and the sulphur metabolism of bacteria. Further analysis of ^{14}C labelled potato tubers has been carried out for SCRI. A method, using sealed radioactive standards and the liquid

scintillation spectrometer, has been developed to determine the chlorophyll concentration in potato leaves. 7038,7046,7047,7049

Radiobiological Safety. The quinquennial inspection by the National Radiological Protection Board on behalf of the Health and Safety Executive was passed with flying colours. New Ionising Radiation Regulations - 1985 which come into effect from the 1 January 1986 will necessitate some modification of working procedures. These will be incorporated into a new Institute Code of Practice against Radiation Hazards. 7050

Plant Tissue Analysis. During 1985 the range of analyses requested for plant tissue samples has increased. Over 9000 Kjeldahl digests for total nitrogen have been carried out and substantial numbers of total N, NO_3-N, B and Mn determinations.

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8. STATISTICS

R.H.E. INKSON

The Department of Statistics provides statistical, computing and other biomathematical services to colleagues throughout the Institute. Collaboration at the planning stages of experimental projects continues to be an important aspect of improving the quality of research and leads on to the production of the most appropriate designs for field, glasshouse and laboratory experiments and to the selection of sampling units for surveys. The investigation of the distribution of experimental data and of methods of statistical analysis is undertaken and the service and collaboration continue to the interpretation and presentation of results stages.

One of the main computing activities is the transition of the Institute's Soil Database into a Soil Information System. General computing services include provision for data entry and verification, for software, hardware and communications development and for graphics, mapping and the management of other databases. Courses of instruction in the programming and use of microcomputers have been given and training with subsequent supervision has been provided in the use of the central computing facilities.

Members of staff have attended meetings of the Royal Statistical Society, the British Computer Society, the British Pattern Recognition Association, the AFRC Modellers' Group and the AFRC Statisticians. In addition, colloquia, training courses and demonstrations have been attended on computer hardware and software, image processing and pattern recognition, networking and information systems. The Department has been represented at meetings concerned with the establishment of a Scottish Soil Fertility Information System and with the availability of and access to soil data in databases.

Computing

The Department contains the central computing system (Data General C/150 Eclipse) for the Institute and is responsible for its management, operation and development. The system now has 25 terminals and 13 other devices on-line in addition to the central facilities of hard and floppy disk drives, magnetic tape and paper tape units, matrix and letter quality printers and graph plotter. Some laboratory instruments are connected via Apple microcomputers and PDP minicomputers which provide local control and preprocessing of the data. 8059

The assessment of three 32-bit computer systems, to upgrade or replace the present 16-bit Data General Eclipse, and of communications equipment

has been made and a decision on the matter is awaited. The enhancement of the computer system will provide the advantages of a fully relational database system and of several important program packages for digital mapping, modelling dynamic systems and extensions to existing statistical programs by using packages such as GENSTAT and MINITAB. 8059

The KERMIT terminal-emulation/file-transfer protocol has been implemented on an Apple IIe microcomputer and on the D.G. Eclipse, and has been used to transfer files between the two machines. A CAMTEC JNT "pad" has been installed along with two Case modems and two Pericom terminals (on loan from the AFRCCC). This has established communication with other computers on the JANET and AGRENET networks via a BT leased line to the Computing Centre at the University of Aberdeen. Some experience has been gained with the VMS and PRIMOS operating systems used at other AFRS institutes and file transfer over the network using KERMIT has been achieved. 8059

The data storage, retrieval and processing package developed for soil trace element data has been expanded to enable it to handle data from other sources. It has already been used for microbial size measurements and water analysis data. 2054, 6027, 8059

The departmental library is now in a database on the Data General Eclipse. The information stored is title, author, publisher, year of publication, keywords, unique accession number, current borrower's initials and room number. The database may be interrogated by using the Query utility or, alternatively, the records may be accessed individually by using a macro called BOOKS which allows the user to read, modify, delete or add records to the database. Plotting programs have been extensively enlarged to allow users to obtain greater benefits from the features of the Benson drum plotter. There are now facilities for including titles, comments and the use of three colours. The subroutine library for the Data General G300 graphics terminal has been extended to include all the Benson level 2 subroutines. These can be used for plotting point symbols, thickened and/or broken lines, ellipses, circles, axes, logarithmic axes and for the drawing of curves expressed in polynomial form. The digitised map of the Scottish outline now contains more islands, including Orkney and Shetland, and it is possible to add text to maps displaying features from the soil database. Users may also produce 3-colour single factor maps of Scotland including user-directed keys. 8059,8802

New general subroutines have been added to the statistical program system in the course of developments for specific projects. A major revision of the plotting program DEALBH has greatly increased its flexibility. Improvements include multiple choice of line types for joining points or plotting curves, a wider range of equations for curve fitting, labelling axes with month names and divisions, additional text options and a paired point option which makes it easier to set up extra or non-standard grids. 8057, 8059

Soil Database. The main soil database contains a) a systematic inventory of profile descriptions taken at 5km national grid intersection points

throughout Scotland with records of chemical, spectrochemical and mineralogical analysis of samples taken at the 10km intersection points, and b) similar information recorded for sites of special interest. By the end of the reporting year there were 2116 profile descriptions in the inventory (67% of Scotland) and 1128 in 94 selected batches of special interest, including 452 points for the Loch Fleet acid rain project. Data from the mineralogical and spectrochemical analysis of selected samples are also held in the database. A description of the design and structure of the database together with examples of information extracted from it has been accepted for publication.[1] 2066, 8802, 9012

Soil Fertility. A program called COMBEX has been developed to handle analysis of variance for series of similar experiments combined together. Some new subroutines have been added to the general library of statistical routines in the course of developing this program. Programs have been written or modified to process a range of data types and set up input files where required for the plotting program DEALBH. A program has been written to permit the fitting of polynomial functions to fertiliser response data with the emphasis on ease of use by the research worker rather than the statistician. A database is currently being set up in the Data General Eclipse containing the analytical results and field information for advisory soil samples from the North of Scotland College of Agriculture. With data from the East and West Agricultural Colleges to be included in the system it will be possible to produce annual analysis of soil fertility data on an all-Scotland basis. A program, hitherto running on a dedicated microcomputer, has been transferred to the Data General Eclipse to produce reports on soil nutrient status and lime requirements for advisory purposes. 7041, 7044, 7048, 8059

Soil Survey. A program has been written to rearrange soil profile descriptions and corresponding water table measurements made over a period of time into a format suitable for input to the plotting program DEALBH. Data from several pits were processed in this way and additional graphs plotted. 8059, 9802

Statistical Advisory and Collaborative Work

Mineral Soils. In an investigation of the relationships between calcium, barium and magnesium and between aluminium, barium and calcium for two sets of data, a total of 28 regression equations were examined. 1003, 8057, 8059

Peat and Forest Soils. The processing and analysis of data from birch sites in Yorkshire and Speyside has continued using regression equations to predict total weights of tree parts and uptake of elements from section areas. The work on litter weights has been completed. The now routine processing and analysis of growth assessment and foliage data has been done for several experiments. 2054, 2056, 8057, 8059

Work has continued on data from an EEC-funded project on mixed stands, mentioned earlier (Annual Report No. 54, 1984). Further sets of data of the same type have been processed for field sites at Culloden and Inchnacardoch. Experiments related to this project have been designed and set up in a glasshouse, and initial processing and analysis of some results from these has begun. 2807, 8057, 8059

Results for mineral N production during incubation of various types of litter, and further results from the controlled water-table experiment at Lon Mor have been processed and analysed. Advice on experimental design has been given and randomisations have been provided. 2055, 8057, 8059

Sites at Loch Ard and Glen Feshie have been selected for the new series of field experiments and catchment studies designed to investigate the role of soils and vegetation in modifying rainwater chemistry and factors contributing to surface water acidification. Random coordinates for the placement of instruments were generated by GLIM and RANDOM.SORT, and for one site (Loch Ard) initial diameter assessments were used to allocate trees to size classes for the selection of trees to be used for collecting stemflow. 2073, 8057, 8059

The series of interactive programs for processing rainfall data, described earlier (Annual Report No. 54, 1984), has been extended. Additional programs cover calculation of kg/ha from mm rain and element concentrations, and also the selection of data values for plotting against time. In the latter case a file is generated which is suitable for use as input to the general plotting program DEALBH. Advice and collaboration have been given on the use and interpretation of analysis of variance and principal components analysis applied to data on the chemical composition of rainwater collected in different catchers at selected sites. 2054, 8057, 8059

The results of the statistical analysis of data from a study of the effects of reseeding on Lewis have been published.[2] 2055, 8057, 8059

The relationships of red and infrared reflectance values from laboratory measurements with soil organic matter, moisture and texture (sand, silt and clay) were investigated using multiple regression equations. Equations were also derived to test relationships with radiance values from an airborne scanner and to investigate relationships of snow cover with altitude. 2032, 2034, 8057, 8059

Work has continued on examining techniques for the classification of remotely sensed data. This has involved the testing of the established texture analysis methods, average gradient, grey level difference histograms and grey level co-occurrence matrices. These methods have been tested in isolation and work is currently being done to incorporate them into a methodology for segmenting Landsat MSS images. The use of cluster analysis has been investigated but this has not proved fruitful so far. It is hoped that clustering techniques may be applied with greater success when more discriminating image features are discovered. 2034, 8057, 8059

Spectrochemistry. In studies[3,4,5] of the distribution and background levels of trace element concentrations in Scottish soils, logarithmic

transformations of the data have been necessary to permit valid tests of significance to be made. 3007, 8057, 8059

Soil Organic Chemistry. In a modelling project, multiple exponential decay curves have been fitted to study and interpret the rates of decomposition of the carbohydrates of ryegrass and cereal straw during incubation in soil. Multiple regression equations have been used to relate reducing sugars to major element concentrations. The angular transformation of percentages was applied to data on the percentage persistence of sugars derived from specific activity. 4020, 8057, 8059

Plant Physiology. A screening program was used to determine whether transformation of data to achieve normality was required for physical and chemical data on sphagnum. Ammonium N, PO_4 and internode length required logarithmic transformations and branch frequency required the square root transformation. For spring, summer and autumn, regression equations were used to predict the physical from the chemical properties. Principal components analysis assisted in the prediction of underlying relationships. 5072, 8057, 8059

Microbiology. Analysis of variance, data screening, transformations, model fitting, solution of dilution series and graphical methods have been used for a range of experiments dealing with soil respiration, tomato growth in bark and peat media, and with soil sterilisation, biomass and nitrate leaching studies providing data on counts and weights of microorganisms. 6027, 8057, 8059

Soil Fertility. A high degree of collaboration has been provided in the design of experiments at the planning stages, in the production of field plans and during the processing of data, the statistical analysis and interpretation of the results.
4020, 4803, 7037, 7038, 7039, 7041, 7042, 7044, 7046, 7047, 7048, 8057, 8058, 8059

Work has continued on the testing of models in investigations of relationships between crop responses to added nitrogen and phosphorus fertilisers. In the nitrogen case, modified inverse quadratic polynomials gave a better representation of the response curves of barley grain than the ordinary second-order polynomial which is necessarily symmetrical in shape about its maximum value. In the case of responses of swedes and potatoes to phosphorus fertiliser, a range of models was used to relate these to a number of laboratory measurements of soil phosphorus. Models using the reciprocal or logarithm of soil P values gave the best fit for most soil series. An account[6] of this latter work has been submitted for publication. 7041, 7048, 8057, 8058, 8059

In an investigation of the relationship between unconfined compressive strength and soil moisture tension, linear regressions were fitted and tested for equality. Further work has been done on studies of the effects of sulphur and of the seasonal pattern of growth for different crops. Other

data processed includes root counts for various crops, neutron probe measurements of soil moisture content and soil penetration resistance measurements. Appropriate statistical analysis has been done for some of the results and this work continues. 7044, 7047, 7048, 8057, 8059

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9. SOIL SURVEY

J. S. BIBBY

The primary task of the Department during 1985 has been the compilation of maps of land capability for agriculture (LCA) at 1:50 000 scale. Despite many other claims on the time of the staff, the production schedules announced in Annual Report No. 54 (p. 155) have been largely realized and, although the 1986 schedules are very tight, there is every reason to believe that the 1987 publication target will be achieved. With increasing use being made of the maps for a large variety of purposes, including the identification of land which would come under pressure to be released from farming because of both urban and, lately, agricultural market pressures, the publication is timely. In addition to compiling the maps many of the staff have explained their work to evening meetings of farmers' clubs, the Scottish NFU and to departmental visitors, in addition to conducting a major series of training seminars for staff of the Department of Agriculture and Fisheries for Scotland (DAFS) throughout the country, in offices and in the field. Consultation with staff of DAFS and the Colleges of Agriculture during map compilation has been extensive and the Department is indebted to these organizations for their full co-operation.

Although most systematic survey has been suspended, some survey has continued with 590 km^2 being completed. Where possible, however, the opportunity has been taken to undertake revision soil mapping in areas surveyed and published over 30 years ago, and the results of this work are to be incorporated in the 1:25 000 map series. Thirteen site surveys have been conducted for DAFS to provide detailed information for planning enquiries, and two major pre-coaling surveys of opencast sites to give guidance on storage and replacement of topsoil have been completed (this part of the work of the Department is increasing in importance and scale.) A number of contracts also reached completion during the year, including an assessment of the impact of abstracting water from the gravels underlying the Spey floodplain, near Fochabers, for Grampian Regional Council, and a contract to provide soil and windthrow hazard maps for the Forestry Commission. The former contract provided an opportunity for collaborative work with the Department of Soil Fertility and the latter with the Remote Sensing Unit of the Department of Peat and Forest Soils. Other contracts, involving study of acid precipitation, have given rise to consultation with the Departments of Mineral Soils, Spectrochemistry, Peat and Forest Soils, and Soil Organic Chemistry, as well as with outside organizations.

Every opportunity has been taken to increase the Department's abilities

in data handling and map analysis by automated means. Work has been undertaken through commercial agencies, academic organizations (Universities of Aberdeen and Strathclyde) and in-house, through co-operation with the Departments of Statistics, Peat and Forest Soils, Mineral Soils and Spectrochemistry. A number of single factor maps of soil properties (e.g. soil texture, pH, cobalt, copper) have been prepared, as well as interpretative maps requiring the development of classification systems and data integration (e.g. drainage guideline maps, suitability for grassland use, and in collaboration with the Scottish Institute of Agricultural Engineering and Colleges of Agriculture, suitability for reduced cultivations). In connection with the above activities both written and oral evidence was given to the Government's Committee of Enquiry into the Handling of Geographic Information, chaired by Lord Chorley. A major data collation exercise for the BBC Domesday Project has provided the opportunity to construct a number of small-scale maps of basic soil and climatic properties, which will be of advantage in placing many soil studies in a national framework, and in formulating others.

Dr R. Tippkötter of the University of Hannover continued to work in the Department in association with the Department of Microbiology. Dr S. Theocharopoulos of the Soil Science Institute of Athens was funded by EEC to study the Scottish system of land classification. Soil mapping and interpretative techniques were discussed with many other visitors to the Department from Universities, Government departments and commercial enterprises.

The Department is represented on the AFRC Soil Survey Research Advisory Committee (SSRAC), the SSRAC/NERC Common Interests Group and its subgroups dealing with databases and projects, the MISR/COSAC Liaison Group and its subgroups dealing with Soil Survey Literature, Trace Element Information and Soil Physical Conditions, the Ordnance Survey Public Agencies Consultative Committee, the Scottish Agricultural Field Drainage Group, the National Coal Board/DAFS Opencast Restoration Group and the COSAC/SIAE Cultivations Working Group.

Field Section

Methodology

Discussions have been continued between representatives of the Soil Survey of Scotland and that of England and Wales for the production of a joint Field Handbook giving terminology for the description of soils throughout Britain. Progress has been less rapid than anticipated, however, due in part to the effects of policy and organizational development in the southern part of the Kingdom. Nevertheless, agreement has been reached on drafts relating to the majority of topics. Consultations with staff of the British Geological Survey have proved mutually beneficial in developing categories for recording the superficial unconsolidated deposits which form the soil parent materials. A decision to adopt particle-size grades and texture classes, currently termed the British Soil Texture Classification, for

use by the two surveys, resolves one of the most difficult questions facing the undertaking. New or modified terms to describe the structure of cultivated horizons, soil packing density and soil wetness classes, based on developments in England and Wales, are being discussed.

Correlation and Classification

During 1985 correlation visits in the Huntly and Banff (Sheets 86 and 96) and Jedburgh and Morebattle (Sheets 17 and 18) areas, the two earliest of the 1:63 360 scale soil maps produced in Scotland, have allowed an assessment of the need to re-examine some map units for both production of 1:50 000 scale LCA maps and the publication of 1:25 000 scale soil maps. Major priorities are the separation of soils of the peaty podzol major soil subgroup in the Huntly and Banff area, and in this area and that of Jedburgh and Morebattle, the delineation of brown forest soils in the imperfectly drained category as distinct from those with free internal drainage.

A field visit has also been undertaken to the Dumfries and Annan (Sheets 6 and 10) areas to consider the relationship between map units recognized in the 1:250 000 scale soil map and the soil series and soil complex map units of the current 1:50 000 survey.

An account of the Scottish soil classification system, as used during the 1:250 000 map programme, was published.[1]

Systematic Survey

Sheets 5 and 9 (Kirkcudbright and Maxwelltown). Drafting of the finalized soil map for publication at the 1:50 000 scale is well advanced.

Sheets 6 and 10 (Annan and Dumfries). A further 170 km^2 of new mapping has been completed, mainly between Dumfries and Annan, and ten profiles have been described and sampled for the National Soil Inventory.

The area surveyed is underlain by Permian sandstones and conglomerates in the Dumfries area, by Silurian greywackes and shales between Torthorwald and Mouswald and by Carboniferous sandstones to the east. Since all the derived tills are red and of similar texture, assigning a specific provenance to these parent materials has proved difficult; they belong, however, to the previously described Holywood, Ettrick and Canonbie Associations. The chief soils are freely drained brown forest soils where drifts are shallow or water-modified, and brown forest soils with gleying on unaltered sandy clay loam tills.

Soils of the Yarrow Association are found over large areas of low ground in both terraced and moundy topography; in spite of the coarse textures of the parent materials (sands and gravels), the soils are not restricted to freely drained brown forest soils. Poorly drained peaty gleys are also found,

particularly near Dumfries, where a former cover of deep peat has been removed from fluvioglacial outwash deposits.

Estuarine areas around the mouth of the Lochar Water consist of soils of the Stirling Association, mainly noncalcareous gleys, though further east the sands of the Kirkcolm Association with a range of soil types become prevalent.

Alluvial soils attain their greatest development along the River Annan, but also flank many of the smaller watercourses locally. The larger peat flows of the region, Lochar Moss and Priestside Flow, form raised moss remnants, the shallower edges of which have been removed for fuel and horticultural purposes.

Sheet 16 (Moffat). During the course of preparation of land capability maps Sheets 72 and 73, soil survey was necessary in the north of Sheet 16 (Moffat), amounting to 420 km^2 from Crawfordjohn in the west to Ettrickbridge in the east. Much of this area is underlain by Ordovician and Silurian greywackes and shales and is dominated by soils of the Ettrick Association, with Linhope Series (brown forest soils), Minchmoor Series (humus-iron podzols) and Dod Series (peaty podzols) the principal soils. On plateau summits in excess of 600 m subalpine podzols of the Merrick Series were mapped. Brochloch Complex, a complex of peat, peaty rankers and Dod Series, was mapped extensively on rocky, ridged hill summits with patchy drift cover, the complex being particularly well expressed on Black Knowe Head and Scar Hill. Large expanses of blanket peat were mapped on more gentle even slopes and plateau summits; much of the peat is eroded.

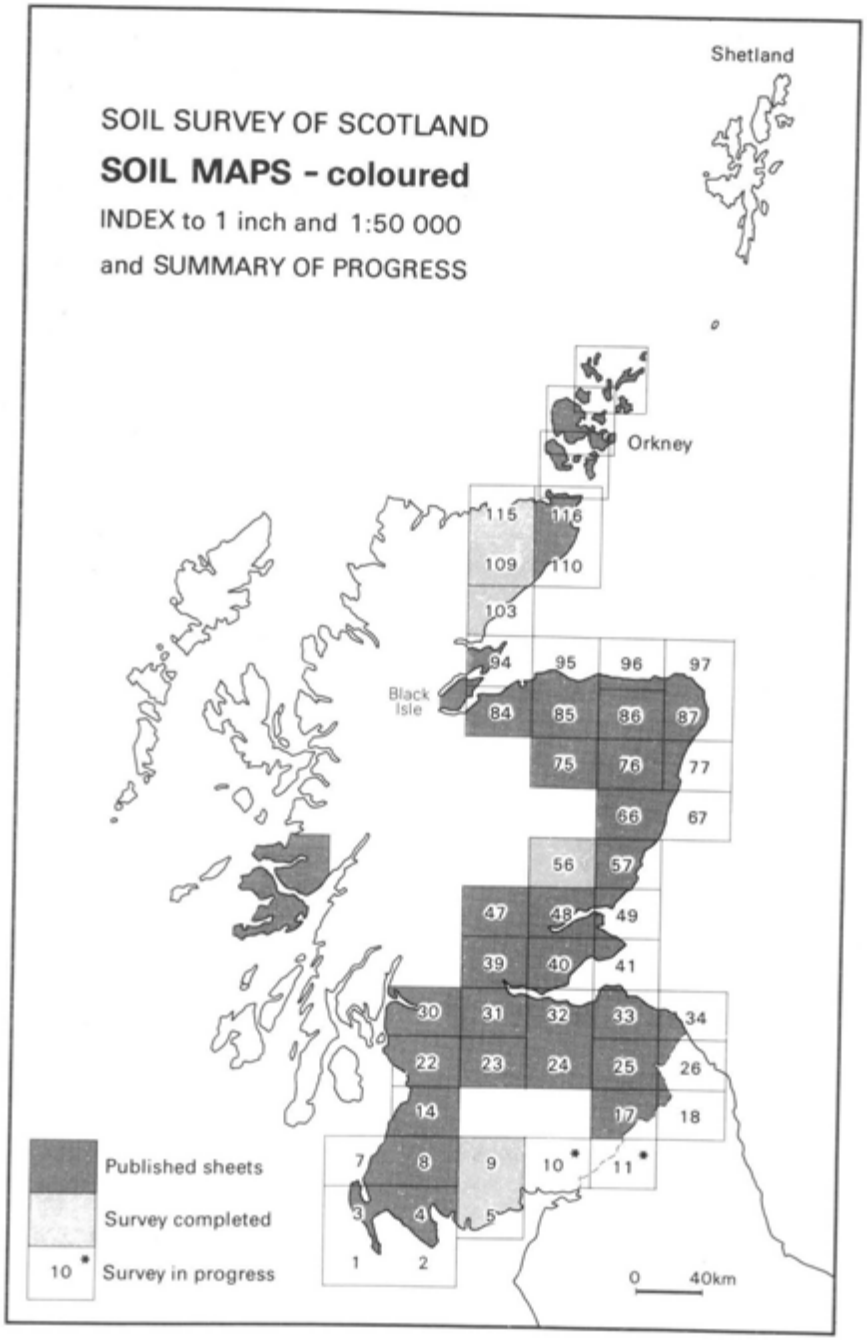
The valleys of the Yarrow and Ettrick Waters are occupied by alluvium and by sand and gravel terrace deposits of the Yarrow Association.

To the north-west of the Duneaton Water, i.e. to the north-west of the Southern Upland Fault, the solid geology is more variable, being dominated by sediments of Old Red Sandstone and Carboniferous age with minor basaltic intrusions. Poorly draining peaty gleys and noncalcareous gleys of the Giffnock, Glenalmond and Lanfine Associations are the principal soils. Blanket and basin peat deposits occur locally, Red Moss being a particular example of the latter.

Peaty gleys (Edgerston Series) of the Sourhope Association were mapped to the north-east of the A74 on tills derived mainly from andesitic lava - an extensive outcrop of which lies immediately to the north of the survey area. An area of fluvioglacial sands and gravels was mapped at Thirstone.

Sheets 25 and 26 (Kelso and Lauder). The soils of the area have been previously surveyed at 1:63 360, but some revision of the Hobkirk and Whitsome Series in particular was undertaken.

The soils of the Hobkirk Series were examined to check for variation in drainage classes within the series and for the presence of imperfectly draining soils. Of particular interest in the Whitsome Series was the occurrence and distribution of soils with partially water-sorted upper layers. Such soils have proved to be strongly represented in an area of Whitsome Series lying to the south-east of Kelso.


SOIL SURVEY OF SCOTLAND
SOIL MAPS - coloured
INDEX to 1 inch and 1:50 000
and SUMMARY OF PROGRESS
Shetland
Orkney
Black Isle
115
116
109
110
103
94
95
96
97
84
85
86
87
75
76
77
66
67
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57
47
48
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32
33
34
22
23
24
25
26
14
17
18
7
8
9
10
11
3
4
5
1
2
Published sheets
Survey completed
10 Survey in progress
0 40km

Sheets 86 and 96 (Huntly and Banff). The soil maps of Sheets 86 and 96 were published at 1:63 360 in 1954, the first in Scotland at that scale. Names of soil series were not given, nor were imperfectly drained soils or peaty podzols separated. Field-work for the land capability for agriculture (LCA) programme in the Huntly and Banff areas has been extended to a soil review to make these distinctions, using to the full the original field-work and present-day aids and experience. This review is invaluable for the LCA mapping: for example, imperfectly drained soils in the lowlands can give better land than freely drained soils. Revised soil maps at 1:25 000 scale will be produced.

The LCA map of Sheet 30 (Fraserburgh and Peterhead) extends to the eastern margins of the soil maps. On the Ordley Association, derived from Old Red Sandstone sediments and argillaceous schists, more detailed examination showed that imperfectly drained soils, Glaschul Series, are extensive south of Gardenstown and are developed on a sandy clay loam till. Farther south around Cairnhill the freely drained series, Ordley, is dominant and is on a sandy loam drift. Peaty gleys, provisionally named Troup Series, are extensive on the hill of that name. Within the Cuminestown Association on a till derived from Old Red Sandstone arenaceous strata, imperfectly drained soils and peaty gleys, provisionally named, respectively, Teuchar and Monquhitter Series, have been distinguished. Around Waggle Hill the soils of the Durnhill Association, on quartzite and derived drifts, were mapped in more detail. The peaty podzol Durnhill Series is dominant and has indurated subsoils.

Other Soil Surveys

Department of Agriculture and Fisheries, Libry Moor, Kirkconnel, Dumfriesshire. A report[2] was produced on the soils of the proposed opencast coal extraction site at Libry Moor, Kirkconnel, Dumfriesshire which has an area of approximately 3 km^2. Thirteen single and multifactor maps, each displaying different aspects of the soils of the site, were computer-plotted from the soils data which had been collected on a grid basis with 100 m intervals between sample points. The format was designed to be readily understood by the non-specialist and allowed individual aspects of the soils of the site to receive focus.

Plots of conventional soil categories included soil association, soil series and land capability class. Plots of texture were produced for surface horizon and subsoil, and thickness plots for mineral topsoil, peat and material suitable as subsoil-making material (to 1 m depth). The plots were central to the discussion of distribution patterns and to conclusions and recommendations for the manipulation of the soils of the site.

Total volumes, mean existing thicknesses and mean restored thicknesses were computed for topsoil and peat on the whole site and for the two sections of the site designated as excavation areas. Figures were also derived for subsoil-making material to 1 m depth.

Department of Agriculture and Fisheries, Dalquhandy, Coalburn, Lanarkshire. A soil survey was carried out of the proposed Dalquhandy

opencast coal extraction site which extends to 9.1 km^2 near Coalburn, Lanarkshire. Soils data were collected on a grid basis with 100 m intervals between sample points.

A report[3] with accompanying computer-plotted single and multifactor maps has been prepared, essentially similar to the one compiled for Libry Moor, although a more comprehensive and detailed analysis of the data was effected.

Mineral and peaty soils of Giffnock, Rowanhill, Sorn and Darvel Associations were identified, but the pattern of soil is complex and only deep peat, as raised mosses, forms substantial homogeneous areas, occupying in total 18% of the site. Soils of Giffnock Association, separated from soils of Rowanhill Association on the texture of the parent material, form the bulk of the material suitable as subsoil-making material, and the total quantity on the site is adequate if material below 1 m depth is taken into account. A considerable deficit of topsoil is projected, although some subsoil material could be substituted.

Barony Agricultural College - Carse of Ae Farm, Parkgate, Dumfriesshire. Farms belonging to the College were surveyed in 1981 and the recent acquisition of Carse of Ae Farm has engendered production of a map of a further 75 hectares at a scale of 1:5 000. Alluvial soils and brown forest soils of the Yarrow Association occupy the south bank of the Water of Ae. They are succeeded upslope by brown forest soils with gleying and noncalcareous gleys of the Holywood Association. 9012

Projects, Applications and Contracts Section

Projects

Plant Ecology Studies. No standard vegetation survey work was carried out during the year, but a wide range of other activities was undertaken under the general headings of training, contract work, preparation of publications, computer work and publicity.

A training programme was organized in conjunction with J.S. Bibby and A. Lilly for the Department of Agriculture officers on the theoretical and practical application of the land capability for agriculture classification. The background aspects of the system were described in a series of one-day lectures held at each of the seven principal Department offices. The ecological input comprised three lectures:

(i) The effects of the environment on vegetation and the classification of plant communities.
(ii) The effects of management on vegetation.
(iii) The assessment of vegetation in terms of its grazing value.

Later, a series of two-day field courses on the application of the LCA system was held at each of the centres, organized by the regional soil surveyor. The ecologist provided instruction on the division of Class 6 land on the basis of vegetation and also acted as correlator for the series. Further field meetings were held on request and dealt with plant and community recognition in hill areas.

A number of catchment surveys were carried out in connection with acid rain investigations. That at Loch Fleet involved the identification of soils and vegetation on a 50 m grid, giving a total of 452 sample points. The vegetation is remarkably species-poor, but exhibits widespread flushing in various degrees. The principal species are *Calluna vulgaris* (heather) and *Molinia caerulea* (flying bent) and it is hoped to demonstrate, once the data have been analysed, that the different proportions of these species reflect the degree of flushing.

The vegetation of catchments at Loch Ard and in Glen Feshie was surveyed and described also in terms of the plant communities and their relationship to soil mapping units, soils, base status and flushing. The vegetation units used in these intensive surveys have to be more finely defined than those used in standard survey work in order to reflect accurately the patterns present on the ground and to make meaningful conclusions on environmental relationships. For example, in Glen Feshie, a dry phase and a wet phase of lichen-rich boreal heather moor (Vaccinio-Ericetum cinereae) were clearly identified on the ground and appear to reflect the degree of waterlogging in the upper horizons of the peaty podzols on which they occur.

Preparation of the soils memoir for the country round Elie and Kinross has been completed and this has now been submitted for editing. Drafting of the vegetation chapter for the Orkney memoir has commenced. Reports on the vegetation of the Loch Ard[4,5] and Glen Feshie[6] catchments have been prepared and a preliminary report on the vegetation of subcatchment VIII in the Loch Fleet catchment has been written. Vegetation data and text have been provided for the BBC Domesday Project.

Preliminary work on creating data files on an Apple computer has been carried out and standard survey data for 1984 and the Loch Fleet grid point data have been entered. This will allow rapid access to vegetation information and obviate the need for record cards. 9015

A paper on the soils and their related plant communities of the Dalradian limestone in Central Perthshire has been published.[7] 9012/9015

Soil Moisture Studies. The monitoring of dip-well sites located in Balrownie Series has continued. Some problems of maintenance were encountered which resulted in the loss of three sites and made it necessary to replace four sites. Five new sites were installed to fill some of the gaps in the sequence. There are now 36 sites being monitored by farmers and it is hoped to increase this number to at least 40 sites by next spring. The first year's results have now been collected and are currently being appraised. They reflect the dry summer of 1984 which was followed by a very wet autumn, moderately snowy winter, dry early spring and generally wet summer in 1985. All the sites have been serviced to ensure that the dip-wells begin the winter period open to the proper depth and protected against damage as far as possible, given the limited resources available.

The Caithness scheme, set up to provide water-table level data for Thurso Series to assist consistent LCA classification in that area, has been relatively trouble-free, thanks largely to regular servicing by the local soil surveyor.

Fruitful collaboration with staff of the North of Scotland College of Agriculture has resulted in the devising of a national legend for drainage guideline maps for the soils of Scotland, and in the production of a COSAC publication[8] on the drainage of soils affected by springs and springlines. Useful discussions have also taken place with the soils advisory staff of the East and West Colleges of Agriculture on the application of the proposed drainage guidelines to the soils of their areas. 9063

Micromorphology Studies. During the reporting year micromorphological work has been severely curtailed due to staff shortages and the ever increasing commitments of the Systems Analysis and Data Processing Section.

This has caused considerable concern, since not only have inter-departmental research objectives suffered (e.g. 1804/9804), but the service aspect of the micromorphology laboratory has also been drastically reduced, to the detriment of other departments within the Institute who require micromorphological expertise.

However, the facilities for the preparation of soil thin sections have been used extensively by several members of the Department of Mineral Soils and by Dr R. Tippkötter (University of Hannover) who has been carrying out micromorphological research on the preservation of biological material in soil thin section under the supervision of the Department of Microbiology. For this purpose undisturbed soil samples were taken in Kubiena cans (8 × 6 × 4.5 cm) from plastic pots of an approximate volume of 3.3 l filled with sandy loam tamped to bulk density of 1.44 gml^{-1}, planted with either rye-grass or barley. In addition delicate living protozoa were inoculated into small plastic containers (250 ml) also filled with sandy loam. Both the soil containing the protozoa and the roots of barley and rye-grass were subsequently fixed with buffered 2.5% (v/v) glutaraldehyde for 2-3 hours.

Soil samples were subsequently dehydrated by a graded series of acetone/water (70, 90 and two changes of 100% v/v). Each stage lasted 1-2 hours and it appeared that this fast dehydration procedure was adequate to replace the water in roots, soil and protozoa by acetone. The acetone-wet samples were then impregnated with a rapidly curing polyester resin mixture with a hardening time within 12 days. The method is effective in preserving biological tissue, as indicated by the appearance of the protozoan cells and root tissues in their thin sections and permits the preparation of soil thin sections up to 6 × 8 cm without any discernible artefact in approximately 14 days.

Due to its colourless appearance and low refractive index biological tissue is often hardly visible in a light microscope. Therefore, these tissues have been stained with Basic Fuchsin which gives a deep red colour to most of the biological features in soil. To avoid the lifting of the section from the glass slide during staining, the stain was applied on the surface of polished blocks of resin-impregnated soil before these were mounted onto the glass slides.

Several attempts have been made to locate microorganisms in soil, especially in and on microaggregates. For this purpose fluorescence microscopy has been applied. Using a range of different fluorchromes on

bacteria, fungi and protozoa, the vital stains and the so-called optical brighteners seemed to be superior to those stains frequently recommended in the past.

Two interdepartmental papers, discussed in Annual Report No. 54, dealing with micromorphology and sub-microscopy of allophane and imogolite in podzol Bs horizons[9], and a comparison of two methods of estimating the soil pore network available to protozoa[10] have been published. A joint paper discussing the application of micromorphology to the understanding of Holocene soil development in the British Isles[11] was presented at the 7th International Working Meeting on Soil Micromorphology in Paris. A paper on multi-area measurements from maps and soil thin sections, using a microcomputer,[12] is still in press. 9804

Applications

Work has continued on the preparation of maps at 1:50 000 scale showing capability of the land for agriculture. Progress is shown in Table 9.1. At this stage it would be inappropriate to submit accounts of the work in individual sheet areas, but as might be expected there are strong correlations with the broader scale 1:250 000 maps published in 1982. Differences are associated in the main with scale, but some reclassification has taken place as more detailed evidence has been collected. The only extensive change so far encountered has been the Thurso Series of Caithness, which has been downgraded primarily because of the impermeable nature of the subsoil. A series of handbooks is planned to accompany the maps and these will contain the rationale for classifying land.

As a result of the work on land classification an increasing work-load of detailed surveys of small areas of land for DAFS case-studies is being

Table 9.1 Programme of 1:50 000 Landranger-based LCA maps. Progress

APRIL 1985	JULY 1985	OCTOBER 1985	JULY 1986	DECEMBER 1986
12 Thurso/Wick Final draft	30 Fraserburgh Final draft	21 Dornoch Firth Final draft	28 Elgin	26 Inverness Field-work
38 Aberdeen Final draft	54 Dundee Final draft	27 Nairn Field-work	37 Strathdon Field-work	29 Banff Field-work
59 St Andrews Final draft	63 Firth of Clyde Final draft	45 Stonehaven Final draft	53 Blairgowrie Field-work	57 Stirling
64 Glasgow Final draft	72 Upper Clyde Final draft	58 Perth/Kinross Final draft	73 Galashiels Field-work	78 Nithsdale
65 Falkirk Final draft	82 Stranraer Final draft	76 Girvan Consultative draft	71 Lanark	83 Kirkcudbright
66 Edinburgh Final draft		74 Kelso Final draft	84 Dumfries	85 Solway
67 Duns/Dunbar Final draft				
70 Ayr/Kilmarnock Final draft				

Printing will be undertaken in two batches during Winter 1986-87 and in Spring 1987.

undertaken. Surveys have been conducted at Barrachander Farm (Argyll), Colombie Farm (Lanark), Greens Farm (Carnwath), Linwood Moss (Paisley), Scotston (Aberfeldy), West Glensherup (Glen Devon), Balquhandy (Dunning), Loanleven (Perth), Craigie Farm (Dundee), Bridge of Earn Hospital, Cairnsmill Farm (St Andrews), Windyheads Hill (New Aberdour) and in the Clatt area (Rhynie). In addition to these reports discussions have taken place on a wider range of farms and guidance has been given in the use of soil information. 9013

Contracts

Contracts are accepted by the Department of Soil Survey if they forward the programme of work laid down by DAFS and/or if the contract is for a public body and the Department is the only organization capable of undertaking the work because of its expertise and national overview. Three new contracts were accepted this year and two from last year continued.

Loch Fleet, Dumfries and Galloway Region for South of Scotland Electricity Board. The field-work for the base-line study of the Loch Fleet catchment, aimed at providing an inventory of the soils, landforms and vegetation, is now complete. Soil profiles, vegetation and associated environmental factors were examined and recorded at 452 sites located on a square grid with 50 m intervals. Samples for chemical analysis were taken from 11 soil profiles and 40 organic surface horizons, selected to encompass the variations in soil, vegetation and environment. The data are held on the Institute's mainframe computer and have been also downloaded to d-Base files for correlation of interpreted items and preliminary data manipulation.

Loch Fleet lies near the middle of an elliptical granite mass measuring 10 km × 18 km and the catchment occupies approximately 113 ha between altitudes of 340 and 470 m. A wide range of slope angle is represented with gentle and moderate slope classes covering about 80% of the area in approximately equal proportions, and steep or very steep slopes occupying the remaining 20%. Rockiness classes are also diverse with one third moderately rocky and one quarter rocky or very rocky. Rock outcrop was encountered at only 10 of the grid intersects, however, indicating that there is a poor correlation between rockiness class, which is based on the distance apart of rock outcrops, and percentage outcrop.

The mineral drifts are thin and rock occurs within 1 m in 54% of the catchment. Till, shallow and colluvial drifts and residual material provide the parent materials for 26% of the soils, but the true extent of these drifts is obscured by the extensive cover of organic parent materials. Organic soils in the lower parts of the catchment may overlie till or shallow drift, but in the col north-west of Fell of Fleet, rock slabs with little or no mineral drift are seen in gullies in the eroded peat. Alluvial drifts are restricted in extent but alluvial processes are active on the small scale, transporting mineral material into the organic horizons by flushing. The till matrix is principally derived from granite but has inclusions of greywackes and shales; the soils were allocated to the Creetown Association. The shallow and colluvial

drifts are locally derived from the granite and the soils developed on the materials belong with the Dalbeattie Association.

The soils of the catchment are almost entirely those with organic surface horizons and 77% have poor or very poor drainage categories. Peat and peaty rankers are co-dominant, each covering approximately one third, with a further quarter taken by peaty gleys. There are also restricted areas of peaty podzols and peaty alluvial soils: mineral alluvial soils were not recorded at any of the 50 m grid intersects but localized pockets of these soils were noted adjacent to the Altiwhat burn.

The many items of soils data and the individual pieces of information recorded at Loch Fleet are currently under examination, with the objective of preparing maps to show the distribution of single or multiple factors, along with a statistical presentation of the results. Separate analysis for individual sub-catchments, or for purposes identified by other scientific contractors, is also envisaged. Information has already been supplied to Liverpool University.

Eleven typical soil profiles and 40 surface horizons were sampled for chemical analysis, the sampling locations chosen from sites previously visited during the 50 m grid survey. 9012

River Spey Abstraction Scheme, Fochabers, for Grampian Regional Council. An area of alluvial farmland bordering the River Spey south of Fochabers has been studied to assess the effects of abstracting water from underlying gravel deposits. The field studies commenced with a soil survey which recorded soil distribution with particular emphasis on soil texture, stoniness, stratification and thicknesses. Samples were taken for laboratory analysis of particle size grade. Concurrently with the soil survey a number of dip-wells, piezometer banks and neutron-probe access sites operated for a 14 month period from harvest 1984 through the 1985 growing season to the end of September 1985. A study of root distributions beneath a number of crops was also undertaken during this period. A number of visits to the site were undertaken by officials of the North of Scotland College of Agriculture to assess crop progress and they have assessed crop patterns in the area. As a background to the study, data on climate was incorporated in several assessments.

A report[13] has been forwarded to the Consulting Engineers, Sir M. MacDonald and Partners, for submission to Grampian Regional Council. The major work-load for the study and the report was carried by the Departments of Soil Survey and Soil Fertility, supported by infra-red investigations done by the Remote Sensing Unit of the Department of Peat and Forest Soils. The consultants to Grampian Regional Council provided predictions of drawdown of the existing water-table levels in the north of the area as a basis from which to assess change. When similar information is made available from the south of the area a further report will be issued.

The results of these observations have been interpreted in the light of current knowledge of soils and their water regimes, and the impact of changes in water-table assessed. In a small area, close to the western edge, a lowering of the water-table would, on balance, be beneficial to farm

operations and cropping. On the eastern edge, close to the river, agriculture is primarily rain-fed, as it is on the higher terraces overlooking the valley, and a reduction in water-table would have no effect upon agricultural potential. In a large part of the central area (Burnside of Dipple and Mains of Dipple farms), associated with the best soil of the flood plain, an effect on agricultural production is anticipated, particularly during drier than average years. Currently, supplementation of the soil moisture reserves is available by capillary rise from an underlying water-table. Following a lowering of the water-table, the extent to which this supplementation becomes essential to crop growth would depend on the length of the dry period and its intensity, and the effectiveness of capillary rates of flow. Quantitative knowledge of the latter, particularly in layered sediments, is limited and more accurate predictions of effects would require elements of new basic research. 9012

Achnafalnich, Glen Orchy, Argyll for the Forestry Commission. A soil survey of 7 km^2 of land at Achnafalnich, Glen Orchy was carried out as a contract for the Forestry Commission, using their soil classification. Soil Survey experience from the national 1:250 000 soil mapping recently completed, and our expertise in identification of landforms and interpretation of air photographs, were most helpful. Measurements were made of the angle of inclination to the horizon at the eight major compass points - topex assessments. Location of topex sites and of soil descriptions, and soil delineations, were transferred from the 1:15 000 air photographs to Ordnance Survey 1:10 000 map by the Wild B8S photogrammetric stereoplotter in the Department of Peat and Forest Soils. That Department also computed the area of each soil polygon using a Digigrid digitizer, and the lines were digitised and stored on floppy disks.

A report[14] has been presented to the Forestry Commission, the sections including accounts of soils, climate, topography, geology, parent materials and windthrow hazard. The last named was derived by scoring assessments of topex, wind zone, elevation and soil, and was portrayed on a 1:10 000 map. A soil map at that scale was prepared. Peaty gleys were the most extensive soil group at 47% of the area, followed by brown forest soils (15%). Soils of the Strichen Association, developed on parent materials derived from acid schists, were dominant. 9012

Kelty Water Catchment, Loch Ard, Aberfoyle for SWAP Programme. A survey of the Kelty Water Catchment within Loch Ard Forest, near Aberfoyle, was carried out to supply information[4] to Departments of the Macaulay Institute for Soil Research with regard to the establishment of experimental sites to investigate surface water acidification.

The main objectives of the survey were:

(i) To produce a soil map at a scale of 1:10 000 to show the distribution of soils in the catchment, and estimate the areas of the various soil map units.

(ii) To produce a report including soil map unit descriptions and other relevant information.

(iii) To describe and sample soil profiles at reasonably accessible sites, so the sites may be used for further investigations.

(iv) To note potential experimental plot sites on the dominant soils and topography of the catchment, with areas 20 m × 20 m of uniform soil, ideally with some slope to assist in the collection of water samples from exposed faces, and planted with 30 to 35-year-old Sitka spruce.

The area, 132 hectares, was surveyed by a combination of free survey and air photograph interpretation (a grid survey being impractical due to the height and density of the trees and the time available for the project), and ranged from 175 m to 505 m OD with an average annual rainfall of 2000 mm and climate ranging from warm wet lowland to cool wet foothill.

The soils are developed on drifts derived from Dalradian metamorphic rocks and belong to the Strichen Association. The soil pattern is intricate and the soils are grouped mainly into complex mapping units. Soils with peaty surface horizons (peaty gleys and peaty podzols) and peat (>50 cm depth) predominate on the gentle and moderate slopes where humus-iron podzols, rankers and rock outcrops occur. A number of potential experimental plot sites were located and liaison with the departments concerned continues.

North Loch Chon, Loch Ard, Aberfoyle for SWAP Programme. The catchment is very roughly circular and defined in the east and west by ridges over 300 m high. The catchment floor ranges from 120 to 180 m, and it has a total area of 187 ha, much of which is planted with conifers approximately 30 years old. The underlying rocks are mica-schists interbedded with quartzose grits, with a few dykes of basalt. The upper hill slopes tend to have shallow stony drifts, while the floor of the basin is covered by deeper moraine and till drifts.

The dense tree cover provided difficulty in survey and the areas of various soil types were approximate. Peat covers 36% of the catchment, peaty gleys 15% and peaty podzols 9%. There was a much larger component of brown forest soils and humus-iron podzols (15% and 16%, respectively) than in the adjacent Kelty Water catchment. The soil textures are usually sandy, sandy loam and fine sandy loam predominating in the topsoils, becoming coarser to loamy fine sand with depth.

The vegetation of the catchment was remarkable for the high proportion of flush elements it contained with base status ranging from dystric to eutric. There was an abundance of flying bent (*Molinia caerulea*) with the major community recognized as flying bent bog with bog myrtle. The mid-slopes on both sides of the catchment carried that peculiarly western community, flying bent-bracken grassland, indicative of water passage at depth in the soil with a freely draining topsoil.

A report[5] describing the mapping units, their soils and associated plant communities has been prepared.

Allt a'Mharcaidh Catchment for SWAP Programme. The Allt a'Mharcaidh catchment is a self-contained hanging valley with a narrow plateau rim situated at the north-western edge of the Cairngorm massif and

has a total area of 10.14 km^2. The site rises in height from 320 m, where the stream leaves the catchment, to 111 m at the summit of Sgòran Dubh Mor, with a large proportion of the land lying above 700 m. The soils of the catchment are developed on granitic drift and belong to the Countesswells Association, although areas of alluvial and organic soils have also been mapped. The granitic drift is generally brown or yellowish brown with a gritty loamy coarse sand or coarse sandy loam texture and is often indurated at lower altitudes. Locally the drift is shallow, notably around tors on the hill summits, but in most areas the deposits are deep.

The variation in altitude gives a climatic zonation within the catchment and four thermal zones can be recognized: boreal, orohemiarctic and both lower and upper oroarctic. Soil development reflects this range with peaty podzols and peat predominant in the boreal zone, subalpine podzols and some peat in the orohemiarctic zone, and alpine podzols in the lower and upper oroarctic zones.

The vegetation is dominated by moorland and oroarctic communities, although grasslands occur locally, for example in snow-bed hollows or on alluvium, as do communities associated with flushes and mires. Due to the severe climatic conditions many moorland communities occur in their northern forms or, in the case of the drier heaths, in the boreal association as the catchment lies within the hemioceanic climatic subsector. The plant communities are also closely related to the soil type.

Proportionately, alpine soils dominate the catchment with 42% of the area; peaty podzols and organic soils account for 26% and 24%, respectively. About one third of the area of organic soils is eroded peat. The remaining 8% of the area consists of miscellaneous soils.

In all, 16 map units were identified. They were categorized in terms of soils, vegetation, landform and variability in order to assess them for a programme of long-term monitoring and instrumentation. Ten profiles were described in detail and sampled for mechanical and chemical analysis. A report[6] has been written. 9012

BBC Domesday Project. This project aims to provide on videodisc, accessed through a microcomputer, a comprehensive database of information about Britain in the 1980s. The Department is contributing information that includes the distribution of Scottish soils, soil drainage classes, parent materials, types of vegetation, texture groupings and land capability for agriculture classes. Data drawn from the Soils Inventory database are being supplemented by assessments made from maps and other existing records. This information will then be sorted by computer into general categories. In addition, a number of short case-studies are being prepared which deal with the use of soil surveys for specific purposes.
9012,9013,9015,9063

Publications, Cartography, Data Handling Section

Publications

A key to the common plant communities of Scotland,[15] a memoir on the soils of the Black Isle,[16] and a handbook[1] describing the organization of the

1:250 000 soil and land capability for agriculture survey have been published.

A technical report on the soils of Orkney is now available.[17]

The manuscript of the memoir for Kinross and Elie (Sheets 40 and 41) has been completed, and nearly completed are the manuscripts of the memoirs covering Forfar, Banchory and Stonehaven (Sheets 57, 66 and 67), and Orkney.

The format for writing map unit description sheets has now been finalized through the Soil Survey Literature Working Party of the MISR/COSAC Liaison Group. Description sheets have now been written for the following 12 series: Balrownie, Caprington, Corby, Countesswells, Darleith, Hobkirk, Linhope, Rowanhill, Stirling, Strichen, Thurso and Winton. Each description is in two sections, the first, compiled by Department of Soil Survey staff, covering environmental factors and soil attributes, and the second, produced by Colleges of Agriculture staff, dealing with soil management for agriculture. Description sheets for a further 48 map units are being written.

A format has been developed to enable a short descriptive account to be written for each of the 1:50 000 LCA maps. These accounts will be written in non-technical language and it is planned to publish them as booklets illustrated with colour photographs.

Systems Analysis and Data Processing

This section is responsible for maintaining an integrated soils data flow between the Department of Soil Survey, its regional offices, and the Departments of Mineral Soils, Spectrochemistry and Statistics, and its remit and general internal structure has been described previously (MISR Annual Report No. 54).

During the period of this report, the data processing function has been expanded in terms of hardware, with additional microcomputing facilities being purchased for the regional offices at Edinburgh and Dumfries; it is hoped to equip the new regional office in Inverness during 1986.

A staff training course, covering microcomputer usage, basic programming and relational database management techniques, was held at MISR, prior to the 1985 field season, for departmental and regional office personnel.

Due to the ever-increasing volumes of data being generated and handled by the Data Processing Section, it has been necessary to expand the main microcomputer facility within the Department of Soil Survey, and a ten-megabyte Winchester hard disc system with magnetic-tape backup facility has been installed. Apart from enabling much larger data files to be manipulated, this has greatly facilitated the transfer of data subsets to and from departmental, regional and mainframe computer files, with a subsequent reduction in data entry and validation procedures.

With the advent of increased contract work being undertaken and to meet the future research and development plans of the department, data capture, input and validation techniques have been examined, and to enable more

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SOIL MAPS - provisional uncoloured

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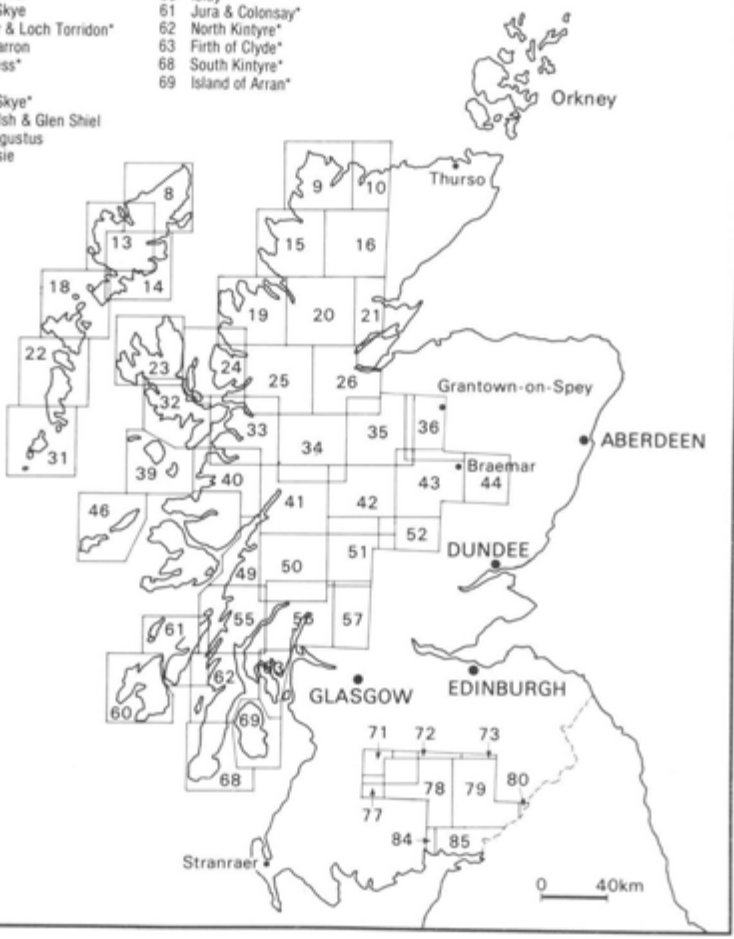
84/85 Dumfries*/ Carlisle & Solway Firth*

*indicates part sheet

o Fair Isle



rapid and efficient methods to be adopted, the use of hand-held field data loggers has been instigated.

Five Husky Hunter microcomputers have been purchased for the regional offices to enable field data capture methods to be employed, and two separate suites of computer programmes have been written, which simulate the field recording cards used at present. These programmes enable either a fully detailed profile description to be recorded (basic site and environmental data, organic and/or mineral horizon descriptions and free text), or where required abbreviated site and profile descriptions when only limited soils data is required as is often the case in large-scale grid survey applications. The data files are then downloaded at the regional offices, where they are immediately available for data interrogation, manipulation or transference on floppy disc to the Data-Processing Section.

Close liaison with the Department of Statistics has been invaluable in ensuring that file structure compatibility with mainframe computer files has been maintained, so that existing Institute Soil Database post-processing functions are immediately available. It is anticipated that these procedures will considerably reduce the overall data entry/validation procedures, improve data purity in the case of interpretative data, and enable contractual reports to be generated more quickly and efficiently.

Staff training in the use of these techniques is presently under way, and initially, for data security reasons, they will be field tested in parallel with more traditional methods, during the early part of the 1986 field season.

General data processing procedures have been used extensively throughout the reporting year, and have been of considerable value in the interpretation of soils data and the preparation of numerous reports prepared for the National Coal Board (Coalburn, Libry Moor), Grampian Regional Council (River Spey Water Abstraction Scheme), British Broadcasting Corporation (Domesday Project) and in various aspects of the Surface Water Acidification Programme, which are dealt with in more detail elsewhere in this departmental report. 9802

Maps, Memoirs and Cartography

Soil Maps. Colour proofs have been received from Ordnance Survey for 1:63 360 Sheet 30 (Glasgow) and Sheet 103 (Golspie). The proofs have been examined and returned to Ordnance Survey. Publication is awaited. Scribed negatives and colour models for Sheet 56 (Blairgowrie) and combined Sheet 109/115 Achentoul/Reay have been completed and despatched to Ordnance Survey for colour proofing.

Production of 1:50 000 soil maps has continued. A further 34 sheets[18–51] have been published, leaving only Sheet 18 (Sound of Harris) to be completed during 1986. Six maps in the Pathfinder-based 1:25 000 soil map series have been published[52–57] all of them in Central and Western Scotland. They are NS 67/77 (Cumbernauld and Kirkintilloch), NS 84/94 (Lanark), NS 85/95 (Carluke and Forth), NS 86/96 (Bathgate), NS 87/97 (Falkirk South) and NS 88/98 (Falkirk North). A number of sheets in Ayrshire are nearing completion. Sheet NS 74 (Strathaven East) has been withdrawn

from circulation pending extensive re-compiling and publication on Pathfinder topography.

1:50 000 LCA Maps. The following Landranger-based sheets have been processed to colour proof stage and either paper or plastic reference copies are in stock: Sheets 38 (Aberdeen), 59 (St Andrews and Kirkcaldy), 65 (Falkirk and West Lothian), 66 (Edinburgh), 67 (Duns and Dunbar) and 70 (Ayr and Kilmarnock).

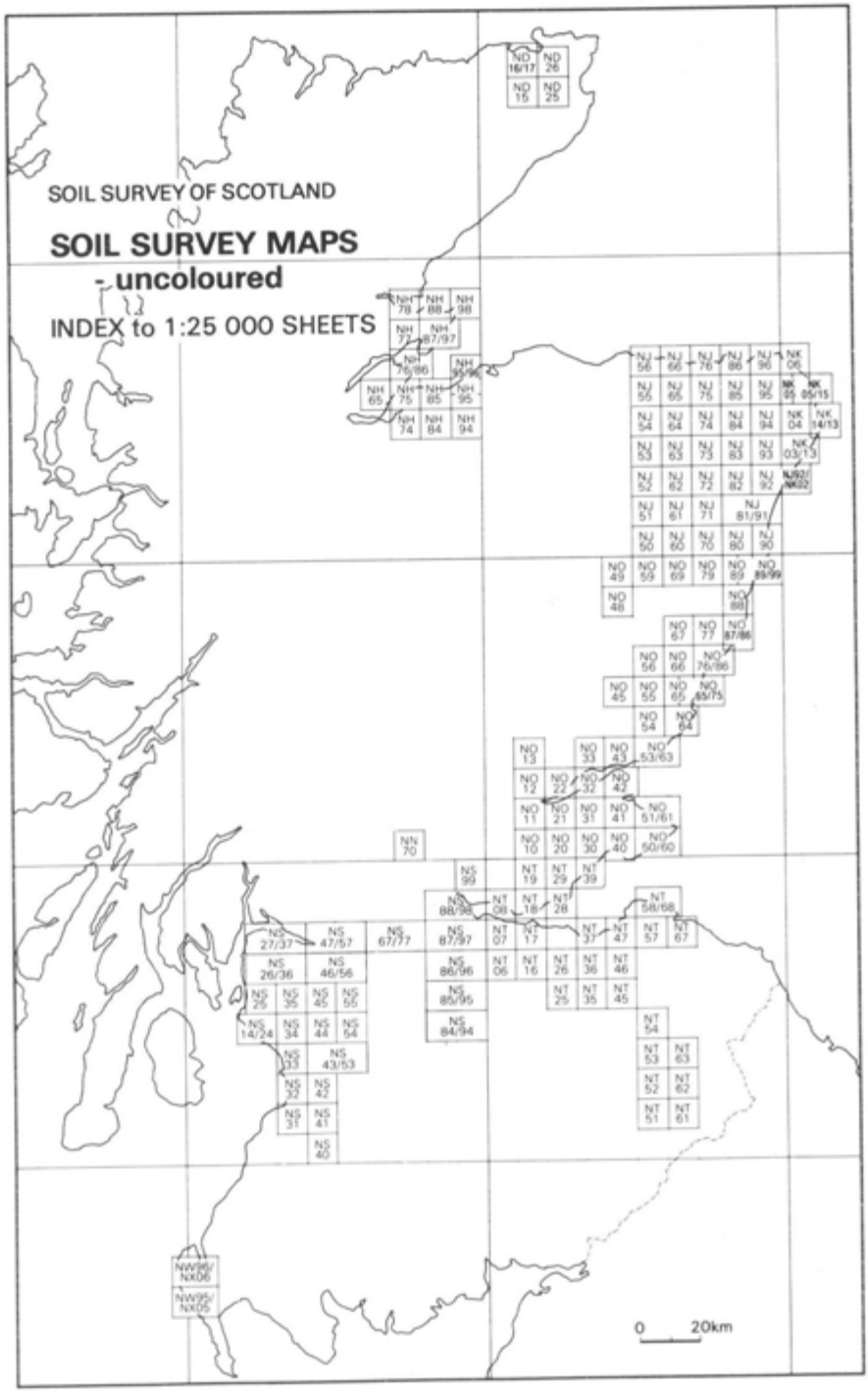
Scribed negatives of the following sheets are at Ordnance Survey and colour proofs are awaited: Sheets 12 (Thurso and Wick), 58 (Perth and Kinross), 63 (Firth of Clyde), 64 (Glasgow) and 72 (Upper Clyde Valley). The following sheets have been compiled: Sheets 21 (Dornoch Firth), 30 (Fraserburgh and Peterhead), 45 (Stonehaven), 54 (Dundee), 74 (Kelso) and 82 (Stranraer and Glen Luce).

Digital Cartography and Single-Factor Maps. Work has continued on the production of single-factor maps from 1:250 000 digital files held at Laser-Scan Laboratories, Cambridge and from those 1:25 000 scale files held in Aberdeen. The 1:250 000 digital files in Cambridge have been used to produce two maps in a series of assessments of topsoils in Scotland. Number 1 shows soil texture and number 2 shows soil acidity. Film composites of the plots were supplied with all of Scotland on 400 × 300 mm Laserplot originals. These plots have been enlarged to 1:625 000 scale and line-proofs have been made from the plate-ready negatives. Some hand-work will be required on editing and generalizing before the next stages of reproduction are undertaken.

A copy of the 1:250 000 digital files has been received from Laser-Scan Laboratories and when time allows a derived soil associations file will be produced, either at the University of Aberdeen Computing Centre on the Honeywell 66/80 or using the facilities at the Institute. A soil associations file with the 580 soil units of the 1:250 000 files amalgamated into 110 units will be used in the production of a soil associations map on the 1:625 000 scale. Work has been suspended on the Routeplanner-based soil associations map which was mentioned in Annual Report No. 54.

Two single-factor maps have been produced for 1:25 000 Sheet NS 43/53 (Kilmarnock and Darvel). The work for them was carried out at the University of Aberdeen. One map shows drainage guidelines, the other shows grassland suitability. Laser-Scan Laboratories have supplied a number of paper plots for the NJ 81/91 (Dyce) sheet. These plots, showing poorly drained soils, sand and gravel deposits and soil associations, have been used to develop a conventional production flowline for reproducing such maps quickly and economically.

A series of conventionally produced single-factor maps has been completed on the 1:50 000 scale for the area around Aberdeen. The soil associations have been categorized by the Department of Spectrochemistry into three levels of trace-element distribution for the following elements: cobalt, copper, nickel, chromium and manganese. Coloured plastic maps have been produced for each of these sheets, together with a coloured map


SOIL SURVEY OF SCOTLAND
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0 20km

of the soil associations. A new part set of percentage contact screens has been purchased and these are working very well with etched peelcoats and the wipe-on proofing technique.

A Cromalin proofing facility has been purchased, surplus to requirements, from a local printer. It will be used to produce smaller format soil maps and other display material.

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48. Upper Clyde Valley/Galashiels and Ettrick Forest (Sheet 72/73). 1:50 000 Soil. By C.J. Bown. Macaulay Institute for Soil Research, 1985.
49. New Galloway and Glen Trool/Nithsdale and Lowther Hills (Sheet 77/78). 1:50 000 Soil. By C.J. Bown. Macaulay Institute for Soil Research, 1985.
50. Hawick and Eskdale/The Cheviot Hills (Sheet 79/80). 1:50 000 Soil. By C.J. Bown. Macaulay Institute for Soil Research, 1985.
51. Dumfries/Carlisle and Solway Firth (Sheet 84/85). 1:50 000 Soil. By C.J. Bown. Macaulay Institute for Soil Research, 1985.
52. Cumbernauld and Kirkintilloch (Sheet NS 67/77). 1:25 000 Soil. By J.M. Ragg, B.M. Shipley, N.A. Duncan and D.W. Merrilees. Macaulay Institute for Soil Research, 1985.
53. Lanark (Sheet NS 84/94). 1:25 000 Soil. By F.T. Dry and N.A. Duncan. Macaulay Institite for Soil Research, 1985.
54. Carluke and Forth (Sheet NS 85/95). 1:25 000 Soil. By J.M. Ragg, N.A. Duncan, J.S. Bibby and J. Menzies. Macaulay Institute for Soil Research, 1985.
55. Bathgate (Sheet NS 86/96). 1:25 000 Soil. By J.M. Ragg, N.A. Duncan and J.S. Bibby. Macaulay Institute for Soil Research, 1985.
56. Falkirk (South) (Sheet NS 87/97). 1:25 000 Soil. By J.M. Ragg, B.M. Shipley, N.A. Duncan, J.S. Bibby and D.W. Merrilees. Macaulay Institute for Soil Research, 1985.
57. Falkirk (North)(Sheet NS 88/98). 1:25 000 Soil. By B.M. Shipley, J.H. Stevens, J.M. Ragg and N.A. Duncan. Macaulay Institute for Soil Research, 1985.

10. TECHNICAL SERVICES

A.W. STUART

All four sections of Technical Services have experienced a heavy workload during the past year. Despite cut-backs in expenditure, the Instrumentation section acquired a tungsten inert gas (T.I.G.) welding system, thus enabling the welding of aluminium and stainless steel to be carried out. A summary of the work undertaken by the individual sections is given below.

Instrumentation

Soil Fertility. Three pressure vessels used in soil moisture measurement were modified to satisfy conditions laid down for insurance cover.

Spectrochemistry. A Leeds Northrop plate carrier was modified to provide a densitometer for reading mass spectrometer photographic plates. A 3- axes auto- sampler was constructed and interfaced to an Apple microcomputer. Further development work on a nebulizer head for an inductively coupled radio frequency spectrometer was carried out.

Peat and Forest Soils. A wide variety of sample collectors were constructed for use in field experiments for the Surface Water Acidification Programme. (S.W.A.P.).

Electronics

This year has been very busy, two staff members having left and an additional work load being imposed during the latter part of the year by the Section's involvement in the Surface Water Acidification Programme.

Work has been done on the installation of various additional computer terminal links, and a prototype device for preventing unused terminals interrupting, and hence slowing down, the Data General main-frame has been successfully tested. It is proposed to protect all the computer's serial lines with similar devices.

Various interfaces for laboratory microcomputers have been built and the high continuing need for routine maintenance of scientific instrumentation has been met as far as possible.

An inexpensive B.B.C. computer has been purchased for computer assisted design of printed circuit boards. The system is undergoing evaluation, and it is anticipated that a considerable time saving will be achieved by its use.

Photography

The photographic needs of the nine departments of the Institute were once more met by the Photo Unit in the form of slides for lectures, prints for publication and general records.

The photography of apparatus in the Unit and laboratory was again undertaken. Root distribution profiles of winter barley and potatoes were photographed in the field as was bracken distribution. A new iron ochre site at Mains of Kirk, Cairnrobin is being monitored, and experiments at Culbin, Culloden, and Kirkton Glen, Balquhidder were recorded for the Department of Peat and Forest Soils. In addition, display material was prepared for exhibits on sulphur, acid rain and for demonstrations at the Royal Highland, Turriff, Black Isle, and Ayr Shows.

The use of colour prints has again seen an increase but at present is being limited through lack of space and processing equipment.

Joinery/Building Maintenance

Peat and Forest Soils. The milling and grinding facilities in the old milling hut were resited in Outbuilding 'F'. This involved the installation of a new dust extraction system. Refurbishment of Room 271 was undertaken and considerable alterations were carried out in Outbuilding 'A' to improve laboratory conditions and to provide additional space for housing specialised equipment.

Administration. Room 220 was refurbished to provide more hygienic catering facilities. Extensive alterations were carried out to the existing stores area, (Rooms 159 and 161) to provide much more suitable office accommodation.

Microbiology. New extractor fans and duct- work to upgrade existing fume cupboards were installed in Rooms 366 and 367.

Plant Physiology. Electrical alterations were carried out in Room 382 prior to the installation of two new environmental growth cabinets.

Spectrochemistry. The refurbishment of Room 304 was undertaken in order to accommodate a new thermal ionisation mass spectrometer (T.I.M.S.).

General Maintenance

Due to the adverse weather conditions throughout the summer months, no further progress was made on the window resealing programme. However, the weather did improve sufficiently to allow the installation of a new drainage system, running parallel to the main driveway, to improve the dissipation of surface water from the road leading to Craigiebuckler House.

11. LIBRARY

A. H. W. DICKIE.

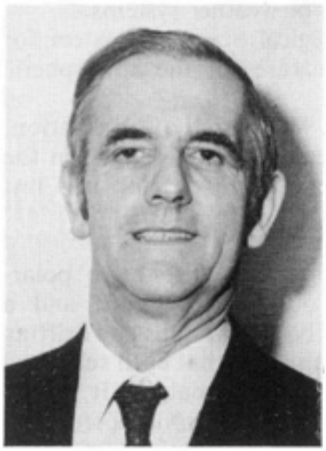
The Library holds an extensive collection of literature on soil science and related subjects. The service is primarily for members of staff, but loans can be obtained by individuals and institutions, either directly or through the national inter-library lending scheme. As members of the Scottish Agricultural Librarians Group and the Aberdeen and North of Scotland Library and Information Co-operative Service, a much higher percentage of requests can be supplied at low cost. The total number of items lent was 209, while 908 requests were fulfilled, of which 428 were from British Library.

Due to a reduction in funding, subscriptions for 22 journals were cancelled, while the total number of books bought was 282 — a further reduction on previous years.

Two Current Awareness publications are produced — a Periodicals Bulletin weekly, and a Book Bulletin monthly. Both are primarily for internal circulation, but copies are also distributed to the other Scottish Agricultural Research Institutes and to local research establishments.

Lists of Available Publications appear at the end of this Annual Report. In response to the last list, 772 reprints were sent out and an additional 452 in reply to direct applications. Copies of reprints and of the lists can be obtained from the Library.

A second microfiche reader — Northwest Microfilm 514 — and a microfilm reader — Northwest Microfilm 2020 — were purchased.



THE TENTH T.B. MACAULAY LECTURE

Aberdeen, 20th November, 1985

RECENT IMPROVEMENTS IN WEATHER FORECASTING

By Sir John Mason, F.R.S.
Centre for Environmental Technology
Imperial College of Science & Technology
London

INTRODUCTION

A very substantial improvement has taken place in weather forecasting during the last decade, due to the continued improvement of objective numerical prediction models that have superseded the earlier more subjective, empirical techniques, and also to better data assimilation and analysis techniques and to some (but not universal) improvements in observations. Leading forecast centres, such as the Meteorological Office centre at Bracknell, produce forecasts for the earth's surface and all levels up to 20 km, covering the whole of the globe, for up to 6 days ahead. There has been some improvement in short-range forecasts for 1-2 days ahead but the greatest advance has been in the provision of reliable medium-range forecasts for up to 4-5 days ahead together with useful guidance for up to 6-7 days ahead. Whilst numerical forecasts, especially the surface forecasts, are not perfect and can usually be improved significantly by the intervention of the human forecaster, they have led to a greater degree of continuity, consistency and confidence in even the short-range forecasts than existed when these depended entirely on the personal experience, skill and judgement of changing teams of forecasters.

The Global Weather Experiment

The subject was given a major boost by the Global Weather Experiment (GWE) organized in 1979-80 by the World Meteorological Organization and the International Council for Scientific Unions and which was the most ambitious and complex international scientific enterprise ever undertaken. Its objectives were to observe and measure, more intensively than ever before, the development of weather systems over the entire globe and to amass an unprecedented data set, analysis of which would make possible:

- a better understanding of atmospheric motions for the development of more realistic numerical models for weather prediction.
- to assess the ultimate limit of predictability of weather systems.
- to design an optimum composite meteorological observing system for numerical prediction of the larger scale features of the atmospheric general circulation.
- to investigate, within the limitation of a one-year period of observation, the physical mechanisms underlying the fluctuations of climate in the time range of a few weeks to a few years and to develop and test appropriate climate models.

Based on observations from five geostationary satellites, two polar-orbiting satellites, traditional ground-based observing systems, and a number of new observing platforms on aircraft, balloons, ships and drifting buoys, the GWE produced a unique global data set that has been subjected to a high degree of quality-control, harmonization and analysis. It has led to new methods of continuous data assimilation and analysis in operational weather forecasting, allowing asynoptic (off-time) observations to be fed continuously into numerical weather prediction models and has stimulated major improvements in the models themselves.

Weather Forecasting using Numerical Models

In weather forecasting it had already become apparent, twenty years ago, that the time-honoured empirical methods, based largely on extrapolation of very recent developments and the experience of individual human forecasters, were unlikely to improve significantly or produce reliable forecasts for more than about 24 hours ahead. Fortunately, with the arrival of powerful digital computers, it became possible to replace these highly subjective, empirical methods by objective techniques that treat weather forecasting as a problem in mathematical physics.

This involves the building of very large and complex mathematical models of the atmosphere based on the physical and dynamical laws that govern the birth, growth, decay and movement of the main weather systems. They incorporate the principles of conservation of momentum, mass, energy and water in all its phases, the Newtonian equations of motion applied to an air mass, the laws of thermodynamics and radiation, and the equation of state of a gas. Parameters which are specified in advance include the size, rotation, geography and topography of the Earth, the incoming solar radiation and its diurnal and seasonal variations, the radiative and heat conductive properties of the land surface according to the nature of the soil, vegetation and snow or ice cover, and also the surface temperature of the oceans.

The physical state of the atmosphere itself is updated every 12 hours from observations made simultaneously over the whole globe both at the surface from land stations, ships and buoys and in the upper air from satellites, balloons and aircraft. The model atmosphere is divided into 15 layers between the ground and 25 km (about 80,000 ft) and each level is divided

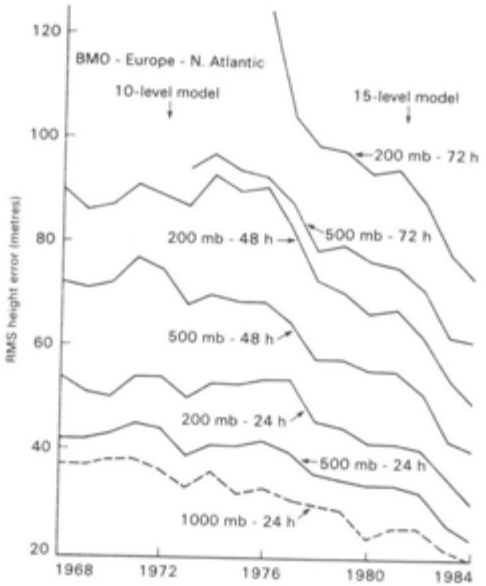


Fig. 1. Annual average rms errors of the heights of the 200,500 and 1000 mb surfaces in numerical forecasts, produced by the Meteorological Office from 1968-1984 for Europe and the N. Atlantic area.

into a network of points about 150 km apart- one-third of a million points in all. Each of these points is assigned new values of temperature, pressure (or heights of constant pressure surfaces), wind and humidity every 12 hours and the governing differential equations are integrated in 15-minute time steps at each point to provide forecast values for up to six days ahead twice daily. A forecast for 24 hours ahead involves about one hundred thousand million (10^{11}) calculations but with a computer making 400 million calculations per second, these are performed in less than four minutes. The whole operation results in the automatic production of hundreds of different forecast charts of pressure, temperature, wind humidity, vertical motion and rainfall that form the basis of the weather forecasts issued to the general public and to almost every weather-sensitive industry.

Assessment of Numerical Forecasts

The performance of numerical models and the accuracy of their predictions are assessed by comparing the forecast values of field quantities such as air pressure, wind and temperature at a large number of grid points at each level with the verifying values derived from the corresponding observations and expressing the differences in terms of root-mean square errors or as correlation coefficients.

Fig. 1. shows a marked improvement in all of the Meteorological Office

forecast parameters for Europe and the N. Atlantic after the introduction of the 10-level, northern-hemisphere model in August 1972 and again after the current 15-level global model was introduced in September 1982. The rms errors in the forecast heights of all the pressure surfaces have roughly halved since 1972. In this respect the 72-hour, 500 mb (5.4 km) forecast are now as good as the 48-hour forecasts were 7 years ago, and the 48 hour forecasts are now as good as the 24 hour forecasts were then. Similar 24-hour improvements in performance are also apparent in the wind fields. The correlation coefficients between the forecast and actual height changes of the 1000 mb level now exceed 0.8 for 72-hour forecasts and exceed 0.9 for 24-hour forecasts. On this basis predictive skill has increased by 48 hours at 3 days and by 38 hours at 6 days since 1976.

Although rms errors and correlation coefficients are useful indicators of the performance of a particular model over a period of time, and for comparing the performance of different models for the same area and period, they are only partial indicators of the predictive skill of the models. A better judgement is obtained by comparing the forecast rms errors with the long-term climatological variance or with the errors of persistence (zero-skill) forecast based on persistence (no-change) from the initial conditions. In 1974 the rms errors of the 3-day forecasts at 500 mb were 80% of the persistence forecast errors; in 1984 the corresponding figure was 48% and the 80% level was not reached until the 6th day, suggesting a gain of 3 days in predictive skill.

Experience shows that numerical forecasts are unlikely to provide good or useful guidance for the issue of surface weather forecasts if their rms errors exceed 75% of the persistence error. Adopting this criterion the average useful predictive range of forecasts issued from Bracknell in 1984 was 5.3 days at 500 mb for extratropical regions in the Northern Hemisphere, 5.0 days in the Southern Hemisphere and one day less for surface forecasts in both hemispheres.

Forecasts for the tropical regions, which are rarely reliable beyond 1-2 days, show much less skill than those for middle latitudes even though the magnitude of the random (rms) errors at all levels is considerably less. The reason is mainly because the tropical forecasts contain relatively large systematic (mean) errors which result from the models' inadequate handling of the large-scale, quasi-stationary systems that dominate the tropical atmosphere. This is exacerbated by poor coverage and quality of observations in the tropics, weak dynamical coupling of the mass and wind fields, and the greater role of physical processes such as deep convection which are rather poorly represented in the model.

In summary, the best computer models now produce good 4-5 day forecasts of the evolution of the major weather systems in the extra-tropical regions of the globe and give a useful indication of major developments for a further 1-2 days ahead in the N. Hemisphere. On some occasions, in rather stable weather regimes, good guidance may be given for up to at least 7 days. Indeed the 7-day forecasts issued twice a week by the Meteorological Office are greatly valued, especially by farmers for the forward planning of their operations.

These performances represent an advance of 2-3 days in predictive skill over the last decade, during which time the proportion of poor 48-hour forecasts of surface weather over the UK has dropped from 25% to only 5% and that of poor 72-hour forecasts from 40% to 20%. Twenty years ago, forecasts beyond 24 hours were rarely attempted.

Further Outlook

Despite these successes, there is considerable scope for further improvements in the accuracy, precision and range of weather forecasts calling for further improvements in the models, greater computing power, and especially for better observations.

The data sets arising from the Global Weather Experiment provide an especially rich source for studying the physics and dynamics of the global atmosphere and for improving our understanding of the complex interactive mechanisms governing changes of weather and climate. This, in turn, will lead to more realistic and detailed physico-mathematical models which alone may extend predictive skill by a further 2-3 days. The new models, incorporating greater spatial resolution and better representation of the physical processes controlling the transfer of heat and moisture by radiation, convection and turbulence, will require greater computing power. A 24-hour global forecast with the current Meteorological Office Model involves about 10 numerical operations taking 4 minutes on the CYBER 205 computer. The next generation of super computers are expected to be at least 25 times as fast, operating at 10^{10} floating-point operations per second, so this is not likely to be the main limitation. A much greater problem is likely to be a lack of adequate observations especially from the tropical and oceanic regions. Indeed without an improved and sustained global observing system for which the Global Experiment provided the scientific rationale and justification, much of the recent gains may be lost. The special observing systems, - ships, balloons and buoys - established for the Experiment have now largely disappeared but it is essential that they be replaced and the operational satellite systems be maintained otherwise weather forecasting in all parts of the world will suffer a setback. The problems of observing the tropical atmosphere at reasonable cost are especially difficult and call for innovation. The large prediction models requiring giant computers can and need be run in only a few centres in the world but, unless and until the observations can be made entirely from space, they will require continuing effort by all countries.

Given an adequate global coverage of observations and continued improvement in the models, it should be possible to extend the range of useful forecasts up to about 14 days which may prove to be the limit of deterministic predictability set by the random nature of atmospheric fluctuations. However, some relatively stable atmospheric states, such as those that produce long, dry summers, may possess greater predictability. Furthermore, it may well be possible to predict average conditions for some weeks or months ahead even if the day-to-day variations are not predictable.

APPENDIX II

VISITS ABROAD — 1985

	Place/Event	*Lectures*	*Date* — 1985	*Financed by*
1. M.J. Adams	Garmisch-Partenkirchen (Germany) XXIV Colloquium Spectroscopicum Internationale	1	September	DAFS
2. C.E. Alexander	Lund University of Agricultural Sciences at Uppsala and Umea (Sweden)	3	June	Swedish University of Agricultural Sciences
3. C.E. Alexander	Dijon (France) 1st European Symposium on Mycorrhizae	—	July	EEC
4. H.A. Anderson	Rivière du Loup, Quebec (Canada) International Peat Society Symposium	1	July	DAFS
5. D. Atkinson	Rimini (Italy) International Society for Horticultural Science Symposium on Growth Regulators in Fruit Production	5	September	DAFS
6. D.C. Bain	Brussels (Belgium) Community Bureau of Reference Plant Materials	—	March	EEC
7. J.S. Bibby	Cesena/Florence (Italy) Symposium on Land Degradation in Hilly Areas due to Hydrological Phenomena	—	September	EEC
8. R.V. Birnie	Falkland Islands and South Georgia, University of Aberdeen Expedition	—	January/ February	Self
9. R.V. Birnie	Ottawa and Toronto (Canada) visits to centres of Remote Sensing	1	October/ November	DAFS
10. J.H. Gauld	New Zealand visits to staff of Soil Survey of New Zealand	1	July/ August	Self
11. B.A. Goodman	Bad Windsheim (Germany) NATO Advanced Studies Institute on "Iron in Soils and Clay Minerals"	2	July	NATO
12. B.A. Goodman	Chicago (USA) American Chemical Society Symposium and visits to Mobil Research and Development Corporation of Dallas, Texas and Texas A and M University at College Station	3	September	Amer. Chem. Soc./Mobil
13. P.D. Hulme	Lullymore (Ireland) visits to Agricultural Institutes and National Soil Survey of Ireland	—	May	DAFS
14. I.R. MacDonald	Wageningen (Netherlands) European Symposium on Photomorphogenesis in Plants	1	April	DAFS

	Place/Event	*Lectures*	*Date* — 1985	*Financed by*
15. A.E.S. Macklon	Haren (Netherlands) Symposium on Nitrogen Metabolism in Higher Plants	—	April	DAFS
16. L. Robertson	Vejle (Denmark) Bureau of Land Data, Ministry of Agriculture to study data processing applications and techniques	—	June	DAFS
17. R.A. Robertson	Bad Alexandersbad (Federal Republic of Germany) Meeting of Executive of International Peat Society	—	April	DAFS
18. R.A. Robertson	Budapest/Keszthely (Hungary) Meeting of Editorial Committee of International Peat Journal	—	April	International Peat Society
19. R.A. Robertson	Jönköping (Sweden) Symposium on Peat and Environment '85 and Meeting of Council of International Peat Society	—	September	Self
20. D. Robinson	Groningen (Netherlands) Symposium on Nitrogen Metabolism in Higher Plants, University of Groningen	—	April	DAFS
21. J.D. Russell	Denver (USA) 8th International Clay Conference	1	July/ August	DAFS
22. B.L. Sharp	Leysin (Switzerland) European Winter Conference on Plasma Spectrochemistry	1	January	Conference Organisers/DAFS
23. A.M. Ure	Lyons (France) 33rd IUPAC General Assembly	—	August/ September	IUPAC
24. A.M. Ure	Clermont Ferrand (France) FAO European Cooperative Network on Trace Elements	1	September	FAO
25. A.M. Ure	As (Norway) Agricultural University of Norway	1	January	Agric. Univ. of Norway
26. A.M. Ure	Oslo (Norway) Workshop on Measurement of Aluminium, University of Oslo	—	April	SWAP
27. T.S. West	Lyons (France) 33rd IUPAC General Assembly	—	August/ September	IUPAC
28. T.S. West	Munich (Federal Republic of Germany) ICSU General Committee	—	October	ISCU
29. M.J. Wilson	Oslo (Norway) Mineral Weathering and Acid Deposition, Norwegian Academy of Science and Letters	1	March	SWAP
30. M.J. Wilson	Poitiers (France) Laboratoire de Pedologie des Alterations Hydrothermales	2	March	University of Poitiers
31. M.J. Wilson	Delft (Netherlands) Meeting on Lateritic Soils	—	April	British Council/ Self

	Place/Event	*Lectures*	*Date — 1985*	*Financed by*
32. M.J. Wilson	Denver (USA) International Clay Conference	1	July/ August	DAFS
33. M.J. Wilson	Stresa, Pisa, Naples (Italy) Italian Soil Science Society/ Italian AIPEA Group	4	October	Universities of Turin, Bologna, and Naples

APPENDIX III
LECTURES GIVEN IN THE U.K. BY MEMBERS OF STAFF

	Place	*Event*	*Date* - 1985
Department of Mineral Soils			
D.C. Bain	Durham	Philips Conference on X-ray Spectrometry	September
E. Paterson	Aberdeen	Electron Microscope User's Group	June
	London	Clay Minerals Group Meeting	November
M.J. Wilson	London	Joint Meeting of Clay Minerals and Engineering Geology Groups	March
	Glasgow	British Association Meeting on Geochemical Aspects of Acid Rain	August
Department of Peat and Forest Soils			
R.V. Birnie	Ballater	Grampian Regional Council Seminar on Remote Sensing	April
	London	Joint Research Councils Remote Sensing Committee	June
	Leeds	International Symposium on the Bracken Fern: Bracken '85	July
	Dundee	Dundee University M.Sc Course in Remote Sensing	November
D.R. Miller	Leeds	International Symposium on the Bracken Fern: Bracken '85	July
M.F. Proe	Aberdeen	Royal Scottish Forestry Society	June
R.A. Robertson	Edinburgh	SPALDA Peat Conference	November
G.G. Wright	Farnborough	NRSC SPOT-Simulation Meeting	May
Department of Spectrochemistry			
M.J. Adams	Glasgow	Scottish Region, Analytical Division, Royal Society of Chemistry	November
J.R. Bacon	Swansea	10th International Mass Spectrometry Conference	September
M.L. Berrow	London	1st. International Symposium on Geochemistry and Health	April
	Birmingham	3rd. European Meeting, Society of Environmental Geochemistry and Health	April
	Otterburn	North of England Soils Discussion Group	September
B.A. Goodman	Cambridge	Royal Society of Chemistry, ESR of Transition Metals	March
B.L. Sharp	Aberdeen	Royal Society of Chemistry	January
	Guildford	1st. Survey Conference on ICP/Mass Spectrometry	September
	Bristol	Atomic Spectroscopy Group, Royal Society of Chemistry	October

	Place	Event	Date - 1985
Department of Soil Organic Chemistry			
H.A. Anderson	Roslin	3rd AFRC Amino Acid Users Group Meeting	September
D.J. Linehan	London	Society of Chemical Industry Agriculture Group Symposium on Trace Elements in Soils, Plants and Animals	January
I.R. MacDonald	Glasgow	SERC Space Biology Panel	March
Department of Microbiology			
C.E. Alexander	Stirling	Stirling University Department of Biological Sciences	October
S.J. Chapman	Aberdeen	Aberdeen University Department of Microbiology	January
B.S. Griffiths	Edinburgh	Annual Meeting, British Section of the Society of Protozoologists	April
D. Jones	Birmingham	International Symposium on Biomineralization in Lower Plants and Animals, organised by the Systematics Association	April
Department of Soil Fertility			
D. Atkinson	Bangor	Society of Experimental Biology	March
	York	Arboricultural Association	April
	Brighton	British Crop Protection Conference — Weeds	November
	Bracknell	ICI Jealotts Hill Research Station	December
	Mintlaw	SAI Crop Check Discussion Group	December
P.W. Dyson	Mintlaw	SAI Crop Check Discussion Group	December
A.H. Sinclair	Aberdeen	North East of Scotland Farm Management Association — Fertilizers — Form, Application and Economic Aspects of Use	January
	Dingwall to Edzell	Farmer Discussion Groups	Various
	Mintlaw	SAI Crop Check Discussion Group	December
Department of Soil Survey			
J.S. Bell	Perth	Field Course for DAFS Staff	April
J.S. Bibby	Thurso to Edinburgh	Training Course in LCA Systems for DAFS Staff, held at 7 Centres	February
	Glasgow	British Geological Survey Seminar	February
		Strathclyde University Department of Geography	April/ October
	Stirling	Stirling University Department of Environmental Science Symposium	June

	Place	*Event*	*Date* - 1985
F.T. Dry	Edinburgh	Field Course for DAFS Staff	April
D.W. Futty	Stirling	Stirling University Department of Environmental Science Symposium	June
J.H. Gauld	Perth	Field Course for DAFS Staff	April
R.E.F. Heslop	Aboyne	National Farmers Union Meeting	February
	Aberdeen	Field Course for DAFS Staff	April
	Clinterty	Aberdeen University Department of Soil Science Excursion	May
	Glen Dye	Aberdeen University Department of Soil Science Excursion	May
	Cuminestown	Field Course for DAFS Staff	September
	Aberdeen	Aberdeen University M.Sc Course in Ecology	October
J.A. Hipkin	Edinburgh	Field Course for DAFS Staff	April
A. Lilly	Thurso to Dumfries	Training Course in LCA System for DAFS Staff, held at 7 Centres	February
	Aberdeen	Field Course for DAFS Staff	April
	Clinterty	Aberdeen University Department of Soil Science Excursion	May
	Cuminestown	Field Course for DAFS Staff	September
	Aberdeen	Clinterty Agricultural College Course	November
A.J. Nolan	Aberdeen	NOSCA HND Students Course	March
	Aberdeen	Field Course for DAFS Staff	April
	Glen Dye	Aberdeen University Department of Soil Science Excursion	May
J.S. Robertson	Thurso to Dumfries	Training Course in LCA System for DAFS Staff, held at 7 Centres	February
	Dundee	Dundee University Department of Biological Sciences	June
	Perth	Biolink '85 Conference	September
	Dundee	Scottish Association of University Teachers	October
L. Robertson	Stirling	Stirling University Department of Environmental Science Symposium	June
W. Towers	Inverness	Field Course for DAFS Staff	April/ November
	Thurso	Field Course for DAFS Staff	May
A.D. Walker	Inverness	Field Course for DAFS Staff	April
Director			
T.S. West	Edinburgh	Royal Society of Edinburgh Symposium on Scotland's Food and Drink	February

PUBLICATIONS

The numbers appearing on the left-hand side of this list are the MISR serial numbers for the items. Please quote these numbers when asking for reprints from the Librarian, Macaulay Institute for Soil Research, Craigiebuckler, Aberdeen, AB9 2QJ. *Reprints with no serial numbers are only available if priced.* Items marked* are publications of the Department of Soil Survey, and can be bought from them at the above address. Current Price Lists are available from both the Department of Soil Survey and the Librarian.

ADAMS, M.J. Microcomputer interfacing in spectroscopy laboratories. *Lab. News.*, 1985, No. **323**, 6-7.
The interfacing of microcomputers to laboratory instrumentation is discussed in terms of the nature of the serial, parallel or analogue computer-to-spectrometer link.

ADAMS, M.J. Multi-element analysis with a computerised micro densitometer for spark source mass spectrometry. *Proc. Coll. Spectrosc. Int., 24th, Garmisch-Partenkirchen*, 1985, 356-357.
A microdensitometer has been assembled for the interpretation of photographic plates from a spark source mass spectrometer. The plate reading system employed permits a 250 mm photoplate to be scanned, and resolution of two-to-three microns. Digitisation is controlled *via* an APPLE Microcomputer which is also linked directly with an Apricot XI computer for the conversion of peak height information to elemental concentration data.

1350 ADAMS, M.J. and EWEN, G.J. A microcomputer system for use with an EPR spectrometer. *J. Automatic Chem.*, 1984, **6**, 202-205.
An Apple IIE microcomputer has been interfaced to a Varian, Model E104-A. EPR spectrometer. Data transfer between the computer and spectrometer is achieved *via* a 12-bit ADC/DAC system, designed and constructed 'in-house'. Computerised data may be manipulated and displayed on a high resolution graphics monitor or a flat-bed recorder.

1366 ADAMS, M.J., EWEN, G.J. and BIRNIE, R.V. A portable two-band radio- meter. *Int. J. Remote Sensing.*, 1985, **6**, 963-966.
A lightweight and portable two-band radiometer is described for use in remote sensing studies. The novel optical arrangement, using a neutral beamsplitter, overcomes the problem of non-coincidence of the target scene that is often encountered with more conventional parallel tube radiometers. The instrument is being applied to the study of a winter barley crop.

ANDERSON, H.A. and VAUGHAN, D. Soil nitrogen: its extraction, distribution and dynamics. In *Soil Organic Matter and Biological Activity*. Edited by D. Vaughan and R.E. Malcolm. The Hague, Martinus Nijhoff/Junk, 1985, 289-327.
Nitrogen is a key component of soil organic matter and as such plays a vital role in soil fertility. Nevertheless, many of the techniques used for extracting and identifying the individual N components are still inadequate. Indeed, more than half of the organic components in soil are as yet unidentified. This review discusses not only the chemical identification of soil N fractions, but also their turnover in the soil as a result of microbial activity. The use of mathematical models to study dynamics of soil nitrogen and hence to predict crop production is also assessed. The important areas where vital information is still urgently required are identified, such as the chemical changes in N components in the soil solution under different physical and biological conditions.

1346 BAIN, D.C. and DUTHIE, D.M.L. The effect of weathering in the silt fractions on the apparent stability of chlorite in Scottish soil clays. *Geoderma*, 1984, **34**, 221-227.
A quantitative X-ray diffraction technique has been used to determine the chlorite content of the silt fractions in a brown podzolic soil and a peaty podzol from a suite of highly chloritic soils. The fine silt fractions contain much more chlorite

than the coarse silt and in both fractions the amounts of chlorite decreases towards the soil surface, markedly so in the podzol. Although an earlier study of the clay fractions appeared to indicate that chlorite was stable, it is now suggested that chlorite is being dissolved out from the clay fractions, but that this dissolution effect is being masked by the replacement of the clay fraction chlorite from the fine silt. Analysis of the total soils confirmed the net loss of chlorite from these profiles.

BERROW, M.L. and BURRIDGE, J.C. A comparison of long-term effects of similar sewage sludge treatments on two different soils. *Proc. Int. Conf. Heavy Metals in the Environment, Athens, 1985*. Edinburgh, CEP Consultants Ltd., 1985, 345-347.
Two long-term sewage sludge experiments, started in 1968 and conducted on different soil types, have been monitored. The same sewage sludges, highly contaminated with zinc, copper, nickel and chromium were applied at the same rates and metal contents. Changes in extractable metal contents with time and the percentage extractabilities of metals 13 years after application show a remarkable consistency. Metal contents in timothy grass at one site are closely related to contents of ryegrass at the other. There is a high degree of "site-coherence" suggesting that data from both sites may be considered jointly when seeking generalised conclusions on the effects of sludge treatments on soils and crops.

BERROW, M.L. and CHESHIRE, M.V. The use of peat and lime treatments for the amelioration of copper pollution of soils. *Proc. Int. Conf. Heavy Metals in the Environment. Athens, 1985*. Edinburgh, CEP Consultants Ltd., 1985, 397-399.
Pot experiments with two soils contaminated by copper from distillery waste showed that the incorporation of peat was effective in reducing the copper concentrations in mature lucerne plants, when accompanied by liming to offset the acidification effects of the peat. In an accompanying laboratory study, incorporation of increasing amounts of peat into a similarly copper-contaminated soil also reduced the acetic acid-extractable but not the EDTA-extractable copper over a period of six years. The reduction in plant availability appears to be the result of a reduction in the amounts of exchangeable rather than complexed copper in the soils.

1353 BERROW, M.L. and REAVES, G.A. Extractable copper concentrations in Scottish soils. *J. Soil Sci.*, 1985, **36**, 31-43.
The distribution of EDTA-extractable copper concentration levels in 3653 samples from 725 Scottish soil profiles is reported. The derived mean for the full set of data is 0.86 mg/kg and the normal range 0.08 to 9.8 mg/kg. The relation of extractable copper to total copper and to some other soil variables is also examined. Extractable copper contents decrease with increasing depth over the first 50 cm and are more or less constant below this. The correlation between extractable and total copper ($r = 0.453$) is statistically highly significant ($P = <0.001$). Extractability of copper (i.e. the percentage of the total extractable by EDTA) is inversely related to ash content though the relationship is not linear. Extractability is enhanced under conditions of impeded drainage but there is no indication that is is related to clay or sand contents. Approximately 18% of the arable topsoil samples contain levels of extractable copper which are inadequate to supply the nutritional requirements of cereal crops and approximately 79% contain levels inadequate to support herbage with a copper content sufficient to supply the requirements of grazing stock.

1367 BIRNIE, R.V. An assessment of the bracken problem in relation to hill farming in Scotland. *Soil Use and Management.*, 1985, **1**, 57-60.
The reasons for bracken encroachment in Scottish hill land are examined. The cost effectiveness of bracken control methods are discussed and it is shown how the real cost of aerial spraying, the most practical method, has increased in the last decade. The waiving of the follow-up requirements under the DAFS grant schemes may alter this cost situation in the future. The need for more accurate estimates of the extent of the bracken problem is highlighted by the possible link between bracken and cancer in humans. Recent surveys utilising remote sensing techniques are described and the cost of a full bracken eradication programme is estimated to

be £80 million which is contrasted with the current level of grant assistance of £135,000 yr^{-1}. The use of bracken as a biofuel is considered as an alternative to eradication.

1358 BIRNIE, R.V. and WILLIAMS, J. Monitoring iceberg production using LANDSAT data. *Proc. Univ. Dundee Summer School. Remote Sensing Applications in Civil Engineering, Dundee, 1984*. Paris, European Space Agency SP-2l6, 1985, 165-167.
The results of a pilot study, on the use of LANDSAT MSS data to monitor iceberg production from West Greenland glaciers, are presented in the context of the importance of such data to "iceberg management" in oilfields off Labrador and Newfoundland.

1343 BRACEWELL, J.M. and ROBERTSON, G.W. Characteristics of soil organic matter in temperate soils by Curie Point pyrolysis-mass spectrometry. l. Organic matter variations with drainage and mull humification in A horizons. *J. Soil Sci.*, 1984, **35**, 549-558.
The organic matter in the surface horizons of a group of 22 Scottish soils ranging widely in drainage and degree of humification was examined by the dynamic pyrolysis-mass spectrometry of whole soil samples. Multivariate analysis of the mass spectra enables the soils to be partitioned successfully in terms of two main factors, one corresponding to drainage and the other to the extent of mull humus formation. Based on present evidence and previous findings, it is explained how these two factors reflect changes in oganic matter composition.

CAMPBELL, C.G.B. and HUDSON, G. Report on the soils and land capability for agriculture of the proposed Libry Moor opencast coal site, Kirkconnel, Dumfriesshire. Aberdeen, Macaulay Institute for Soil Research, 1985. (Restricted circulation)

CAMPBELL, C.G.B. and HUDSON, G. Report on the soils and land capability for agriculture of the proposed Dalquhandy opencast coal site, Coalburn, Strathclyde. Aberdeen, Macaulay Institute for Soil Research, 1985. (Restricted circulation).

CHESHIRE, M.V. Carbohydrates in relation to soil fertility. In *Soil Organic Matter and Biological Activity*. Edited by D. Vaughan and R.E. Malcolm. The Hague, Martinus Nijhoff/Junk, 1985, 263-288.
Carbohydrate in soil mostly occurs as polysaccharides. It influences soil fertility in several ways. It is one of the principal binding agents in the aggregation of soil particles. It is a source of nutrient for the microbial population and influences the cation and anion sites in soil: it affects soil water retention. More specific functions relate to plant root growth, adhesion in microorganisms and the protection of enzymes.

1380 CHESHIRE, M.V., SPARLING, G.P. and MUNDIE, C.M. Effects of oxidation by periodate on soil carbohydrates derived from plants and microorganisms. *J. Soil Sci.*, 1985, **36**, 351-356.
Treatment of soil with periodate and tetraborate releases much of the carbohydrate and destroys an equivelant proportion of the aggregation. The residual carbohydrate is proportionately richer in the sugars characteristic of plant remains, namely glucose, arabinose and xylose, than the whole soil. Studies with labelled soil polysaccharide have now shown the same pattern of persistency whether the carbohydrate is derived from plant residues or microbially synthesized polymers. The composition of the more stable residue can therefore not be used as an indicator of polysaccharide origin in any comparison of the relative effects of aggregation of plant and microbial derived material.

CHESHIRE, M.V., GOODMAN, B.A., McPHAIL, B.D. and SPARLING, G.P. Electron spin resonance characteristics of the humic acids from a podzol. *Proc. Int. Humic Substances Soc. Int. Conf., 2nd, Birmingham, 1984*, 52-53.
Electron spin resonance (ESR) spectra have been recorded for humic acids extracted from the horizons of a podzol developed on acid igneous till under pine forest, and compared with results from substances with similar solubility characteristics derived from undecomposed plant and fungal material present at

the site. The free radicals derived from the humic acids from the litter horizons have many similarities to those of lignin extracted from fresh pine needles, but those from the humified 0- and mineral E- and B- horizons have none of these characteristics. The fungal materials produced free radicals that gave ESR spectra that were completely different to those from any of the humic samples.

1381 CLARK, D.R., BRACEWELL, J.M. and PATERSON, E. Inter-element relationships from microprobe analysis using multivariate statistical methods. *Micron*, 1985, **16**, 151-157.
The application of multivariate statistical methods to chemical analyses obtained using the electron microprobe has been shown to provide a useful indication of the associations between the different elements in the sample. The method has been tested using a series of prepared mixtures and should be of value in mineral identification, the study of cation-exchange reactions and in determining the active components in adsorption of anions such as sulphate and phosphate.

1375 DARBYSHIRE, J.F., ROBERTSON, L. and MACKIE, L.A. A comparison of two methods of estimating the soil pore network available to protozoa. *Soil Biol. Biochem.*, 1985, **17**, 619-624.
Two methods of estimating pore size distributions in different soil horizons were compared. The two methods involve either an image analyser or a camera lucida and yielded very similar results. The use of these methods in the ecology of soil microorganisms is discussed.

DEEP Drainage. Scottish Agricultural Colleges Publ. No. 157, 1984.

*DRY, F.T. and SINCLAIR, A.H. The soils of Orkney. MISR Technical Report No. 2. Aberdeen, Macaulay Institute for Soil Research, 1985.

1355 FARMER, V.C. McHARDY, W.J., ROBERTSON, L., WALKER, A. and WILSON, M.J. Micromorphology and sub-microscopy of allophane and imogolite in a podzol Bs horizon : evidence for translocation and origin. *J. Soil Sci.*, 1985, **35**, 87-95.
Detailed microscopic studies show that aluminium, silicon and iron, liberated by intense acidic weathering of minerals in the upper horizons, are deposited as allophanic gels in the Bs horizon. Fibres of imogolite, associated with the gels, can be seen in specimens dried under zero surface tension. Adsorption of fulvic acids releases silicon, and colours the deposits, to give features which are usually ascribed to illuviated organic complexes of aluminium and iron. Such features cannot, therefore, be taken as evidence for the translocation of iron and aluminium as organic complexes.

FERTILISER Recommendations. SAC/MISR. Scottish Colleges Publ. No. 160, 1985.

1371 FILIP, Z., CHESHIRE, M.V., GOODMAN, B.A. and McPHAIL, D.B. The occurrences of copper, iron, zinc and other elements and the nature of some copper and iron complexes in humic substances from municipal refuse disposed of in a landfill. *Sci. Total Environ.*, 1985, **44**, 1-16.
The decomposition of municipal refuse in landfills could result in the release of noxious substances, inclusing metals present in the refuse, into drainage waters. During decomposition humification occurs. A study has, therefore, been made of the extent to which the humic substances formed can complex, and so bind some of the metal species present. Examination of the humic substances by electron paramagnetic resonance spectroscopy indicates that the bonding of copper involves ligands containing nitrogen as well as oxygen. Several forms of iron complex are present, including one with parameters commensurate with a ferric porphyrin type of structure.

FILIP, Z., CHESHIRE, M.V., McPHAIL, D.B. and GOODMAN, B.A. The occurrence of heavy metals and the nature of some copper and iron complexes in humic substances from municipal refuse disposed of in a landfill. *Proc. Int. Humic Substances Soc. Int. Conf., 2nd, Birmingham, 1984*, 222-224.
An investigation has been made of the effects of different decomposition processes

of municipal refuse on the extent to which humic substances formed in the refuse are able to complex heavy metals that are present. In addition to elemental analyses, information on the nature of some of the iron and copper species have been obtained by electron paramagnetic resonance (EPR) spectroscopy and compared with complexes found in soil humic acid.

1391 FITZPATRICK, E.A., MACKIE, L.A. and MULLINS, C.E. The use of Plaster of Paris in the study of soil structure. *Soil Use and Management*, 1985, **1**, 70-72.
Plaster of Paris ($CaSO_4/½H_2O$) infiltration was used (i) to study the continuity of cracks and pores and the variation of macroporosity and crack width with depth and (ii) to maintain an undisturbed seedbed for subsequent resin impregnation. Examples are also given in which the remains of gaps between and at the bottom of the furrow slice can be clearly seen. The method is a useful qualitative visual techniqe, limited to the larger soil pores. Due to this limitation, it is more useful for showing pore continuity than for quantifying porosity.

1356 GAULD, J.H. and ROBERTSON, J.S. Soils and their related plant communities on the Dalradian limestone of some sites in central Perthshire, Scotland. *J. Ecol.*, 1985, **73**, 91-112.
The soil sub-groups and plant communities developed on Dalradian limestone sites in central Perthshire are discussed. The soils range from a rendzina on limestone rock *in situ* through to high and low base status brown forest soils on the glacial drift of mixed origin surrounding the rock outcrops, reflecting a progressive increase in the degree of leaching. The chemical composition of the soil plays a vital role in determining the specific vegetative cover. The plant communities on each soil sub-group are named, classified and briefly described. The relationships of the vegetation units with the soil is outlined. Because of the scientific interest in both the rendzinas and the calcareous grassland, neither of which can be re-created, attention is focused on their conservation.

1372 GOODMAN, B.A. and McPHAIL, D.B. EPR parameters for some copper (II)-bis(amino acid) complexes. *J. Chem. Soc. Dalton Trans.*, 1985, No. **8**, 1717-1718.
By using the ^{63}Cu and ^{65}Cu isotopes seperately in D_20 solutions, isotopic values have been obtained for the electron paramagnetic resonance spectra of some copper (II)-bis(amino acid) complexes, which had previously been shown to be of importance in the uptake of copper by wheat roots.

GOODMAN, B.A. and CHESHIRE, M.V. A Mossbauer-effect study of the reduction of iron by fulvic acid. *Proc. Int. Humic Substances Soc. Int. Conf., 2nd, Birmingham, 1984*, 180-182.
The effect of pH on the reduction of iron by fulvic acid extracted from an iron podzol has been investigated by Mössbauer spectroscopy. The results show that the degree of reduction increases with decreasing pH and that reoxidation occurs when the pH is raised. At pH4, a significant amount of iron is in the ferrous form, a result which tends to support the hypothesis that iron in podzols may be transported as ferrous ions. On raising the pH there is precipitation of an iron oxyhydroxide.

1336 GOODMAN, B.A., GREEN, H.L. and McPHAIL, D.B. An electron para- magnetic resonance (EPR) study of the adsorption of copper complexes on montmorillonite and imogolite. *Geochim. Cosmochim. Acta.*, 1984, **48**, 2143-2150.
In order to gain some insight into the possible chemical behaviour of copper in soils, the interactions of the free hydrated ion and of both low and high molecular weight copper complexes with an expanding layer clay mineral, have been investigated by electron paramagnetic resonance (EPR) spectroscopy. The resulting EPR parameters show distinct differences between the adsorbed species depending on their freedom of movement, the number present and the mode and site of adsorption.

1370 GOODMAN, B.A., VAUGHAN, D., McPHAIL, D.B., CHESHIRE, M.V. and SPARLING, G.P. ESR investigations of some fungal pigments. *Biochem. Soc. Trans.*, 1985, **13**, 623-624.
The pigments from 3 fungi, *Aspergillus niger, Rhizoctonia solani* and *Marasmius androsaceus*, have been extracted with dilute alkali and studied by ESR

spectroscopy both as solids and in alkaline solutions. In the case of *Aspergillus niger* a low molecular weight component, obtained by fractionation on Sephadex, was also investigated in alkaline solution. Variations of the spectra with alkali strength and time are discussed for each sample.

1389 GOODMAN, B.A., RUSSELL, J.D., MONTEZ, B., OLDFIELD, E. and KIRKPATRICK, R.J. Structural studies of imogolite and allophanes by aluminium-27 and silicon-29 nuclear magnetic resonance spectroscopy. *Phys. Chem. Miner.*, 1985, **12**, 342-346.
Al spectra have been obtained from some allophanes and imogolites of both natural and synthetic origin. In allophanes, six-coordinate aluminium can be readily distinguished by this technique from that with four-fold coordination. The chemical shift anisotropy of the six-coordinated aluminium in the allophanes is different from that in the imogolites, whereas the spectrum of the four-coordinated aluminium is indistinguishable from that of a synthetic silicon-aluminium gel.

GOODMAN, B.A., VAUGHAN, D., McPHAIL, D.B., CHESHIRE, M.V. and SPARLING, G.P. ESR investigations of humic materials extracted from some fungi. *Proc. Int. Humic Substances Soc. Int. Conf., 2nd, Birmingham, 1984*, 57-64.
Humic materials extracted from the fungi *Aspergillus niger, Rhizoctonia solani* and *Marasmius androsaceus* have been investigated by ESR spectroscopy as solids and in alkaline solutions. The spectra of the solids all showed the presence of components from Fe^{3+}, Cu^{2+} and free radicals, but in different relative proportions; the copper species were different in each sample, the *Rhizoctonia* HA having its Cu as a porphyrin. In alkaline solutions, narrow hyperfine split components that changed with time and strength of alkali were observed from each sample.

GREEN, H.L. and GOODMAN, B.A. The use of EPR spectroscopy in the characterization of copper complexes of humic acids. *Proc. Int. Humic Substances Soc. Int. Conf., 2nd, Birmingham, 1984*, 187-188.
The nature of the copper complexes with a soil humic acid, fractionated by solubility in aqueous ethanol, have been investigated by electron paramagnetic resonance (EPR) spectroscopy. With increasing ethanol concentrations the humic acid fractions had increasing copper contents and greater involvement of N-containing functional groups in the complexes. A complex consistent with S-coordination to the copper was also tentatively assigned. Samples were also prepared with added copper and the spectra from these additional complexes were all similar and consistent with the copper being bound to 0-containing groups.

1400 GUZEL, N. and WILSON, M.J. High-magnesium clays from alluvial soils of the Acipayam Plain, Southern Turkey. *Proc. Meeting European Clays Group, 5th, Prague, 1983*. Prague, Charles Univ., 1985, 117-123.
The alluvial soils of the Acipayam Plain in Southern Turkey contain an unusual assemblage of magnesium-rich clay minerals including smectite, sepiolite, palygorskite, serpentine, chlorite and talc. The origin of sepiolite and palygorskite is discussed and it is concluded that they have formed because geology and climate have combined to create an unusual environment characterized by high pH, high Si and Mg activities and minimal Al activities.

HENDERSON, D.J., CAMPBELL, C.G.B. and ROBERTSON, J.S. Surface water acidification programme: the North Loch Chon catchment area. Aberdeen, Macaulay Institute for Soil Research, 1985. (Restricted circulation)

HESLOP, R.E.F. and HIPKIN, J.A. Site survey of Achnafalnich. Aberdeen, Macaulay Institute for Soil Research, 1985. (Restricted circulation)

HUDSON, G., HIPKIN, J.A. AND ROBERTSON, J.S. Surface water acidification programme: soil survey of the Kelty water catchment. Aberdeen, Macaulay Institute for Soil Research, 1985. (Restricted circulation).

HULME, P.D. The peatland vegetation of the Isle of Lewis and Harris and the Shetland Isles, Scotland. *Aquilo Ser. Bot.*, 1985, **21**, 81-88.
The peatland vegetation of the Isle of Lewis and Harris and the Shetlands is described and classified according to the Braun-Blanquet phyto-sociological system.

HULME, P.D. Peat. In *Soils of the Black Isle. Memoir of the Soil Survey of Scotland*. By J.C.C. Romans. Aberdeen, Macaulay Institute for Soil Research, 1984.

HULME, P.D. and BLYTH, A.W. Observations on the erosion of blanket peat in Yell, Shetland. *Geografiska Annaler*, 1985, **67A**, 119-122.
A peatland erosion process, combining the effects of drought and heavy rain, is described.

HULME, P.D. and SHIRRIFFS, J. Castlehill of Strachan pollen analysis. *Proc. Soc. Antiq. Scotland*, 1984, **114**, 315-364.
The pollen analysis of a thirteenth century primary occupation deposit and a pre-occupation soil has provided information about the vegetation, woodland clearance and agriculture around the site prior to and during its occupation.

HULME, P.D., GREATREX, P.A. and WILMOTT, A. Peat stratigraphy. In *Observations on the peat ecology of Upton Fen, Norfolk*. . . . By B.D. Wheeler. *Trans. Proc. Norfolk and Norwich Naturalist Soc.*, 1985, **27**, 9-32.
A stratigraphical investigation of part of Upton Fen, Norfolk, showed that peat cutting produced two major features, namely, deep ponds or broads which are still open water, and shallow turf-ponds which have become recolonised by peat forming fen vegetation. This investigation was part of a Mires Research Group field meeting and is published with results of vegetational and hydrological investigations carried out during the meeting.

1369 JONES, D. AND McHARDY, W.J. Scanning electron microscopy of cryofixed and critical point-dried *Corpinus cinereus*. *Micron*, 1985, **16**, 115-123.
Surface features of the gills of a soil-inhabiting mushroom are described from observations made on tissue which had been quickly frozen (cryo-fixed) in liquid nitrogen and subsequently examined in a scanning electron microscope at approximately −150°C on a specially designed cold stage (Hexland Cryosystems). Many features, including shrinkage and wrinkling, often found in critical point-dried, chemically-fixed material, are absent from the cryofixed gills.

1383 JONES, D. and McHARDY, W.J. Cryofixation techniques with special reference to soil fungi. *Microbiol. Sci.*, 1985, **2**, 225-226, 229-230.
Because of the high vacuum in the specimen chamber of the scanning electron microscope, biological specimens require to be preserved in chemical fixatives and to be dehydrated prior to examination. Fixing and dehydration, however, result in deformities and over-all shrinkage of the specimen and in recent years much effort has been devoted to cryo-fixing biological material. This short review discusses cryo-fixation of mycological specimens, using a commercially available cryo-apparatus attached to a scanning electron microscope.

1377 JONES, D. and WILSON, M.J. Chemical activity of lichens on mineral surfaces — a review. *Int. Biodeter.*, 1985, **21**, 99-104.
The growth of lichens on rocks and minerals may lead to the breakdown of such substrates. This mineral decomposition is associated mainly with the excretion by the lichen fungus of chelating organic acids and the evidence for the involvement of the so-called lichen acids and of oxalic acids in this process is critically discussed.

1341 JONES, D., ANDERSON, H.A., RUSSELL, J.D. FRASER, A.R. and ONIONS, A.H.S. Vermiculine, a metabolic product from *Talaromyces wortmanii*. *Trans. Brit. Mycol. Soc.*, 1984, **83**, 718-721.
This communication describes the occurrence and identification of crystals in agar and liquid culture media supporting growth of a soil fungus *Penicillium wortmanii*, which was isolated during decomposition studies on phenolic acids. These crystals proved to be identical in composition to vermiculine, an antibiotic

previously extracted from culture media of *Penicillium vermiculatum* by Czechoslovakian research workers.

LEE, R., BACHE, B.W., WILSON, M.J. and SHARP, G.S. Aluminium release in relation to the determination of cation-exchange capacity of some podzolised New Zealand soils. *J. Soil Sci.*, 1985, **36**, 239-253.
Anomalies in the cation exchange behaviour of some acid New Zealand soils have been resolved by comparing determinations performed by various methods, with aluminium extracted into solution when the soils were leached with various cation salts, and with the behaviour of the clay minerals in the soils when saturated with these cations. Dioctahedral vermiculite clays collapsed on saturation with NH_4^+ or K^+, so restricting the exchange of Al and gave low CEC values. This did not occur when Mg^{2+} or Ba^{2+} were the saturating cations, nor when Al-chlorite clays were present. The importance of patterns of Al release when interpreting CEC values of acid soils is emphasised.

LINEHAN, D.J. Organic matter and trace metals in soils. In *Soil Organic Matter and Biological Activity*. Edited by D. Vaughan and R.E. Malcolm. The Hague, Martinus Nijhoff/Junk, 1985, 403-421.
This short article summarises rather briefly some aspects of the solution chemistry of trace metals and their chelation by organic ligands. It discusses the role of humic substances and of biochemicals, of both plant and microbial origin, in these reactions and the effects of various types of organic molecule on the uptake of trace elements by plants. Finally some suggestions are made regarding the future of research on soil organic matter and trace elements indicating a move away from emphasis on gross chemical characterisation of humic substances and towards more detailed studies of chelation reactions involving biochemicals as well as humic substances.

LINEHAN, D.J. and SINCLAIR, A.H. Micronutrients in soil solutions. *J. Sci Fd. Agric.*, 1985, **36**, 531-532.
Relationships between the trace element contents of barley plants at various stages and amounts of chemically extractable trace elements in the soil were generally poor. As the barley rhizosphere developed there were increases in Mn, Zn, Cu and Co producing maxima in early to mid summer. These changes were not related to pH changes. The dependence of trace element deficiency on the balance between the growth rate of the plant and the concentration of nutrients in the soil solution is described.

1368 LINEHAN, D.J., SINCLAIR, A.H. and MITCHELL, M.C. Mobilisation of Cu, Mn and Zn in the soil solutions of barley rhizospheres. *Plant and Soil.*, 1985, **86**, 147-149.
Plants obtain their mineral nutrients largely if not exclusively from solution so that their mineral nutrition is dependent on the composition of the soil solution. We have shown that the concentrations of the micronutrients copper, manganese and zinc in the soil solution are low in early spring but increase in barley rhizosphere soils, reaching maximum values during late spring or early summer, subsequently decreasing until at harvest time they are again comparable with those of early spring.

1392 LIVINGSTONE, A. and RUSSELL, J.D. X-ray powder data for susannite, and its distinction from leadhillite. *Miner. Mag.*, 1985, **49**, 750-753.
Susannite and leadhillite, two of the polymorphs of $Pb_4 SO_4 (CO_3)_2(OH)_2$, can be distinguished by infrared spectroscopy, but their X-ray powder patterns are virtually identical. Close inspection of a weak line near 6.6Å, however, reveals that it consistently appears at 6.50-6.56Å (average of 8 specimens 6.52Å) in susannite, and at 6.67-6.80Å (average of 14 specimens 6.74Å) in leadhillite with no specimens giving intermediate values. Both spacings can be detected in a mixture of the two polymorphs.

1357 MACDONALD, I.R. and HART, J.W. Apical involvement in geogrowth responses of the horizontal hypocotyl. *J. Plant Physiol.*, 1985, **118**, 353-356.
The directional growth of seedlings orienting themselves in relation to gravity has traditionally been viewed as subject to apical control. In recent years this view has

been disputed. In this paper the demonstration that the georesponse of the basal end of a horizontal hypocotyl differs according to the orientation of the apex, is adduced as evidence in favour of an apical role in the control of directional growth.

1359 MACDONALD, I.R. and HART, J.W. The role of the apex in normal and tropic growth in sunflower hypocotyls. *Planta*, 1985, **163**, 549-553.
The control of seedling growth by agrochemicals is of great importance in crop husbandry but the mechanisms of normal growth regulation are still obscure. In this study the contribution of the apical region to the growth of sunflower seedlings has been examined by progressive apical ablation in conjunction with an accurate technique for measuring regional growth of the hypocotyl. The results demonstrate that a distinction can be made between the region of growth and a region of growth regulation, indicating that the site of production of a growth regulator is remote from the site of action.

1402 MACKENZIE, R.C. Soil clays: subjects for chemistry, mineralogy or physics? *Proc. Meeting European Clay Groups, 5th, Prague, 1983*. Prague, Charles Univ., 1985, 25-31.
Surface soils of temperate regions are particularly complex solid-liquid-gas systems, where the liquid and gas phases are represented by the soil solution and the soil atmosphere, respectively, and the solid phase is a complicated biological-organic-inorganic miscellany. As all the phases and constituents are in dynamic equilibrium in the field, even the processes of taking a sample can cause changes. Consideration of the changes likely to occur during separation and preparation of the clay fraction lead inevitably to the conclusion that the chemistry and physics as well as, sometimes, even the mineralogy of particles are affected. One cannot, therefore, extrapolate directly from the laboratory to the field, but the disturbance decrease with depth until, for the parent material, they are similar to those encountered with any other geological deposit, attention should therefore be paid to chemistry and physics, as well as mineralogy, when dealing with soil clays.

1363 MACKLON, A.E.S., VAUGHAN, D., SIM, A., McFARLANE, I.D. and ORD, B.G. Protein dysfunction and inhibition of amino acid incorporation in root segments from wheat and mung bean seedlings caused by some amino acid analogues. *J. Exper. Bot.*, 1985, **36**, 911-918.
Amino acid analogues can become incorporated in place of their naturally occurring counterparts to produce non-functional protein, and are used as tools in the investigation of protein involvement in ion uptake and transport in plants. In this paper, the effects of several analogues on enzyme activity and amino acid incorporation are examined to establish that they behave in the expected manner, and do not have an inhibitory effect on protein synthesis and general metabolism.

1403 McPHAIL, D.B. and GOODMAN, B.A. Characterization of copper (II) diglycine complexes by EPR spectroscopy. *J. Chem. Res.*, 1985, M2901-2923, S276-S277.
Electron paramagnetic resonance studies on model copper(II)(amino acid) complexes, already undertaken because of the involvement of such complexes in the uptake of copper by plants, have been extended to include the peptide diglycine. Spectra obtained from fluid and frozen solutions showed nine copper(II)-diglycine complexes existing in the pH range 1.15-14. Nitrogen superhyperfine structure present in most of the fluid solution and some of the frozen solution spectra was able to give information on the coordination of the peptide around the central metal ion. Two isomers were shown to exist in equilibrium in a solution of the bis-complex, each with two nitrogen atoms coordinated to the copper. Structures postulated by workers using electrochemical techniques were not always in agreement with the EPR results. The discrepancies which arose are discussed.

MELLOR, A. Soil chronosequences on Neoglacial moraine ridges, Jostedalsbreen and Jotunheimen, southern Norway: a quantitative pedogenic approach. In *Geomorphology and Soils*. Edited by K.S. Richards, R.R. Arnott and S. Ellis. London, Allen & Unwin, 1985, 289-308.

Two soil chronosequences, existing on Neoglacial moraine ridges, are examined. Chronofunctions are constructed for a variety of soil morphological, physical and chemical properties, using linear and non-linear models. These results are supplemented with surface textural, clay mineralogical and micromorphological information in order to identify the nature and rate of organic, weathering and translocatory soil-forming processes. This quantitative approach, based on a more detailed soil analytical framework than has previously been available, allows comparison of rates of soil development between the two sites, and interferences concerning the effect of environmental factors on pedogenic processes.

MISR/COSAC. Advisory soil analysis and interpretation. *Working Party Bull. No. 1.* Aberdeen, NOSCA, 1985, £2.50.

MILLER, H.G. Acid-rain — are there soil mediated effects? *Proc. 12th Int. Students Forestry Symp. on Forestry and Pollution. Univ. Edinb. Dept. of Forestry and Natural Res. Edinburgh, 1985*, 72-81.
Concern has been expressed that acid rain may be causing soil changes, perhaps entailing adverse effects on tree growth, or leading to drainage of acidity into streams, with consequent fish death. Consideration of the available evidence does not support the claim that soils are being significantly damaged, and the tree death reported from Germany seems more likely to result from direct gaseous pollution, particularly with ozone, than from any soil mediated effects, including high aluminium levels. Loss of acidity to streams, however, does occur, particularly where soils are thin and drainage is rapid. Possible ameliorative measures are discussed.

MILLARD, P., SHARP, G.S. and SCOTT,N.M. The effect of sulphur supply on the yield and composition of ryegrass. *Proc. Sulphur '85.* London, British Sulphur Corp., 1985.
Grass was grown on a soil low in plant-available sulphur (4mg/kg), and sulphur applied either as ammonium sulphate in the seedbed or as a foliar spray programme of elemental sulphur. Sulphur application increased the yield of grass at each cut after the first. The maximum increase in total yield was 64% for 20 kg S/ha applied as ammonium sulphate. Total S and SO_4^{2-}-S concentrations in the grass were increased and the N/S ratio decreased. The pattern of nitrogen incorporation was altered by sulphur application. The concentration of amides descreased and the proportion of total nitrogen recovered in amino acids, particularly cyst(e)ine, methionine, arginine and glycine increased by the second cut. By the third and fourth cuts sulphur application also gave corresponding increases in leucine, serine, lysine, histidine and threonine concentrations. These changes in composition are discussed in relation to the value of the grass as a feed for ruminants.

NADEAU, P.H. Clay particle engineering: a potential new technology with diverse applications. Report for the British Technology Group. (Restricted circulation)

1362 NADEAU, P.H., WILSON, M.J., McHARDY, W.J. and TAIT, J.M. The conversion of smectite to illite during diagenesis: evidence for some illitic clays from bentonites and sandstones. *Miner. Mag.*, 1985, **49**, 393-400.
Complementary X-ray diffraction and electron microscope investigations of illitic clays from bentonites and sandstones provide evidence to show that in both instances the clays formed by the crystallization of extremely fine particles directly from solution. This mode of formation could also account for the genesis of illitic clays in deeply buried pelitic sediments.

1385 NADEAU, P.H., FARMER, V.C., McHARDY, W.J. and BAIN, D.C. Compositional variations of the Unterrupsroth beidellite. *Amer. Miner.*, 1985, **70**, 1004-1010.
The nature of isomorphous substitution of various size fractions of Na- dispersed Unterrupsroth clay is characterised by a variety of complementary analytical techniques including XRD, XRF, SEM, TEM, IR, and solid-state NMR. The results demonstrate that the coarse fraction is more beidellitic (Al for Si tetrahedral substitution) and the fine fraction is more montmorillonitic (Mg for Al

octahedral substitution). These observations demonstrate the heterogeneous nature of some smectites, whose high surface areas and cation exchange capacities make them very influential mineral components of soil.

1348 NADEAU, P.H., WILSON, M.J., McHARDY, W.J. and TAIT, J.M. Inter-particle diffraction: a new concept for stratified clays. *Clay Minerals.*, 1984, **19**, 757-769.
Transmission electron microscope and X-ray diffraction evidence indicate that interstratified clay minerals, which occur widely in soils, are composed of aggregates of fundamental particles whose interfaces can absorb water or organic molecules. The various kinds of fundamental particles range from 10 to 50A in thickness and the layer sequence examined by X-ray diffraction is determined by the types and proportions of the particles present. This new model has far-reaching implications with respect to the chemistry, genesis and behaviour of interstratified clay minerals in soils.

NOLAN, A., LILLY, A. and ROBERTSON, J.S. Surface Water Acidification Programme: the soils of the Allt a' Mharcaidh catchment. Aberdeen, Macaulay Institute for Soil Research, 1985. (Restricted circulation).

PALLATT, N., WILSON, M.J. and McHARDY, W.J. Insights into the relationship between permeability and the morphology of diagenetic illite in reservoir rocks. *J. Petroleum Tech.*, 1984, **36**, 225-227.
This study, which was carried out in conjunction with the BP Research Centre at Sunbury-on-Thames, shows that the permeability of some reservoir sandstones depends largely upon the distribution, location and morphology of diagenetic illitic clay. The morphology of the illite in these sandstones is related crucially to the manner of drying the specimen and is only properly revealed after critical point drying. This study follows investigations of similar sensitive clay materials in soil.

*ROBERTSON, J.S. A key to the common plant communities of Scotland. Soil Survey of Scotland Monograph. Aberdeen, Macaulay Institute for Soil Research, 1984.

*ROMANS, J.C.C. The soils of the Black Isle. Memoir of the Soil Survey of Scotland. Aberdeen, Macaulay Institute for Soil Research, 1984.

1347 RUSSELL, J.D., BIRNIE, A. and FRASER, A.R. High grade magnetic separation (HGMS) in soil clay mineral studies. *Clay Minerals*, 1984, **19**, 771-778.
The identification of individual minerals in a soil clay is greatly facilitated by fractionating the clay in a magnetic field, using a modification of a technique known as high gradient magnetic separation (HGMS). Depending on their content of iron and the nature of the minerals themselves, that is whether they are oxides, hydroxides or silicates, different minerals appear in fractions collected at different strengths of magnetic field. Using clays of three different origins, the HGMS technique concentrated the more iron-rich minerals such as hematite, goethite, lepidocrocite and hornblende in relatively low-field fractions, and less iron-rich minerals including certain chlorites, biotite and hydrobiotite in the higher-field fractions. There was some evidence from analysis by infrared spectroscopy and X-ray diffraction, that ferruginous chlorites had been fractioned in this way. Traces of manganese-rich minerals, such as vernadite, were also concentrated in the higher-field fractions. The concentrations of some minerals in the HGMS fractions were up to several decades more than those in the original clays.

SCOTT, N.M. Sulphur in soils and plants. In *Soil Organic Matter and Biological Activity*. Edited by D. Vaughan and R.E. Malcolm. The Hague, Martinus Nijhoff/Junk, 1985, 379-401.
This review describes the forms of inorganic and organic sulphur in soils, their transformations by micro-organisms (mineralisation, immobilisation, oxidation and reduction); the occurrence and diagnosis of sulphur deficiency in soils and plants; and the significance of man-induced atmospheric sulphur inputs.

SHARP, B.L. Analytical plasma spectroscopy. In: *Annual Reports on Analytical Atomic Spectroscopy*, 1985, **14**, 8.

SHARP, B.L. Patent: the Conespray Nebulizer-method of and apparatus for the nebulization of liquid suspensions. British Technology Group Assignment No. 8432338, 1984.
This patent describes a nebulizer dispersing liquids and liquid suspensions into a fine aerosol with a minimum consumption of the propellant gas. It is based on the use of an over-expanded nozzzle that caused liquid to be strongly entrained into the flow of a supersonic free-jet. The resultant spray is compatible with the sample introduction requirements of sources used for analytical atomic spectrometry.

SINCLAIR, A.H. Trace elements — keeping a fine balance. *Scottish Farmer*, 26.1.85.
Trace element problems in arable farming are reviewed and suggestions are given on maintaining an adequate balance without the use of unnecessary chemicals.

SINCLAIR, A.H. Efficient use of soil and fertilizer phosphate. *Farmers Newsletter*. North of Scotland College of Agriculture, 1985.
Strategies for the efficient use of fertiliser phosphate are described and are related to soil phosphorus status.

SINCLAIR, A.H. Soil and fertiliser sulphur update. *Farmers Newsletter*. North of Scotland College of Agriculture, 1985.
On completion of further sulphur trials on a range of crops, sulphur fertiliser recommendations are updated and are related to soil sulphur status.

SINCLAIR, A.H., LINEHAN, D.J. and ROSS, J.A.M. Soil manganese and manganese deficiency in barley. *MISR Technical Note No. 4*. Aberdeen, Macaulay Institute for Soil Research, 1985.
Seed treatment of spring barley by soaking with manganese sulphate under experimental conditions improved manganese nutrition early in the season and increased grain yield. Two forms of mobilisation of soil manganese are described, one dependent on pH and the other non-dependent on pH but affected by the presence of barley roots.

SINCLAIR, A.H. and COOKE, S. Monitoring the effect of grass on soil fertility. *Norgrass*, No. 25, 1985.
The basis of the Soil Fertility Information System for Scotland is described. Data are given on present levels of soil pH and major nutrients in North East Scotland.

1352 SMITH, B.F.L. and MITCHELL, B.D. Characterization of X-ray amorphous material in a Scottish soil by selective chemical techniques. *Clay Minerals*, 1984, **19**, 737-744.
A range of chemical techniques has been used to examine the inorganic gel content of a Scottish brown forest soil developed on glacial till derived from epidiorite. The reactivity of the gel, as determined by fluoride exchange, is similar to those reported for Japanese and New Zealand allophanic soils.

1376 SMITH, B.F.L. and MITCHELL, B.D. Differences in silica release from soils of two Scottish associations as assessed by trimethylsilylation. *Geoderma*, 1985, **35**, 333-342.
The ease with which silicate rocks weather to form soil is related to the arrangement of the silica units in their structures. A trimethylsilylation method to measure silica, released by acid attack on these units, was applied to a range of soil groups developed on two widely contrasting parent materials. Significantly higher amounts were obtained for soil derived from basic and intermediate parent materials than from those on acidic conglomerates and sandstones. For all profiles silica released from the eluvial horizons was smallest with maximum being, in general, obtained from the illuvial horizons. Leached soil groups released more silica than gleys. The principal source of monomeric silica was attributed to aluminosilica gels of low Si : Al ratio.

*SOIL SURVEY STAFF. Soil maps of Scotland. Scale 1:25000. Sheet NS 88/98 (Falkirk North); NS 85/95 (Carluke and Forth); NS 86/96 (Bathgate); NS 67/77 (Cumbernauld and Kirkintilloch); NS 87/97 (Falkirk South); NS 84/94 (Lanark). £2 + VAT + Post and Packing £1.

*SOIL SURVEY STAFF. Soil maps of Scotland. Scale 1:50 000. Sheet 57 (Stirling and the Trossachs); Sheet 8 (Stornoway and North Lewis); Sheet 13 (West Lewis and North Harris); Sheet 14 (Tarbert and Loch Seaforth); Sheet 22 (Benbecula); Sheet 31 (Barra); Sheet 39 (Rhum and Eigg); Sheet 43 (Braemar); Sheet 44 (Ballater); Sheet 42 (Loch Rannoch); Sheet 51 (Loch Tay); Sheet 52 (Pitlochry and Aberfeldy); Sheet 20 (Beinn Dearg); Sheet 21 (Dornoch Firth); Sheet 2 (Shetland-Whalsay); Sheet 3 (Shetland-North Mainland); Sheet 4 (Shetland-South Mainland); Sheet 1 (Shetland-Yell and Unst); Sheet 25 (Glen Garron); Sheet 26 (Inverness); Sheet 71 (Lanark and Upper Nithsdale); Sheet 72/73 (Upper Clyde Valley/Galashiels and Ettrick Forrest); Sheet 77/78 (New Galloway and Glen Trool/Nithsdale and Lowther Hills); Sheet 79/80 (Hawick and Eskdale/The Cheviot Hills); Sheet 84/85 (Dumfries/Carlisle and Solway Firth); Sheet 32 (South Skye); Sheet 23 (North Skye); Sheet 33 (Loch Alsh and Glen Shiel); Sheet 34 (Fort Nevis); Sheet 50 (Glen Orchy); Sheet 35 (Kingussie). £2.50 + VAT + Post and Packing £1.20.

*SOIL SURVEY STAFF. Agricultural Studies: River Spey Abstraction Scheme. (For Sir M. MacDonald & Partners and Grampian Regional Council.) Aberdeen, Macaulay Institute for Soil Research, 1985. (Restricted circulation)

*SOIL SURVEY STAFF. Organisation and methods: soil and land capability for agriculture 1:250 000 survey. Aberdeen, Macaulay Institute for Soil Research, 1984.

SPARLING, G.P. The soil biomass. In *Soil Organic Matter and Biological Activity*. Edited by D. Vaughan and R.E. Malcolm. The Hague, Martinus Nijhoff/Junk, 1985, 223-262.

A review of the soil microbial biomass in relation to the soil organic matter is presented. Methods of estimating the microbial biomass are discussed with particular emphasis on the chloroform fumigation technique. The biomass comprises only 1-3% of the organic C and N of soil, but it is a comparatively labile fraction and a potentially important source of plant nutrients. The fungi dominate the biomass, but their activity is generally limited by the low levels of available substrates. However, the organisms are responsible for mineralization of organic compounds, immobilization of plant nutrients, they can affect root physiology and modify soil structure, and thus have an important role in soil processes and crop productivity.

1351 SPARLING, G.P. and BERROW, M.L. Effect of air drying, y-irradiation and chloroform fumigation of soil on extractability of trace elements. *J. Agric. Sci.*, 1985, **104**, 223-226.

Trace elements in soils occur in many different forms, and various chemical extractants have been used to assess the "plant available" fraction. Soil microorganisms are also known to accumulate certain elements and microbial activity can influence their availability and rate of turnover in soil. A study using an arable soil, showed that the amounts of trace elements released from the killed microbial cells were small, and made only a minor contribution to the exchangeable levels with the exception of Mn and Co. However, microbial activity greatly increased the exchangeable levels of some elements, particularly Mn and Co, when the organisms were stimulated by the addition of glucose.

SPARLING, G.P. and CHESHIRE, M.V. Effect of periodate oxidation on the polysaccharide content and microaggregate stability of rhizosphere and non-rhizosphere soils. *Plant and Soil.*, 1985, **88**, 113-122.

The relationship between the water stability of soil micro-aggregates and the soil polysaccharide content has been studied in rhizosphere and non- rhizosphere samples of three soils that had grown peas, barley or grasses over a period of 6 weeks. Although the polysaccharide contents of the rhizosphere soils were greater than the non-rhizosphere soils, rhizosphere polysaccharide appeared to make less contribution to aggregate stability than that from the non-rhizosphere soils.

1399 SPARLING, G.P., GASKIN, G. and CHESHIRE, M.V. An inexpensive photometer for turbidity measurements on soil suspensions. *Comm. Soil Sci. Plant Anal.*, 1985, **16**, 1219-1225.

A photometer detector has been devised suitable for determining the turbidity of soil suspensions. The detector allows a measure to be made of the extent of disruption of soil micro-aggregates.

THOMSON, W.J., DYSON, P.W. and MATTHEWS, S. Effects of chlormequat and nitrogen on the growth, development and yield of winter barley. *Proc. BCPC Conference — Weeds, Brighton, 1985.*, **2**, 4C-20, 529-534.
The response of winter barley, cv Igri, to chlormequat (2-chloroethyltrimethyl ammonium chloride) and to nitrogen was investigated in a replicated multifactorial field trial in 1982/83. Single or sequential chlormequat treatments increased yields at all four nitrogen levels examined. The mechanism by which chlormequat achieved these yield increases depended on the time of application and on nitrogen level. Chlormequat controlled severe early lodging at the highest nitrogen level of 200 kg N/ha. The yield increases at the lower levels of nitrogen were attributed to small increases in all three yield components (ear number per plant, grain number per ear and grain weight).

1364 THORNTON, B. and MACKLON, A.E.S. Effects of some amino acid analogues on the uptake and transport of K+ and Ca+ in wheat and mung bean seedlings. 1. Cortical cell fluxes and transport to the stele in excised root segments, as affected by p-fluorophenylalanine. *J. Exper. Bot.*, 1985, **36**, 919-929.
Uptake and transport of nutrients by plants depend on the involvement of specific proteins. When the roots are supplied with amino acid analogue, protein synthesis is not inhibited, but the analogue becomes incorporated, in place of its naturally occurring counterpart, producing "nonsense" protein, which cannot function normally. The results of such effects on the uptake and transport of potassium and calcium were interpreted as supporting the "two pump hypothesis" of ion transport in plants, which envisages control at both the uptake step into the root, and at the point of entry into the conducting tissue. Results presented in this paper relate to studies at the cellular level.

1365 THORNTON, B. and MACKLON, A.E.S. Effects of some amino acid analogues on the uptake and transport of K+ and Ca+ in wheat and mung bean seedlings. 11. Uptake and translocation in whole seedling plants. *J. Exper. Bot.*, 1985, **36**, 930-936.
Uptake and transport by plants depend on the involvement of specific proteins. When the roots are supplied with an amino acid analogue, protein synthesis is not inhibited, but the analogue becomes incorporated, in place of its naturally occurring counterpart, producing "nonsense" protein, which cannot function normally. The results of such effects on the uptake and transport of potassium and calcium were interpreted as supporting the "two pump hypothesis" of ion transport in plants, which envisages control at both the uptake step into the root, and at the point of entry into the conducting tissue. Results presented in this paper relate to studies on whole seedlings.

VAUGHAN, D. Controlling the ochre problem in field drainage systems using coniferous bark. *MISR Technical Note No. 1. 1985*. Aberdeen, Macaulay Institute for Soil Research, 1985.

VAUGHAN, D. Ochre is the villain. *J. East of England Agric. Soc.*, 1985, No. 29, 16.

VAUGHAN, D. Conifer bark tackles ochre deposition. *Farm Contractor.*, 1985, January, 47.

VAUGHAN, D. and MALCOLM, R.E., Eds. Soil Organic Matter and Biological Activity. (Developments in Plant and Soil Sciences. Vol. 16). The Hague, Martinus Nijhoff/Junk, 1985.

VAUGHAN, D. and MALCOLM, R.E. Influence of humic substances on growth and physiological processes. In *Soil Organic Matter and Biological Activity*. Edited by D. Vaughan and R.E. Malcolm. The Hague, Martinus Nijhoff/Junk, 1985, 37-75.
This article shows that current thinking on the influence of humus on plant growth is still dominated by historical concepts of the nature of soil organic matter,

particularly those of humic and fulvic acids. It reviews the confusing, conflicting and often exaggerated claims in much of the literature and reveals that often inadequate controls and culture conditions contribute to the overall results. Evidence is presented for some direct effects of humic substances on plant growth and nutrient uptake, but it is concluded that these effects are of minor importance under field conditions where many other factors exert dominant influence.

VAUGHAN, D. and ORD, B.G. Soil organic matter — a perspective on its nature, extraction, turnover and role in soil fertility. In *Soil Organic Matter and Biological Activity*. Edited by D. Vaughan and R.E. Malcolm. The Hague, Martinus Nijhoff/Junk, 1985, 1-36.
This review article describes the evolution of techniques used for extracting and fractioning humus. Particular emphasis is given to humic substances. The role of humus in soil fertility is also discussed. It is concluded that, although there is a substantial literature purporting to show a direct effect of humus on plant growth, the major effects of soil organic matter are indirect in that they involve such factors as for example providing a reservoir of plant nutrients, influencing the buffering capacity of the soil and helping in water retention.

VAUGHAN, D., MALCOLM, R.E. and ORD, B.G. Influence of humic substances on biochemical processes in plants. In *Soil Organic Matter and Biological Activity*. Edited by D. Vaughan and R.E. Malcolm. The Hague, Martinus Nijhoff/Junk, 1985, 77-108.
Plant growth is the ultimate expression of a series of biochemical reactions. Any substance which alters the rates of such reactions can, therefore, influence plant growth with a resultant effect on crop production. This review article summarises our present knowledge on the mode of action of soil organic matter on biochemical processes such as respiration, photosynthesis, ion uptake and nucleic acid and protein synthesis. The most likely soil organic matter fractions to evoke such responses are also discussed.

1361 WHITEHOUSE, M.J., BOON, J.J., BRACEWELL, J.M., GUTTERIDGE, C.S., PIDDUCK, A.J. and PUCKEY, D.J. The results of a pyrolysis mass spectrometry interlaboratory trial. *J. Anal. Appl. Pyrolysis.* 1985, **8**, 515-532.
An interlaboratory comparison of pyrolysis mass spectrometry, by the Macaulay Institute and five other research centres, showed a reasonable agreement in the analysis of technical polymers, but a larger divergence in the analysis of more complex biopolymer samples. The results indicated that inter-laboratory reproducibility is affected by differences in pyrolysis systems, and also highlighted the problem of reproducing low electron energies (< 20eV) with different instruments. The study underlines the need to set up practical instrumental reference standards for this technique.

1387 WILLIAMS, B.L., BOGGIE, R., COOPER, J. and MITCHELL, J.W. Changes in some physical and chemical characteristics of peat following reseeding and grazing. *Irish J. Agric. Sci.*, 1985, **24**, 229-236.
Samples from adjacent natural and reseeded peatland areas at 4 sites on Lewis have been examined to determine the effects of pasture improvement on the physical structure and chemical composition of the peat. Reseeding has increased the percentage air volume two-fold in the top 10 cm but compaction and shrinkage had reduced porosity slightly. Contents of potassium, calcium, magnesium and sodium in the peat were high compared with those in mainland peats and showed the influence of the sea. Nitrogen and phosphorus contents were higher in reseeded than in natural peat and at the two sites the net gain of nitrogen, approximately 80 kg N ha^{-1} yr^{-1}, corresponded closely to reported inputs from biological nitrogen fixation in grass-clover swards.

WILLIAMS, L.D., BIRNIE, R.V. and GALLAGHER, J.G. Millimeter-wave backscatter from snowcover. *Proc. IGARSS 85, Univ. Mass.*, 1985, 842-847.
Ground-truth measurements of snowcover properties were made in Bavaria in 1984 in support of helicopter-mounted radar measurements of 80 GHz and 94 GHz backscattering coefficient due to variations in grain size, surface roughness and volumetric regression. The results confirmed that for wet snow both surface

roughness and water content were important but for dry snow the backscattering coefficient decreased with increasing grain size. The latter result was contrary to expectation.

WILSON, M.J. The mineralogy and weathering history of Scottish soils. In *Geomorphology and Soils.* Edited by K.S. Richards, R.R. Arnett and S. Ellis. London, Allen & Unwin, 1985, 233-244.
The clay mineralogy and weathering history of Scottish soils may be readily interpreted in terms of the effects of (a) parent material (b) pre-glacial weathering and (c) post-glacial weathering. Mineralogical criteria are suggested by which the influence of these weathering episodes can be recognised. In general, the occurrence of kaolinite, halloysite or gibbsite in soils of widely varying drainage class, where the influence of parent material can be excluded, is a good indication of the effect of pre-glacial weathering episodes. Post-glacial weathering is confined mainly to the transformation of micaceous minerals and to the formation of poorly-ordered clays.

1354 WILSON, M.J. and NADEAU, P.H. Interstratified clay minerals and weathering processes. In *The Chemistry of Weathering.* By J.J. Drever. Dordrecht, D. Reidel, 1985, 97-118.
The major types of interstratified clay minerals are reviewed with particular emphasis on those that occur in soils and weathering environments. During weathering, interstratified clay minerals form mainly by transformation reactions involving relatively large crystals of mica or chlorite. In contrast, during diagenesis neoformation is more general and the interstratified minerals formed consist mainly of extremely fine-grained particles, typically some tens of Angstroms in thickness when examined in their fundamental form.

1349 WILSON, M.J., BAIN, D.C. and DUTHIE, D.M.L. The soil clays of Great Britain. 11. Scotland. *Clay Minerals*, 1984, **19**, 709-735.
This paper reviews the clay mineralogy of all the major soil associations in Scotland, as determined by X-ray diffraction. Scottish soils are usually developed upon glacial drift which derives ultimately from a variety of parent materials, including granite and granitic gneiss, gabbro, basalt/andesite, mica schist and related metamorphic rocks. Lower palaeozoic greywackes and shales, Old Red Sandstone sediments, carboniferous sediments, fluvioglacial sands and gravels and estuarine silts and clays. The nature of the soil clays is very strongly influenced by inheritance from these materials, but the effects of pre-glacial weathering and recent pedogenesis are also discernible. Inheritance has contributed a wide variety of clay minerals to the soils including illite, kaolinite, and recent pedogenesis has brought about the transformation of inherited layer silicates by a vermiculitization process, with concomitant interlayer alumination, particularly in surface horizons.

1378 WOOD, S. A method for the examination of the substrate mycelium of actinomycetes by scanning electron microscopy. *J. Gen. Microbiol.*, 1985, **131**, 2493-2495.
A method is described which enables substrate mycelium to be observed with scanning electron microscopy using a solidifying agent in the growth medium which liquefies on cooling, allowing substrate mycelium to be removed without cellular damage. This method will enable studies to be carried out on growth patterns and kinetics of microbial growth into solid substrate and to analyse this growth chemically.

1360 WRIGHT, G.G. Distribution and area of winter oilseed rape within eastern Scotland: a survey based on LANDSAT data. *Res. Dev. Agric.*, 1985, **2**, 41-45.
Over the last four years, there has been a considerable increase in the acreage of winter oilseed rape in eastern Scotland. From around the first or second week of May, when flowering commences, the bright yellow colour and therefore the discrete spectral response of this plant provide an excellent opportunity to further investigate and develop the potential of space imagery for crop mapping and monitoring applications. Methods used to establish the distribution and to estimate the total acreage of winter oilseed rape in north-east Scotland in 1984 are presented and discussed together with an assessment of field area accuracy given the constraints of field size and the current spatial resolution of LANDSAT Imagery.

AGRICULTURAL RESEARCH INSTITUTES IN GREAT BRITAIN

The research programmes of the following agricultural research institutes supported by public funds are co-ordinated by the Agricultural and Food 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 concerned.

ARC Institutes

Animal Breeding Research Organisation,	King's Buildings, West Mains Road, Edinburgh, EH9 3JQ.
Food Research Institute,	Bristol, Langford, Bristol, BS18 7DY.
Food Research Institute,	Norwich, Colney Lane, Norwich, NR4 7UA.
Poultry Research Institute,	Roslin, Midlothian, EH25 9PS.
Weed Research Organisation,	Begbroke Hill, Sandy Lane, Yarnton, Oxford, OX5 1PF.

State-aided Institutes (Scotland).

Hannah Research Institute,	Ayr, KA6 5HL.
Hill Farming Research Organisation,	Bush Estate, Penicuik, Midlothian, EH26 OPY.
Macaulay Institute for Soil Research,	Craigiebuckler, Aberdeen, AB9 2QJ.
Moredun Research Institute,	408 Gilmerton Road, Edinburgh, EH17 7JE.
Rowett Research Institute,	Bucksburn, Aberdeen, AB2 9SB.
Scottish Crop Research Institute,	Invergowrie, Dundee, DD2 5DA. and Pentlandfield, Roslin, Midlothian, EH25 9RF.
Scottish Institute for Agricultural Engineering,	Bush Estate, Penicuik, Midlothian, EH26 0PH.

State-aided Institutes (England & Wales).

Animal and Grassland Research Institute,	Hurley, Maidenhead, Berks, SL6 5LR.
Animal Virus Research Institute,	Pirbright, Woking, Surrey, GU24 0NF.
East Malling Research Station,	East Malling, Maidstone, Kent, MEl9 6BJ.
Food Research Institute,	Reading, Shinfield, Reading, Berks, RG2 9AT.
Glasshouse Crops Research Station,	Worthing Road, Littlehampton, West Sussex, BN17 6LP.
Houghton Poultry Research Station,	Houghton, Huntingdon, PE17 2DA.
John Innes Institute,	Colney Lane, Norwich, NR4 7UH.
Long Ashton Research Station,	Long Ashton, Bristol, BS18 9AF.
National Institute of Agricultural Engineering,	Wrest Park, Silsoe, Beds., MK45 4HS.
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.

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