ISSN 0369-0385

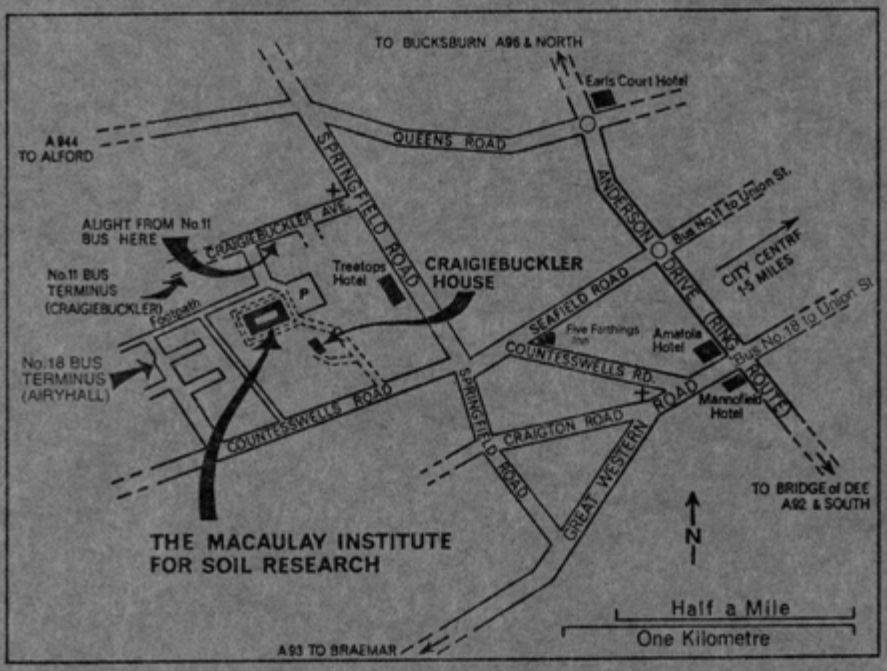
THE MACAULAY INSTITUTE FOR SOIL RESEARCH

FOUNDED 1930

1984 ANNUAL REPORT

No. 54

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



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The main part of this report covers the period from 1st January to 31st December, 1984. The staff list is that current in December, 1984, and the Introduction is similarly updated. The report was published in May, 1985.

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

THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

(Founded 1930)

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Left to right: Mr Loudon Hamilton, Secretary of The Department of Agriculture and Fisheries for Scotland and Lord Gray of Contin, Minister of State for Scotland, in discussion with Mr M. F. Proe and Mr R. A. Robertson on the occasion of their visit to the Institute on 26th October, 1984.

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1984

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D. Johnston.

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Miss M. Malcolm — appointed 22/10/84.
Miss M. E. Stamm — appointed 22/10/84 (Term Contract)
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E. Lawson — retired 29/3/84.
M. S. Davidson — appointed 12/3/84.

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I. D. McFarlane.
R. G. Baker, B.Sc. (HIDB Term Contract) — appointed 15/10/84.
Mrs M. R. Tyler.

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B. S. Griffiths, B.Sc., Ph.D.
S. Wood, B.Sc., Ph.D.
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K. Ritz, B.Sc. — appointed 1/6/84.
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Mrs H. A. Kidd — resigned 16/4/84.
Mrs B. Doyle — resigned 20/4/84.
Mrs J. M. A. Milne (née Melvin) — resigned 27/9/84.
Miss S-A. Mason — appointed 4/6/84.
Miss K. D. Webster — appointed 4/6/84.
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SOIL FERTILITY

Head of Department: B. W. Bache, M.A., Ph.D., C.Chem., F.R.S.C. — resigned 31/3/84.
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J. W. S. Reith, B.Sc., (Agric) Ph.D., C.Chem., F.R.S.C. retired 31/12/83.
A. H. Knight, B.Sc. — retired 31/12/83.
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C. J. Wilkinson.
Miss S. Main — appointed 4/1/84.
Miss J. Smith, 5/3/84-21/9/84.
Miss P. J. Anderson — appointed 21/5/84.
Miss C. M. Stott — appointed 29/10/84.
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A. R. Douglas.
J. S. Morrison.
J. A. M. Anderson.
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D. W. Nelson — appointed 12.3.84.

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T. Gilmour, B.Sc.
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Mrs M. E. Wilson.
Miss J. M. C. Cowe — appointed 2/7/84.

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A. J. Nolan, B.Sc.
A. Lilly, B.Sc.
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Mrs A. F. Stewart, M.A.
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R. O. Scott, B.Sc., Ph.D., A.R.C.S.T., C.Chem., F.R.S.C.
P. C. DeKock, M.Sc., D.Phil.
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J. W. S. Reith, B.Sc., Ph.D., C.Chem., F.R.S.C.

HONORARY RESEARCH ASSOCIATE

Professor 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, Unversita di Torino, Italy).

M. Akram, Departments of Spectrochemistry and Mineral Soils. (Ayub Agricultural Research Institute, Faisalabad, Pakistan).

*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.

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

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

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

*M. F. Proe, Department of Peat and Forest Soils, NERC/CASE Research Student.

C. A. Shand, Department of Spectrochemistry, Scottish Hospitals Endowment Research Trust Fellowship.

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

F. Tsuyuki, Department of Soil Organic Chemistry, (Laboratory of Processing of Agricultural Products, Oita Prefectural Food Research Center, Oita, Japan).

E. D. Wells, Department of Peat and Forest Soils, (Newfoundland Forest Research Center, St. John's, Newfoundland, Canada).

* Ph.D. Student.

CONTENTS

INTRODUCTION

T. S. West

Towards the end of 1983 the Institute was able to fill some of the vacancies that had been held pending the outcome of the 1982 Programme Group Report. This impetus continued in 1984 when several more recruits joined the staff in priority areas identified in the Programme Review such as Microbiology, Remote Sensing, Trace Element work and Soil Physics. The gathering storm in the AFRS and further restrictions expected in the 1986-1988 biennium suggest that this pattern may not be carried on into 1985, but that it may be reversed in subsequent years. Nevertheless, despite these uncertainties and the loss of so many experienced staff to retirement in 1983, excellent progress has been made in 1984. During the year the staff have published 107 papers as opposed to 93 in 1983, 104 in 1982, 80 in 1981 and 92 in 1980. Several new initiatives set in hand in the past few years are now beginning to bear fruit.

New Data Base on Fertility of Scottish Soils

For example, work with the advisory services of the three Scottish Colleges of Agriculture and their soil scientists channelled through the Macaulay Institute/COSAC Liaison Group has led to the production of the first MISR/COSAC Bulletin on Major and Trace Element Assessment following progress during the past two years in harmonising methodology, sampling, etc., for all areas of Scotland. A Scottish Soil Fertility Information System (SFIS) has been established between the Institute and the three Colleges of Agriculture. Separate, but uniform data banks are to be held in micro-computers in all three College advisory areas and transferred and stored in the Macaulay Institute main-frame, thus to produce a Scotland-wide data bank which will serve all concerned. Furthermore, and quite remarkably, agreement has been reached with a major fertiliser supplier to come into uniformity with the SFIS sampling-analysis-reporting system further to input data and enhance the value of the data base.

The format of SFIS has been made as compatible as possible with the Institute's Scottish Soils Information Data Base which holds information on soils sampled systematically by the Soil Survey of Scotland both from the routine ongoing survey and the National Soils Inventory (which is also being done simultaneously in England and Wales by the Soil Survey of England and Wales (SSEW). The Soils Data Base holds the pedological description of the profile, its mineral composition as established routinely by the Mineral Soils Department and bioessential trace element constitution as established by the Department of Spectrochemistry, together with data on some physical characteristics.

Systematic Acquisition of Physical Data Determining the Properties of Scottish Soils

Plans have also been formulated during the year to include more physical data in the data bank following the setting up of a suitable physical laboratory by the Department of Mineral Soils in conjunction with the soil physics group in the Department of Soil Fertility and the Soil Surveyors of the Soil Survey of Scotland. The physical data planned to be measured and recorded have been agreed with the Colleges of Agriculture through the MISR/COSAC Liaison Group's Working Party on Physical Characteristics. They include liquid/plastic limits, bulk density, moisture release characteristics and structural stability measurements of top soils and subsoils. Full discussions have also been held with the SSEW staff so that techniques and assessments will be as uniform as possible. In this way it is envisaged that knowledge of the physical characteristics of Scottish soils will be acquired on a systematic basis and that this in turn will lead to meaningful and worthwhile research on the major factors that control the physical properties of Scottish soils and which in many cases determine their agricultural productivity. A common handbook on agreed laboratory techniques of soils examination is being planned in conjunction with SSEW. New work has also begun on the characterisation of the structure-forming processes of Scottish soils and, in particular, those factors controlling the variable capacities of soils to recover their natural structures after damage by compaction. The specialised optical and scanning electron microscopy techniques now available in the Institute will play a major role in this study.

Work of Environmental Significance

The Institute has long had an interest in the environment and much of its work has had environmental significance for a considerable period of time. It is, perhaps, therefore not surprising that it submitted evidence to the House of Lords Select Committee on Agriculture and the Environment[1] as it did in 1983 to the House of Lords Select Committee on the European Communities discussion on Sewage Sludge in Agriculture[2]. In the context of the movement of aluminium within the soil profile which is further promoted by acid precipitation, fundamental work done in the Department of Spectrochemistry on the laboratory synthesis of imogolite has provided the impetus for the formulation of a completely new theory of podzolisation in which Al, Fe and Si are translocated in soils not as organic complexes as hitherto supposed, but as positively charged hydroxy sols[3]. The concept of aluminium being mobile at low pH in this co-called proto-imogolite sol form may well have implications for the release of aluminium from soils to 'acidified' surface waters and the speciation of the aluminium subsequently may account for its particular toxicity to many freshwater fish.

Similarly, work going on systematically in the Department of Mineral Soils relates to possible deleterious effects of acid rain on the environment. It is based on routine monitoring of the major element composition of streams draining small catchment areas characterised by soils derived from contrasting types of parent material. The data collected over a two year period, show the contributions of two major components, namely the base

status of the different parent material geologies and the influence of marine input. It was found that there is a seasonal variation with both components, with the influence of parent material increasing in the summer and that of marine input in the winter. The results suggest that aluminium is leached from soil organic horizons during periods of surface run-off and that calcium and magnesium are removed from soil mineral horizons when base-flow is dominant. These investigations are now being continued in other areas of Scotland where it is thought that acid rain may have had damaging effects on the environment.

Studies in the Department of Peat and Forest Soils on the biochemical cycling of nutrients, and pollutants, in upland ecosystems have shown that, despite the neutralising capacity of all but the poorest soils, a broad correlation exists between the distribution of rainfall acidity and the occurrence of acid streams and lakes. Among the many factors involved, rates and pathways of water movement through, and chemical reactions within, the soil are not yet fully understood and the roles of vegetation and management practice remain unexplained.

As a result of its experience and expertise in relation to soil acidification phenomena several research contracts related to acid rain have been placed with the Institute. The biggest of these comes from the Surface Water Acidification Programme (SWAP) being co-ordinated by The Royal Society, the Norwegian Academy of Science and Letters and the Royal Swedish Academy of Sciences as part of the integrated UK contribution to the overall programme in the three countries. The Institute has been made responsible for the soil-vegetation part of the programme and involves the co-ordinated effort of the Department of Soil Survey, the Department of Peat and Forest Soils, the Department of Mineral Soils, the Department of Soil Organic Chemistry and the Department of Spectrochemistry. The work will be done in collaboration with the DAFS Freshwater Fisheries Laboratory, the Institue of Hydrology, the Freshwater Biological Association, the Imperial College of Science and Technology and the University of Aberdeen. The contract, which will begin in Spring 1985, is valued at *ca.* £425,000 over the next four years and will involve the term appointment of several staff and the acquisition of several sophisticated items of instrumentation to supplement that already present in the Institute and being used for its ongoing programme.

The Institute was also invited to tender for and was awarded a contract for £29,000 by the CEGB, SSEB, NSHEB and NCB for work to investigate the conditions and processes that have led to acidification and loss of fish stocks at Loch Fleet, Galloway, which integrates well with work already being undertaken partly on the same site by the Department of Peat and Forest Soils in conjunction with the University of Aberdeen and the University of Cambridge under a Department of the Environment Grant of £244,000 over five years. Two term appointment staff are already working on the DOE contract. Experimental sites subjected to different levels of acid input have already been selected and instrumented using equipment devised in the Institute over a period of years during field studies on the forest-soils ecosystem on a long-standing contract from the Forestry Commission.

Particular attention is being given to monitoring changes in the chemistry of rainwater as it passes through the plant-soil system, to hydrological conditions and land use practices likely to induce periodic rapid drainage and to control measures for the management of riparian zones that will reduce streamwater acidity.

Coniferous Bark: The Iron Ochre Problem

In the introduction to the two previous Annual Reports attention has been drawn to developments arising out of our earlier fundamental studies relating to the interaction of organic matter with metallic elements. Iron is mobilised in its reduced state (FeII) by soil drainage and, in emerging from the soil profile, it becomes oxidised by aerial and possibly bacterial processes to the higher oxidation state (FeIII) which promptly precipitates as the voluminous iron (III) hydroxides known as iron ochre. This substance is notorious for blocking field drains all over Scotland[4] and the clearing of such field drainage systems is time-consuming and expensive and requires to be done repeatedly. The nature of the iron ochre has been studied and established[5]. Phenols and phenolic acids form particularly stable Fe(II) complexes which are resistant to oxidation. These chelants were found to be present in appreciable amounts in the bark of indigenous coniferous trees. Furthermore, the phenolics in bark are immobilised against solubilisation by the bark matrix. Consequently we have found that weathered conifer bark deposited in porous plastic sacks in the inspection pits of drainage systems completely immobilises iron(II) in emergent drainage water and prevents the deposition of iron ochre downstream. Continued experimentation in 1984 has again confirmed earlier experience and the system is now being widely adopted by the farming community in the advisory areas of the three Colleges of Agriculture in Scotland. The trials so far have been concerned with two situations. At sites where it is practicable to have inspection chambers in the system, sacks of bark have been inserted in the chambers and these can be replaced when the bark is saturated with the ochre-forming iron constituents. At other sites the bark, mixed with gravel, is used as a backfill when the drains are being laid. The tests with the chambered system have been under way successfully for years at one site where blockages formerly occurred every six months. Tests using backfill were begun within the year and it will take some time to establish its effectiveness, but already it has been found to reduce markedly the iron concentration in the drainage water.

Soil Clay: Fundamental Particles

Fundamental studies on the nature of the finely divided fractions of the soil known as clay have led to some interesting new ideas which may in due course have considerable influence on management practices in relation to soil fertility since many of the physical and chemical properties of soils are strongly and disproportionately influenced by the type and amount of the soil clay minerals that they contain. But although this relationship is understood in a general way, a more complete understanding depends upon the elucidation of the fundamental nature of the clay particles themselves.

During the year, integrated transmission electron microscope and X-ray diffraction studies have resulted in the development of a new conceptual model of the so-called interstratified clays, which are of ubiquitous occurrence in Scottish soils. This model postulates that these clays may be made up of a small number of very thin particle types — so-called fundamental particles — and the concept promises to be useful, not only for explaining soil properties, but also for the development of the industrial applications of these materials. During the year, also, a review study of the clay mineralogy of Scottish soils was completed and will be published in conjunction with a similar review of the soil clays of England and Wales. This information, collected from widely dispersed and unpublished sources, should be an extremely useful reference source of basic clay mineral data on Scottish soils.

New Evidence on Nature of Soil Organic Matter

Despite many years of research by soil scientists in government-funded research institutes and universities, much is yet unknown about the nature and identity of the organic matter in the soil. The traditional extractive methods for the determination of the various types of organic matter in mineral soils have always been time-consuming and suffer from the serious risk of structural alteration and artefact formation. With the development of pyrolysis-mass spectrometry (Py-MS) methods in the Department of Mineral Soils, however, it is now possible to assess the organic matter status in whole soils rapidly and semi-quantatively. This technique, coupled with multivariate data analysis, has been highly successful in determining the different types of organic matter in a wide variety of the A and B horizons of Scottish soils. Py-MS is also able to discriminate between the molecular species responsible for such differentiation and shows, for example, that there are more polysaccharide and lignin-derived products in A horizons and more aromatic hydrocarbons in B horizon pyrolysates. The effect of particular soil processes, such as gleying and podolization, on organic matter composition is another feature distinguished by Py-MS. This work is, therefore, now at the stage where for the first time Py-MS can be used to correlate organic matter status with soil history, physical structural conditions and soil fertility.

Biological Effects of Soil Organic Matter on Crops

The beneficial properties of soil organic matter in providing nutrients and improving the physical texture of the soil are well known but controversy continues about the extent of other effects which the organic components may have on the growth of healthy crops. For example, some people claim that organically farmed crops cannot be matched in quality by those produced by the use of inorganic chemical fertilizers alone, but others just as vigorously disagree. There is no doubt that some organic components in soil can affect enzyme systems relevant to plant nutrition or morphology but the net effects under field conditions are not easily established. Many scientific papers have been published on the biological effects of soil organic matter and it was considered timely to produce a book reviewing and

assessing the observations which have been made. This is being edited in the Department of Soil Organic Chemistry with chapters contributed by authors from several Institute departments and also from the University of Aberdeen, the Grassland Research Institute, the Glasshouse Crops Research Institute, the Australian CSIRO and New Zealand DSIR. The chapters have all now been submitted and it is hoped that the book will be published in late 1985 or early 1986.

Widespread Sulphur Deficiency now Acknowledged

The pioneering work of Dr N. M. Scott of the Department of Soil Fertility on sulphur deficiency in crops has now received widespread recognition even in areas where its existence was stoutly denied. In former years the sulphur was added inadvertently in superphosphate fertilizer and in basic slag, but the modern practice of using triple phosphate and the clean-up of atmospheric inputs of sulphur dioxide at levels at which it could possibly have counteracted such deficiency has changed the situation markedly. Apart from increasing the yield of many crops, sulphur fertilization also increases the quality of crops by maximizing the production of essential amino acids and proteins. Collaborative work on this latter topic with the Rowett Research Institute on animal nutrition is now showing considerable promise.

The effect of sulphur on crop yields has continued to interest farmers and a grass experiment at Fordoun in 1984 has illustrated the reason why. The experiment was set up to compare the effectiveness of sulphur applied as ammonium sulphate to the soil and elemental sulphur as a foliar spray.

The results show that a substantial yield response occurred irrespective of the sulphur form used, as shown in Table 1.

Table 1 *Effect of sulphur on yield of ryegrass*

S treatment	oven-dried yield t/ha				
Kg S/ha	Cut 1	Cut 2	Cut 3	Cut 4	Total
Nil S	5.6	1.0	0.9	0.6	8.1
10 kg S applied as foliar treatment before first, second and third cuts	5.8	1.7	3.1	2.6	13.2
20 kg S as ammonium sulphate to soil	5.8	2.1	3.0	2.4	13.3

The experiment generated tremendous interest locally because of the visual differences between sulphur treated and untreated plots. Analysis of third and fourth cuts showed distinctive differences in crop composition and of particular interest was the effect of sulphur treatments on the total amino acid content of acid hydrolysates of crop materials. The experiment has highlighted crop yield and quality aspects and has provided an ideal site for a collaborative experiment with the Rowett Research Institute in 1985.

Microbiological Cycling of Sulphur and Microbial Interaction with Invertebrates

Work began in 1984 on the microbiological cycling of sulphur and trace elements following the appointment of a member of staff with this responsibility as approved by the DAFS on the recommendation of the 1982 Review of the Institute's Programme. Preliminary studies in the Department of Microbiology on the transfer of sulphur from three Scottish soils suffering from sulphur deficiency suggest that the microbial biomass contained only 3-6 mg S kg^{-1} soil. In addition, the importance of the microbial biomass in the oxidation of sulphur fertilizers applied to sulphur-deficient soils is being assessed in collaboration with the Department of Soil Fertility. Sulphur applied as potassium sulphate to a local soil (Boyndie Series) was partly incorporated into the biomass, but very little elemental sulphur was assimilated by the microbes. Whether there is any connection with the known fungicidal action of micronised elemental sulphur is as yet unresolved.

The interactions between soil invertebrates and soil microorganisms have continued. With the collaboration of the Departments of Spectrochemistry and Mineral Soils, the microbial decomposition of the exoskeletons of a common woodlouse *(Oniscus asellus)* have been studied in soil. Apart from chitin and protein, these exoskeletons contain two forms of calcium carbonate, crystalline calcite and an amorphous form of $CaCO_3$. This amorphous form was previously unrecognised in such exoskeletons. Preliminary studies suggest that calcium carbonate protects the chitin from microbial decomposition.

Nitrogen

Work on nitrogen goes on in several programmes of the Institute and sometimes in collaboration with other Institutes and the Scottish Colleges of Agriculture. Two such examples are cited in this Introduction.

Effect of Nitrogen in Potatoes

Nitrogen application can alter the pattern of potato crop growth to increase yields by (1) increasing the total intercepted radiation, (2) improving the efficiency with which light is used for dry matter production, or (3) altering the harvest index. Light interception measurements made on a potato crop grown with eight levels of nitrogen has allowed actual total dry matter yields to be compared with those predicted by the model of potato growth used by SCRI. Throughout the season, the measured yields were between 63-68 per cent of those predicted by the model, except those from the treatment receiving no fertilizer nitrogen where yields were only 52 per cent of those predicted. Since the model uses the total intercepted light to predict yield, it appears that nitrogen fertilizers enhance yield by increasing total light interception, there only being a decrease in efficiency of use of that light under conditions of extreme nitrogen deficiency.

Controlled-release Nitrogen Fertilizer

As a direct consequence of fundamental spectroscopic studies of the reactions between anhydrous ammonia gas and expanding clays such as montmorillonite and vermiculite, a controlled-release nitrogen fertilizer, ammonia-treated vermiculite (ATV), has been realised, in which the rate of release can be controlled by the choice of vermiculite flake size. The efficiency of this ATV fertilizer has been demonstrated in pot-trials with a variety of crops and is being further evaluated in a limited field trail on ryegrass. Among the advantages of this material are its resistance to nitrogen leaching by rain while still making nitrogen available to plant roots as illustrated in Fig. 3.3, p. 84.

Nitrogen-15 Experiments

With the installation of a "SIRA 9" mass spectrometer[6] analysis of small ^{15}N tracer samples from soils and crops is now possible, and ^{15}N tracer sample crop analysis can be done with high precision, using a triple collector and rapid sample/reference gas comparisons, controlled by a Hewlett-Packard computer.

Detailed operating procedures and software modifications to optimise the performance of the equipment for routine ^{15}N analyses have been developed by G. W. Robertson of the Department of Soil Mineralogy and D. Robinson of the Department of Soil Fertility and an Institute ^{15}N analytical service will become available in early 1985.

The mass spectrometer should yield valuable information on current ^{15}N field experiments with regard to the fate of applied nitrogen in soils and crops in relation to climatic variations, soil type and agricultural practice.

Progress in Trace Element Work

One of the problems of trace analysis for soils and plants is that, quite frequently, reliable analysis and data are required at a level which is below even the detection limit of the currently available instrumental methods of spectroscopy or electrochemistry. Under such circumstances preconcentration techniques have to be used to remove the trace element from the analyte and concentrate it in the process to the extent of say 10-100 fold. Extraction from an aqueous solution of the analyte into a non-miscible solvent is a common method of preconcentration and co-precipitation in the crystal matrix of an isomorphus but acceptable host crystal, also from solution, is another.

A new technique which involves *in situ* preconcentration of free atoms within an air-acetylene flame has been devised in the Institute[7], [8]. The successful evolution of this technique of atom-trapping atomic absorption spectrometry for trace and ultra-trace analysis has made a timely and significant contribution to the assessment of environmental pollutants such as Cd and Pb in waters, sewage sludges, soils and soil extracts. Conventional atomic absorption spectrometry for these elements is often too insensitive and requires time-consuming prior separation techniques whereas ATASS can usually make the determination directly on the sample. One of the

practical consequences has been that it has now become possible to assess total cadmium contents of soils quite rapidly and, to date, over 500 Scottish soil samples from a wide range of soil types have been analysed with a mean cadmium content of 0.47 mg/kg and a range of 0.009 to 2.4 mg/kg. The high sensitivity for cadmium (<1 μg/kg) has also made it possible to determine the element in 0.05 M $CaCl_2$ extracts of soils directly — a capability of importance in view of the evidence suggesting that $CaCl_2$ extracts of soils are predictive of the cadmium content of, at least, some horticultural crops.

Copper Deficiency in Scotland

The extent and the economic importance of copper deficiency in Scottish soils is strikingly emphasised by the conclusion drawn from the survey of soil copper contents discussed in Section 3, p. 70. This reveals that approximately 18 per cent of Scottish topsoils contain extractable copper contents inadequate to supply the nutritional requirements of cereal crops and some 79 per cent, levels inadequate to support herbage with a copper content sufficient to supply the needs of grazing cattle.

Work on bioessential trace element uptake — particularly cobalt — has continued in the Department of Plant Physiology, but due to difficulties in allowing the vacant post allocated to this work to be filled even after one year, the work has so far had to be confined to studies of cobalt uptake and transport in wheat seedlings.

Environmental Hazards from Water Treatment Byproducts

An informed and factual submission of the Institute's views on the EEC Draft Directive on the use of Sewage Sludge in Agriculture, and an assessment of the current situation in this regard, was made to the House of Lords' Select Committee on the European Communities[2]. This work was based on the combined experience in trace element problems of the Departments of Soil Fertility and Spectrochemistry and on the latter department's involvement in the ADAS long-term experiments on the effects of sewage sludge on agricultural land. Some of this work, presented in Chapter 3, p. 74, Fig. 3.1, emphasises the long-term persistence, in mobile forms in soils, of elements such as Cd, Cr, Cu, Ni and Zn added in metal-contaminated sewage sludges. Soil treatment with molybdenum used, for example, to counteract Mo-deficiency in *brassicas* has also been shown to result in persistent elevated soil contents with potential danger to the health of ruminants. These effects reinforce the need for firm guidelines for the application of heavy metals, in sludge or other form, to land and the need for continuous monitoring of their levels and effects in relation to agriculture and the environment.

Remote Sensing Surveillance of Crop Nutritional Status

Good progress has been made during the year by the Remote Sensing Unit in the Department of Peat and Forest Soils. The survey for DAFS of the spread of bracken has continued with greater emphasis being placed on aerial photography than on satellite imagery and detailed ground truth work

being done on six widely differing geographic sites with a wide range of soil-management conditions, topography and climate (p. 56). Access to the imagery of the SPOT 1 satellite due to be launched in October 1985 will greatly improve the Remote Sensing capability *vis à vis* present facilities. Not only will panchromatic and multispectral imagery with special resolution of 10 and 20 m respectively become available, but a single "picture" element will represent 0.01 ha, whereas with LANDSAT each element represents 0.44 ha (p. 60). Work is also being done on a systematic basis for SCRI in relation to land used for potatoes and for the Plant Breeding Institute, Cambridge.

A spin-off benefit from the Institute's earlier work on aerial remote sensing using light aircraft to differentiate between different vegetation species has been the new work on devising techniques for monitoring crop status. A second generation twin channel crop-reflectance spectrometer has now been built and is being put into commission in monitoring the nitrogen status of crops, *e.g.* potatoes, and in collaboration with the North of Scotland College of Agriculture who provide the crop facilities, on the status by remote sensing of winter barley.

The perfection of facilities for monitoring crop status by remote sensing requires considerable development, but the early results are very encouraging and such a facility will undoubtedly be a major asset for the future of agriculture.

New Technology Permits Study of Undisturbed Roots

During recent years we have shown increasing interest in the root-soil interface with respect to studies of rhizosphere soils in the Departments of Soil Fertility, Microbiology and Soil Organic Chemistry. More recently, we have become active in studying the behaviour of roots themselves. The availability of new technology has greatly facilitated the direct undisturbed *in situ* examination of root behaviour in the dark. Work in the Department of Soil Organic Chemistry employs an extended red-range Newvicon camera sensitive to non-visible light >800 nm in conjunction with infrared emitting diodes to observe the behaviour of roots under conditions of total "plant darkness" (root-phytochrome pigment is insensitive to light >800nm). Growth cabinets, linked to a video camera and fitted with panels of photodiodes on all sides offer a uniquely useful way of observing the response of roots to many chemical and physical stimuli and their behaviour under conditions of varying restraint. This work links in with the seed-bed studies approved by DAFS following the Programme Review and with previous strategic and basic work on seedling growth and response to light, orientation and geotropic forces.

Tree Nutrition: Nurse Species Decrease Need for Fertilizers

It is outwith the scope of the Annual Report to join in the debate about the future strategy of the use of available land for agriculture. Some authorities forecast smaller areas of particularly useful land being farmed much more intensively using "high-tec" methods with the return of less

suitable land to nature or non-agricultural use, abandonment of marginal land and upland farming. Others forecast low-input farming, with lower output and consequently lower levels of subsistence for the farming community and possibly with less technological input and more manpower. Nevertheless, irrespective of agricultural policy problems against the background of EEC food surplus mountains and the spectre of famine in countries with primitive agriculture, the UK is unable to provide even 10 per cent of its timber needs. The current large-scale afforestation programme presently being undertaken in Britain relies heavily upon the use of coniferous species on hill and marginal land. Against this particular background, the Institute's work on forest soils and tree nutrition is significant and timely and is likely to become increasingly so — as recognised by DAFS following the Institute's recent Programme Review.

It is of particular interest that Sitka spruce accounts for 60 per cent of recent planting and requires heavy input of fertilizers when established on poor peatland and upland heaths. The high cost of such fertilizers may pose severe economic restrictions and there are worries in some quarters concerning the run-off of fertilizers into waterways that may feed urban water supply systems. The Institute is now, therefore, investigating the "nurse species" phenomenon whereby mixed growth of Sitka spruce with species such as pine or larch can reduce, and apparently even on some occasions remove, the need for nitrogen fertilization. This work is being done in conjunction with the Forestry Commission to try and determine the processes responsible for the efficiency of the mixed culture and is supported in part by an EEC contract from the research and development programme "Wood as a Renewable Raw Material". Field work at two sites in Scotland, Culloden and Inchnacardoch Forests, is under way and, in collaboration with the Research Branch of the Irish Forestry and Wildlife Service, at Ballyhooley Forest.

The work so far has concentrated upon characterizing mixed and pure stands in terms of biomass and nutrient distribution within each. Nutrient fluxes in litterfall and rainwater passing through tree canopies (which we have previously shown to be an outstandingly important contributor to tree nutrition) and different soil horizons are being measured together with rates of decomposition and microbial activity. In respect of the latter, we plan to examine the effect of mycorrhizal and saprophytic fungi on the ability of spruce roots to take up nitrogen. At the Institute, glasshouse experiments have also been set up to examine interactions between tree species, soils, litter and ground vegetation.

It is anticipated that this work will lead to a much fuller understanding of the processes that enable nitrogen and other nutrients to cycle more rapidly in mixed rather than in pure spruce stands and further to the development of low input management systems with minimal loss of productivity.

Similar modelling work on nutrient cycling in birch, which is often cited as a soil improver, is designed to examine the ability of trees to modify the nature and nutrient-supplying characteristics of soils. Preliminary results are in agreement with our earlier work on pine, that in birch woods nutrient demands on the soil fall dramatically upon canopy closure. As yet, however,

there is no evidence forthcoming to substantiate the beneficial nature of birch trees. This work is being done in conjunction with staff of the Institute of Terrestrial Ecology at one site where birch invasion has resulted in soil changes (Craggan's, Speyside), and another where it has not (Silpho, North Yorkshire). Three Departments of the Institute are involved, Peat and Forest Soils, Microbiology and Soil Organic Chemistry.

Progress and Developments in The Soil Survey of Scotland
Computerization and User-Orientated Survey Literature and Maps

In the previous Annual Report, mention was made of changes in the approaches taken by the Department of Soil Survey as full map cover began to be achieved and user demands on its services became more apparent. Following re-organization and restructuring, substantial progress has been made in data-handling and automated cartographic techniques, the former making use of the Institute's computer services and a small microcomputer network serving regional offices, the latter using bureau-digitizing and the University of Aberdeen Honeywell computer, a combination which has proved effective and cost-efficient. Steps have also been taken to fulfil a long-felt requirement, that of the characterization of soils in Scotland in physical terms. A modest, but important, attempt is being made to monitor soil moisture relationships in the Balrownie Series the scope of which is to be broadened on the appointment of a soil physicist to include hydraulic conductivity, moisture release characteristics and other field and laboratory measurements. Following discussions in the MISR/COSAC Liaison Group, important collaboration is now in train, involving the preparation of summary soil map unit description sheets linked to agricultural management recommendations for each soil type, with the Scottish Colleges of Agriculture. This work should provide a stronger link between soil research, maps of the distribution of relevant properties, agricultural advisers and the farming community.

Following consultation with the three Colleges of Agriculture *via* the MISR/COSAC Liaison Group and collaboration with their soils staff, the Department of Soil Survey has, in conjunction with the Departments of Spectrochemistry and Soil Fertility, planned a series of ten Trace Element Status maps on a scale of 1:625,000 showing average trace element contents in a Soil Association map of Scotland. This work is now well in hand.

The 1:250,000 series of maps devised in 1983 has also been used as the basis of a study to provide the CEGB with data on soils in Scotland at risk to acidification problems. The data used are the texture, cation exchange capacity, base saturation and pH of the surface horizons and are presented as an extended map unit key.

Assistance was also given to the SIAE in the development of a handbook on minimum cultivation requirements by grouping the soil series of Scotland on the basis of SIAE experimental observations.

A project is in hand *via* the MISR/COSAC Liaison Group and the DAFS Maximum Yield Constraint Group to produce land capability assessment (LCA) maps showing suitability for specific crops and practices.

Land Capability Cover of Arable Soils

Throughout the year, increasing emphasis has been placed on the preparation of maps of land capability for agriculture to assist the Department of Agriculture and Fisheries in its statutory role of providing information on changes in land use to the Scottish Development Department. This important function, which involves strategic, regional and district authorities throughout Scotland, will in future take the research work of the Institute fully into account through the 1:50,000 scale maps now in preparation. The series of 31 maps will cover the arable land of Scotland and be ready for issue in 1987. Their preparation will involve survey teams for the next two years, and will also require considerable co-operative effort with staff of the Department of Agriculture and Fisheries for Scotland and with soils and advisory staff of the three Colleges of Agriculture.

The Macaulay Institute Land Capability for Agriculture (LCA) system is to be adopted by DAFS as the basis of its advice to planning authorities throughout Scotland on national land use policy and because of this and in order to reduce confusion with the system currently used during planning enquiries, no LCA maps will be issued until the series is completed in 1987. Indications are, on the basis of present use, that the Scottish Land Court, The National Farmers' Union of Scotland and other organizations will in future also base their assessments on the Macaulay LCA system.

New "Wildscape" Maps Including Ecological/Environmental Features

A sustained effort has been made to complete mapping in the Blairgowrie region during 1984, the last major arable area for which cover was required. Several important, if less extensive, areas remain, however, and survey coverage of these will be acquired within the next two years with more ground control than was possible during the 1:250,000 survey. Even so, during the latter project much more detail was collected than could be indicated on the soil maps; this detail is now available on a new series of 1:50,000 scale maps of the soils of the Highlands. The keys also carry details of the principal plant communities, and will, therefore, be a valuable contribution to ecological and environmental studies in one of the largest remaining wildscape areas in Western Europe.

Survey Contracts for Environmentally Concerned Bodies

The Department of Soil Survey has, in pursuance of its tasks of categorizing soils, providing information on the distribution of soil properties in Scotland, and interpreting these properties for use, undertaken a considerable amount of contract work this year. The Lochaber District Council, the Highland and Grampian Regional Councils, the Highlands and Islands Development Board, British Alcan Aluminium Limited, the South of Scotland Electricity Board, the Hydro Electric Board, the Central Electricity Research Laboratories and the National Coal Board have all sponsored investigative work aimed at predicting and understanding the consequences of various land uses in environmental terms. These have included work on sites proposed for opencast work, water

abstraction schemes, establishment of ski-runs, land restoration. The Soil Survey of Scotland is also involved in the "Acid Rain" SWAP project to begin in 1985 and in the CEGB "Loch Fleet" acidification programme.

As a postscript to the above paragraphs on the reorientated work of the Soil Survey Teams, it has to be reported that concern expressed in the 1983 Annual Report over our not being able to restore vacancies held over for the Programme Review is now felt even more keenly. The Soil Survey staff has been reduced by *ca.* 20 per cent since 1980-81 and is now more than fully stretched. Much of the excellent progress made by the Soil Survey of Scotland and its service, which is sought increasingly by the community well beyond purely agricultural interests, is now at risk and work is increasingly having to be declined. The omens for 1985-88 are such that the Survey, despite re-organization, will not be able to cope with the increasing workload, and that this must inevitably slow down progress in many areas which depend on the basic data that can only be supplied by the Soil Survey in Scotland.

Concern with The Past as well as The Present and The future

In the context of the fertility of Scottish soils it is often forgotten that much of it depends on the presence of weathering products such as kaolinite, gibbsite and halloysite that were formed during the preglacial period when sub-tropical conditions prevailed in Scotland, whereas postglacial weathering has been confined chiefly to further degradation of these pre-existing micaceous minerals. A chapter on this subject, p. 47 has been completed for a book entitled "Geomorphology and Soils" for the British Geomorphological Research Group.

Other historically orientated work p. 94, relates to dating Iron-Age post holes for the Department of Ancient Monuments, based on observations on the organic matter contents of soil samples and to paleobotanical studies undertaken for the Central Excavation Unit of the SDD in samples from Strathallan which, p. 155, revealed that light sandy soils in the area appear to have been in almost continuous cultivation for several thousand years.

EVENTS AND PEOPLE

Ninth T. B. Macaulay Lecture

The Ninth T. B. Macaulay Lecture entitled "Nitrogen — from Soil to Seed" was delivered by Sir Leslie Fowden, Director of Rothamstead Experimental Station, in the Marine Suite of the Amatola Hotel on 22nd November 1984. The lecture, which was attended by an audience of over 200 from the Institute, the University and other local research laboratories, is presented as Appendix I of this Report. Sir Leslie's account of the importance of nitrogen nutrition inputs and crop performance, the biochemical pathways in which it is involved within the plant and the ability of some strains to out-perform others, leads to a consideration of genetics which makes fascinating reading. 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 at the lecture and the Director presented the Macaulay Scroll to Sir Leslie at the end of the proceedings.

Retirements

During the year there have again been a number of retirements as follows:

Mr George Forbes retired on 21st February, having been Clerk of Works at the Institute for 11 years. Initially on appointment and until 1975 he was responsible for the refurbishment of Craigiebuckler House and during the years since then has been involved in various projects covering the Main Building, Outbuildings and Grounds. An appreciation of Mr Forbes' service to the Institute appeared in the Institute magazine Profile[9].

Mr Eric Lawson, EW1 in the Department of Spectrochemistry, retired on 29th March, having been responsible during the past 8½ years for the control and storage of the Department's soil samples and in drying and milling soils for spectrochemical analysis. He also contributed to the machining of carbon electrodes for dc arc spectrographic analysis. An appreciation of Mr Lawson's work and personality is given in the Institute magazine Profile[10].

Mr B. D. Mitchell, Principal Scientific Officer in the Department of Mineral Soils, retired on 31st July. Mr Mitchell graduated with an Honours BSc degree in Chemistry from St Andrews University and joined the Macaulay staff as a soil surveyor in 1948. In the mid-fifties he became a full-time member of the staff of the Physical Chemistry Section. In 1959 he was appointed Head of the Section and in 1970 was put in charge of the Chemistry and Mineralogy Section of the Department of Pedology. On the division of the Department in 1979 he was appointed Deputy Head of Mineral Soils. An appreciation of Bruce Mitchell's contribution to the life and work of the Institute is recorded in Profile[11].

Resignations

Dr B. W. Bache, Head of the Department of Soil Fertility, resigned on 31st March, 1984 to take up a senior post in the Department of Applied Biology at the University of Cambridge. Dr Bache joined the Macaulay Institute as a PSO in the Department of Soil Fertility in October, 1966 and became Head of the Department in 1981.

Dr H. G. Miller, PSO in charge of forest soil work in the Department of Peat and Forest Soils, resigned on 31st March, 1984, having accepted the post of Professor of Forestry at the University of Aberdeen. Dr Miller became a member of the Institute staff in 1963.

Both Dr Bache and Dr Miller gave sterling and inspired service to the Institute and their loss as team leaders of the highest quality will be sadly felt. Nevertheless, it is a matter of considerable satisfaction to us that they were both selected against very stiff competition from at home and overseas for their new high posts in academic life. Perhaps we may be forgiven if we note with some pride that, although the Selection Panel of the (then) ARC did not find them sufficiently worthy to be considered as ARS candidates for

merit promotion in the (then) Civil Service competition, the ancient Universities of Aberdeen and Cambridge had absolutely no doubts as to their past record and future potential. Both of them have left behind a legacy of excellence and thoroughness that survives them in the staff who were fortunate enough to be associated with them.

Accounts of their careers appear in the Institute magazine Profile[12, 13].

New appointments

After a rather long delay awaiting decisions that DAFS had to observe pending work on trace elements under consideration elsewhere in the AFRC, Dr A. E. S. Macklon was appointed Head of the Department of Plant Physiology on 1st June, 1984, having been Acting Head of the Department since Dr DeKock's retirement on 30th September 1982.

Dr D. Atkinson, presently employed at East Malling Research Station, Maidstone, Kent, has been appointed Head of the Department of Soil Fertility in succession to Dr Bache, as from 1st February, 1985.

Also during the year, and largely arising out of the holdover of vacancies for the 1982 Programme Review, and despite difficulties, we have been fortunate enough to appoint eight more research staff and to add three term appointment staff as a result of the placement of research contracts by the Department of the Environment and the Highland and Islands Development Board. These are Mr M. F. Proe and Mr D. R. Miller (Peat and Forest Soils), together with Dr Ann F. Leech and Dr T. R. Nisbet, both on the DOE Contract in the same Department; Dr C. A. Shand (Spectrochemistry); Mr R. G. Baker, on the HIDB Contract; Dr S. J. Chapman and Dr K. Ritz (Microbiology); Dr Lorna Mackie and Dr D. Robinson (Soil Fertility); Mr I. A. Williamson (Cartography — Soil Survey). It is a pleasure to welcome so many young researchers to the staff of the Institute at a time when recruitment is becoming not only exceedingly difficult but probably, in the near future, almost impossible. Their presence augurs well for the future vitality of the Institute.

Visitors to the Institute

Lord Gray of Contin, Minister of State for Scotland, visited the Institute on 26th October, 1984, accompanied by Mr Loudon Hamilton, Secretary of the Department of Fisheries and Agriculture for Scotland, and inspected several of our research programmes.

Sir John Mason, Treasurer of The Royal Society and Programme Director of the SWAP Group, based at the Centre for Environmental Technology, Imperial College of Science and Technology, London, visited the Institute on 24th May, 1984, accompanied by Dr D. Drummond, to discuss matters related to acid rain with various staff groups in the Institute.

Visits were also made by members of staff of AFRC and DAFS,

including Mr A. Johnston, the newly appointed Principal at DAFS, on 22nd October, 1984.

Other visitors to the Institute who also delivered lectures were: Professor Z. Filip, Institut für Wasser -, Boden-und Lufthygene des Bundesgesundheitsamtes, Frankfurt, West Germany, on "Microbial formation of humic substances as influenced by clay minerals"; Professor N. Ishibashi, Department of Applied Analytical Chemistry, Kyushu University, Fukuoka, Japan, on "Potentiometric sensors in chemical speciation"; Dr M. A. Wilson, CSIRO Division of Fossil Fuels, New South Wales, Australia, on "Applications of modern NMR (nuclear magnetic resonance) techniques in the analysis of organic and inorganic materials"; Dr R. M. Taylor, CSIRO Division of Soils, Glen Osmond, South Australia, on "Induced hydrolysis: its application to mineral formation and soil processes"; Dr S. Chakraborty, CSIRO Division of Soils, Glen Osmond, South Australia, on "Fungal feeding by mycophagous amoebae and its ecological significance"; Professor M. Grasserbauer, Institute for Analytical Chemistry, Technical University, Vienna, Austria, on "Surface analysis in materials research with secondary ion mass spectrography".

A Seminar on Nuclear Magnetic Resonance (NMR) was held at the Institute on 18th January, 1984 when lectures were given by Dr P. S. Belton, Food Research Institute, Norwich, on "NMR in the AFRC", and by Dr B. A. Goodman of the Macaulay Institute on "Applications of NMR in soil research". The seminar concluded with a discussion on potential applications of NMR and the instrumentation required.

Short-term visitors came to the Institute from seventeen countries during the year, including staff from the Department of Soil Science, Reading University, the Department of Forestry, Aberdeen University, Department of Geography, St. Andrew's University, Robert Gordon's Institute of Technology, Aberdeen, and the British Antarctic Survey, Cambridge, to use the Institute's facilities and the staff's expertise. Group visits included delegates from various conferences held in Aberdeen, *e.g.* Scottish Peat and Land Development Association, Fifth (TEMA) Trace Elements in Man and Animals Conference, Aberdeen Image Processing/Remote Sensing Group, Grassland Division Technicians, NOSCA, overseas students attending a seed potato course at NOSCA/EOSCA. Students from the Agriculture, Biochemistry, Forestry and Soil Science Departments of the University of Aberdeen, Chemistry and Geography Departments of the University of Strathclyde, Remote Sensing students from the University of Dundee and NOSCA students from the School of Agriculture and Clinterty College, Aberdeen, as well as pupils from Hazlehead Academy Computing Society, Mackie Academy, Stonehaven and Turriff Academy.

In September, the SARI Safety Officers held their meeting at the Institute.

Long-term visitors were welcomed from Canada, Federal Republic of Germany, France, Italy, Japan, New Zealand and Pakistan.

In October, the Institute took on seven YTS trainees for one year's training — the trainees concerned are working in various Dpartments throughout the Institute.

Honours and Appointments

Dr M. J. Wilson, Head of the Department of Mineral Soils, was awarded the degree of DSc of the University of Wales for a thesis entitled "Processes and Products of Mineral Weathering".

Mr R. A. Robertson, Head of the Department of Peat and Forest Soils, has been re-elected Vice-President of the International Peat Society and has been nominated Chairman of the Editorial Board of a new International Journal of Peat Science and Technology to be launched by IPS in 1985. He has also recently been appointed Honorary Vice-President of the Scottish Peat and Land Development Association.

Miss Sheila Fraser, Department of Spectrochemistry, was awarded the degree of PhD of the University of Aberdeen for a thesis entitled "The development of a gas detection system utilizing a piezoelectric crystal sorption detector".

Mr P. Wilson, Department of Soil Fertility, was awarded the degree of PhD of the University of Aberdeen for a thesis entitled "A laser differential absorption system for the measurement of atmospheric sulphur dioxide".

Dr D. C. Bain, Department of Mineral Soils, was elected Honorary Secretary of the Clay Minerals Group of the Mineralogical Society of Great Britain and Ireland.

Dr R. V. Birnie, Remote Sensing Unit, Department of Peat and Forest Soils, was elected Chairman of the Land Applications Working Group of the National Remote Sensing Centre at Farnborough.

Mr J. M. Bracewell, Department of Mineral Soils, has been appointed to serve on the Organizing Committee of the Seventh International Symposium on Analytical and Applied Pyrolysis.

Dr P. D. Hulme, Department of Peat and Forest Soils, has been appointed Secretary of the Mires Research Group of the British Ecological Society.

Mr W. S. Sherriffs, Department of Soil Survey, accepted an invitation to serve as a member of the Judging Panel for the British Cartographic Society John Bartholemew Award — this is an annual award for excellence in the field of small scale thematic cartography.

Professor T. S. West, Director, accepted an invitation from AFRC to serve as a member of the Council's Working Party on Agricultural and Environmental Research. Mr Maitland Mackie, a member of the Council of Management as well as an AFRC Council Member, also serves on the Working Party.

Professor West also agreed to serve as an External Expert to the Board of Advisers Standing Panel of Experts in Chemistry of the University of London for the period from 1984 to 1987 and accepted an invitation from the Science and Engineering Research Council to serve on the Physical Chemistry Sub-committee of the Science Board's Chemistry Committee — this appointment is for three years from 1984.

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 II and III.

Post-graduate Students

Miss Charlotte A. Flower, a BSc graduate in Ecological Science of the University of Edinburgh, has been awarded an AFRC Studentship from March, 1984 to work in the Department of Peat and Forest Soils towards a PhD degree of the University of Aberdeen. Miss Flower previously worked on a term contract for one year at the Institute, funded by the Central Electricity Generating Board.

Mr M. F. Proe has now completed his experimental work for the degree of PhD and is currently writing up his thesis for submission to the University of Aberdeen.

Mr M. J. Hepher has completed his work for the degree of PhD and has submitted his thesis to Aberdeen University.

Prof. J. C. Holmes.

Institute Events

The Council of Management met twice on 25th May and 22nd November, 1984. Professor N. F. Robertson retired from the East of Scotland College of Agriculture and Professor J. C. Holmes has succeeded him as the East of Scotland College of Agriculture representative on the Council.

Institute Caravan: Publicity Literature

During the year the Institute Caravan was taken to the Royal Highland Show at Ingliston, the Ayr Agricultural Show and the Turriff Agricultural Show as well as the Black Isle Show where various aspects of the Institute's work were exhibited. Exhibits were also set up at the Barley '84

The Macaulay Institute Exhibition Caravan at the Ayr Agricultural Show, 1984.

demonstration at Northallerton and at the Royal Agricultural Show at Stoneleigh.

A series of Technical Leaflets relating to soil and crop fertility, the prevention of formation of iron ochre in field drains and the Institute's Remote Sensing facilities has been prepared and widely distributed during the year, making full use of the caravan facilities at agricultural shows. The literature of the Soil Survey of Scotland and its maps of Soils, Land Capability for Agriculture, Vegetation and Climate have also been exhibited and sold at these shows — even several of the memoirs of the Soil Survey of Scotland and special booklets prepared for such occasions, *e.g.* "The Soils of Easter Ross". The popularity of these exhibits and the genuine interest of the public at these exhibitions has been most rewarding and it is planned to continue with them, despite financial restrictions envisaged in 1985.

MISR Contracts

The SWAP contract for *ca.* £425,000, awarded by the Management Group of The Royal Society-Norwegian Academy of Sciences and Letters-Royal Swedish Academy of Sciences in late 1984 for work in 1985, has been mentioned above, as has the CEGB Loch Fleet contract of £29,000 and the HIDB contract of £16,500. All these contracts run for a period of several years and together with the other relating long-term contracts awarded in 1983 by the DOE and the EEC total some £835,000 over the next 3-5 years.

Associateship of the Institute

In recognition of his outstanding service and continuing involvement with the research programme of the Institute, the Council of Management conferred the title of Honorary Research Associate of the Institute on Dr H. G. Miller, now Professor of Forestry in the University of Aberdeen.

Equipment and Buildings

It was not possible to acquire much new equipment for the Institute during the year because of limited funding available from DAFS. Items included a replacement X-ray Diffraction Spectrometer for Mineral Soils, a GEMS Image Processing System for the Remote Sensing Unit, a Graphite Furnace Atomic Absorption Spectrometer for Spectrochemistry and a High Performance Liquid Chromatograph for Soil Fertility.

The assembly of a temporary Portacabin unit within the west quadrangle of the main Institute building has provided additional and much needed accommodation for the Department of Peat and Forest Soils. The 125m^2

block, pre-fabricated and installed in five sections, now contains four offices and a cartographic laboratory for peat survey and remote sensing personnel and an open-plan area to accommodate visitors and staff on research contracts and the storage of Departmental maps and field records. This welcome provision has enabled a re-organization and better utilization of space within the Institute's main and outbuildings. A purpose-built laboratory has now been established to house and integrate the Department's computer, image processing, digitising and photogrammetric systems. Plans are in hand to upgrade facilities for physical investigations and sample preparation and storage in Outbuilding A following the re-location of the botanical laboratory in the main building. The re-organization has also enabled the provision of a small amount of additional laboratory space for the Departments of Microbiology and Statistics.

Section of prefabricated building for offices for the Department of Peat and Forest Soils being lowered by crane into the central quadrangle of the main building.

Programme Units and Research Objectives

There have been some changes in the Research Objectives (RO) since the 1983 Report. Readers referring to the 1983 Annual Report should use the DAFS project numbers rather than the AFRC/ARCIS code letters which are likely to cause confusion. ARCIS re-uses letters from discarded research objectives and invariably stacks projects, a, b, c, etc. The DAFS numeration never re-uses the number of a discarded RO and is consequently

unequivocal. For example, MISR PU1 (b) in 1984 is quite different from ARCIS PU1 (b) in 1983, etc., whereas the DAFS code numbers always refer to the same project as in previous years.

In 1984 ROs 1002, 1004 have been discarded in PU1 and three new ROs introduced, *viz.* 1060, 1061, 1062. In PU2, RO 3009 has been discarded and a new conjoint project included, ROs 3803 and 4803. In PU3, 9014 has been discarded and substituted by conjoint 1804 and 9804 and a new objective 9063, introduced. In PU4, 4022, 4023 and 4064 have been discarded and replaced by conjoint 3805, 4805 and 4064. In PU5 RO 6030 has been discontinued. In PU6 a new RO, 2065, has been introduced. In PU7 there are no changes. In PU8 a new conjoint RO 3806, 4806 has been introduced. In PU9 a new conjoint project 2807, 6807 has been introduced and 2066. In PU10 there are no changes except that 3802 has been added to the former conjoint 1802, 8802 and 9802.

In the body of the Annual Report, as in the above paragraph, the first two numerals of the DAFS six digit code, being 00, are omitted as a matter of convenience.

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 01 in Mineral Soils; the numbers 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.

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2. "Sewage Sludge in Agriculture", Select Committee of the House of Lords on the European Committees, 1st Report 1983-84 HMSO, London, 143-155.
3. Annual Report, 1983, **53**, 71-74.
4. Annual Report, 1980-81, **51**, 80.
5. Annual Report, 1983, **53**, 38, 1981-82, **52**, 37.
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7. Annual Report, 1981-82, **52**, 17-18, 62.
8. Annual Report, 1983, **53**, 65.
9. A. W. Stuart, Profile 1984, **81**, 10-11.
10. A. M. Ure, Profile 1984, **82**, 17.
11. R. C. Mackenzie, Profile 1984, **85**, 4-5.
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13. R. A. Robertson, Profile 1984, **82**, 4-5.

PROGRAMME OF WORK

(1984)

PROGRAMME UNITS AND RESEARCH OBJECTIVES

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

RO

1001 Determine systematically chemical and physical characteristics of profile samples provided by the Soil Survey of Scotland and relevant to soil development and soil use.

1006 Characterise and examine trends and composition of soil solution and soil atmosphere in relation to soil development, type and use.

1060 Determine the nature, origin and properties of the inorganic and organomineral constituents of Scottish soils.

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

3005 Characterise soil minerals and study their surface properties and weathering by infrared, Mössbauer and EPR methods.

1061 Determine the nature, origin and susceptibility to weathering of minerals in Scottish soils, with particular reference to the release and sorption of nutrient elements.

1062 Determine the fundamental reasons for important differences in properties and behaviour between various soil series and associations in Scotland.

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

RO

3007 Establish the origin, distribution and mobility of trace elements in Scottish soils and their agricultural significance.

3008 Investigate the effects of soil conditions on the uptake of trace elements by plants and establish the distribution of trace elements in different species and plant parts.

3803/ 4803 Investigate the forms of occurrence of trace elements in soils and the mechanisms of their transport to the plant root.

3010 Develop multi-element spectrochemical techniques using d.c. arc optical emission and spark source mass spectrometry with, mainly, solid samples.

3011 Develop spectrochemical methods using atomic absorption and inductively coupled plasma emission spectrometry with, mainly, solution samples.

C

PU 3: SOIL SURVEY OF SCOTLAND

RO

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

9013 Produce maps of land capability for agriculture.

1804/9804 Characterise the structure-forming processes of Scottish soils in relation to their physical behaviour.

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

9016 Assess the grazing quality of the plant communities using a scale of grazing values for the component plant species.

9063 Monitor the soil moisture status of a number of the principal soils of Scotland to check: (i) the accuracy of morphological assessments, (II) the seasonal and annual variations within soil moisture classes.

PU 4: NATURE AND PROPERTIES OF SOIL ORGANIC MATTER

RO

3017 Characterise soil organic matter by infrared and ultraviolet spectroscopy.

1018 Assess the nature and behaviour of organic constituents in soils by analytical pyrolysis methods.

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

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

4021 Investigate the nature, distribution and properties of soil humic substances.

3805/4805 Characterise soil humic substances and their metal complexes by paramagnetic resonance and other forms of electron spectroscopy.

4064 Examine the effects of organic constituents of soil on the growth, nutrition and biochemical processes of plants.

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

RO

6025 Investigate the interrelationships between soil actinomycetes, bacteria and protozoa with plant roots.

6026 Investigate the interrelationships of fungi with plant roots.

6027 Investigate the microbial transformation of soil organic matter in relation to soil fertility and structure.

6028 Investigate the survival of fungi in soil and their transformation into soil organic matter.

4029 Examine the chemistry and biochemistry of organic material of microbial origin.

6031 Investigate the nature, distribution and metabolic activity of protozoa in soil.

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

RO

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

2033 Investigate digital image processing of remotely sensed data and photogrammetric mapping applications.

2034 Provide an advisory and application centre for remote sensing activity within the AFRS and undertake relevant tasks for other agencies on a contractual basis.

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

2036 Study the chemical and physical characteristics of peat and peat products.

2065 Survey, map and monitor the distribution and spread of bracken in Scotland and record its relationship to soil type and land capability class.

PU 7: SOIL FACTORS AFFECTING CROP PRODUCTION

RO

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

7038 Measure the ability of soils to provide the sulphur requirements of crops, from inorganic and organic sources.

7039 Estimate the mobility of native and applied nitrogen in soils, in relation to water movements and crop uptake.

7040 Assess rates of development of soil acidity, its effects on crops and its correction by liming.

7041 Measure the responses of field crops to added lime and nutrients, in order to predict fertiliser requirements.

7042 Measure the trace element status of soils and crops, and diagnose deficiencies and excesses.

7043 Assess the lime and major nutrient status of soils.

7044 Measure the mechanical stability of the structure of contrasting soils, and assess its importance for crop growth.

7045 Develop automated electrochemical techniques for analysing soil solutions and extracts.

7046 Study physico-chemical factors determining the uptake of trace elements from soils by plants.

1801/ 4801/ 6801/ 9801 Assess the mechanisms involved in ochre formation, identify the nature of the ochreous material and devise practical field methods of preventing or minimising its formation.

PU 8: FACTORS AFFECTING CROP AND PLANT COMPOSITION

RO

7047 Measure the organic and inorganic constituents of plants in relation to age and yield.

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

7049 Develop and apply radioactive isotopes in soil-plant investigations.

5050 Characterise cation uptake by roots and transport to the shoot in terms of cell transmembrane fluxes and electrochemical diffusion gradients.

5051 Characterise and compare the efficiency of uptake and transport of ammonium and nitrate ions, and assess the effects on uptake of other nutrients.

5052 Examine quantitative and qualitative aspects of trace element uptake and transport, and identify plants and management practices most likely to provide supplies of trace elements adequate for animal diets.

3806/ 4806 Determine the forms of trace elements in plants with reference to their dietary availability in animals and man.

4053 Examine the influence of environmental forces on plant growth and morphogenesis and assess the physiological mechanisms involved.

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

RO

2054 Study the biogeochemical cycling of nutrients and pollutants in forests and moorland vegetation including assessment of environmental consequences and possible soil changes of management practices or alterations in land use.

2055 Determine the factors controlling nutrient availability in highly organic soils such as peat and mor humus.

2056 Develop means of forecasting and diagnosing nutritional requirements on marginal lands and of prescribing ameliorative treatments.

2807/ 6807 Determine the factors controlling nitrogen mineralisation in forest ecosystems on poor soil and suggest means by which this rate can be manipulated by managers.

2066 Determine the factors contributing to the passage of acidity into streams, despite the neutralizing capacity of the ecosystem, and hence suggest means of management of riparian zones to minimise the problem.

PU 10: 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/ Establish an information system for Scottish soils by means of database and statistical techniques.

MISR Research Objectives 1984 —

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
PU 2	a	003007
	b	003008
	c	003803/ 004803
	d	003010
	e	003011
PU 3	a	009012
	b	009013
	c	001804/ 009804
	d	009015
	e	009016
	f	009063
PU 4	a	003017
	b	001018
	c	004019
	d	004020
	e	004021
	f	003805/ 004805
	g	004064
PU 5	a	006025
	b	006026
	c	006027
	d	006028
	e	004029
	f	006031
PU 6	a	002032
	b	002033
	c	002034
	d	002035
	e	002036
	f	002065
PU 7	a	007037
	b	007038
	c	007039
	d	007040
	e	007041
	f	007042
	g	007043
	h	007044
	i	007045
	j	007046
	k	001801/ 004801/ 006801/ 009801/
PU 8	a	007047
	b	007048
	c	007049
	d	005050
	e	005051
	f	005052
	g	003806/ 004806
	h	004053
PU 9	a	002054
	b	002055
	c	002056
	d	002807/ 006807
	e	002066
PU 10	a	008057
	b	008058
	c	008059
	d	001802/ 003802/ 008802/ 009802

1. MINERAL SOILS

M. J. WILSON

Most soils used for agricultural purposes in Scotland are classified as mineral soils in that they consist predominantly of mineral matter and usually contain <20 percent organic matter. The work of the Department is to investigate the formation, composition, structure and properties of these soils and to relate this information to soil behaviour largely, but not entirely, from an agricultural point of view. The investigations currently in progress involve eight inter-related research objectives and encompass the physical and chemical characterization of total soils and their inorganic or organic constituents, the determination of the nature and chemical activity of soil particle surfaces, the elucidation of geochemical processes particularly those involved in the release and sorption of plant nutrients, and the study of texture and structure especially as affected by natural processes and management practices. Some projects, such as that dealing with the composition of soil and stream waters in selected catchments, also have a bearing upon matters of environmental importance and there is every reason to think that more attention will be given to such aspects in the immediate future.

As in previous years the instrumental facilities and technical expertise within the Department have been made available, on request, to a number of outside organizations including, for example, other SARIs, British Rail, CEGB, British Antarctic Survey, the Forestry Commission and oil-related companies in Aberdeen.

Soil, Plant and Water Analysis

Soil Analysis. The systematic chemical and physical analyses of soil profile samples collected by the Soil Survey of Scotland during the 1983 field season have almost been completed. Soil samples have also been examined for other departments in the Institute and for outside bodies such as the Scottish Crop Research Institute (SCRI), the Forestry Commission and others. Input of chemical and physical data into the Institute's Soil Data Bank has continued and almost 70 percent of the National Inventory profile samples and 63 percent of all profile samples analysed between 1979 and 1983 have now been entered. Increasing demands for more determinations of the physical properties of soil have lead to the setting up of new methods for the analysis of these properties and to the planning of a new physical laboratory which will shortly become operational. 1001, 9012, 1802

Collaborative studies with the Department of Spectrochemistry have continued on the extraction by selective chemical techniques of inorganic

forms of translocated alumimium, silica and iron. In particular, work is in progress to determine whether the mobile aluminium precipitated on clay mineral surfaces can be more suitably extracted with sodium oxalate rather than with the more widely used ammonium oxalate. A paper describing a method whereby silicon can be determined spectrophotometrically in ammonium oxalate extracts at levels where conventional flame atomic absorption methods are not sensitive enough has been published[1]. An account of the way in which selective chemical methods can be used to characterize X-ray amorphous material in a Scottish soil has been accepted for publication[2], and a further paper has been submitted on the relationship between the degree of polymerization of silica, as revealed by the formation of organosilicon derivatives, and the combined influence of parent material and degree of weathering of some Scottish soils[3]. 1001, 1061, 9012, 3005.

Plant Analysis. The demand for chemical analysis by X-ray fluorescence spectroscopy has increased considerably in the past year. About 1100 samples of oil seed rape, turnips, barley, wheat, oats and various types of herbage have been analyzed for sulphur for the Department of Soil Fertility. Sulphur has also been determined in about 170 samples at a much lower level (100-200 ppm) for the Department of Microbiology in extracts from fumigated and unfumigated soils. Low levels of aluminium (70-320 ppm) were measured in some 40 samples from different parts of Sitka Spruce for the Department of Peat and Forest Soils, revealing that aluminium is highest in the litter and lowest in the bark. At the request of the Rowett Research Institute, bromine was determined in some 94 samples of brominated straw as part of an investigation into the breakdown of lignin. 7038, 6027, 2054.

A service in ^{15}N has been set up for the requirements of several Institute departments performing ^{15}N stable isotope tracer experiments. A VG SIRA 9 triple collector mass spectrometer was commissioned in February 1984 but, due to staff shortages, did not become operational until October. To date, several initial technical problems have been overcome and the service can operate on the basis of about 100 samples per week as soon as staff are available.

Stream and Soil Water Analysis. The results of a study extending over a period of six years on the major element composition of streams draining small catchment areas situated on the main soil associations of north-east Scotland have been assessed by statistical analysis using a principal components method (see later). The streams were analysed for pH, calcium, magnesium, sodium, potassium, aluminium, iron, silicon, bicarbonate, chloride, sulphate, phosphate, nitrate and ammonium. Examination of the data collected over a two year period clearly shows contributions from two major components. The first component relates to the base status of the different soil associations, whose parent material range from 'acid' rocks such as granite, gneiss and schist to 'basic' rock such as gabbro and serpentinite, and accounts for most of the variation in pH, bicarbonate, calcium, magnesium and silicon. The second component relates to the influence of marine input and accounts for the variation in sodium, chloride and sulphate. Both base status and marine input vary seasonally, with the former increasing in the summer and the latter increasing in the winter.

Another point of interest is that both aluminium and iron correlate positively with rainfall, whereas calcium and magnesium show an inverse correlation. This suggests that aluminium and iron may be leached from soil organic horizons during periods of run-off but that calcium and magnesium are leached from soil mineral horizons during periods of base-flow. The results collected in this study represent essential baseline data for further investigations of this type that are currently being planned to extend to other areas of Scotland and which bear generally on the problem of acid rain. 1006, 9012

Thermoanalytical Studies. Although the number of thermoanalytical techniques available over the years has gradually increased[4,5] the most common for soil studies are differential thermal analysis (DTA), differential scanning calorimetry (DSC) and thermogravimetry[6]. Development work on the data system based on the Apple II microcomputer has been extended to include the differential thermal apparatus. A paper on historical aspects of thermal analysis has now been published[7]. 1060, 1003

Inorganic Soil Constituents

The nature of the minerals occurring in soils, as well as the ways in which they are associated, control the inherent fertility of soil to a considerable extent. Not only do these minerals represent the nutrient capital of the soil, they also influence soil texture and structure, in addition to important soil properties such as water availability, water movement, nutrient 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 clay minerals. This approach demands the utmost care in the separation and pretreatment of clay samples[8]. 1060, 1003, 3005

Clay Minerals. The nature of the soil clays, as assessed by X-ray diffraction (XRD), in all the major soil associations of Scotland has ben critically reviewed as part of a joint study with the Soil Survey of England and Wales on the soil clays of Great Britain. Because of their relative youth, Scottish soils are strongly related to the nature of the geological material from which they derive and, for this reason, there are marked variations in their clay mineralogy. The influence of parent material is most obvious where the soils are related to sedimentary rocks of different ages but it can also be discerned in soils derived from various igneous and metamorphic rocks. Illite, kaolinite and chlorite are the major crystalline clay minerals found in Scottish soils, but many types of interstratified clays, which often show swelling properties and possess a high cation exchange capacity, also occur. 1060, 1061, 1802

The ubiquity of interstratified clays in soils and sediments has led to an extensive series of investigations into the actual physical nature of these minerals. Currently, interstratified clays are assumed to exist as relatively large crystallites made up of a regular or random arrangement of different silicate layers. However, transmission electron microscope observations show that such crystallites do not exist in selected <0.1 um fractions, although these fractions still yield XRD patterns typical of interstratified

clays. Such fine fractions consist of fundamental particles only one or two unit cells thick and evidence has been presented to show that the XRD patterns result from an interparticle diffraction effect[10]. Further studies have shown that many of the common types of interstratified clay minerals are composed of aggregates of fundamental particles and that a wide range of interstratification can be modelled experimentally by using only three types of particle[11]. These observations have been synthesized into a new concept for interstratified clays[12]. Regular types, such as rectorite and corrensite, consist of a homogeneous population of 20A and 24A thick particles, corresponding to elementary "illite" and "chlorite" respectively. Random types can be regarded essentially as mixtures of very fine particles, and partially ordered types are thought to be composed primarily of particles up to about 50A thick. In each case, swelling behaviour arises because the interfaces between these thin particles are capable of absorbing water or organic molecules. The concept that randomly interstratified clays consist of mechanical mixtures of discrete phases was tested by mounting a TEM study of the fine fraction of several soil clays that had been shown by XRD to contain considerable amounts of randomly interstratified illite-smectite. The results could be readily interpreted in terms of separate illite and smectite components that are morphologically and chemically distinct. This new conceptual model for interstratified clays has broad implications for their chemistry, genesis and behaviour, as discussed later.

1060

Iron and Manganese Oxides. These constituents which affect a range of important soil properties including water adsorption, ion adsorption and soil aggregation, are easily synthesized in the laboratory under near natural conditions, so that their identification in soils gives some indication of pedogenetic processes. The manganese oxides are particularly implicated in the sorption of heavy metals in many soils and investigations have continued into a number of manganese pans and other zones of enrichment in Scottish soils. Various techniques have shown that the potassium—and barium-containing manganese oxides are the minerals cryptomelane and hollandite respectively, whilst the aluminium manganese oxides have been tentatively identified as lithiphorite. The transition metal cations, Cu, Co, Ni and Zn are associated with all these minerals, although preliminary results suggest that lithiphorite may be particularly active in the accumulation of these elements. Other poorly ordered manganese oxides have been found in some soils, but remain to be characterized completely.

1003, 3005, 1062

A study of the iron oxide phases present within the profile of an immature, alluvial soil at Linross, Perthshire has now been completed and a paper accepted for publication[13]. A similar study has been made of an alluvial soil belonging to the Stirling Association. This soil is characterized by a deep blue-grey horizon and yields drainage waters of pH 3.3 with a high sulphate content (482 ppm). Microscopic examination shows the presence of framboidal pyrite (FeS_2) and organic residues associated with silica phytoliths. These observations suggest that marine inundation of the site resulted in the development of anaerobic conditions and in the formation of

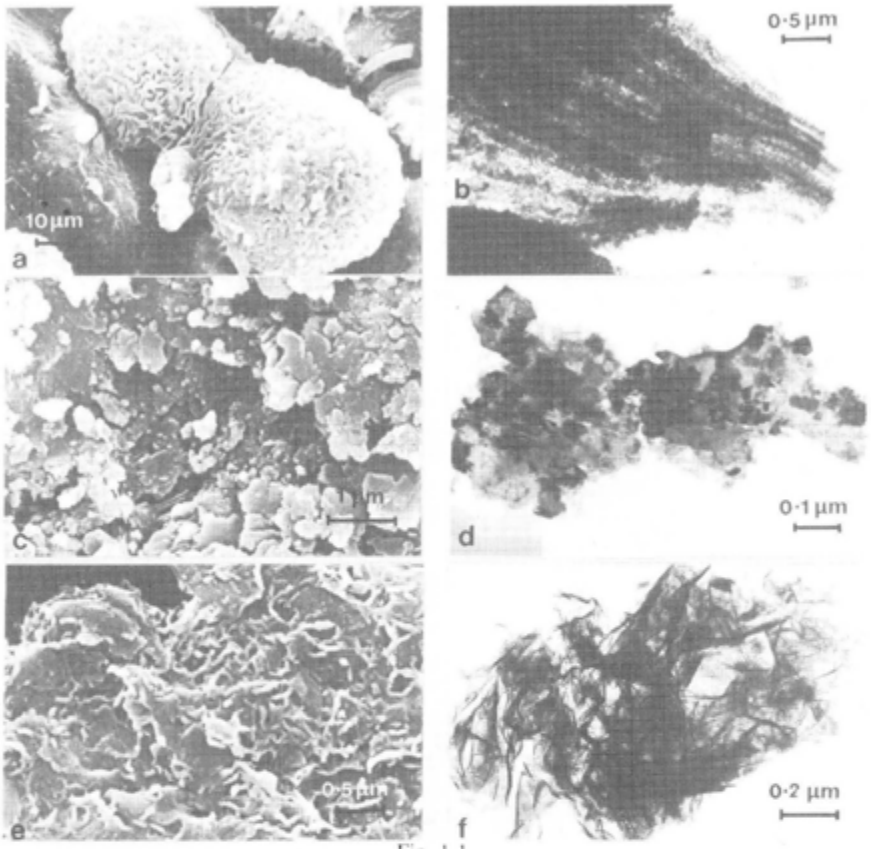

Fig. 1.1.
Scanning and transmission electron micrographs (SEM and TEM) of soil iron and manganese oxide minerals. a. SEM of globular ferrihydrite, a poorly ordered hydrous iron oxide, b. TEM of ferrihydrite showing "onion-skin" structure of globules; c. and d. SEM and TEM of the more highly crystalline iron oxide, lepidocrocite, showing its platey morphology, e. and f. SEM and TEM of vernadite, a poorly ordered manganese oxide showing a crumpled sheet morphology.

iron sulphide, following release of ferrous iron from the soil and reduction of sulphate from sea water. The possible occurrence of ochre being produced following drainage of these soils is now being considered. 1003, 1801, 1804

A study of the morphological and chemical characteristics of iron and manganese oxides in a hydromorphic soil has now been completed[14]. In this soil a $^{B}_{Fe/Mn}$ horizon has formed, consisting of an upper iron oxide layer, containing lepidocrocite and a lower, black layer, composed of an intimate mixture of poorly ordered manganese and iron oxides, the minerals vernadite and feroxyhite respectively. The Bg horizon of the same profile contains ochreous mottles of lepidocrocite, but in the B_3/Cg horizon the predominant iron oxide is goethite. The former has a distinct flake-like morphology, whereas the latter occurs as globules that are made up of acicular particles. The poorly ordered iron oxide, ferrihydrite, occurs in several forms including microcrystalline aggregates, globules and

sometimes gelatinous masses, possibly of biological origin. Fig. 1.1 illustrates some of the morphological variability typical of soil iron and manganese oxides. 1804, 1003, 1801

Other Minerals. A full understanding of the nature of the soil clays and other fine-grained minerals can only be attained by careful investigation of pure minerals using modern analytical techniques. In collaboration with the Department of Spectrochemistry a study has been made of the compositional variation of beidellite, a swelling clay mineral[15], involving the complementary use of several different techniques including nuclear magnetic resonance. The results show an increasing magnesuim for aluminium substitution within the clay mineral structure with decreasing particle size. A paper describing the unusual chromium-bearing swelling mineral, volkonskoite, has been published[16], as well as one dealing with the early history of the mineral[17]. A paper has also been published describing a new mineral, Macaulayite[18]. This mineral which was found in deeply weathered granite, has an ideal formula of $Fe^{3+}_{24}\ Si_4O_{43}(OH)_2$ and has a layer structure which is thought to consist of double hematite units terminated on both sides by silicate sheets. Another new mineral, so far not named, has been found associated with the crustose lichen *Pertusaria corallina* growing on manganese ore[19]. This mineral, which consists of manganese oxalate dihydrate, formed as a result of the interaction between the oxalic acid-secreting lichen fungus and the substrate manganese ore, an observation suggesting that a variety of hitherto unreported oxalate minerals may exist where such lichens have colonized substrates of unusual composition. This study was undertaken in collaboration with the Department of Microbiology. 1060, 1003, 6027

Organic and Biological Materials

The combined use of three techniques, namely advanced pyrolysis, mass spectrometry, and computerized multivariate analysis (Py-MS), has proved a viable approach to the analysis of the complex organic materials found in mineral soils. The advantage of examining whole soils with minimum sample preparation permits large numbers of samples to be investigated and shows up significant variation in composition which can be related to major soil properties.

Previous work demonstrated the partitioning of a representative sample suite of Scottish soil A horizons by two main factors of organic composition, which related to drainage class and to humification respectively[20]. During the current year analysis by Py-MS of corresponding B horizons showed that they were clearly different from the A horizons. In particular, the latter contained more polysaccharide and lignin-derived products whilst the pyrolysates of the former contained more aromatic hydrocarbons. The so-called "Bh" horizons of podzols were found to be similar to A horizons in composition, suggesting that they originate through *in situ* humification of organic materials. The true podzol B horizon products are typical of organic matter translocated in solution down the profile.

Separate analysis of the B horizons gave clear distinction by two major factors into four categories of organic composition. One factor widely

separated gleyed (Bg) from freely drained but well humified soils (Bw), whilst podzolized B horizon material (Bs) was clearly differentiated as intermediate. Alkenes and aromatic hydrocarbons characterized the Bg end of this sequence and polypeptide the Bw end, not unlike the corresponding A horizons. A second factor separated the podzol Bh group, based on greater levels of polysaccharide and lignin products as mentioned above. The organic matter of an unknown soil sample can be assessed, therefore, in terms of its pyrolysis mass-spectrum, by first making an A-B discrimination followed by further tests for successive subdivisions of A and B horizon organic matter.

Py-MS has also been used to detect differences in the organic matter associated with the various particle size fractions of three mineral soils. In particular, the clay fractions yielded more products characteristic of the polypeptides and less of the hydrocarbons suggesting a higher degree of humification. It is intended to extend these methods of examination to other types of soil fractions, such as those of densimetric and classical soil organic fractions.

The well-established relationship between soil aggregate stability and organic matter is also being investigated in relation to composition, as reflected by Py-MS, to try to identify the biopolymers or constituents responsible. Soils depleted in organic matter are being investigated for changes in organic matter composition. Palaeosols are being examined principally to test the hypothesis that the aromatic hydrocarbon precursors prevalent in anaerobic soils represent very old organic matter depleted in O and N.

Samples have also been analyzed, on request, for groups within and outwith the Institute, to characterize transformations in the microfaunal gut passage, tree bark composts, specific organic soil separates, lignin in archaeological samples and organic matter in shales. Other samples were analyzed as part of an exercise to test the interlaboratory reproducibility of Py-MS[21]. The results show reasonable agreement for technical polymers, but increasing quantitative divergence for more complex biopolymers, underlining the needs for careful mass spectrometer source tuning on standards and greater stability. The stability of the present instrument has been improved by redesigning and fitting an accurate digital meter in co-operation with the Technical Services Unit.

Quantitative pyrolysis-gas chromatography studies of the origin of soil nitrogen pyrolysis products have been concluded, showing the origin of pyrrole and acetonitrile in specific amino acids[22]. 1018, 4020, 4021, 4029

Surface and Physical Characteristics of Soils

XPS Studies. The ability of manganese oxides to adsorb a range of heavy metal cations has been referred to above, but the mechanism of sorption remains obscure. However, recent work using X-ray photoelectron spectroscopy (XPS), a method capable of determining the composition of thin surface layers and the chemical environment of adsorbed species, has provided some significant information. Thus, treatment of a synthetic non-stoichiometric manganese oxide with Cu and Co results in a change in

the relative amounts of Mn(II) and Mn(IV) remaining in the solid after equilibration. In addition, there is evidence that enhanced sorption of Co with increasing pH is probably due to the formation of Co/OH species in the vicinity of the surface. Examination of the Ols line supports this conclusion, the presence of a high binding energy component indicating the presence of OH.

In conjunction with the Department of Soil Fertility a series of sulphur-containing compounds has also been examined by XPS to establish the "chemical shifts" associated with increased oxidation of S. The results from this study were used to interpret the spectra obtained from two commercial S foliar sprays. It was found that, although both products contained elemental S in suspension, some S is oxidized and is present as S/O species. Comparison of water-washed and untreated material shows that the amount of oxidized S is decreased in the water-washed state, indicating that water-soluble S compounds are present. This observation could have considerable implications for any suggested mechanism for S uptake from those foliar sprays.

A collaborative study with the Rowett Research Institute has now been completed. In this study XPS was used to compare the quantity of Br present in the surface of partially digested straw with that on original material, after both had been subjected to a chemical reaction specific to the presence of lignin. The partially digested material had a higher Br content indicating the presence of a lignin layer near the surface.

A paper presenting electron microscope evidence to show that the ability of high surface area gibbsite to absorb Cu^{2+} is related to growth steps in the gibbsite crystals has now been published[23]. 1003, 7038, 3005

Physical Properties of Soils. In collaboration with the Department of Soil Survey, work has commenced on the characterization of the structure-forming processes of Scottish soils in relation to their physical behaviour. In particular, the problem of soil compaction is being studied to try to determine why some soils are able to recover their natural structure after compaction whilst others possess no such ability. Samples of a Winton series soil, which was used in field trials by the Scottish Institute of Agricultural Engineering (SIAE) to study the effect of compaction on crop yields, are currently being studied by optical and scanning electron microscopy. Samples of different soil types in north-east Scotland have also been collected to determine the major factors controlling their physical characteristics — currently being analyzed — and to see whether the soils can be classified according to their restructuring capacity.

Work on the aggregate stability of surface horizons of Foudland and Laurencekirk Series soils has been carried out using a method based on the influence of rate of wetting on the particle size distribution. The soils in each series fall into two categories, namely, arable and 2-3 year grass. A wide range of stability of the macroaggregates has been observed and, although the stability index correlates highly with organic carbon content, there is little indication of increased aggregate stability of the soils after 2-3 years in grass, suggesting that recovery from structural damage in these soils will

take in excess of three years. Disruption of the soil macroaggregates results in a large proportion of material in the size range 100-200μ, probably representing stable microaggregates, and work is continuing in an attempt to characterize the chemistry and mineralogy of this material and to assess its stability.

In a collaborative project with SIAE, a set of 26 surface soils from south-east Scotland was studied to determine whether their physical properties, which had been previously characterized, could be correlated with soil mineralogy and other factors. Initial results are extremely encouraging. In particular, total layer silicate content (as assessed by X-ray diffraction) 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 the pipette method. Moreover, the different contributions of the major types of clay minerals could be readily separated using principal components analysis. Further work is under way to explain these results. 1804, 1003, 1062, 1060

Soil Processes

A new project has been initiated to study weathering reactions and pedogenic processes in soils where the amounts of extractable trace elements vary markedly according to drainage status. A detailed mineralogical examination has been carried out on several particle size fractions from soils in a hydrologic sequence from the Strichen Association, where the extractable Cu from gley soils is higher than that from the freely and imperfectly drained profiles. It was found that the mineralogy of the clay and silt fractions of these soils derives largely from the weathering of biotite, a common host for Cu. Detailed studies of the weathering of this mineral, in collaboration with the Department of Spectrochemistry, are being pursued. A paper describing the weathering of chlorite in the silt and clay fractions of Scottish soils has now been accepted for publication[24]. This work shows that although the chlorite in the clay fractions is being totally dissolved, at the same time it is being replaced by chlorite that is being physically broken down from the silt fraction. This effect might lead one to conclude (falsely) that the chlorite in the clay fraction was stable to weathering. 1061, 3007

The general mineralogy and weathering history of Scottish soils has now been reviewed in a geological context[25]. Preglacial weathering, which took place under a sub-tropical climate, has had a profound influence on the constituents and, therefore, on the properties of some soils, particularly in north-east Scotland. Typical weathering products of this period are kaolinite, gibbsite and halloysite, which may now be found in soils of all drainage classes. The effect of postglacial weathering is confined mainly to the transformation of pre-existing micaceous minerals and to the formation of poorly ordered clays. 1061, 1060, 9012

Transformation reactions often involve the formation of interstratified minerals and the nature and origin of these minerals in soils and rocks have been compared and contrasted[26]. The evidence suggests that fundamentally different types of interstratified minerals are formed during weathering in

soils and during diagenesis in rocks, a distinction that has never previously been made. In soils, interstratified minerals form by transformation of relatively coarse grained layer silicates, whereas in rocks the interstratified clays crystallize from solution and consist of extremely fine-grained particles that exhibit the phenomenon of interparticle diffraction. Further evidence has been presented on the nature of diagenetic interstratified illite-smectite, and a new mechanism proposed to account for its origin[27]. These clays have a major influence on the fluid flow properties of sandstone rocks[28] and it seems likely that they could be equally important in the context of soils.

1060, 1061

Poorly ordered allophanic soil components are particularly conspicuous in the Bs horizons of podzolic soils developed upon coarse sandy material. In collaborative studies with the Department of Spectrochemistry, electron microscope and X-ray diffraction evidence have been presented to show that aluminium, silicon and iron were liberated from the upper horizon of a podzolic soil by intense acidic weathering of feldspar and biotite and were deposited in the B horizon as allophanic gels[29]. Fibres of imogolite associated with the gels were observed by SEM when soil specimens were dried under zero tension conditions (Fig. 1.2.). Electron microscope observations have also indicated that iron is not substituted into the imogolite structure, but occurs as discrete clumps of iron oxide in the dispersed protoimogolite sols[30]. Where podzolized soils develop on material containing expansible layer silicates, the mobilized aluminium may be trapped in the interlamellar spaces of the clay, so that discrete allophane is not formed. A collaborative study with the Department of Soil Fertility showed that aluminium-interlayered vermiculite clays occur in the B horizons of some New Zealand podzols, where they strongly influence the cation exchange behaviour of the soils[31]. 1060, 3005, 1061, 7040

A collaborative study with the Faculty of Agriculture, Cukurova University, Adana, Turkey, on the relationship between the chemical,

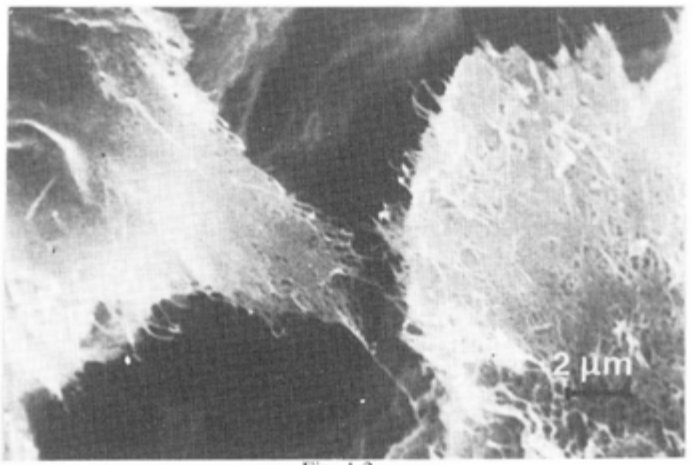

Fig. 1.2.
SEM of the poorly ordered, fibrous mineral, imogolite in a critical point dried soil fragment from the Bs horizon of a podzol.

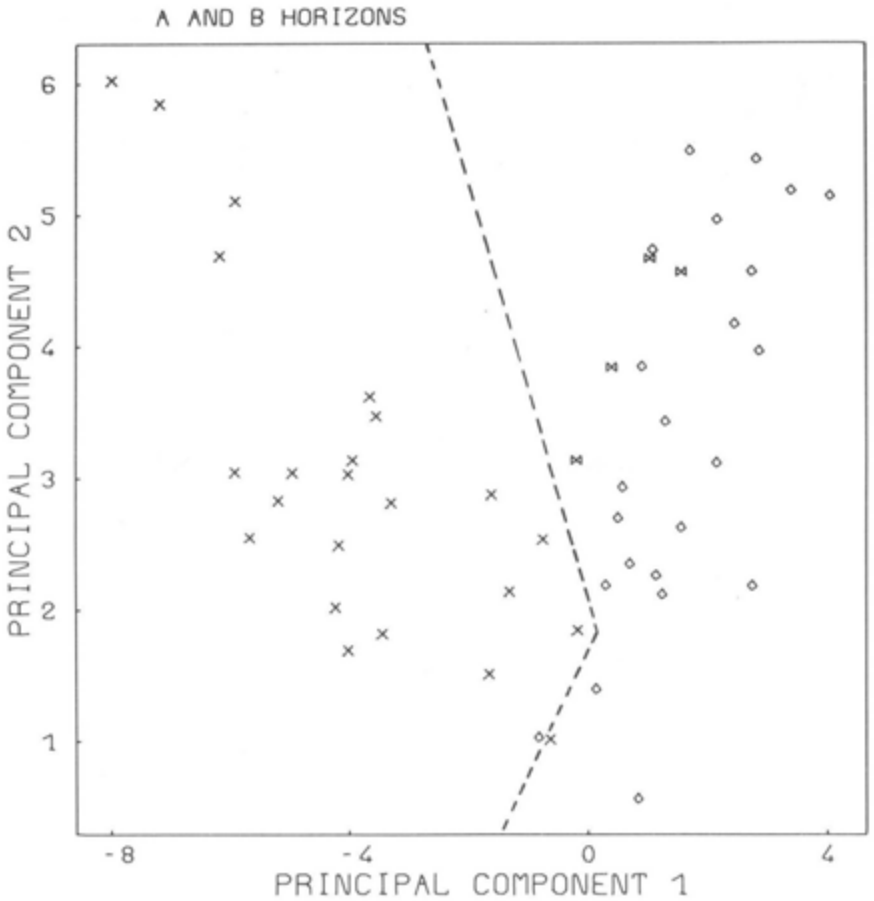

Fig. 1.3.
Scores of the first two principal components from the pyrolysis-mass spectral data for 22 soil profiles ◇ A horizons; X B horizons; ⋈ Bh horizons.

physical and mineralogical characteristics of some Turkish soils derived from volcanic material has now been published[32]. A further study of an unusual assemblage of high magnesium clay minerals in some Turkish alluvial soils has also been completed[33]. A collaborative study with the Faculty of Agriculture, University of Riyadh, Saudi Arabia has established the widespread occurrence of the clay mineral, palygorskite, in the wadi soils of that country, irrespective of the underlying geology[34].

Development of Methods

Computerized multivariate analysis is now widely used where significant patterns and relationships are sought in large quantities of data. The method enables the essential relationships between large numbers of variates and samples to be extracted and represented by plotting only two or three compound factors or principal components, each of which is a linear

combination of the original variates. A program for principal components analysis has been developed for extracting factors from pyrolysis-mass spectrometry (Py-MS) and has now been supplemented by the development of various graphic options. Figure 1.3 illustrates the plot of factor scores for the Py-MS analysis of the organic matter in a set of A and B horizon soil samples and clearly shows a successful discrimination. This represents 73 per cent of the total variance. A vector diagram of variates can also be displayed to show strongly intercorrelated groups of variates and the principal directions in which they affect the scores. The variance distribution in the plane may be plotted as a polar diagram to show such directions and the factor loadings may be plotted as a factor spectrum. Fig. 1.4 demonstrates the molecular species responsible for the separation along the x axis

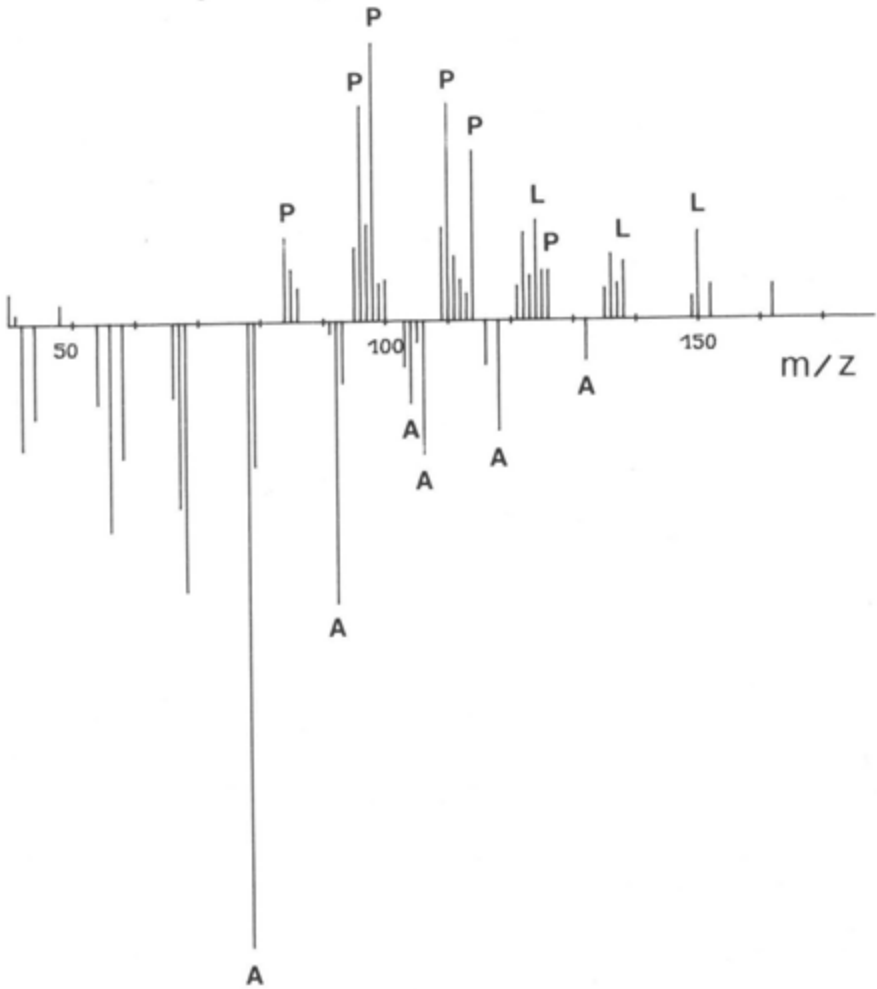

Fig. 1.4
Factor spectrum for the horizontal dimension of Fig. 1. (each mass ion treated as a variate). P. polysaccharide-derived ions; L lignin-derived ions; A aromatic hydrocarbon ions.

direction of Fig. 1.3 and shows more polysaccharide-and lignin-derived products from A horizons (positive direction) and aromatic hydrocarbons from B horizons (negative direction). 1018

Multivariate statistical techniques have also been applied to microprobe analyses to demonstrate inter-element relationships. In the work on iron and manganese oxides, it was found that the phases active in the sorption of particular species could be identified by this method[35]. For example, following $CuSO_4$ treatment of a mixture of finely particulate Ca manganate, Al-substituted geothite and talc, it was clear that Cu adsorption was associated with the manganese oxide phase, SO_4 was adsorbed by the geothite and talc was unaffected. Again, in some collaborative work with the University of Reading on the sorption of phosphate fertilizers in tropical acid soils, multivariate methods indicated that the reaction products were aluminium phosphate complexes. 1018, 3005

The separation of individual soil clay mineral types has always been fraught with difficulty, but the development of a modified high gradient magnetic separation system by the Department of Spectrochemistry has yielded encouraging results.[36]. Iron-rich minerals such as hematite, goethite and lepidocrocite can be separated in relatively low field fractions and chlorite and hydrobiotite in higher field fractions. Traces of manganese-rich minerals were also concentrated in higher field fractions.
1003, 1060, 3005, 1804

In collaboration with the Department of Microbiology the utility of low temperature scanning electron microscopy has been demonstrated on various biological specimens[37, 38, 39]. 6028, 1804

Other Work

As in previous years there has been a steady demand for the specialized facilities and expertise available within the Department. On request, advice has been given on the composition and properties of mineral soils from Sudan, Colombia, Malawi, Zimbabwe, New Zealand, Sierra Leone, Nigeria and British Antratica. Samples have also been analyzed for other SARIs, the Forestry Commission, the Building Research Establishment and for industrial concerns such as British Rail, CEGB and companies associated with the oil industry. Collaborative assistance has also been given to various departments within the University of Aberdeen, St Andrews, Reading, Salford and elsewhere. In collaboration with the Department of Chemistry, University of Wales, Aberystwyth, an investigation has commenced into the potential use of synthetic interstratified clays, as heterogenous catalysts, this work being supported within the Institute by a grant from the National Research and Development Corporation of the British Technology Group.

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2. PEAT AND FOREST SOILS

R. A. Robertson

The programme of work of the Department has continued to expand and progress along the lines previously reported, the main emphasis being on the development and deployment of remote sensing, image processing and photogrammetric techniques for resource mapping, terrain analysis and crop monitoring operations and on field, laboratory and glasshouse experiments designed to provide a better understanding of the biogeochemical cycling of nutrients, and pollutants, in upland ecosystems and the interactive role of soils and vegetation in modifying rainwater chemistry and the passage of acidity into streams and lakes. The complementary nature and closer integration of Programme Units 6 and 9 have important implications with respect to assessing and monitoring the effects of current management practices and possible future changes in land use and underlines a change in emphasis towards environmental research.

Development and application of specific remote sensing strategies and methodologies have been carried out in association with the National Remote Sensing Centre, Royal Aircraft Establishment, Farnborough, the European Space Agency, the Department of Industry (Space Division), the Scottish Development Department (Air Photo Library), Robert Gordon's Institute of Technology, the Scottish Crop Research Institute, the Plant Breeding Institute, Cambridge, the North of Scotland College of Agriculture and the Universities of Aberdeen, Dundee and Glasgow. Close collaboration has also been established or maintained with the Forestry Commission (Research and Development Division), the Institute of Hydrology, the Central Electricity Research Laboratories, the Irish Forest and Wildlife Service, the Natural Environment Research Council, the Department of the Environment, the Forth and Clyde River Purification Boards and the Departments of Forestry and Soil Science at the University of Aberdeen in the planning and operation of field experiments designed to investigate the size and rate of nutrient fluxes, including atmospheric inputs, in different plant/soil systems, the input, retention and loss of nutrients in upland catchments, the effect of tree species on the rate of nitrogen mineralization and the level of microbial activity in different soil horizons and the environmental impact of acid rain.

These and other investigations have resulted in close and fruitful co-operation with other Departments within the Institute and with external organizations including the Highlands and Islands Development Board, the Scottish Development Agency, the Scottish Development Department, the North of Scotland Hydro-Electric Board, the U.K. Peat Producers'

Association, Highland and Strathclyde Regional Councils, the Institute of Geological Sciences and the Scottish Colleges of Agriculture.

Members of staff have continued to serve on a number of national and international committees and working groups. These include the Executive 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 NERC Terrestrial Life Sciences Grants Committee and the Aberdeen Institute of Ecology (H. G. Miller) : the Remote Sensing Applications Committee and the Land Applications Working Group of the National Remote Sensing Centre (R. V. Birnie) : and the Mires Research Group and Meetings Committee of the British Ecological Society (P. D. Hulme).

Following the appointment of Dr H. G. Miller to the Chair of Forestry at the University of Aberdeen, Mr Michael F. Proe, who had just completed his 3-year contract at the Institute on a NERC/CASE award, was recruited to take over responsibility for work on forest soils and related aspects of the Department's programme. A sincere welcome is also extended to Mr David R. Miller, who joined the staff in July, 1984 with specific responsibilities for mapping and monitoring the distribution and spread of bracken in Scotland using a combination of aerial photography and space imagery, and to Dr Anne Leech and Dr Tom Nisbet who have been appointed on fixed contracts, funded by the Department of the Environment, to investigate factors contributing to the passage of rainwater acidity into streams and to suggest appropriate control measures.

Terrain Resource Survey and Monitoring Operations

Peat Survey and Evaluation. Growing interest in the commercial production, processing and utilization of peat and peat products has greatly increased demands for information and advice on the nature, extent and development potential of Scottish resources and on the chemical and physical characteristics of different peat types which determine their suitability for horticultural or energy-related purposes. In recent years, peat has become a highly competitive fuel and its future potential as an alternative energy source is currently being subjected to detailed assessment. Improved technologies for the extraction, drying, harvesting and combustion of peat fuel coupled with recent advances in fuel conversion processes now provide a unique opportunity to expand and diversify the peat industry in Scotland[1]. These trends and applications fully justify the Department's remit to act as a centre for the documentation and dissemination of scientific and technical information on all aspects of peat research and development. 2035, 2036

Remote sensing and photogrammetric techniques, used in conjunction with ground survey operations, are finding increasing applications in the production of peat resource maps and reports for development and other agencies within the public and private sectors[2]. During the year a survey to identify and evaluate sites suitable for peat production has been undertaken in the Orkney Islands at the request of the North of Scotland College of Agriculture[3]. Examination and characterization of an area of blanket bog in

Ayrshire has also been completed on behalf of the National Coal Board prior to open cast mining operations and the subsequent rehabilitation of the site. The comprehensive survey and classification of peatlands in the Shetlands Isles, previously reported, is nearing completion. This study is based primarily on land use and vegetation characteristics using information derived from ground survey, aerial photography and space imagery. Results from both detailed topographic-stratigraphic and reconnaissance surveys continue to provide information on peat resources for inclusion in Memoirs of the Soil Survey of Scotland[4,5]. In order to reduce the time and effort spent in obtaining complete cores from deep or compact peat deposits, a mechanical aid for the existing manually-operated sampling equipment has been successfully developed and tested[6]. An account of a peatland vegetation classification of Lewis and Harris has been published and a similar, though provisional, classification for the Shetland Isles is currently in press[7,8]. In both cases the traditional European phytosociological classification system has also been applied to the results so that the peatland communities of these remote areas can be placed and reviewed in their European context. 2032, 2034, 2035, 2036

In collaboration with the Highlands and Islands Development Board, investigations to determine the effects of peat type, drainage intensity, field moisture conditions and sod size on the rate of drying, yield and quality of peat fuel have continued at Dale Moss, Caithness. 2035, 2036

Palaeobotanical studies. Collaborative work with the Central Excavation Unit of the Scottish Development Department has continued at Strathallan, Perthshire[9]. Stratigraphic and palaeobotanical studies, complemented by micromorphological investigations undertaken by the Department of Soil Survey, have revealed that the light sandy soils of fluvioglacial origin could have been in almost continuous cultivation for several thousands of years. A study of the pollen content of soil from medieval site in Kincardineshire is awaiting publication[10]. 2035

Rates of upland blanket peat erosion in Shetland. Erosion is a common phenomenon in Scottish peatland, but little is known about the rate at which it occurs. In 1982, four observation transects were laid out on an eroded area of hill peat on the Mid-Kame in mainland Shetland (G.R. 408594). Along each transect cranked wire pins were inserted at intervals of 0.2 m. The transects have been measured and reset three times. Damage from sheep trampling was found to be common so, in 1983, 18 wooden stakes were emplaced to provide additional reference points. Over the period of observation (814 d), the recorded average rate of erosion has been from 0.033 m yr^{-1} to 0.04 m yr^{-1}. These preliminary results indicate that, locally, 1.5 m. of peat could be lost over a period of 38-46 years. A paper reporting this work is in preparation. 2032, 2035

Bracken Survey. With the pilot study completed, a mapping programme is now under way to establish the extent of bracken infestation in Scottish hill land[11], and to determine the rate at which bracken spread has occurred during the post war period. The pilot study indicated that aerial photography at scales greater than 1:15,000, taken in the period mid-July to late September, was the most suitable base for mapping bracken. For

Scotland, such large-scale photographic cover is limited. Accordingly, availability of suitable photography has been the first criterion in selecting sites for studying rates of bracken encroachment. At the present time six sites, in widely differing geographic locations and providing a range of topographic, climatic, soil and management conditions, have been selected: Kilmartin (Argyll), Gatehouse (Galloway), Brora (Highland), Glensaugh (Grampian), Sourhope (Borders) and Loch Tummel-side (Tayside). For each site a standard procedure is being followed. In the field, the present position of both the diffuse and main bracken fronts are being recorded by theodolite survey and the position of selected fronts marked with wooden pegs to act as future reference points. In the laboratory, photogrammetric plots are being prepared from the available post-war photo-coverage and, by comparison with the ground survey results, the rates of bracken spread will be established. The field component has been completed for the Kilmartin site. 2065

The second phase of this programme is to provide national estimates of bracken infestation and, initially, satellite imagery was considered the most convenient mapping base for this purpose. However, the pilot study indicated that even the 80 m spatial resolution of Landsat multispectral scanner imagery was too coarse for bracken to be consistently identified. However higher resolution imagery (30 m) will soon become available from the Landsat Thematic Mapper and this will also be examined. Alternative sampling techniques, using satellite imagery as part of a stratification procedure, are now being considered in collaboration with the AFRC Unit of Statistics. These techniques will utilise aerial photography to obtain assessments of local bracken infestation and, subsequently, to provide regional and national estimates by extrapolation. 2065

Snow Surveys. Detailed analyses have been carried out on two Landsat multispectral scanner (MSS) images from 20/4/76 and 3/4/81 to determine whether it is possible to distinguish wet and dry snow using MSS data. A paper reporting upon this work is in preparation. 2034

A contract has been awarded to the University of Aberdeen, in conjunction with the Macaulay Institute, to investigate the reflectance characteristics of snow at mm wavelengths (MOD Agreement No. 2116/017). This project is being carried out by a post-doctoral research assistant and commenced in January 1984. Field work was conducted in the Bavarian Alps during February-March in collaboration with RSRE Malvern and preliminary data analysis has been completed. The results indicate that the scattering coefficient of dry snow is sensitive to grain size whilst for wet snow it is more sensitive to surface roughness than to water content. These results relate to 94GHz data[12]. 2034

Aerial Surveys. In collaboration with the Department of Soil Survey, 1:10,000 vertical infrared coverage has been obtained of a proposed drainage scheme near Fochabers and additional photography relevent to the SPOT-simulation campaign has also been acquired. Between October 1983 and April 1984 vertical photography of the Hermitage Valley in southwest Scotland was obtained as part of a joint exercise between the Macaulay Institute, the University of St. Andrews (Department of Geography) and

the University of Dundee (Department of Biological Sciences). The object was to document a number of erosional features, including several peat slides, which occurred as a result of a period of intense rainfall on 25/7/83. The peat slides are considered to be rare forms of peatland erosion in Scotland and have not been documented previously. 2032, 2034

Crop Investigations

Winter Oilseed Rape Survey. Following on from the AGRISPINE Experiment[13] (Annual Report, 1983), a survey of winter oilseed rape has been carried out in eastern Scotland[14]. Using Landsat multi-spectral scanner (MSS) data from 30/5/82, when the rape crop was in flower, 70 fields were identified with an estimated total area of 497 ha. Within Grampian Region, a total of 122 ha were identified as rape which compared favourably with the North of Scotland College of Agriculture's estimate of 100-110 ha. However, comparison between image-based estimates and actual field areas showed that accuracy of these estimates is highly sensitive to field size and shape. It is, therefore, recommended that, where Landsat MSS data are used as a basis for crop surveys in agricultural areas with mean field sizes<40 ha, crop area estimates should not depend solely upon the satellite data. A technique whereby fields are identified using the satellite data and areas are subsequently computed by reference to existing large scale maps, or a geographic database, is proposed. This study has provided baseline information on the adoption of winter oilseed rape in eastern Scotland and has demonstrated the utility of Landsat MSS data for crop inventory investigations. 2032

Potato Crop Survey. This is a joint project with the Scottish Crop Research Institute, Invergowrie. The object is to map the potato crop distribution in eastern Scotland for 1982 using a multitemporal classification of two geometrically corrected Landsat MSS images (May and October). This distribution will then be compared with the distribution of drought-prone soils defined on the basis of topographic, climatic and soil characteristics. Statistics on the percentage of the potato crop being grown on drought-prone soils will be produced on a district-by-district basis. 2032

Geometrical rectification of the Landsat images is now complete, and preliminary image analysis has been conducted on both scenes. On the May image, both potato and turnip fields show up as bare soil. On the October image, the turnip fields are still vegetated, but the potato fields are once again fallow. By classifying bare soil on the May image, and vegetated areas on the October image, it has proved possible to separate potato from turnip fields. The production of a potato crop distribution map is under way. 2032

With the assistance of staff at RAE, Farnborough, software for digitising and converting map data to image (raster) form has been implemented. The following maps relevant to the above study have been digitised: agroclimatic areas; regional and district boundaries (derived from O.S. 1:250,000 Admin. map); urban boundaries (derived from O.S. 1:250,000 Routemaster series). A 1:250,000 soil association map has yet to be obtained in digital form. It is intended to complete this project by March 1985. 2032

AGRISPINE Experiment

Both the winter oilseed rape and potato surveys are based upon Landsat MSS data obtained during the AGRISPINE experiment[13]. Additional research has also been carried out in conjunction with the National Remote Sensing Centre at the RAE on the application of Landsat MSS data for

Crop Key

1 Winter Oilseed Rape
2 Winter Wheat
3 Raspberries
4 Permanent Grass
5 Spring Barley
6 Rotation Grass
7 Winter Barley

Fig. 2.1
Infrared waveband of an element of the SPOT-simulation test area west of Dundee obtained on 12.4.84. Most of the major crops are identifiable. Information for one farm is presented for comparative purposes.

monitoring iceberg production using the AGRISPINE, West Greenland, image data set[15,16]. This research has demonstrated that it is possible to derive information on iceberg production from Landsat MSS data. However, with respect to the significance of this work to the offshore oil industry, a more complete study, covering a larger number of glacier sources, would have to be done before predictions of iceberg populations off eastern Canada could be made. 2032

National Remote Sensing Centre: SPOT-simulation programme

The French satellite SPOT-1 (System Probatoire pour l'Observation Terrestre), due to be launched in October 1985, will be the first to provide panchromatic and multispectral imagery with spatial resolutions of 10 m and 20 m, respectively. This represents an order of magnitude improvement in the resolution of the satellite imagery presently available to us. With SPOT imagery, a single picture element will represent 0.01 ha whereas with Landsat MSS each element represents 0.44 ha (Fig. 2.1). 2032

To ensure that the potential uses of SPOT imagery are well understood, the National Remote Sensing Centre at RAE, Farnborough initiated an airborne SPOT-simulation programme during 1984, in which the Macaulay Institute participated. Two test areas were originally chosen but poor weather conditions at the time of overflight (11/5/84) meant that only one was covered. This comprised a 10 km wide swath extending from the Carse of Gowrie, near Dundee, to Lintrathen Loch, north of Alyth (north corner No. 250550, No. 350550; south corner No. 250230, No. 350230). This area covers a wide range of land use categories (from intensive arable to extensive hill grazing) and soil types. Field sizes also vary from <1 ha to >39 ha. At the time of overflight, detailed ground information was collected for 7 farms. This included data on crop cover, growth stage and soil characteristics. Observations were made on 160 fields and 14 different crops. In addition, 50 samples were taken from an area where soil conditions varied markedly; these have now been analysed for organic matter, moisture, clay, silt and sand content. Radiometric measurements (visible/near infrared) were also made of the soils *in situ* and in the laboratory. It is intended to examine the potential of SPOT data for crop mapping and crop monitoring purposes, and to evaluate what soil information might be derived from it. The simulation data arrived in October 1984 and the analysis is now under way. 2032

Crop Reflectance Studies

In collaboration with the Departments of Spectrochemistry and Soil Fertility, work on the development and application of field radiometry in crop monitoring has continued. A portable two-band radiometer has been constructed utilising a novel optical arrangement[17]. This is now being used routinely. In addition, a scanning ratio-ing radiometer is being constructed to replace the present scanning instrument which has proved unreliable in field use[18].

For the second year, a programme of vertical ground photography has been carried out in conjunction with nitrogen application trials on potatoes.

Photographs, taken weekly, are used to compute percentage ground cover as the crop develops. This year, at the same time as the photographs were taken, radiometric measurements were also made of the developing crop. The objective is to examine what relationship exists between the radiometric characteristics of the crop canopy and percentage crop cover or standing biomass. Preliminary results suggest that the ratio of infrared/red reflectance is highly correlated with percentage crop cover. 2032

Further work on high resolution (2nm) single-leaf reflectance spectra has indicated that the relationship between leaf chlorophyll content and the position of maximum slope on the "red edge" is not consistent for potato leaflets. A crop reflectance study on winter barley is now under way in collaboration with the North of Scotland College of Agriculture. 2032

Automated Photogrammetry and Image Processing

The GEMS image processing system, PRIME 250 mini-computer and Ferranti-Cetec System 4 digitising system have been rehoused in a purpose-built laboratory. The PRIME now provides a central computing facility and the existing automated photogrammetric and image processing system (MAPIP)[19,20], is being reconfigured. It is intended to link the PRIME 250 to the three peripheral systems, for map digitising, photogrammetric plotting and image processing. The necessary hard-linkages are being installed and an associated programme for software development is under way (Fig. 2.2).

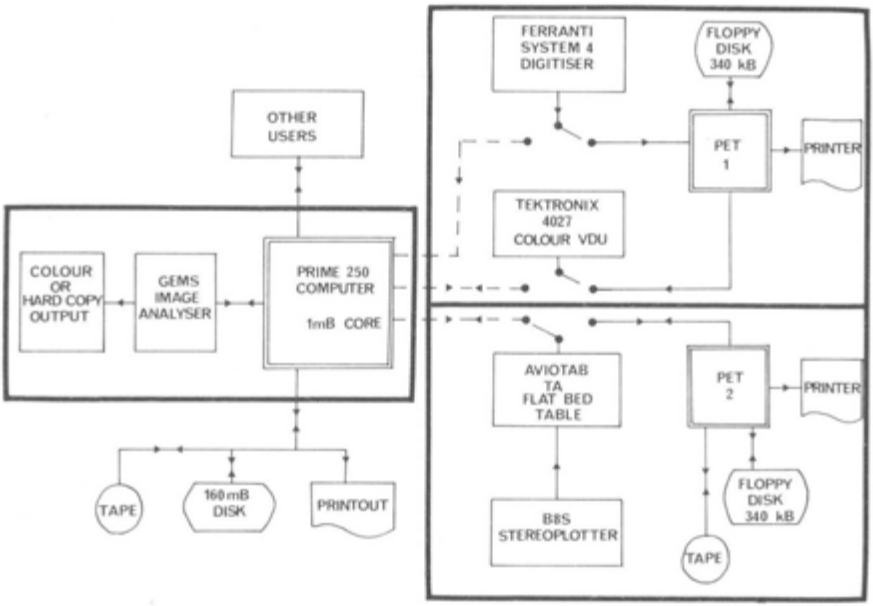

Fig. 2.2
Components and linkages of the reconfigured computing system. In this configuration, data obtained from satellite imagery, aerial photographs and existing maps can be superimposed, thus producing the basic tools necessary to establish a geographic information system.

A further large scale map of field experimental plots at the Plant Breeding Institute, Cambridge, has been prepared. Photogrammetric plots have been produced for Loch Fleet/Fleet forest and the Douglas Water and Causeymire peat workings. A total of nine ground survey computation programs have been written in Basic for use with the Wild Aviotab TA plotter. Programs for orientation of photogrammetric models, and also for aerial triangulation, are being developed to run on the PRIME 250, in Fortran IV. 2033

Nutrient Cycling in Forests

Attention continues to centre on the cycling of nutrients, in particular nitrogen, within forest ecosystems, the inter-relation with plant growth and the response to either management operations or pollution inputs. Recently, emphasis has been given to the influence of different species and ages of tree on the nutrient supplying ability of the soil. As described in the previous report, a major investigation has started in order to elucidate the mechanisms by which Sitka spruce *(Picea sitchensis* (Bong.) Carr.), when planted in mixture with pine or larch, avoids the nitrogen deficiency shown by this species when grown pure on poor peats and upland heaths (Fig. 2.3). This work, which is being carried out in conjunction with the Forestry Commission and the Irish Forest and Wildlife Service and is partly financed by the Commission of the Eurpopean Communities, includes investigations by the Department of Microbiology into changes in microbial activity associated with the presence of nurse species within mixed stands. Work is centred on experiments at Inchnacardoch (near Fort Augustus) and Culloden (near Inverness) forests and equipment has now been installed to monitor rates of litterfall and changes in the chemistry of rainwater as it passes through the tree canopy. Results from root excavations conducted at Culloden have allowed the optimum allocation of soil water samplers, which now include ion exchange resin bags developed during recent laboratory and field studies. Whole tree sampling was completed during the summer of 1984 and the results are currently being processed by the Department of Statistics. Laboratory and field incubations of both soil and litter have been carried out to determine rates of nitrogen and phosphorus mineralisation across the different treatments. The first year of this study has been used to characterise each of the forest stands under investigation and to monitor seasonal changes which may occur in litterfall, water chemistry, microbial activity and rates of nitrogen mineralisation. Future work will concentrate upon the analysis of soil water to identify the forms and quantities of nutrients available to spruce roots in different treatments. Inoculations will also be conducted to determine the effect of mycorrhizal and saprophytic fungi upon the ability of spruce roots to take up nitrogen. Glasshouse experiments have been set up to examine interactions between tree species, soil, litter and ground vegetation. It is also proposed to crop ryegrass (*Lolium perenne* L.) on soils taken from mixed and pure stands and thus ascertain differences in nitrogen availability. 2054, 2055, 2056, 2087

A somewhat related study has been a short-term investigation of nutrient cycling in birch, initiated in 1983. This was also designed to examine the

ability of trees to modify the nature and nutrient supplying characteristics of soil. In a paper-study of nutrient cycling in birchwoods[21], mathematical models revealed that, as with pine, nutrient demands on the soil fall dramatically following canopy closure and no indication was found as to why birch should have the reputation as a "soil improver". Soil changes have been documented by Dr J. Miles, of the Institute of Terrestrial Ecology, during birch invasion of heather heathland. The current work was set up, in conjunction with Dr Miles, with the object of obtaining, over one year, sufficient information to model nutrient cycling in birch of different ages at a site where birch invasion has led to soil changes (Craggans, Speyside) and at a site where it has not (Silpho, North Yorkshire). Whole tree sampling was carried out in mid-summer and litterfall has been collected monthly beneath replicated plots. Regressions developed for weights of different tree

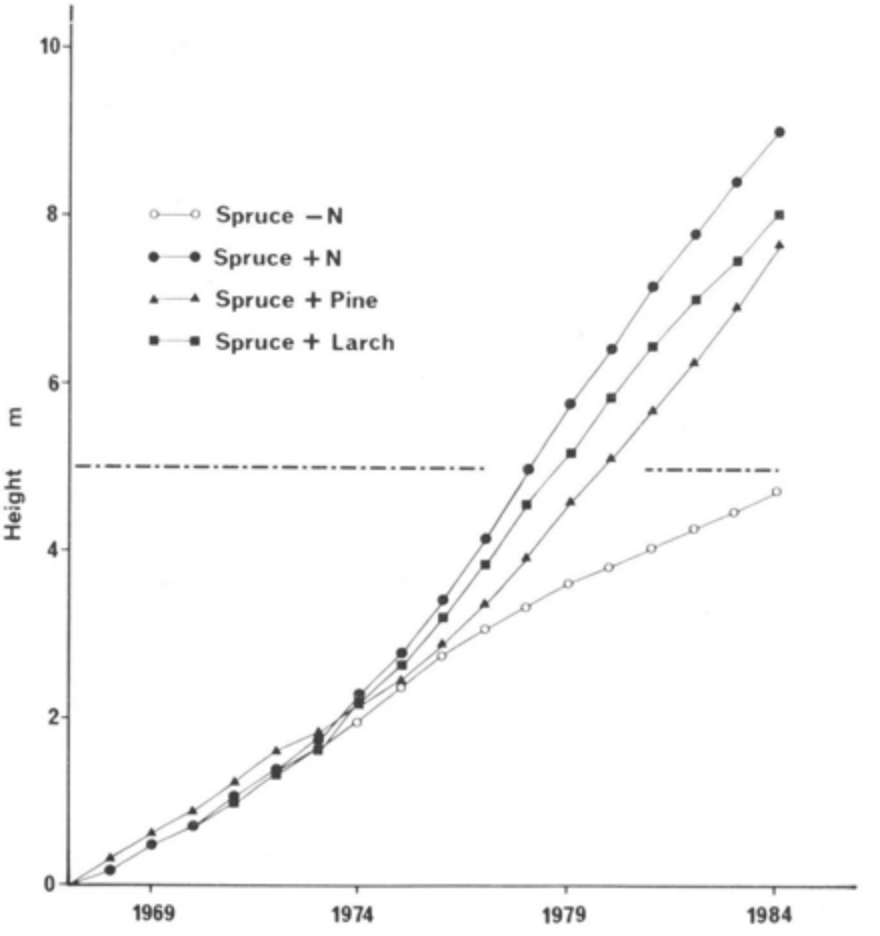

Fig. 2.3
Comparison of the effects of nurse species and nitrogen fertiliser on the mean height of Sitka spruce at Inchnacardoch Forest.

components on stem sectional area were surprisingly similar for both sites. Chemical analyses of litter samples taken during 1983 have now been completed together with those for leaves and twigs taken during whole tree sampling. The analysis of branch and bole material have taken longer and during this time foliage samples from both sites have been collected and analysed. In addition samples from Silpho have been analysed by the Department of Soil Organic Chemistry, so enlarging the data-base upon which a nutrient cycling model will be developed. 2054

Analysis of the samples collected from the ten-year study on nutrient cycling in Sitka spruce is nearing completion. This investigation centred on six experiments designed to elucidate the relationship between element cycling and tree growth. Samples from vegetation and soil organic layers were taken from replicated NPK-fertilised and unfertilised plots at the initiation of each experiment and again after five years. Measurements of incident rainfall and, from all plots, throughfall, stemflow and litterfall have been made during the intervening years and samples of each removed, at fortnightly intervals, for laboratory analyses. Foliage samples have also been taken for analysis each autumn; this sampling will cease in 1985. Thereafter, processing of the large amount of data collected will continue, in close collaboration with the Department of Statistics. 2054

Recently, the Institute of Hydrology, under the auspices of a consortium including the Forestry Commission and the Scottish Development Department, has installed gauging stations in the streams draining a forested catchment (Kirkton) and an unforested catchment (Monachyle) near

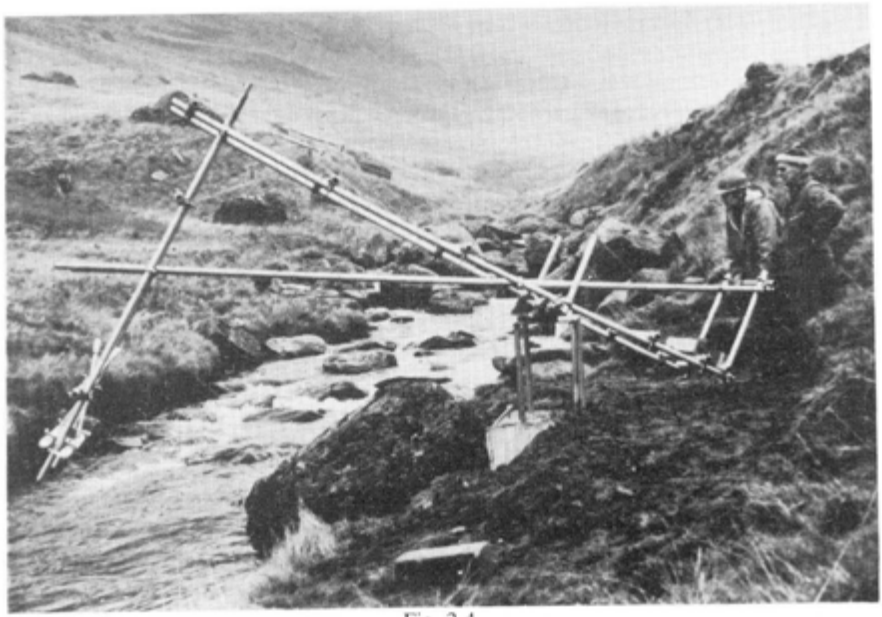

Fig. 2.4
Proportional streamwater sampling device installed in Strathyre Forest.

Balquhidder, Strathyre Forest. This presented an opportunity to initiate a new investigation to determine the input, retention and loss of nutrients and other elements in adjacent forested and unforested areas and to assess changes consequent to felling or afforestation. Assessment plots have been laid out and whole tree sampling will be carried out in early 1985 to determine the relationships between tree size, biomass and accumulated nutrients. Samples of bulk precipitation (including aerosol enriched), throughfall and stemflow have been collected and analysed at monthly intervals. In addition, the proportional sampling devices installed last year have provided weekly composite stream samples from both the forested Kirkton and unforested Monachyle catchments (Fig. 2.4). These records will provide a datum from which changes in streamwater chemistry can be assessed during the progressive clearfelling of Kirkton and the afforestation of Monachyle due to commence in 1985. The wide range of organisations involved in studies at Balquhidder, including the Institute of Hydrology, the Water Research Centre, the Freshwater Fisheries Laboratory and several river purification boards in addition to the Forestry Commission and the Macaulay Institute, has provided the opportunity to set up a Water Quality Working Group who have now devised an Analytical Quality Control Scheme for harmonised water monitoring. 2054

The simulation model of the nitrogen control of growth of pine (FENDS) which was financed by a NERC/CASE Studentship and mentioned in last year's report, is now complete. Data from Forestry Commission fertiliser trials and management tables were used to validate the model prior to its use for testing different concepts relating nutrient cycling and tree growth[22]. Areas which proved to be of particular interest included competition between trees and ground vegetation, the demands made upon soil nutrient reserves by tree stands at different stages of development and the long-term consequences of intensive biomass harvesting from forest plantations. 2054, 2056

Forest Nursery Nutrition

As in previous years the Department continues to provide a nutrition advisory service to forest nurseries based on soil analysis carried out by the Department of Soil Fertility. During the year discussion with nursery managers has centred around possible changes in the format and nature of presentation of this advice. 2054, 2056

Studies on Acid Rain

Interest has continued in work pertinent to the acid rain debate that has attracted increased attention from both the government and the general public. As already mentioned, many of these studies designed to examine nutrient cycling in forest and upland ecosystems have included standardised instrumentation to measure bulk precipitation, aerosol input, throughfall and stemflow. Information collected during these experiments form the basis of several recent papers reviewing the changes in water chemistry which occur during movement through forest canopies[23,24,25]. A major development in this field of research has been sponsorship, by the

Department of the Environment, of a new series of investigations. The overall objective of the new work is to elucidate how acidity, both pollution-derived and natural, passes through upland ecosystems and into streams without being neutralised within the soil[26], and to establish the role, if any, of trees in this process. Such an understanding will help to resolve the relative importance of introduced, as against natural, acidity in the reported acidification of streams and to suggest possible means of managing the riparian zone to eliminate or minimise the effect. The necessary staff have now been appointed and two suitable sites have been chosen, one at Fetteresso, Aberdeenshire and the other at Loch Fleet, Galloway. The large amount of instrumentation required was designed and constructed during the summer of 1984 and has been partly financed by the Central Electricity Research Laboratory which forms part of a large consortium conducting a catchment study at Loch Fleet. Equipment is currently being placed in the field to monitor changes in rainwater chemistry on passage through both vegetation and soil horizons to enable comparisons to be made between forested and unforested sites. It is proposed that there be close collaboration with the University of Aberdeen where related biochemical and physiological studies have recently begun under the supervision of Professor Miller in the Department of Forestry. 2066

Although the nutrient content of rainwater, as collected by standard rain gauges, has been known for some time, it has only recently been realised, as a result of studies in America and the United Kingdom, that a large additional amount of many chemical elements may be filtered from the atmosphere by impingement and trapping on vegetation surfaces. In spring 1983, an AFRC-sponsored research student began an investigation of the input from the atmosphere of nutrients and pollutants to vegetation on marginal soils and the significance of such inputs for plant growth and soil development in upland areas. One full year's samples have now been collected and analysed and the results are currently being processed with the aid of the Institute's mainframe computer. 2054, 2056

Analytical Procedures

The heavy commitment to field experiments has resulted in approximately 7500 samples being collected over the last year for laboratory analyses, each requiring between 3 and 16 different chemical determinations. The purchase of a multi-channel data handling system to measure and process peak heights generated by continuous flow analysis systems and to transfer this data directly to the mainframe computer has greatly improved the analysis systems. The Department of Statistics has also provided a package of data handling programmes which enable more effective processing of field data and laboratory results. These include, for example, a complete system from initial entry of field data to a final assembled analysis report for water samples produced from a series of field experiments including those concerned with both nutrient cycling and acid rain at Glen Tanar, Culloden, Inchnacardoch and Balquhidder. Particularly important is the facility to check cation-anion balance and cross compare with conductivity

measurements so drawing attention, at a very early stage, to any possible analytical faults. 2054, 2055, 2056, 2066, 2807

Nutrient availability in highly organic soils

Peats, mor humus and many upland soils contain appreciable amounts of nitrogen and phosphorus in organic forms, but the availability of these elements to herbage and tree crops is generally low. This is attributed to slow rates of organic matter transformations by micro-organisms, whose activity is controlled by climate and temperature as well as by soil physical and chemical conditions. In upland areas, climate and temperature are important factors but cultivation treatments such as drainage and liming may also indirectly affect the availability of these nutrients to plants. 2055

The effects of reseeding treatments on the physical structure and chemical composition of peat from Lewis have been examined in a comparative study of adjacent treated and semi-natural areas. Samples taken from five sites, including areas that have been reseeded for up to 20 years, have now been analysed and the results submitted for publication[27]. 2055, 8057, 8059

Peatland can be classified by topographical and vegetation characteristics, which also relate to the amounts of nitrogen and other plant nutrients in the peat. In a laboratory study of the rates of mineral nitrogen production in samples of peat from a range of different peatland types, ammonium release correlated with total nitrogen content and pH[28]. 2055

The soil microbial biomass is regarded as a relatively labile pool of nutrients and is probably an important source of available phosphorus and nitrogen for plant uptake. In a joint study with the Department of Microbiology, the applicability of methods of estimating biomass C, N and P, based on fumigation with $CHCl_3$ and developed for near neutral mineral soils, has been tested and modified for organic soils[29]. 2055, 6027

Chemical and microbiological changes occuring in peat as a result of drainage have been studied jointly with the Department of Microbiology at the controlled water table experiment on the Lon Mor, Inchacardoch forest (Highland Region). The results are now being prepared for publication. 2055, 6027, 8057, 8059

A collaborative study has been initiated with the Department of Grassland Husbandry of the North of Scotland College of Agriculture to examine the fate of fertilizer nitrogen applied to reseeded grassland on deep peat. Preliminary tests for mineral nitrogen in peat from a reclaimed area in Caithness failed to detect residual fertilizer-N, and growth response in the sward was poor. The applied N may have been lost in run-off or immobilized, in the short term, by the microbial biomass, though during particularly dry periods from late April onwards this year, losses in run-off would not account for large losses of N. More detailed studies to investigate this problem are planned. Laboratory investigations on the fate of different forms of nitrogen added to peat are being studied in collaboration with the Department of Soil Organic Chemistry. Investigations with ^{14}C labelled glycine have been completed and possible abiotic interactions have been investigated by the addition of ^{15}N labelled glycine to sterilized peat[30]. 2055, 4020, 6027

The nitrogen reserves in peats and mor humus are seemingly exploited to a greater extent by mixtures of tree species, such as Scots pine (SP) and Sitka spruce (SS), than by SS planted singly. As part of the EEC funded project on nitrogen cycling in mixed stands, studies on N mineralization have been carried out in collaboration with the Department of Microbiology. Work has been concentrated at Culloden forest where samples of the L + F + H horizons and the underlying soil have been taken to a depth of 10 cm at monthly intervals for both chemical and biological analyses. Higher levels of mineral N in fresh and incubated samples from the mixture plots indicate more active N cycling in SS + SP, but this may only be a reflection of the more vigorous growth of the mixed crop. The possibility that there is a transfer of N from the nurse species (SP) to the SS during litter decomposition has been investigated by continuously leaching SS, SP and SS + SP litters in a 1:1 mixture (by dry weight). After 11 weeks, leached labile N (soluble organic−N + NH_4 −N + NO_3−N) accounted for 36% of the total nitrogen in SS, 11% in SP and 29% in SS + SP. Moreover, a large proportion of the mineral−N leached from SS litter occurred as NO_3−N, whereas in the SP samples amounts were very low.

2055, 2807, 8057, 8059

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3. SPECTROCHEMISTRY

A. M. URE

The work of the Department of Spectrochemistry encompasses five main themes. 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.

Various national and international conferences have been attended by members of the Departmental staff and papers presented to them are detailed elsewhere in this report. The Department has been represented on several 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), Royal Society of Chemistry Council (A. M. Ure) and Royal Society of Chemistry, Analytical Editorial Board (A. M. Ure, B. L. Sharp), Annual Reports on Analytical Atomic Spectroscopy (B. L. Sharp, Chairman; J. C. Burridge), Scottish Regional Committee of the Royal Society of Chemistry (M. J. Adams), MISR/COSAC Working Party on Advisory Soil Analysis and Interpretation (M. L. Berrow) and the Association of Scottish Industrial Analysts (J. C. Burridge). A. M. Ure was a member of the local committee responsible for organising the 5th TEMA (Trace Element Metabolism in Man and Animals) conference held this year in the University of Aberdeen, while M. L. Berrow was on the Technical Programme Committee of the International Conference on Environmental Contamination held in London.

Trace elements in soils, plants and biological materials

Soils and Soil parent materials

In collaboration with the British Geological Survey and the Scottish Soil Survey a project designed to study the relationship between total trace element contents of soils and those of their underlying parent rocks has been

started. Rocks and related soils sampled this year have been prepared for analysis.

Further analyses of soil profiles from the area of Sheet 84 have been carried out to supplement those already made on profiles from the Black Isle (part of Sheets 83, 84, 93 and 94). The data have been used to prepare a report on trace elements in the soils of the Black Isle. Selected profiles from the area covered by Sheet 30 around Glasgow and a further seven profiles from the Rahoy Deer Farm, Morven (Sheet 52) have been analysed for extractable trace elements.

Fifteen podzol profiles with well developed iron pans have been analysed for *aqua regia*-extractable trace elements. This has provided information on the distribution of Zn, Cd and Pb which was not obtainable by direct current arc analysis. None of these elements shows any evidence of accumulation with iron in iron pans, but they are generally retained and accumulated in upper organic horizons to varying degrees.

The role of soil analysis in diagnosing and predicting anomalies in the supply of nutrients to animals and a poster illustrating relationships between trace element availability and the soils and geology of the Aberdeen area were presented at the Fifth International Symposium on Trace Element Metabolism in Man and Animals[1,2].

A paper reporting background concentrations of eleven trace elements in uncontaminated Scottish soils has been published in the Proceedings of an International Conference on Environmental Contamination in London[3]. The positively skewed frequency distributions of many trace elements in Scottish soils results in the arithmetic mean content being biased high relative to a typical or modal value. A logarithmic transformation of the data was, therefore, performed to provide a more satisfactory means of describing the distributions. A normal range, covering about two orders of magnitude in each case, and a derived mean for eight elements in Scottish soils was reported and discussed in relation to the proposed EEC draft directive on the use of sewage sludge in agriculture.

Papers on total and extractable lead contents of Scottish soils detailed in Annual Report 53, 1983 have been published[4,5]. Papers on total and extractable copper in soils are due to appear in the Journal of Soil Science in early 1985[6,7]. In the latter paper the distribution of EDTA-extractable copper concentrations in 3653 samples from 725 Scottish soil profiles is reported. The derived mean for the full set of data was 0.86 mg kg^{-1} and the normal range 0.08 to 9.8 mg kg^{-1}. Extractable copper contents decreased with increasing depth over the first 50 cm and generally remained constant below this depth. The correlation between total and extractable copper ($r = +0.453$) was statistically highly significant ($P = 0.001$). The extractability (i.e. the percentage of the total copper extractable by EDTA) was also considered in relation to other soil variables. Extractability was inversely related to ash content though the relationship was not linear. Extractability was enhanced under conditions of impeded drainage but there was no indication that it was related to clay or sand contents.

In comparision, a survey of the world literature showed that EDTA-extractable copper contents in some 14,000 soil samples ranged from

0.53 mg kg^{-1} in a group of copper-deficient sandy soils in South Australia to 14.1 mg kg^{-1} in a group of peaty soils from Northern Ireland. The overall arithmetic mean content was 4.6 mg/kg^{-1}.

A detailed study of the behaviour of copper in four profiles of the Strichen Association with increasing degrees of drainage impedance is in progress. The solubility of copper in mineral subsoil horizons increased strikingly as drainage became progressively more impeded from the freely to the very poorly drained profile. Total copper contents tended to increase with increase in depth, but were around 25 mg kg^{-1} in the mineral subsoil horizons of all four profiles. The percentage of total copper extractable by EDTA in subsoil horizons increased from about 2 per cent. in the freely and imperfectly drained soils to about 10 per cent. in the poorly drained and nearly 30 per cent. in the very poorly drained profile. Selected horizons from each profile have been separated into sand, silt and clay fractions in order to examine their mineralogy and the distribution of copper in more detail. Total copper contents increased with decrease in particle size and more than 50 per cent. of the total copper was held by the silt + clay fraction in the B horizons of the poor and very poorly drained profiles.

To assess the relative incidence of atmospheric inputs to soils from the marine aerosol and industrial emissions, peaty topsoils from the Scottish Soil Inventory have been selected along two SW-NE transects across Scotland in the direction of the prevailing wind. These are still in process of being analysed for total trace and heavy metal contents but preliminary results indicate that for the southerly transect from Islay to Fraserburgh the mean Zn and Pb contents, of 44 and 71 mg/kg respectively, are greater than those from the more northerly (and more remote from industrial activity) transect from Mull to Helmsdale of 24 and 24 mg/kg respectively. 1001, 3007

To speed up the *aqua regia* digestion of soils and sewage sludges the use of a 12-hole block digestion apparatus with air-cooled condensers has been tested and compared with digestion in conventional flasks with water cooled condensers. With light samples containing much organic matter, frothing can cause problems because of the narrower bore of the block digester tubes. Ashing the sample prior to digestion overcomes this problem and the results so obtained for Cu, Mn and Zn were only slightly lower than those obtained using the conventional flasks without a prior ashing. The results for Cr, Ni and Pb were the same using both methods. Similar results were obtained with sewage sludges. 3007, 3011

Trace element availability and soil/plant relationship

It is becoming clear that dilute acetic acid extractable soil contents are not a good measure of the availability of cobalt to plants on certain soils to which cobalt has been applied, particularly when the assessment is made several years after cobalt application. In an attempt to find a better extractant cobalt-treated and untreated soils from a field experiment on a freely drained soil of the Laurencekirk association have been examined in detail. The soil is developed on till derived from Lower Old Red Sandstone sediments, mainly marls and fine grained sandstones. After application of cobalt in 1977 herbage cobalt contents declined steadily from 1978 to 1981

yet the acetic acid extractable levels in the treated soils remained constant over the four year period (means 0.50 to 0.53μg/g). Acetic acid-extractable cobalt levels in the treated soils were increased by about 0.1μg/g. Ammonium acetate extractable cobalt levels also showed no decline over the four year period. Ammonium acetate + hydroquinone extracts were tested to see whether these showed a better relationship with herbage content, but a comparison of soils sampled in 1978 and 1980 again showed little difference. Extraction with 0.05 M $CaCl_2$ has also been tested on the same soils to see whether this extractant is more discriminating. Values in the cobalt-treated soils sampled in 1980 were, however, greater than those for soils sampled in 1978 and did not reflect therefore the decrease in herbage contents over this period. Further studies are in progress. 3007, 3008, 7042

Soil profile studies of the Corby and Ordley Associations, for Cu, Mn and Zn, and on a soil of the Foudland Association for Co, have shown that copper, applied at a rate of 5.7 kg/ha in 1956/57 and cobalt at a rate of 0.5 kg/ha applied in 1972 are still largely retained in the upper (25 cm) soil horizons [as assessed by EDTA (Cu) and acetic acid (Co) extraction]. Acetic acid extractable concentrations in the 0-20 cm horizon, for example, of treated soils were still enhanced by about 0.15 mg/kg compared to the untreated soils even 10 years after the application. Ammonium acetate extracts of Co however, in contrast, showed no enhancement at the end of the 10 year period. There was no evidence of movement of extractable Co or Cu down the profile.

Accounts of studies previously reported (Annual Report 53), of the effect of fertilizer treatments on copper and molybdenum[8] uptake by herbage have now been published as has the chapter on trace element uptake, distribution and effects on plants[9]. 3007, 3008, 7042

Pot experiments carried out in collaboration with the Department of Soil Organic Chemistry on the effects of adding peat of low copper content to two soils heavily contaminated with copper from distillery wastes have continued. Soil containing 390 and 300 mg/kg total copper were mixed with various rates of peat before potting up and growing crops in 1979 and later. The soils still contained an average of 220 and 205 mg/kg EDTA-extractable copper respectively in 1984. The incorporation of peat however, considerably reduced the copper contents of lucerne grown on both soils after adjusting the pH of all treatments to 5.5. Similar findings were made with a copper contaminated soil mixed with peat and maintained in a moist condition in the laboratory for several years. The original soil contained 290 mg/kg total copper in this case and after four years the EDTA-extractable copper still remained as high as 250 mg/kg. EDTA-extractable copper concentrations in contaminated soils appear, therefore, to change little with the passage of time and the addition of peat appears to have a small effect in reducing these. In the laboratory experiment acetic acid extractable copper contents were, however, in contrast to the EDTA-extractable contents, reduced by incorporation of peat. 3007, 3008, 4022

The long-term sewage sludge experiments carried out at ADAS experimental stations continue to be monitored. The published findings[10,11] that the high levels of metal contaminant persist in soils over long periods

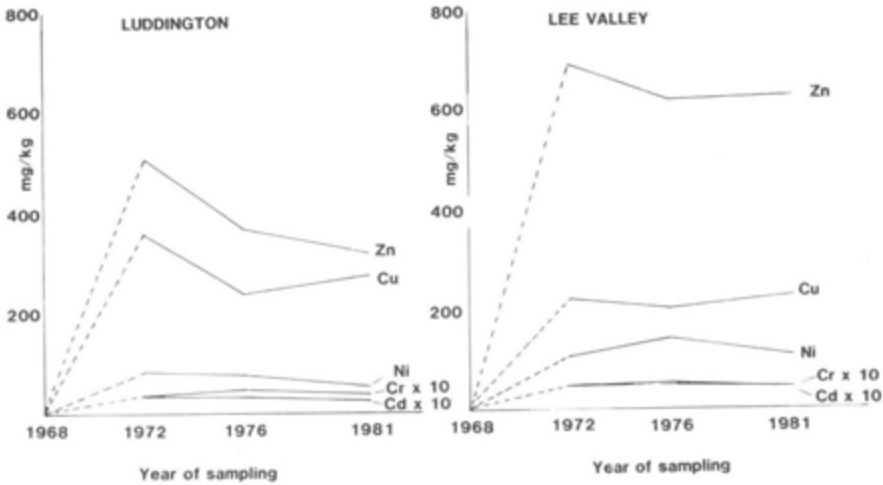

Fig. 3.1
Persistent effects of adding 125 t/ha of four contaminated sewage sludges in 1968 on the EDTA extractable metal levels in soils at Luddington and Lee Valley — as mg/kg in dry soil.

have been confirmed by the analysis of 1981 samplings, some thirteen years since the first application of sewage sludge. Some of this data is illustrated in Fig. 3.1 which shows that the increased extractable soil contents of Cu, Zn, Ni, Cr and Cd produced by treatment of soil with metal-contaminated sludge in 1968 persist up to 1981. These experiments will be re-sampled again next year.

Studies on the use of sewage sludge as a fertilizer for forest trees at two sites in Scotland have continued. Surface soils, soil profile samples and the sludge used in the experiment at Ardross Forest, near Tain have been analysed. At this site the soil is of the Sabhail Association derived from sandstones of Middle Old Red sandstone age and have very low concentrations of Cu, Mn, Zn, Cr and Ni. Analysis of fungal fruiting bodies from the other forestry experiment at Montreathmont near Brechin have shown that the treatment of soils with a copper-rich sewage sludge enhanced fungal contents of copper (*Hygrophoropsis aurantiaca* and *Tricholomopsis rutilans*) and tin (*Trichomolopsis rutilans*).

A paper reporting the effects of air-drying 8-irradation and chloroform fumigation of soil on extractability of trace elements (Annual Report No. 53) has been published[12]. 3007, 6027

The Department has collaborated in the collection, preparation and analysis of soils and crops for a study by the FAO European Co-operative Network on Trace Elements. Winter wheat or ryegrass and soils were sampled at twelve sites in Scotland on a range of soil types and the results together with those from some twenty-four institutions in fifteen European countries, are now being evaluated with a view to elucidating soil/plant trace element relationships on this generalized data base.

Miscellaneous samples analysed for trace elements have included soils and peats from the Forestry Commission, soils and plants from the East of

Scotland College of Agriculture, ochre from drains supplied by the Depts. of Microbiology and Soil Organic Chemistry, cabbages from the National Vegetable Research Station, Wellesbourne, soils from the West of Scotland College of Agriculture and metal samples from Loughborough University.

The Department has continued to take part in a joint comparison of the analytical methods used at the three Scottish Colleges for the analysis of major and trace elements in soils and crops with a view to harmonising procedures. Good agreement was obtained in the results for extractable B, Co, Cu and Zn in a range of 22 different soils determined at the three laboratories. Further studies are in progress on the determination of extractable trace elements on a soil weight and a soil volume basis, particularly for organic soils. The mean density of <2 mm air-dry samples of 34 Scottish topsoils was 1.0 g/ml.

Spectrochemical Methods of Analysis

Arc emission

Arc methods have continued unchanged, but a newly designed machine for cutting carbon rods into short lengths for arc analysis has been constructed by Technical Services, replacing the machine built about 25 years ago. The new machine cuts rods faster and requires no elaborate mechanical adjustments when changing the diameter of the rods being cut.

Alternatives to thionalide as a reagent for precipitating lead have continued to be investigated (Annual Report 53, 1983). Several compounds containing the thioglycollic acid grouping have been synthesized in the Soil Organic Chemistry Department (Dr H. Anderson) and tested, but none was as effective as sodium sulphide for precipitating lead. Thionalide itself was found to precipitate only 50-70% of lead, whereas with the sodium sulphide method proposed, a full recovery was obtained. In the analysis of such concentrates, effects on emission intensity make it necessary that calibration standards for the cathode-layer d.c. carbon arc be prepared by precipitation under the same conditions as the samples to be analyzed. These findings have been submitted for publication[13].

A report on the depressive effect, on molybdenum emission in the d.c. arc, produced by the high zirconium levels consequent on the use of zirconium crucibles, discussed in last years report (Annual Report No. 53) has been published[14].

3010

A new rapid-scanning microdensitometer is currently being constructed to evaluate the photographic plates from the spark-source mass — and d.c.-arc emission spectrometers. This instrument will be directly linked to a microcomputer system for automatic recording of data and the calculation of elemental concentrations. This will speed up analyses by spark source mass spectrometry and make it possible to prepare, for example, 62-element soil fingerprints directly, and facilitate the manipulation of analytical data, the application of pattern recognition techniques and the presentation of information in graphical form. It will also make it possible to use all the information available from d.c.-arc spectrographic plates and provide multi-element analysis more flexibly than by polychromator. An

improvement in the precision of the current semiquantitative spectrographic technique for total soil contents will be a further important consequence.

3010

Atomic Absorption Spectrometry

A new atomic absorption spectrometer with a graphite furnace atomizer (Pye Unicam SP9 Video Furnance) has been installed. This is in process of being interfaced with an HPLC fractionation system for the speciation of trace elements such as Al, Co, Cu, Mn and Zn in waters, soil extracts and the soil solution itself. Currently it is also being applied to the development of a method for selenium in plant and biological samples which are prepared for analysis by combustion in oxygen using the VAE Trace-O-Mat combustion apparatus (Paar Scientific) followed by refluxing in nitric acid. Results so far indicate that using copper as matrix modifier, detection limits of a few ppb are possible and that, because the ash is discarded after the initial combustion, matrix interferences are unlikely to be a problem. The use of hydride generation for As and Se, using an auto-analyser approach and sample preparation by the above combustion method is also being investigated with the prospect of extending the analytical sensitivity far enough for direct analysis of selenium in the soil solution itself.

Graphite furnace atomic absorption spectrometric analysis of the soil solution, obtained by soil centrifugation, for Co, Cu, Mn and Zn has been carried out in a collaborative study with the Departments of Soil Organic Chemistry and Soil Fertility. This investigation has shown that mobilization of trace elements occurs during the growing season in the rhizosphere of growing crops. A preliminary report has been accepted for publication[15]. The success of this analytical procedure for element concentrations at ppb levels has confirmed its viability for the work envisaged on the speciation of trace elements in the soil solution. Some limitations have been imposed on these studies by the lack of suitable clean laboratory, and particularly for Zn, and in other studies for Al, contamination of sample solutions by laboratory dust has been troublesome.

The analysis of *aqua regia* digests of soils envisaged (Annual Report 53, 1983) as a method for assessing total soil trace element contents and the extent of heavy metal pollution has been further investigated. The increase in efficiency of extraction gained by milling the soil has been assessed using six Scottish topsoils and a Welsh reference soil. Extraction of the 2 mm unmilled Scottish soils removed on average 88% of the Cr, 94% of the Cu and Mn, 87% of the Ni, 100% of the Pb, 80% of the Fe and Al and 85% of the Zn extracted from the same soils after milling. Milling thus somewhat improves the efficiency of extraction for the elements Al, Cr, Fe, Ni and Zn, but for Pb, Cu and Mn the improvement is small.

The acid-insoluble residues from the unmilled soils after *aqua regia* digestion were examined mineralogically to see which minerals had been broken down by the treatment. The 75 to 212 m fractions were separated and subdivided into light and heavy mineral fractions using tetrabromoethane (SG 2.95) and examined optically. The minerals biotite, biotite-chlorite and apatite were generally decomposed and calcium-rich plagioclase feldspars

showed evidence of attack together with hypersthene, sphene and opaque minerals. On the other hand hornblende, zircon, rutile and tourmaline appear to be resistant to the acid treatment.

Very peaty soils can occasionally cause problems by frothing during the digestion procedure. A range of peats and peaty soils with loss-on-ignition values of 95, 92, 50 and 30% were, therefore, analysed in order to test whether removal of organic matter prior to acid digestion would improve the efficiency of extraction. The samples were analysed in three different ways:

(i) refluxing with *aqua regia* in the normal way
(ii) ashing at 450°C prior to refluxing with *aqua regia*
(iii) treatments with hydrogen peroxide prior to drying and refluxing with *aqua regia*

There was no evidence that either ashing or treatment with peroxide improved the efficiency of extraction over normal refluxing of the untreated sample for the elements Cd, Cr, Cu, Mn, Ni, Pb, Fe or Zn. Ashing of peaty samples or treatment with peroxide to destroy organic matter prior to acid digestion are therefore time-consuming and unnecessary pretreatments which are better avoided.

The atom-trapping atomic absorption spectrometric technique described in earlier reports is now in routine operation for the analysis of waters, and extracts and *aqua regia* digests of soils. Its advantage in sensitivity over conventional flame techniques, particularly for Cd and Pb has made it especially suitable for their determination in environmental and agricultural samples. The technique and its advantages have been described by The Director at a Conference on Newer Techniques of Analysis under the auspices of the Society of Chemistry and Industry and are the subject of a paper submitted to Analytical Chemistry[16].

Analysis of a variety of samples, potatoes, wheat and milk powder, and some secondary reference materials have been carried out by flame and furnace atomic absorption methods in pursuit of a collaborative study under the auspices of the FAO European Co-operative Network on Trace Elements. The Department has co-operated in the collaborative analysis of a new candidate reference material (horse kidney) for the International Atomic Energy Agency, Vienna.

A study has begun of the combined use of coprecipitation and flotation for the separation and preconcentration of trace elements such as Mo from soil extracts. Suitable flotation cells for this work have been constructed.

Various specialized analyses have been carried out by atomic absorption methods for major and trace elements including Ba, Ca, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Sr, Tl and Zn, for Institute departments and other AFRS institutes including the Scottish Crop Research Institute, Rowett Research Institute, Meat Research Institute, National Vegetable Research Station and West of Scotland College of Agriculture. Some have involved only a few samples others have been more extensive e.g. 80 potato samples from Scottish Crop Research Institute for Ca and 90 soils from West of Scotland College of Agriculture for Co. Sample types have included rat diets, minerals, soils, crops and metals.

The number of routine determinations of the major cations Ca, Na, K and Mg increased this year by some 10% to a total number of about 11,600. Trace element determinations for Co, Zn, Cd, Ni and Pb remained at similar numbers to last years, but determinations of Al declined markedly and those for Cu and Mn respectively increased by 50% and 30%. Trace determinations by these techniques totalled some 10,000.

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

Molecular Fluorescence

Selenium has hitherto been determined by a fluorimetric procedure involving complexation with diaminonaphthalene (DAN). Although the method is intrinsically very sensitive the detection limit is dependant on the level of the reagents blank. An investigation has shown that the blank is largely due to impurities in the DAN reagent which fluoresce at the analytical wavelength. When the DAN reagent was purified by forming its hydrochloride salt and recrystallising from ethanol the overall reagents blank was reduced by a factor of 15. Since many of the sample solutions analysed have Se concentrations approaching that of the blank, this simple modification offers a significant improvement in the detection limit. Commercially available DAN hydrochloride has also been shown to be suitable but expensive. 3011

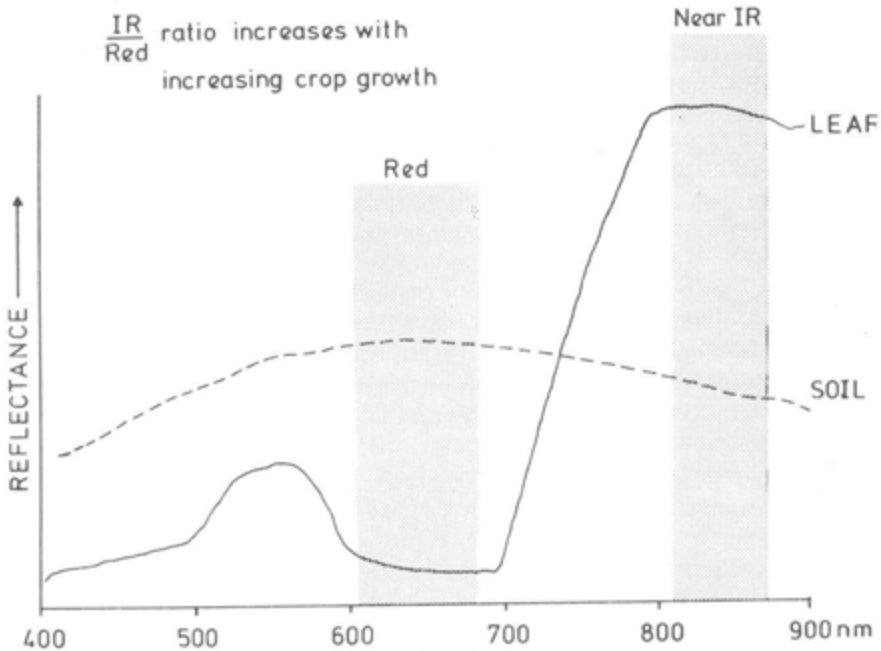

Fig. 3.2

Green vegetation exhibits characteristically high reflectance of near-infrared radiation compared with strong absorption in the visible red region, due to chlorophyll. By measuring the infrared-to-red reflectance ratio with a simple two-band radiometer an estimate of crop growth can be made which is indepedent of the kind of soil.

Reflectance Spectroscopy

In collaboration with the Remote Sensing Unit and the Department of Soil Fertility a study has been undertaken of the use of derivative reflectance spectroscopy to monitor *in-vivo* chlorophyll and plant nutrient status. Laboratory-recorded spectra of leaves from a potato crop indicate that the wavelength of the 'red-edge' is a function of factors other than chlorophyll concentration. Further studies are planned and a new scanning reflectance spectrometer for field measurements is currently being designed. This instrument is based on an existing computerised rapid-scanning spectrometer[17].

A portable two-band radiometer has been developed in the Department for the study of the reflectance properties of crops and soils in the field[18]. The instrument, with red and near-infrared optical filters, is being used by the Remote Sensing Unit to study a winter barley crop. The principle of this method is shown in Fig. 3.2. Results indicate a high correlation between infrared-to-red reflectance ratio and crop growth or biomass. Such radiometers commonly fail to make accurate corrections for rapidly changing ambient light conditions. To overcome this problem this dual-beam radiometer automatically corrects for ambient light levels.

Radiofrequency Plasma Emission

The inductively-coupled plasma (ICP) emission spectrometer is now in routine use for the determination of both major and trace elements in soil and plant materials. The largest workload has been the determination of major elements in Kjeldahl sulphuric acid digests of crop samples used for other analyses. A method has also been developed for the determination of B in water extracts of soils. Preliminary studies have been carried out on the determination of Ca, K, Mg, Na, Cr, Mn, Ni, Cu, Zn, Cd and Pb in *aqua regia* soil digests and of Mo in ammonium acetate soil extracts.

The photomultiplier used in the scanning spectrometer is not suitable for wavelengths above 600 nm and a second optical channel is, therefore, being added for Na and K determinations. A glass fibre optic is used to conduct light from the higher regions of the plasma tail-flame to two interference filters or a low resolution monochromator, equipped with a red-sensitive photomultiplier.

The research on nebulizers and spray chambers has produced a novel design of nebulizer and miniaturized spray chamber that have been taken up for patent application and commercial exploitation by the British Technology Group. This device combines high precision with excellent tolerance of high dissolved solids, or particulate matter contents, and fast, sample change-over times.

A review on nebulizers and spray chambers for the 'Analyst' is nearing completion and a review of agricultural applications of ICP emission spectrometry still awaits publication[19]. 3011

Microwave Plasma Emission

The equipment for determining ^{14}N : ^{15}N isotope ratios by optical emission spectrometry has been used intermittently for about 200 samples

with ^{15}N contents in the range 0.4-30 atom per cent. The paper detailing N_2 bandhead shifts has been published[20].

Laser Spectroscopy

The work on the laser remote sensing system, constructed from equipment supplied by the Royal Society, the Science Research Council and the Agricultural Research Council was completed in December 1983 and the results are described in the thesis of P. Wilson, University of Aberdeen, 1984, for which he obtained his Ph.D. A research paper summarizing this project is in preparation.

A joint application with the National Physical Laboratory (NPL) for EEC funding to study field emissions of N_2O using infrared laser long-path absortion spectrometry was unsuccessful. In order that progress should be made, therefore, a simplified pilot study is being planned with NPL for 1986. 3011

Spark Source Mass Spectrometry

The spark source mass spectrometer has been in continuous operation throughout the year and has been used mainly for the multi-element survey analysis of sets of samples of different types. The multi-element nature of the technique with its relatively uniform sensitivity for all elements allows panoramic analyses to be made with little knowledge of sample type and element concentrations. In this way unsuspected problems of element toxicity or deficiency can be detected. As an example, comprehensive analyses have been made of 16 soil samples taken from the vicinity of a chemical waste disposal plant in order to determine whether associated problems of animal disorder could be attributed to elevated trace element concentrations. The concentrations of 55 elements were determined, but did not in the event indicate any unacceptable trace element levels. Similar exploratory analysis for unknown toxic constituents have been carried out for rat diets.

Samples of different fungi have been analysed and concentrations have been determined for more than 40 elements including Cu, Zn, As, Se, Ag and Sb. The data are being assessed. Other analyses currently in progress include peat samples from two transects across Scotland taken to assess aerial pollution inputs to soils and comparative analysis of soils and their parent rocks to ascertain whether soils can be used to define the geological parent material. 3007, 3008

The determination of the rare earth and other elements has made a contribution to a study of the geochemistry of some zirconium minerals — eudialyte, eucolyte and catapleiite — carried out in collaboration with the Institute for Petrology, Copenhagen[21]. 3007, 3010

Relative Sensitivity Coefficients (RSCs) have now been established for 54 trace elements in both liver and soil matrices and some data are available for the plant matrix. In general the RSCs for heavier elements are lower in the liver matrix than in the soil matrix, but at low mass the RSCs for most elements are virtually independent of matrix as demonstrated, for example, by Ti (0.90, 0.87 and 0.90 in soil, liver and plant matrices, respectively), Co

(1.00, 1.13 and 0.97) and Ag (0.91, 0.87 and 0.94). At higher masses RSCs are generally higher or lower in all three matrices, but RSCs in the plant matrix do not follow any trend relative to the other two matrices.

All element concentration calculations are now made using interactive programs, written for the PET computer, which allow the operator to accept or reject data as presented by the computer. Corrections for superpositional interferences are included in these procedures, details of which have been published[22].

The second instrument has been in operation and the new vacuum system has proved to be successful. The two turbomolecular pumps hold the analyser section at about 3×10^{-8} Torr and the diffusion pump maintains a pressure of about 1×10^{-7} Torr in the source without the use of liquid nitrogen which is no longer required except for fast pumping down from atmosphere. Conversion to a thermal ionisation instrument is complete and its use is currently being evaluated for the accurate measurements of isotope compositions. Applications envisaged for isotope ratio measurement include the use of stable isotopes as tracers in soil and plant studies and in animal and human nutritional investigations, the determination of lead isotope ratios in plant samples to identify the origin of the lead, and the use of isotope dilution analysis for very accurate element concentration determination. The present instrument is being used to gain experience of the thermal ionisation techniques and to develop methods of sample preparation and instrumental techniques for these applications. A dedicated commercial instrument with the very high precision required for tracer studies and for the measurement of small differences in isotopic composition will, however, be essential for future work.

A comprehensive review of the developments and applications of spark source mass spectrometry since 1972 has recently been published[23]. 3010

Multi-element analysis of biological materials

Preparative and analytical methods developed for the multi-element analysis of biological materials of animal and human origin by Research Fellow Dr C. A. Shand (Annual Report 53, 1983) in collaboration with Dr P. J. Aggett of Aberdeen University and supported by the Scottish Hospitals Endowment Research Trust, have now been applied to the analysis of a range of foetal tissues supplied by Dr E. Widdowson. Data for 30 elements in 17 liver samples has been obtained and compared with those for livers from adults, and where available, with published data for human foetal livers. In summary, the results show, in comparison with adult tissue, the anticipated enhanced levels of Cu, Zn and Fe and a decrease in the potentially toxic elements Pb and Cd. An enhanced level of Ag and a decreased content of Mo were also apparent. These analysis were carried out mainly by spark source mass spectrometry but were supported by conventional atomic absorption techniques for major elements such as Na and K. This work was reported at the 5th Conference on Trace Element Metobolism in Man and Animals in Aberdeen and will be published in its Proceedings[24]. Analysis of the other human and animal tissues is in progress and data obtained for human foetal kidneys is now being assessed.

Molecular Spectrometry of Soil Components

The new mechanism proposed for podzolization (Annual Report No. 53) is still controversial and continues to stimulate work in many laboratories. It suggests that a major mechanism for the translocation of Al and Fe during podzolization does not necessarily involve organic matter complexes of these elements, and that the occurrence of allophane and imogolite in Bs horizons can be explained by the migration of inorganic, positively charged Al-Fe-Si hydroxide sols. In response to a counter-proposal that allophane in Bs horizons arises by *in situ* microbial decomposition of Al fulvates, it has been carefully argued from the properties of the inorganic protoimogolite sol and imogolite, and from the appearance of coatings on mineral grains that protoimogolite allophane was deposited from solution *before* the influx of organically charged solutions[25]. These findings have been further illustrated by the observation that this allophane is present in a cemented Bs horizon where in addition to filling voids, it forms pseudomorphs of root structures[26]. It is also clear from this work that the origin of the chemical constituents of the allophane is related to the intense weathering of plagioclase and biotite in the elluvial and Bh horizons. Papers on the occurrence of protoimogolite allophane in podzol concretions[27], a proposed new mechanism of formation of certain gley polzols[28], and the synthesis, properties and possible applications of imogolite[29] have now been published. Despite many years of research, the structures of allophanes are still not fully understood. To this end, the results from infrared and ^{29}Si and ^{27}Al NMR are providing a clearer picture of the co-ordination and environments of these elements in a range of allophanes and imogolite[30]. The two techniques clearly illustrate the diversity of allophanes, and more importantly, the NMR results show that imogolite and protoimogolite allophane are indistinguishable, as far as the environments of Si and Al are concerned, a finding that confirms the close relationship between these two minerals. 1002, 3005, 9012, 9804

A general review of the occurrence and properties of allophanes and imogolite in non-volcanic soils, their participation in the podzolization process and their likely role in soil aggregation and cementation will appear in a NATO Advanced Studies Workshop publication[31]. 3005

Papers on the substitution of iron in low pH aluminosilicate sols[32] and the characterization of the iron in podzols[33] have now been published. 3005

Current work in this area in collaboration with the Department of Mineral Soils is being directed towards a combined study in which results from immature podzols and laboratory synthesis will be used to establish rates of formation of imogolite during podzolization. A further study is being directed towards the identification of the source of the high levels of oxalate-extractable Al in brown podzolic soils developed on andesitic parent materials.

In studies of soils, the complexity of the mineral suite can present serious problems in the identification and characterization of individual minerals. Conventional magnetic methods for separating iron-containing minerals exist, but they often lack sensitivity. A modified magnetic method, high gradient magnetic separation (HGMS), has proved particularly useful in

separating and concentrating a wide range of ferruginous minerals from several soils[34]. An earlier paper in which the HGMS was used to concentrate Macaulayite (Annual Report No. 51), thereby enabling it to be more completely characterized, has now been published[35]. The HGMS method would appear to have the potential to fractionate chlorites according to their iron content, and has the ability to separate iron oxides and hydroxides. 3005, 1002, 1003

Enrichment of oxide and hydroxide minerals by the HGMS method could assist in the measurement of the sorption characteristics of their surfaces which IR studies have shown to be involved in the adsorption of fertilizer anions such as phosphate, sulphate and nitrate (Annual Report No. 46). In a follow-up to this work on fertilizer ions, an IR study has been made of the sorption by goethite of the arsenate ion, of increasing importance in the environment as a pollutant. The arsenate ion is adsorbed at the goethite surface by the same ligand exchange mechanism as phosphate, replacing singly co-ordinated hydroxyl groups. The larger arsenate ions have a greater effect on the absorption bands of the non-exchanged hydroxyl groups, and this has enabled a new assignment of the bands arising from these groups to be made[36]. A paper on the sorption of Cu(II) by synthetic gibbsite has now been published[37]. 3005

To maintain the broad base of experience necessary in spectroscopic investigations of soil clay minerals, it is necessary to continue IR studies of pure minerals of known composition, so that spectra-structure correlations can be established. To this end, several minerals have been investigated; these have included a variety of the Cr-smectite, volkonskoite, an earlier paper on an iron-free variety of which has now been published[38], and the vanadium-rich mica roscoelite. The paper on the IR identification of leadhillite and its two polymorphs susannite and macphersonite has been published[39], and a note on the possibility of distinguishing between leadhillite and susannite from their X-ray powder diffraction patterns, previously thought to be identical, has been accepted for publication[40]. A chapter to appear in a standard text on laboratory methods of IR spectroscopy, describing the use of this technique in clay minerals studies, still awaits publication[41].

A preliminary study of the IR spectra of ochreous deposits from field drains has revealed a range of iron-containing products from goethite to ferrihydrite. Deposits from a number of different sites are currently being studied, to characterize their structures more fully and to elucidate their modes of formation. 3005, 1060, 4801

The small field-trial using ammonia-treated vermiculite (ATV) as a slow release N-fertilizer for rye-grass (Annual Report No. 53) has begun to indicate higher yields of crop and lower loss of N by leaching from ATV- than from ammonium nitrate-treated plots. The exploratory nature of fine root hairs in searching for the nutrient N in ATV is clearly seen from the marked root growth in the vicinity of the ATV flakes and from the ability of the hairs to exfoliate them (Fig. 3.3). The experiment will be continued to establish the statistical significance of the results. 3005, 7048

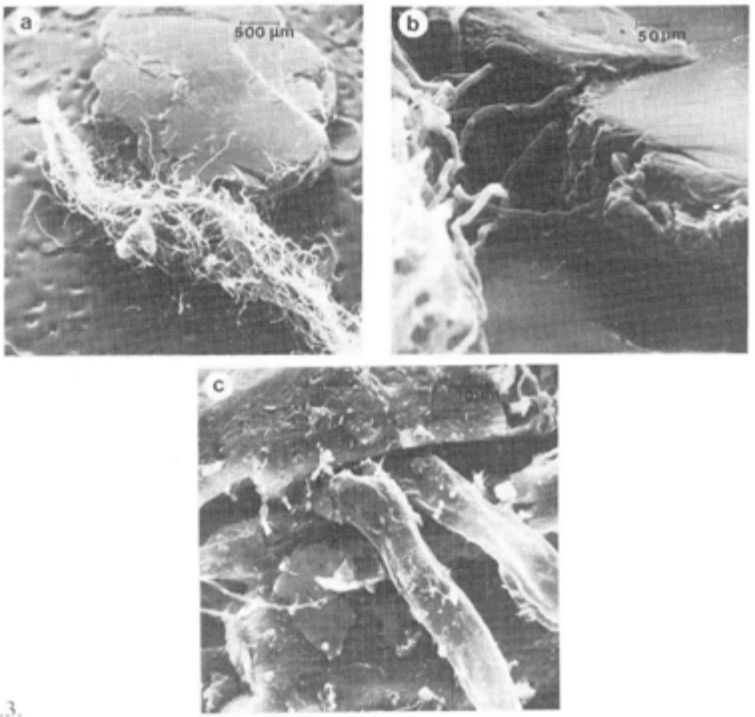

Fig. 3.3.
Scanning electron micrographs showing the penetration of fine oat root hairs into the lamellae of ammonia-treated vermiculite (ATV) particles. Chemical analysis shows that the roots remove N and K from the mineral interlayers. The bar indicates the scale: a) 500 µm, b) 50 µm, and c) 10 µm. Electron micrographs by courtesy of W. J. McHardy, Dept. of Mineral Soils.

Collaborative lines of research involving the Departments of Microbiology, Soil Organic Chemistry and Soil Fertility have also continued. The value of IR in these studies was demonstrated by the positive identification of the antibiotic vermiculine as a metabolic product from the soil organism *Talaromyces wortmannii*[42], and this method has been used to monitor the formation of the metabolite under various cultural conditions.

Investigations by IR and UV of soil polysaccharide and soil humic fractions have continued, and a preliminary study of the organic mineral dopplerite, while confirming its predominantly humate nature, has revealed a possible microbial origin for this substance which is being more fully investigated. 3017, 6026, 4029, 4019, 4020

Mössbauer spectroscopy

Little new experimental work has been carried out during the past year because of instrumental problems, which kept the spectrometer out of commission for long periods, and a delay of six months in obtaining delivery of a new source. A general paper on Mössbauer spectroscopy and its use in the study of colloidal materials was presented at a NATO Advanced Studies

Workshop on Soil Colloids and their Association in Soil Aggregates. This will be published in the conference proceedings[43]. 3005, 3803

In work with aluminosilicate minerals, the paper on the transformation of biotite to vermiculite as a function of the degree of oxidation of the structural iron (Annual Report No. 53) has now been published[44], as has the work on attempts to incorporate iron into imogolite structures[32]. A study of some illites has begun in collaboration with the Department of Mineral Soils. 3005

A study of the forms of iron in alkaline EDTA and NH_4OH extracts of podzol Bh horizons (Annual Report No. 53) has now been published[33]. Work on the low temperature (4K) parameters of some ferrihydrites with isomorphous substitution of iron by silicon or aluminium has demonstrated that their Mössbauer parameters are sufficiently different from those of other poorly-crystalline oxyhydroxides to permit unambiguous identification[45].

Experiments on the reaction of iron with fulvic acid showed that reduction could occur in the air at pH values as high as 4, a result in contrast with the reaction with humic acid, where reduction occurs only at very low pH (Annual Reports No. 47 and No. 49). A paper on this work was presented at the 2nd International Conference of the International Humic Substances Society[46]. 3803, 3805

Nuclear Magnetic Resonance (NMR) Spectrometry

No new NMR experiments have been carried out in the past year but some of the work performed at the University of Illinois (Annual Report No. 53) has now been prepared for publication. A paper on the use of NMR for the determination of tetrahedral aluminium in montmorillonites has been published[47], and a paper on the structures of imogolite and allophanes using ^{27}Al and ^{29}Si NMR has been accepted for publication[30]. 3005

Electron Paramagnetic Resonance (EPR) spectroscopy

New laboratory facitities have been completed this year for EPR and Mössbauer spectroscopy and improved computer facilities installed. In work with model systems that are of relevance to soils and plants, the paper on the copper (II) diglycine system (Annual Report No. 53) has now been accepted for publication[48], as has a paper on the use of both ^{63}Cu and ^{65}Cu isotopes for deriving fuller spectroscopic parameters than could be obtained with single or natural abundance isotopic studies[49]. The work performed at the University of Illinois on bimetallic complexes of copper and either platinum or iridium (Annual Report No. 53) has now been published[50]. A paper has been published[51] on the use of TRIS buffer in work on metalloenzymes. It was shown that TRIS can remove a substantial proportion of the copper from a commercial preparation of superoxide dismutase, but work is continuing in order to establish the extent to which the enzyme's activity is affected as a result of treatments with TRIS at different pHs. 3803

A study of the characterization of iron in alkaline EDTA and NH_4OH extracts of podzols[33] shows how EPR spectroscopy can identify

Fe(III)-EDTA monomers and monomeric complexes of Fe(III) with soil organic matter. Papers dealing with the occurrence of copper and iron complexes in humic acids extracted from municipal refuse decomposed in model landfills have been accepted for publication[52,53] and demonstrate the power of EPR specroscopy in identifying certain specific chemical forms. A further paper has been accepted for publication on the nature of copper complexes with soil humic acids, at natural levels and with added copper[54].
3005, 3803, 3805

Attempts to incorporate iron into imogolite have been described[32], as has the work on the adsorption of copper complexes on montorillonite and imogolite[55]. 3005, 3803

During the past year four papers have been written on the nature of free radicals in humic materials of different origins. Two deal with the variations in free radical contents and forms from different horizons of a podzolic soil[56,57]. Large differences are observed both in the solid state and alkaline solution; the spectra of the latter varying with both alkali strength and time. Work is now under way to assess the effects of alkali exposure on the free radical contents measured for solid humic acids. Two papers have also been accepted for publication on free radicals and metal complexes observed in humic materials extracted from a variety of fungi[58,59]. Again, the unique nature of the information that is obtained from EPR is clearly demonstrated. Work has been commenced on model systems in order to investigate types of compounds, other than semiquinones, that can produce free radicals under alkaline conditions. Success has been achieved with certain types of pyrone. Different methods of oxidation have also been investigated and some radicals have been obtained with well-resolved hyperfine structure. 3805, 4805

Work has continued on the investigation of paramagnetic species in plants. Attention has been given this year to the free radical component and a considerable number of measurements have been made on seeds and the roots of seedlings. With roots, several types of plant including sunflower, wheat, cress, raddish, broad bean, mung bean and maize were tested and wheat was chosen for further investigations of factors that might influence the free radical contents. The effects of light and dark, heavy metal ions, such as Cu^{2+}, Zn^{2+} and Cd^{2+}, oxygen and the herbicide, paraquat, were studied. The most dramatic effect was observed with O_2; the radical content increasing dramatically after a short exposure to the gas. Attempts to trap the radical with a spin trap have so far been unsuccessful. We have found no relationship between free radical contents and seed viability due, we believe, to the fact that much of the free radical content is in the seed husks. Measurements of Mn^{2+} contents are now being made in order to see if they show any correlation with viability. 3806, 4806

Computerisation and Automation

Following the successful use of microcomputer systems in the infrared and atomic spectrometry laboratories for instrument control and data logging (Annual Report No. 53), studies have continued with the computer interfacing of the EPR and Mössbauer spectrometers. The EPR

spectrometer has been linked to an Apple II microcomputer via a high-speed, 12-bit analogue-digital/digital-analogue interface unit, designed and constructed within the Department[60]. This link enables spectral data to be recorded by the computer directly from the spectrometer and, following any arithmetic manipulation, e.g. signal averaging, digital smoothing etc., replotted on the flat-bed recorder of the spectrometer[61]. An asynchronous serial interface, also constructed in the Department[62], allows the data to be displayed on a high resolution graphics work-station. The same microcomputer is also employed to record data from the Mössbauer spectrometer, thus eliminating the older Teletype unit and the perforated paper-tape output previously employed with the spectrometer. The microcomputer has been linked to the Institute DG Eclipse mainframe computer. Spectral data from both spectrometers can be stored in and retrieved from the mainframe computer and advantage can be taken of the larger computer's more powerful operating system. 3005, 3803, 3805, 3806

Due to an increased use of the mainframe computer for the library of infrared spectra, new programs have been developed which simplify data transfer between the laboratory microcomputer and the mainframe computer.

Studies are being undertaken to evaluate multivariate statistical analysis techniques to aid the interpretation of trace metal data obtained from multi-element analytical methods.

Output from the E789 49-channel polychromator is now routinely transferred to the Intitute's mainframe computer *via* magnetic disks and Apple II microcomputers, as described last year. Punched paper-tape is still prepared as an emergency back-up, pending the upgrading of the Apple II system to withstand a mains power failure without loss of data.

A microcomputer system has been installed in the Institute library and linked *via* a modem unit to the telephone network. The control programs and interfacing developed in the Department permit the computer to be used for on-line searching and literature retrieval using the Dialog data base. 3010

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4. SOIL ORGANIC CHEMISTRY

G. ANDERSON

The work of the Department has continued along the general lines described last year. Among the main objects of the research programme are to establish the chemical nature and properties of soil organic components, assess their effects on soil fertility and examine the transformations which occur when fresh organic residues reach the soil. There has been an increasing emphasis on the cycling of nitrogenous compounds in Scottish soils, using ^{15}N labelled fertilizers, and this has entailed a re-appraisal of methods of measuring the individual N components. Further work has also been carried out on factors affecting the movement and availability of bio-essential trace elements near the root surface. Investigations on effects of organic components on the structural stability of soils has continued and new methods are being used to examine the effects of compaction on seedling development. More tests have been carried out on the use of naturally occurring organic materials, such as coniferous bark, for preventing or delaying the accumulation of iron ochre in field drainage systems. The use of such materials for removing toxic pollutants from some organic manures and slurries is also being investigated.

Laboratory, pot culture and field experiments are carried out by the Department, in many cases in collaboration with other Departments of the Institute and also with staff of, *inter alia*, the Scottish Colleges of Agriculture, the Department of Agriculture and Fisheries for Scotland, Aberdeen University and institutes overseas.

A book chapter giving a general perspective on the nature of soil organic matter, and its role in soil fertility has been submitted for publication[1].

Nitrogen

For many years, with increasingly intensive agriculture, there has been a tendency to apply very high rates of nitrogenous fertilizers to achieve large crop yields. In many cases this may not only be wasteful of fertilizers which require much energy to produce, but it may also cause environmental problems due to the release of potentially harmful levels of nitrate to water courses serving public supplies. With the changing demands on agriculture the aim should now be to add sufficient nitrogen to give a good economic return without waste and without damaging the environment. Unfortunately this amount is not easy to assess because it requires a prediction of the contribution released from the soil organic matter and this depends on several factors including the nature of the nitrogenous compounds present,

temperature, moisture, biological activity, clay content etc. Mathematical models are likely to provide the best means of prediction, but data for constructing such models are still extremely limited. Experiments are, therefore, being carried out in the Department to characterise the organic nitrogen in agriculturally important Scottish soils and assess the transformations and cycling which occur under different conditions.

The two pot experiments using ^{15}N-labelling techniques described in last years Report have been continued. In the first, successive crops of barley have been grown in three soils representative of large areas locally, following application of labelled ammonium sulphate, and the crop residues were returned to the soil after each harvest. Samples from this experiment are now being analysed. In the other experiment, successive crops of fescue are being grown on, and composted in, corresponding subsoils initially containing no organic matter. The incorporation of labelled residues into the soil is being followed, and the nature of the nitrogenous components formed will be determined. Until now only about half of the organic N has been identifiable in soils and considerable efforts are now being made to characterize the remainder. Various theories have been suggested involving the incorporation of nitrogen from ammonia or amino substituted compounds into phenolic structures or, as noted in Annual Report No. 53 (1983) into carbohydrate materials by a Maillard reaction which produces coloured products, the so-called "melanoidins", which are familiar in "browning reactions" between carbohydrate and protein in foodstuffs. (An experiment to test this possibility is outlined in the Section on Humic Substances, below).

One major problem is that most of the methods used to fractionate and characterise soil nitrogen have employed techniques such as acid hydrolysis to deal with the known forms, for example peptides and proteins. Such hydrolysis, in the presence of other compounds, especially carbohydrates, can lead to the incorporation of amino acid nitrogen into new structures which then become part of the 'unknown-N' fraction. There are numerous difficulties of this kind associated with such heterogeneous polymers as humic substances.

In an attempt to prevent or reduce artefact formation we have been testing a number of separation techniques to concentrate the unknown nitrogenous components where possible before hydrolysis. One method uses the resin XAD-8 which adsorbs polar acidic compounds at low pH when they are undissociated but desorbs them at high pH when they are in an anionic form. It adsorbs the polycarboxylic acids typical of soil fulvic acid fractions, along with considerable peptide, but low amounts of polysaccharide. A Polyclar AT resin (a polyvinyl-pyrrolidone), used on the eluate, removes more polycarboxylic acids from solution, with less peptide content, and the adsorbed material commonly contains 55 to 65% of its N in unknown form.

A book chapter, reviewing methods of extracting soil nitrogen components, and their distribution and dynamics in soil, has been prepared for publication[2]. 4019

Humic Substances

An examination has been carried out of the material called Dopplerite, which occurs in some peats as a black gel, and is considered a rich source of humic acid (HA). The sample is part of a large deposit found by staff of the West of Scotland College of Agriculture in a sand quarry, under peat, near Ayr. It contained 85% moisture and when dry became hard and brittle with an ash content of 71%. Sonnication of a suspension in water released loosely bound silicaceous material and produced an organic fraction with less than 7% ash. This was insoluble in water, ethanol and diethylether, but dissolved completely in 0.2 M NaOH from which it was all precipitated with HCl, conforming to the properties of HA. The C:N:H ratios of the precipitate and the original material were similar to that of a typical HA isolated from an alkali extract of soil, but gel chromatography showed that the Dopplerite HA contained a larger proportion of high molecular weight materials. Infrared spectrometry showed the presence of aromatic structures, polysaccharide and carboxylate groups. Removal of polysaccharide by acid hydrolysis gave a residue with an infrared spectrum resembling those of pigments from fungi such as *Aspergillus niger* suggesting that it may have a predominantly fungal origin. A paper on the chemical characterization of Dopplerite is now being prepared for publication. 3017, 4029

Investigations into the transformations of humic substances in soil are facilitated if radioactive labelling techniques can be used. A new technique has been devised in which the duckweed *Lemna gibba* L. is grown axenically in simple inorganic media and ^{14}C-labelled glucose. The labelled *Lemna*, of specific activity up to 2.2 n Ci mg^{-1} carbon is produced in three weeks and then incubated with soil to produce labelled humic substances. The soil material is comparable to that obtained from labelled ryegrass, a plant material more costly and time-consuming to produce initially.

4020, 4029, 4064

The reactivity of humic acids towards other soil components is likely to be influenced by their content of organic free radicals, and these can be detected and characterized by electron spin resonance spectrometry (ESR). In previous work it was shown that radicals displaying hyperfine structure occurred in humic acids from soils and peats with a pH less than about 4.2 in water whereas from soils with higher pH values a featureless ESR signal was obtained. There are several possible explanations. Firstly, very acid soils often have an accumulation of undecomposed plant material one of whose components, lignin, possesses free radicals. Secondly a pH value around 4 may represent the point at which the soil microflora became fungal rather than bacterial and fungal material can display free radicals. Thirdly, abiotic polymerization or condensation reactions of common soil metabolites to form humic substances may be pH-dependent with different polymers resulting under very acid conditions. In a collaborative study to explore these possiblities, along with the Departments of Spectrochemistry and Microbiology, a range of humic acids have been analysed. They were obtained from the various horizons of a podzol formed under pine forest, including the litter layer, and from some fungal products.

The free radical content of the HA increased down the profile through the organic horizons, but there was a sixfold decrease when the mineral layer was reached. Hyperfine structures were present in the NaOH solution spectra of the HA from all horizons but their nature differed. Those from the upper L and F horizons, for example, contained some signals similar to those from pine needle lignin and differed from those from the more humified O, A and BS horizons. At least five different radicals were present in the latter[3].

Fungal products from *Aspergillus niger*, *Rhizoctonia solani* and *Marasmius androsaceus* also gave spectra differing from those of the well humified organic matter despite the fact that the last-named fungus was prevalent in the litter layer of the podzol[4,5]. 3009, 4029, 4805, 6027

Various theories have been proposed about the mechanisms which lead to the formation of humic substances in soils. One possibility, akin to the Maillard reaction, is that amino acids condense with sugars to form dark brown soil polymers. To determine if such simple substances can form humic substances in a relatively short period, compounds labelled with ^{13}C and ^{15}N have been incubated axenically with peats for about six months and the humic substances then analysed by ^{13}C and ^{15}N nuclear magnetic resonance spectrometry. Forms of C and N which occur in melanoidins have been detected. An account of some of this work, carried out in collaboration with staff of the Department of Peat and Forest Soils and of the Canadian Department of Agriculture, has been submitted for publication[6].

2055, 4020, 6027

In collaboration with the Department of Ancient Monuments of the Scottish Development Department, analyses were performed on soil samples from supposed Iron-Age post-holes uncovered at Eskbank, Lothian Region. The distribution of phenolic acids in the humic acids, along with high pH values, a preponderance of Ca-bound humus and the high organic phosphate content of the soils, were typical of the surrounding arable soils, rather than resembling authentic post-hole soils, sampled for comparison, from the Bannockburn area. A report dealing with this work has been incorporated into a paper awaiting publication[7] 4021

A book chapter describing the influence of humic substances on growth and physiological processes in plants has been prepared for publication[8].

4064

Micronutrients and Metal-Organic Interactions

A book chapter on the relationships between soil organic matter and trace metals in soils is awaiting publication[9]. A paper has been published on the role of the physical adsorption of micronutrient metals by plant roots and their uptake by plant[10]. 4803

Collaborative investigations with the Department of Soil Fertility have continued on the mobilisation of trace elements near the roots of barley plants. Mobilisation, reaching a maximum in mid summer, of manganese, zinc and copper was again observed on a number of widely different sites. As was found previously, most substantial mobilisation occurred in the case of manganese, where up to 30 fold increases were found. Substantial

mobilisation (more than 10 fold increase in concentration) of cobalt was observed, but only at one site. Analysis of the aerial parts of spring barley, by the Department of Soil Science of the University of Aberdeen, indicate that the occurrence or otherwise of deficiency of a particular trace element depends on the balance between the growth rate of the plant and hence its need for the trace element and the extent of mobilisation of that trace element in the soil solution. Where early growth is rapid, as was the case in the spring of 1984, then demand is high prior to any substantial trace element mobilisation so that trace element deficiency symptoms may develop. However, as the extent of mobilisation increases then deficiency is alleviated thus explaining the common observation that cereals, for example, may "grow out of deficiency". A paper describing some of these results has been accepted for publication[11]. 4803, 7041

The interactions which occur between organic matter and metal elements during the composting of refuse are being studied in collaboration with Professor Z. Filip of the Institut für Wasser-, Boden- und Lufthygiene des Bundesgesundheitsamtes, in West Germany, and the Department of Spectrochemistry. Alkali extraction of the refuse at various periods up to 20 months gave small yields of humic acid-like materials. These were analysed for a range of elements and an attempt made to determine the nature of some of the complexes present using electron spin resonance spectroscopy. Copper was mainly present in either a square planar or tetragonally-distorted ochtahedtral environment and was probably co-ordinated to two N and two O atoms. Iron (Fe^{3+}) was present in at least 3 different types of environment. One appeared to be a complex with rhombic symmetry and another is an axially symmetric environment which may be ferric porphyrin. Humic acids prepared in the same way from two contrasting soils showed a similar content of most elements in comparable forms, but they contained more than twice as much iron and the ferric porphyrin-type complex was not observed. Only a small proportion of the total metal contents of the refuse appeared to be strongly bonded to the humic acid component. This work was presented to the meeting of the International Humic Substances Society at Birmingham in July 1984 and forms the basis of a paper submitted for publication[12]. 4805, 3009

A paper has been prepared in collaboration with colleagues from the Land Resources Research Institute in Canada and the Centre de Pedologie Biologique in France which discusses the interaction of soil minerals with natural organic matter substances in the context of soil genesis[13]. 4805

In another collaborative study with the Department of Spectrochemistry, further work on the interaction of soil organic matter and metals has involved the influence of pH on the reduction of iron Fe (III) $\rightarrow$Fe (II) which occurs in the presence of fulvic acid. This reduction occurs to a significant degree in solutions of extracted fulvic acid at pH 4 and so must be taken into account as a possibility in many soils where the pH may be as low as 3. A report of this work was given to the International Humic Substances Society in Birmingham[14]. 3009, 4805

Soil Enzymes

Some of the biological transformations occurring in soil are brought about, not by living organisms, but by enzymes which, although originally of plant, animal or microbial origin, survive for a time outside the living cells. Some, such as phosphatases and sulphatases, can be involved in the release of nutrients in plant-available form from soil organic matter. Others are likely to play a part in the breakdown of high molecular weight organic polymers or the synthesis of some humic substances. Their level of activity has been shown by a number of workers to indicate the level of soil fertility and of its biomass content.

Work has continued on the measurement of the activities of enzymes such as phosphatase, invertase, amylase and dehydrogenese under different cropping regimes (see Annual Report No. 52, 1981/82). In such studies, comparative levels in different soils are likely to be more meaningful than absolute levels and it is unfortunate that no standard methods of measurement have been adopted in different laboratories. In the case of invertase, an enzyme which has received considerable attention, we have now made an assessment of assay conditions with particular emphasis on buffers, pH and substrate concentration[15]. Different buffers can affect the activity of an enzyme to different extents at a given pH and in soils which themselves have considerable buffer capacity the use of buffers should perhaps be avoided (Table 4.1). It is recommended that in any studies of a soil enzyme its Km value and pH optimum should first be determined. 4064

TABLE 4.1.

Influence of 0.25 M acetate-phosphate buffers on invertase activity* in different Scottish soils

Soil series	Water alone at soil pH	Buffer at soil pH	Buffer at optimal pH
Foudland	1030	690	1190
Insch	320	120	980
Boyndie	420	250	710
Countesswells	780	670	680

*Activity expressed as μg glucose g^{-1} soil h^{-1} formed at 30°C.

Soil Carbohydrates

Aggregation. One very beneficial effect of the organic matter in soil is its influence on soil physical conditions, particularly structural stability. The way in which it stabilises structure is still poorly understood, but there is strong evidence that carbohydrates are among the components having this effect. For example if soils are treated for varying lengths of time with periodate, an oxidising agent which attacks components containing hydroxyl groups on adjacent carbon atoms, such as sugars, the degree of disruption of the microaggregate structure is inversely related to the residual sugar content[16]. Even after a long period of oxidation some structure still remains, together with some carbohydrate. This residual carbohydrate is distinctive in having above-average proportions of glucose, xylose and, in

particular, arabinose. This could mean that the more readily oxidised sugars, mannose, galactose and the deoxyhexoses, are involved in aggregation to a greater extent that the other sugars. They are also the more likely to have been synthesized by microorganisms, the pentoses xylose and arabinose possibly being in the residues of decayed plant material. Attempts were, therefore, made to distinguish the origin of these residual sugars by comparing the behaviour of ^{14}C labelled plant residues with products from the microbial metabolism of ^{14}C labelled glucose[17]. Interpretation of the results from such studies is difficult, firstly because such small amounts of pentose derivatives are synthesized by the microflora and secondly because a very large proportion of the product is oxidised by the subsequent periodate treatment. A number of experiments have given similar results, however, and lead to the conclusion that the resistant pentose sugars are of both plant and microbial origin. This suggests that their resistance is attributable to their chemical structure *per se* rather than the physical form in which they occur.

During these experiments it was found that after oxidation ceased, if the soil was treated with the reducing agent sodium borohydride, further oxidation could then take place. Such behaviour has been observed with xylans and alginates and has been attributable to the formation, on initial oxidation, of resistant hemiacetal bonds between neighbouring sugar residues. Borohydride converts these back to more readily oxidisable structures. A paper describing these observations, and the nature of the resistant sugar polymers as determined by methylation analysis, is in preparation.

Much of the work on soil carbohydrate is now being aimed at understanding how polysaccharide contributes to the aggregation of soil particles, and a discursive paper on this subject was presented to a Nato Workshop in September[18]. A book chapter discussing the contribution made by carbohydrates to soil fertility is awaiting publication[19]. 4020, 6027

Soil Carbohydrate Structural Studies. The principal mechanism by which polysaccharides are bound by, and link, clay particles is thought to be adsorption, the extent of which depends on the shape or conformation of the molecules and the configuration of the component sugars. The conformations of many polysaccharides in other systems have been established from a precise knowledge of their structures. But the soil polymers, containing as they do a mixture of sugars, present a much more difficult task.

The position of linkages between sugars is commonly assessed by methylation analysis. If the fully methylated polysaccharide is hydrolysed, the carbon atoms involved in the linkage between the component sugars will not possess methoxy groups and can thus be identified. Soil polysaccharide can be methylated without prior extraction, but several treatments with the methylating agent are required to complete the reaction. Extraction with chloroform then leads to the isolation of high molecular weight polymers containing about 70 per cent of the total soil sugars, most of the remainder being separated during purification by dialysis. Methods have now been developed to recover this low molecular

weight material, presumably present as oligosaccharides in the soil. Such methods will be necessary to characterise the residues which resist periodate oxidation (see above) since they are likely to contain a higher proportion of oligosaccharide fragments. 4020

Field Observations. An examination has been made of the natural variability of the carbohydrate in a Countesswells series soil which had been under grass for 15 years. The carbohydrate contents in thirty plots about 2.4 m^2 within an area of about 350 m^2 ranged from 16.1 to 20.6 mg g^{-1} and were directly proportional to the total nitrogen. Surprisingly, the values were inversely proportional to the available phosphate measured by dilute acetic acid extraction. The plots are now being cropped in a variety of rotations and the effect on carbohydrate content is being monitored. 4020

Seedbed and Related Investigations

Considerable success has been achieved in assembling time-lapse cine (Fig. 4.1) and video (Fig. 4.2) equipment with which precise measurements of seedling growth can be carried out in a specially designed miniature growth chamber. It was first used to study the growth of the hypocotyl, especially as it is affected by light and gravity but the current objective is to adapt the equipment to allow the growth of root or shoot to be observed while the plant organ is still in contact with soil or other solid media, a modification which will assist in the investigation of problems relating to seedling growth in compacted soil. This is being undertaken in collaboration with the Department of Soil Fertility. The miniature growth chamber is equipped

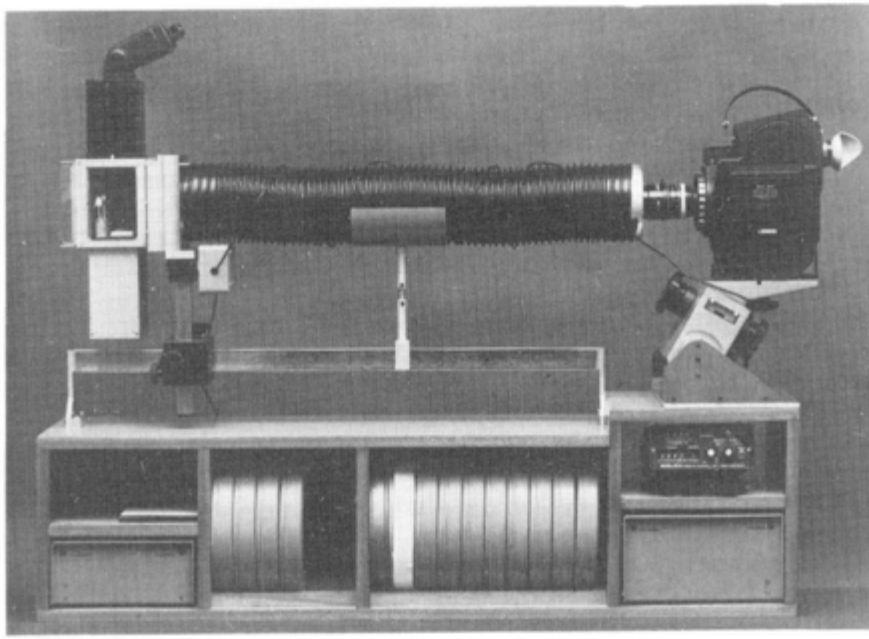

Fig. 4.1
View of ciné camera and associated equipment showing miniature growth chamber *in situ*.

Fig. 4.2
General view of video camera and image analysis equipment. The miniature growth chamber is in the inverted position and the re-orientated seedlings can be seen on the monitor.

with infrared emitting diodes so that growth can be observed under conditions of plant darkness, i.e. above 800 nm. The potential usefulness of this facility has been enhanced by the purchase of "night-vision" or image-intensifying binoculars which permit the assembling of experiments under conditions of non-visible radiation. In order to achieve maximum benefit from this equipment an enlarged darkroom with a light-trap door is being fitted out. 4053

In the past year a detailed description of the methodology developed for image analysis of seedling growth has been published as part of a study of seedling re-orientation following inversion through 180°. This study[20] has demonstrated the capability of the apparatus for characterising, spatially and temporally, the growth responses of a seedling subjected to repeated geo-stress. The results emphasize the complex changes that occur in contiguous regions of a seedling hypocotyl and the impressive level of growth co-ordination that exists in even the simplest type of plant organ. The results also draw attention to the inadequacies of any theory of growth regulation based on an environmentally imposed gradient of a single growth substance.

A paper referred to in last year's report dealing with the role of the apex in shoot geotropism was published in the course of the year[21]. The question is an important one in the consideration of the overall regulation of plant

growth and further evidence has now been adduced in support of a positive role for the apex in the co-ordination of directional growth. Specifically, it has been demonstrated that geostimulated growth, the characteristic response of the basal region of a horizontal hypocotyl, does not occur in that region when the hypocotyl is flexed in such a way that the apical end is kept vertical while the basal end is horizontal. This evidence supports the view that the geostimulated basal growth of a horizontal hypocotyl is not an independent response occasioned simply by the horizontality of that tissue. On the contrary, it indicates that the response of the basal region is modulated by the orientation of the apical region and it points to a co-ordinating role for the apex in the regulation of growth in all regions of a seedling. This work has been accepted for publication[22].

The influence of the apex on growth of the hypocotyl when either vertical or horizontal has also been investigated. In vertical hypocotyls excision of the cotyledons has little effect on subsequent growth in the short term. On the other hand, growth is drastically affected by excision of the apical hook. Marking of the hypocotyl into discrete regions revealed that this curtailment of growth was not a consequence of the removal of the region of growth but a consequence of the removal of a region on which growth is dependent. This is evidence in support of the classical hormone-inspired distinction between a region of growth and a region of growth regulation. The situation in horizontal hypocotyls is more complex inasmuch as growth can be maintained in a horizontal hypocotyl with a smaller proportion of apical hook and adjacent tissue than is necessary in vertical hypocotyls. These experiments, the detail of which is given in a paper accepted for publication[23], point to a means of separating tropic growth from normal growth, a distinction that is usually impossible to achieve since the former is normally superimposed on, and inseparable from, the latter. A further paper dealing with the influence of adjacent tissue on apical hook opening referred to in last year's Report, was published in the current year[24].

The research proposals mentioned in last year's Report as having been submitted to the European Space Agency for evaluation for space research were judged as having met the criteria relative to scientific merit, space relevance and the probability of success and were recommended for inclusion in a space flight. However the level of funding which has to be contributed by participating laboratories proved to be an insuperable obstacle for us.

Using the time-lapse videography equipment, a start has been made on a study of soil strength and seedling growth by examining root growth in relation to mechanical impedance. A root chamber designed to channel roots into narrow apertures has been constructed to permit filming of root growth in constricted conditions. Preliminary results suggest that the generally accepted view that roots are incapable of entering a rigid aperture having a diameter less that that of the root tip is only partially correct. While it is probably true to say that a root cannot penetrate a rigid circular pore of smaller diameter than itself it would seem that the root tip does possess sufficient plasticity to permit it to enter an aperture which is narrower that the root tip in one dimension, provided that the other dimension is not

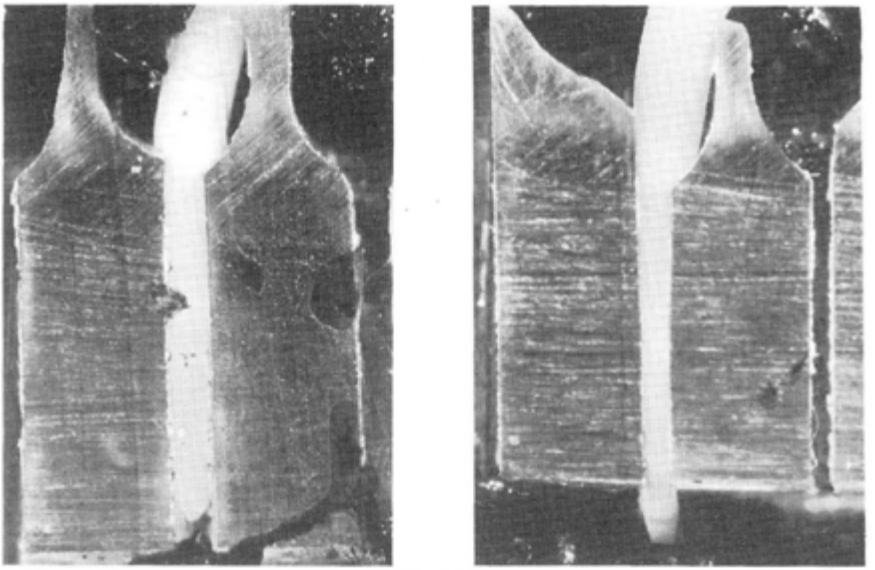

Fig. 4.3
Sunflower roots shown at different stages of passage through a narrow channel demonstrating the ability of the root to constrict its growth in one dimension.

equally restrictive. Confronted with this type of constricted aperture the root can alter its external shape to allow it to pass through a constricted zone (Fig. 4.3, a, b). The plasticity of a sunflower root is such that when growing down a tube only slightly wider than itself, on being confronted with a barrier to further growth the root can bend through 180° to retrace its passage back up the tube. Such flexibility must endow the root with considerable powers for penetrating the most obstructive soil. The time-lapse equipment now in use should contribute to our understanding of root reaction to physical obstruction. 4053

Ochre in Field Drains

Collaborative work with the Department of Soil Survey has continued on the problem of ochre deposition in field drains (Annual Report No. 53, 1983). On a number of sites where the drainage systems include inspection chambers (Fig. 4.4) tests have continued on the ameliorating effects of coniferous bark. The weathered bark, contained in loose-weave polypropylene sacks is inserted into the chambers and on a number of farms as far apart as Aberdeenshire and Kintyre, the rate of ochre deposition has been greatly reduced. In the past 30 months no blockages have been encountered at any of our test sites. Three papers describing this use of bark have been published during the year[25,26,27].

Ochre is formed by the conversion of soluble ferrous iron salts in the drainage water into insoluble ferric compounds which soon form a thick sludge and solidify in the pipes. The effectiveness of bark is due to its content

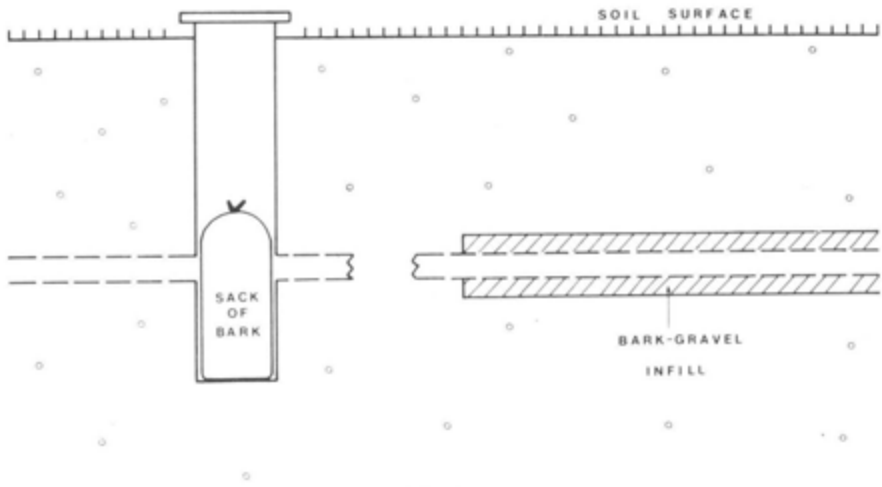

Fig. 4.4
Methods of using weathered coniferous bark to combat the ochre problem in field drains. Where the drains have inspection chambers, renewable sacks of bark are inserted into the sump as shown on the left. Alternatively, as on the right a 50/50 bark-gravel mixture can be used as infill when the drains are laid, which may give more complete protection.

of tannins which complex with the ferrous iron and remove it from solution before it is oxidised.

In some sites it is not practicable to install inspection chambers and, therefore, the use of bark as a backfill around new drains is also being tested (Fig. 4.4) in collaboration with the North of Scotland College of Agriculture. At a site near Elgin, a mixture of equal parts of bark and gravel have been used to maintain permeability. The outflow is sampled at monthly intervals and in the first five months of the experiment the iron concentration in five out of six treated lines has been much lower than in untreated controls. A more comprehensive experiment is planned for a site in Grampian Region to compare the effects of various barks and filter wrap materials.

Laboratory analyses of ochre have shown that it is very variable between sites and even within a given site. The organic matter and iron content both vary between about 2 and 20%. Infrared spectrometry confirms the large differences in composition, depending on location, varying from clay-rich material containing minor amounts of iron to highly ferruginous deposits containing the hydrated iron oxide ferrihydrite. It has also shown that the nature of the organic matter varies in different samples and work is planned to clarify its nature and origin, and the part it plays in ochre deposition. 4801, 9801, 3017

Arising from our observation that bark absorbs many cations from solution (Annual Report No. 53, 1983) a new collaborative investigation has recently been undertaken to evaluate the use of bark in removing potentially toxic metal ions from industrial byproducts used as manures or composts in agriculture.

Other Investigations

During the year collaborative work has been undertaken with the Department of Plant Physiology into the effects of some amino acid analogues on the incorporation of ^{14}C-labelled leucine into roots of wheat and mung beans. It was concluded that continuous protein synthesis is essential for the active uptake of cations and probably for their subsequent transport to the shoot. A paper dealing with this investigation has been submitted for publication[28]. 4064, 5050

In collaboration with the Departments of Microbiology and Spectrochemistry, an antibiotic produced by the fungus, *Talaromyces wortmannii* has been identified as a macrolide dilactone, vermiculine[29]. 3017, 4029, 6026

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5. PLANT PHYSIOLOGY

A. E. S. MACKLON

The main objective of the Department's programme is to contribute to the improvement of dietary supply of trace elements to grazing animals. Common causes of ill-thrift of stock in Scotland are related to deficiencies of copper, cobalt and selenium. Since, at present, there is little known about the movement of these trace elements at the cellular level in plants, the priority is to characterise their uptake, exchange and transport, individually, in electrochemical and metabolic terms, in crop and pasture species. Information from studies of individual elements forms the basis for interpreting the results of interaction studies, and differentiating between interactions which affect the availability of elements for uptake (soil solution effects) and interactions occuring at the uptake step (at root cell membranes). These studies are designed to lead towards an understanding of the mechanisms which limit transport of trace elements, absorbed by the root, to the shoot.

Amounts of trace elements transported from root to shoot are commonly adequate for, or non-essential to, plant growth, but inadequate for ruminant animal requirements due either to the low absolute quantity present or to reduced availability related to interactions with other elements in the diet. It is, therefore, the ultimate aim of the research programme to identify species and cultivars of pasture plants which provide adequate levels of available bio-essential trace elements in animal diets, from soils which are average or low in content of the trace elements in question.

Work on the characterization of trace element uptake and transport, started last year, has continued, as have studies on nitrate and ammonium absorption. Neither project, however, has been without obstacles to progress. These have arisen from extended delays in filling vacancies due to the redeployment exercise currently under way in the AFRC institutes. We have, therefore, as yet been unable to proceed with recruiting staff to work on the trace element programme. Staffing delays have also prevented the inception of an analytical service for nitrogen isotopes using a mass spectrometer installed a year ago. There are signs, however, that progress on the recruitment front may be seen in 1985.

Trace element studies

Flux analysis experiments using radioactive cobalt, described in last year's Annual Report, await analysis of plant samples for total cobalt before full assessment of the results can be made. Due to the exigencies of the experimental method, the tissue available for total cobalt analysis is limited,

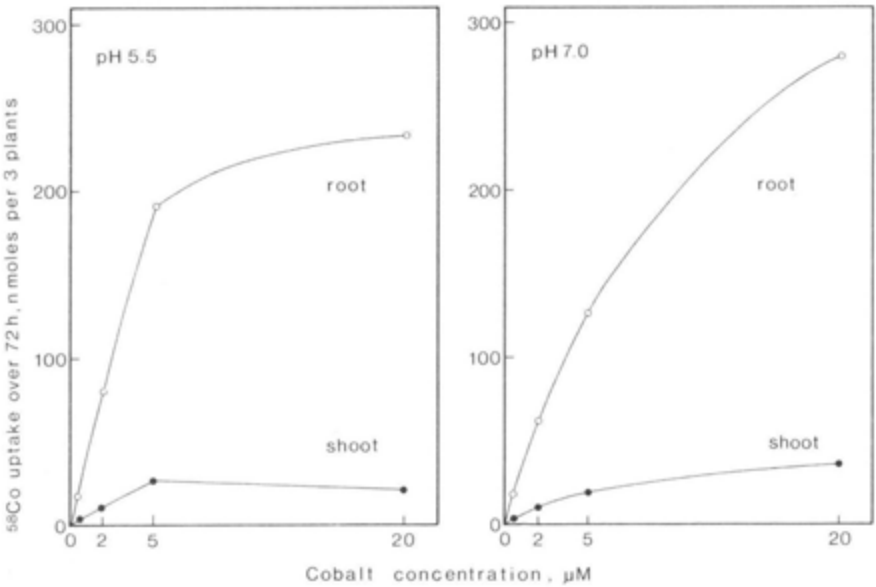

Fig. 5.1
Effect of cobalt concentration on ^{58}Co uptake by roots, and transport to shoots of wheat seedlings, at two pH levels. The plants were grown for 6 days in nutrient solution containing non-radioactive cobalt at each concentration, before labelled cobalt was introduced and uptake measured over 72 hours.

and a method for estimating cobalt in such small plant samples is currently being developed by the Department of Spectrochemistry.

Meanwhile, work on cobalt uptake and transport in whole wheat seedlings has continued using ^{58}Co to examine concentration and time-course effects. Compartmental analysis indicates that the bulk of cobalt absorbed by the roots is accumulated in the root cell vacuoles. The amount absorbed, and transported to the shoot, increases with external concentration, at pH 5.5, up to about 5 μM Co, but thereafter falls away (Fig. 5.1) suggesting that at 20 μM, cobalt is becoming toxic. At pH 7.0, however, uptake and transport show more nearly the usual hyperbolic relationships with concentration over the whole range of cobalt concentrations tested (Fig. 5.1). This extended down to 0.02 μM Co, and can be fully illustrated only on a logarithmic plot. The relationships between log uptake and log external concentration, and between log transport and log concentration, are found to be linear up to 5 μM Co, but above this both uptake and transport fall below linearity at pH 5.5, and to a lesser extent at pH 7.0

Time course experiments have been carried out using mainly 2 μM Co. Radiocobalt was added to the nutrient solutions of 6 day-old seedlings, which had been grown in nutrient containing 2 μM non-labelled cobalt. Uptake to the roots progressed steadily for 72 hours (8 nmoles per seedling per day), during which time transport to the shoot increased from 0.3 nmole after 24 hours to 2 nmole ^{58}Co per seedling per day, between 48 and 72

hours. After 96 hours, further accumulation in both root and shoot slowed down considerably. However, even if cobalt was withdrawn from the nutrient solution of 6 day-old seedlings, grown in ^{58}Co from the start, transport to the shoot, from cobalt stored in the root, continued at least for the ensuing 72 hours. Early indications are that if the roots are killed by briefly plunging in liquid nitrogen, the ^{58}Co released is much more available to the shoots. All these observations illustrate the degree of control the living root exerts over cobalt transport to the shoot. 5050

Nitrogen flux studies

Our first investigations of nitrate and ammonium fluxes were carried out using onion root segments, a system well characterised for major nutrient cation fluxes over a number of years. Assessment of these experiments still awaits ^{15}N abundance determinations, for reasons referred to above.

Our research on the fundamental mechanisms of nitrogen uptake and transport is designed to provide information useful for other Departments in the interpretation of field experiments concerning nitrogen nutrition, particularly of cereal crops. We have started studies on characterising nitrate and ammonium absorption, both singly and in competition, in wheat and barley seedlings. This is the first occasion that we have used barley in ion transport studies, and some time has been devoted to assessing cultivars and seed sources suitable for uptake and efflux studies under sterile conditions. 5051

Major cation absorption and transport

Work on the effects of some amino acid analogues on uptake and transport of potassium and calcium in seedlings has now been written up in two papers[1,2] submitted for publication. In conjunction with this work, and in collaboration with the Department of Soil Organic Chemistry, a study has been made of the effects of the amino acid analogues on enzyme activity and amino acid incorporation in seedling roots. Essentially, the analogues were found to reduce enzyme activity without affecting amino acid incorporation, confirming, for our plant tissue, the view of earlier workers that the analogues become incorporated, during protein synthesis, into enzymes and carriers which fail to function properly. The analogues are thus a useful tool in investigating the role of proteins in ion absorption and transport to the shoot, and may well be used to advantage in trace element transport studies. This work has also been submitted for publication[3]. 5050

Experimental work on the calcium status of brussels sprouts in relation to "internal browning", funded by a DAFS research studentship, is in its last season. Further work on compartmentation of calcium in buttons from plants grown in ^{45}Ca-labelled nutrients solutions has just been completed, and is being extended to buttons from field experiments for which yield data have been collected in relation to ammonium sulphate, sodium nitrate and calcium cyanamide fertilizer treatments. 5050

Work has just started, in collaboration with the Department of Forestry, University of Aberdeen, on ion flux studies in spruce needles and birch leaves to evaluate the effects of acid rain on crown leaching in forests, and to

differentiate between nutrient down-wash originating from dry deposition and that originating within leaves. This work is funded by the Department of the Environment. 5050

Following an editorial invitation, a review article on calcium fluxes across cell membranes has been published[4].

Growth and morphology of Sphagnum

A twenty-month pilot study funded by HIDB, exploring the growth of *Sphagnum* moss species, began in October, 1984. The intention is to elucidate the optimum conditions for growth with the eventual aim of bulk production. *Sphagnum* moss is often the dominant plant on bogs and marshes, but is, nevertheless, usually slow growing in these nutrient poor sites, to which it is largely restricted.

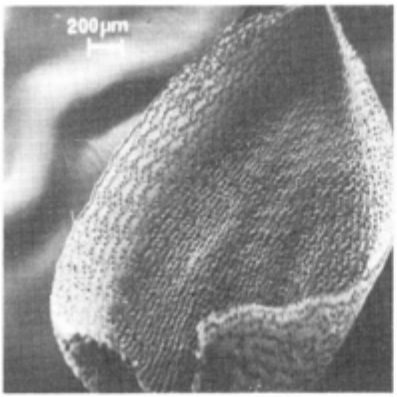

Fig. 5.2
Scanning electron micrograph of a whole leaf from *Sphagnum papillosum*.

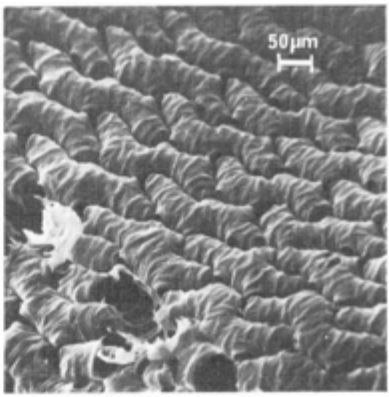

Fig. 5.3
Scanning electron micrograph of part of a leaf from *Sphagnum palustre*, showing detail of the hyaline cells.

Sphagnum is able to absorb large quantitites of water and the reason for this lies in the structure of the leaves. The leaves are one cell thick (Fig. 5.2) and composed of long narrow chlorophyllose cells alternating with large, balloon-like dead hyaline cells (Fig. 5.3). The latter have large pores in the walls allowing water to enter the cavity within, and enabling the plants to survive periods of drought. 5072

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6. MICROBIOLOGY

J. F. DARBYSHIRE

Most of the research in the Department 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 (N, P, S, minor and trace elements) in the soil microflora in both organic and mineral soils. Studies are also in progress on a range of secondary decomposer microbes and animals (actinomycetes, protozoa, nematodes, insects and worms) concerned with lysis and predation of the soil microflora. Some research is concerned with microbial weathering of parent rocks and soil minerals. It is the aim of these investigations to improve the understanding of the mode of transfer of nutrients from either inorganic or microbial fertilizers to plant roots. Extensive collaboration exists between members of the Department and with scientists in other Departments of the Institute and elsewhere.

Interrelationships between plant roots and microbes

Investigations have started on the decomposition of root systems of local crops (barley, grasses, peas and rape) in soil to determine the rate of release of nutrients (e.g. nitrogen and phosphorus) from the decaying roots to soil microorganisms and subsequent crops. The sequence of tissue degeneration in roots and the longevity of root channels and other biopores formed by worms will also be studied. 6025, 6027, 6028

A collaborative study with the Department of Soil Organic Chemistry on the nature of the root mucigel and other material released from cereal roots is being prepared for publication. The results were discussed in the previous Annual Report. 4020, 6025, 6027

Microbial decomposition in soil beneath Sitka spruce *(Picea sitchensis)* is being studied to understand the beneficial effect of planting mixtures of tree species on the nitrogen nutrition of Sitka spruce. This is a joint research project with the Department of Peat and Forest Soils and the University of Edinburgh; it is partly financed by an E.E.C. contract. Microbial activity was measured every month in fresh samples of litter, humus (L, F and H) and mineral soil from pure spruce and spruce-pine mixtures of Culloden forest in Inverness-shire. Microbial activity was estimated on each occasion by measuring basal respiration, glucose-amended respiration (Anderson and Domsch method), length of all hyphae, length of metabolically-active hyphae stained with fluorescein diacetate (F.D.A.) and the number of living bacteria stained with fluorescein isothiocyanate (F.I.T.C.). In the

preliminary results, the microbial biomass as estimated by the Anderson and Domsch method, the numbers of F.I.T.C.-stained bacteria and length of F.D.A.-stained hyphae were usually greater in the humus in the mixed stands than in the same horizon in pure spruce. Samples from the mineral soil beneath the humus showed no consistent trend with treatment and it is concluded that the increased growth in the mixtures is due to increased microbial activity and faster cycling of plant nutrients in the mixed stands. Supplementary experiments on the rates of decomposition of spruce and pine litter, intermittently watered to simulate rain and packed in large glass columns in the glasshouse, have shown that although the different types of litter have similar standing crops of microbial biomass, the microbial activity and the rate of nitrogen mineralization are greater in the pine litter. When pine and spruce litter were mixed together, greater microbial activity and nitrogen mineralization occurred in such mixtures than would be expected from the results from litters of individual species. It was also noted that large populations of enchytraeid worms developed amongst the litter in these glass columns and a new method of cultivating these worms may be developed from this discovery. 2055, 2807, 6027

A study of the phytotoxins and phytosanitary compounds in tree bark composts has started with the support of an A.F.R.C. studentship. Several horticultural crops (tomatoes, cabbage, cucumber, capsicum and cyclamen) were found to be stunted in fresh bark from Sitka spruce when compared with weathered bark or when grown in peat/sand composts. Tomatoes proved to be an ideal test plant. Leached bark and bark heated to 70°C also retarded growth of the same plant species. In the future, bark derived from carefully controlled fermentations will be investigated in an attempt to identify the toxins involved. The suppression of plant pathogens and pests (e.g. nematodes) in tree bark composts may be due to other constituents in the bark or to the stimulation of antagonistic microbes in the rhizosphere or on the root surface. The use of fluorescent lyzozyme conjugates to observe such antagonistic actinomycetes and bacteria is being investigated. 6025, 6026, 6027

Fungi

Ultrastructure. A comparison between the external morphology of two soil fungi, *Acremoniella atra* and *A. velata* has been published[1]. Both species have an epispore, but in *A. atra* this veil is not shed in contrast to *A. velata*. Originally, *A. atra* was isolated from soil within the grounds of the Institute and described as a new species. The same species has now been reported from rhizosphere soil attached to several plant species in West Germany.

The Hexland cryo-apparatus continues to be used in studies of soil fungi. Two lectures dealing with cryofixation for scanning electron microscopy were given in Edinburgh and London[2]. In collaboration with the Department of Mineral Soils, a poster was presented on the same subject at the 8th European Congress on Electron Microscopy in Budapest[3]. *Coprinus cinereus* was one of the fungi illustrated in this poster and was isolated from plant debris on the soil surface. A detailed study of the spore-bearing gills of this fungus have been made and differences in the morphology of the

cystidia were noticed between samples preserved by different methods. Cryofixed cystidia showed no distortion unlike other forms of fixation. Further details of these meetings will be found in appendixes I and II.

6026, 6028

Actinomycetes

Identification of *Streptomyces*. A probability matrix program in the main frame computer has been used to distinguish four species of *Streptomyces (S. albidoflavus, S. atroolivaceus, S. exofoliatus* and *S. chromofuscus)* isolated from the alimentary canals of soil invertebrates, litter, soil and composted bark. 6025

Protozoa

In collaboration with the Departments of Soil Survey and Soil Fertility, a comparison between two methods of estimating the size distributions of pores in different soil horizons has been submitted for publication[4]. These methods involve the use of either an image analyser or a camera lucida. The former method is rapid, but any enlargement of the original image of the soil pores yields inaccurate porosity measurements. In the camera lucida method, the outlines of the pores were drawn on to a digitizing tablet of a microcomputer; the areas of the pores were estimated by the computer and stored on floppy disks. Using serial sections and a suitable computer program, it is possible to view a selected group of pores in three dimensions. These methods will be tested for use in ecological studies of soil protozoa.

6031, 9014

Organic Matter

Microbial synthesis. In collaboration with the Departments of Soil Organic Chemistry and Spectrochemistry, a paper describing the production of vermiculine crystals by the soil fungus, *Penicillium wortmannii (Talaromyces wortmannii)* has been accepted for publication[5]. Vermiculine is a macrolide dilactone antibiotic. This fungus was isolated during studies of the microbial degradation of phenolic acids in fallow and

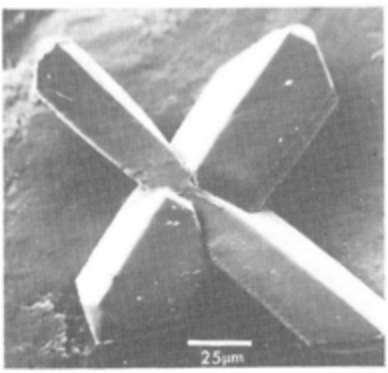

Fig 6.1.
Cruciform twin crystal of vermiculine, a macrolide dilactone antibiotic from liquid cultures of the soil fungus *Penicillium wortmannii*.

rhizosphere soils. Colourless crystals are produced in stationary cultures, but when the culture flasks are shaken the cultures turn orange or pink and more complex crystals are formed (Fig. 6.1). Infrared spectroscopy was used to establish that the crystals were vermiculine. Chloroform extracts of the culture filtrates are being investigated by thin layer chromatography and UV spectroscopy. As there are indications that the rate of production of vermiculine is dependent on such factors as aeration and supply of carbohydrate, further experiments are planned using a continuous culture fermenter with better control of pH, temperature, aeration and carbohydrate concentration in the cultures. The largest yield of vermiculine obtained from shaken batch cultures was 500 mg from 3.2 l. of culture filtrate. Further experiments with the Macaulay isolate of *P. wortmannii* are also envisaged to test its antagonism to other soil microbes.

3017, 3055, 4029, 6026

The candle snuff fungus, *Xylaria hypoxylon*, is another species under investigation with the Departments of Spectrochemistry and Soil Organic Chemistry. During March and April, it is possible to find black, erect and compressed fruit bodies of this fungus on the soil surface. The young fruit body or stroma can be produced in malt extract liquid media or agar, but not on potato dextrose agar. It has also been discovered that 20°C is the optimum temperature for growth. Sufficient stromas have been harvested from pure cultures to make it possible to examine the composition and location of the black pigment in this fungus. The sclerotia of the soil fungus, *Rhizoctonia solani*, are parasitized by *X. hypoxylon*, which forms a black rind of tissue around the outside of the sclerotia. These investigations are primarily concerned with the resistance of melanin-containing fungal material to decomposition and with the transformation of melanins into humin or other humic compounds in the soil (see Annual Report No. 53, p. 99).

3017, 4029, 6028

Polysaccharides. Recent studies of soil polysaccharides have included the effects of soil invertebrates on the decomposition of plant polysaccharides. Experiments with the common leatherjacket, *Tipula paludosa*, fed ^{14}C-labelled grass in soil have shown that these larvae stimulate the release of $^{14}CO_2$ from the soil. The nature of the soil polysaccharides in these experiments are being determined in collaboration with the Department of Soil Organic Chemistry. A paper dealing with the effect of sodium periodate on the stability of soil aggregates and discussed previously (see Annual Report No. 53, p. 100) has been published[6].

4020, 6027

Biomass. The sulphur in the microbial biomass has begun to be considered as a labile sink of this nutrient for crop plants in mineral soils. Preliminary results from three Scottish soils with sulphur deficiency indicate that the microbial biomass, as determined by Jenkinson's chloroform fumigation technique, contained only 3-6 mg S kg^{-1} soil. The ratio of biomass carbon:sulphur for two of these soils was approximately 150. In addition, the importance of the microbial biomass in the oxidation of

sulphur fertilizers applied to sulphur-deficient soils is being assessed in collaboration with the Department of Soil Fertility. Sulphur applied as potassium sulphate to a local soil (Boyndie Soil Series) was partly incorporated into the biomass, but very little elemental sulphur was assimilated by the microbes. 6027, 7038

A paper dealing with the availability of nitrogen and phosphorus to plant roots in peat and mor humus has been published[7]. The results were discussed in Annual Report 1983, No. 53, 101.

The first results of complementary studies of the reserves of trace elements in the microbial biomass discussed previously (see Annual Report No. 53, p. 101) are in the press[8]. It is intended to continue these studies in trace element deficient and toxic soils with the collaboration of the Department of Spectrochemistry. 3007, 6027

Suitable methods are being sought for extracting a large proportion of the microbial population directly from soil. Such methods will enable more direct measurements to be made of the nutrient reserves (N, P, S and trace elements) present in the biomass than is possible at present. 6027

Soil invertebrates. With the collaboration of the Department of Mineral Soils, pyrolysis-mass spectrometry continues to be used to study the changes in organic matter during digestion by soil invertebrates. Several species of woodlice and millipedes have been collected from several sites in Britain and the food, gut contents and faeces are being analysed by this technique. 1018, 6027

More detailed chemical analysis of the faeces of the common leatherjacket, *Tipula paludosa*, showed that the major nitrogenous compounds excreted were uric acid (4.4 μg. g^{-1}) and ammonium nitrogen (0.3 μg. g^{-1}). Only small amounts of urea (0.04 μg. g^{-1}) were excreted and not as reported previously (see Annual Report No. 53, p. 102). Anaerobes were the dominant bacteria in the digestive tract of *T. paludosa* and were confined to the hind gut. Bacterial numbers declined as the larvae matured and three species of ureolytic bacteria were isolated *(Enterobacter cloacae, Aeromonas sp,* and a coryneform bacterium). The microflora colonising the digestive tracts of two common species of woodlice *(Oniscus asellus* and *Porcelia scaber)* have also been examined with the light and scanning electron microscopes. Contrary to previous reports, the hind guts of both species were colonised by bacteria. The size of the bacterial population depended on the age, habitat and diet of the woodlice, but many bacteria were stained with tetrazolium salts and were presumed to be metabolically active. Attempts are being made to identify one of the dominant bacteria colonising the hind guts of these woodlice. 6027

With the collaboration of the Departments of Spectrochemistry and Mineral Soils, the microbial decomposition of the exoskeletons of *O. asellus* has begun to be studied in soil. It is well known that these exoskeletons contain calcium carbonate apart from chitin and protein, but it has now been demonstrated that in addition to crystalline calcite an amorphous form of calcium carbonate is present. Preliminary studies suggest that calcium carbonate provides the chitin with some protection from microbial

decomposition. In the future, it is hoped to determine the relative importance of bacteria, fungi and actinomycetes as the early colonists of these exoskeletons.

The relative effects of different invertebrate predators on the flux of nitrogen and phosphorus from bacteria in soil are being investigated in simple mixed cultures. Sterilized soil was inoculated with the bacterium *Pseudomonas fluorescens*, and amended with varying amounts of glucose. The bacterial predators used in these experiments were the ciliate, *Colpoda steini*, and the nematode, *Rhabditis* sp. It was found that ciliates increased more rapidly in the presence of nematodes than in their absence. Nematode populations, however, increased most rapidly in the absence of ciliates. Nematodes in their turn appeared to stimulate bacterial growth, but supplementary experiments in liquid culture suggest that this was not due to the secretion of sugars or amino acids by the nematodes. In contrast to earlier reports in the literature, the greatest flux of ammonium nitrogen into the medium occurred when the grazing pressure was low. The influence of the size of the population of micropredators on the availability of microbial nitrogen and phosphorus to plant roots is being investigated in pot experiments. 6027

Peat microbiology. An abstract of a lecture on the distribution of anaerobic bacteria in a local deep peat deposit at Lyne of Skene has been published[9]. The results of the controlled water-table experiment at Lon Mor near Fort Augustus are being prepared for publication and were the subject of a lecture in Nottingham[10]. These studies are in collaboration with the Department of Peat and Forest Soils. The numbers of both aerobic and anaerobic bacteria decreased as one moved down the profile and drainage resulted in an increase in numbers of aerobes above the water table. The numbers of ammonifying bacteria also significantly increased above the water table after drainage. The absence of nitrifying bacteria and small numbers of nitrate reducers suggest that drainage may not necessarily lead to a loss of nitrogen from organic soils. The very significant increase of nitrogen-fixing bacteria above the water table after drainage could result in an overall increase in nitrogen in the long term. 6027, 2055

The results of recent studies of iron ochre deposits in field drains were presented at the International Peat Congress in Dublin[11]. Two other papers have been published on this subject[12, 13]. These investigations were in collaboration with the Departments of Soil Organic Chemistry and Soil Survey. Laboratory experiments have shown that the rate of precipiatation of iron in ground water is more than twice as rapid in the presence of iron-oxidising bacteria compared to bacteria-free solutions. For example, in a ground water containing 12 mg Fe. 1^{-1}, all the iron was precipitated in 70 h, in samples filtered to remove all microbes compared with 32 h. for unfiltered samples. 4801, 6027

In collaboration with the Department of Chemistry at Bristol University, a paper describing the extended hopanoids in different peat deposits has been published[14].

Microbiological Weathering. Collaborative studies with the Departments of Mineral Soils and Spectrochemistry on microbial weathering of soil

minerals and rocks has continued with the publication concerned with occurrence and significance of manganese oxalate in the lichen, *Pertusaria corallina*[15]. At a meeting dealing with lichen physiology in Bristol, a poster was presented with the title "Manganese oxalate dihydrate associated with a crustose lichen colonizing a manganese ore". 1002, 3005, 6028

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7. SOIL FERTILITY

N. M. Scott

The overall objective of the Soil Fertility Department programme remains the development and use of field, pot and laboratory investigations to improve the efficiency of applied fertilisers and consequently, the quantity and quality of crops. To achieve this, investigations are carried out on contrasting soils, and crops to measure the chemical and physical processes which regulate nutrient supply and crop growth, with the emphasis remaining on the behaviour of soils, which is both the matrix in which crop roots grow and the source of their nutrient supply.

Consultative studies and advisory soil testing in collaboration with the North of Scotland College of Agriculture (NOSCA) continues to be a major role within the Department, and increasing importance is being given to attendance by Department personnel at agricultural shows and farmer meetings. These are important channels through which Departmental research findings are disseminated, and are of vital importance to elicit practical problems as subjects for research investigation.

The Department was also represented at the "Barley 84" exhibition and Royal Show, and a Technical Note, entitled "Maximising the yield of winter barley" was prepared for distribution at both events. The note summarised factors which affect the nitrogen requirement of the crop, and made observations relating to yield potential. A further note on the effects of nitrogen on the yield and yield component of spring barley has also been prepared and is now available. The programme has also been extended to include studies on the effect of timing of nitrogen and sulphur applications on tiller die-back and spikelet mortality in barley.

Collaborative studies with the Rowett Research Institute have begun on the feeding qualities of sulphur deficient and sufficient grass and a joint study with the Scottish Crop Research Institute (S.C.R.I.), as detailed in last year's report will continue in 1985.

The Department is represented on a number of committees; the COSAC/MISR Liaison Committee and its Working Groups on yield Constraints, Working Parties on the Soil Fertility Information System and Soil Advisory Analysis, COSAC Fertiliser Recommendations Review Group and the Soil Analysis Users Group.

Several staff changes occurred during the year. Dr B. W. Bache resigned as Head of Department to take up an appointment in the Department of Applied Biology, at Cambridge University, while two new members of staff, Drs David Robinson and Lorna Mackie have been appointed to work on

crop and soil nutrition, and soil physics respectively. Dr Robinson's remit is to investigate nitrogen transformations in soils using ^{15}N, while Dr Mackie will study soil compaction effects on root growth.

Dr Peter Wilson was awarded the degree of PhD by the University of Aberdeen for a thesis entitled "A laser lidar differential absorption system for the measurement of atmospheric sulphur dioxide".

Field Crop Studies

Nitrogen for Winter Barley. Based on 22 trials carried out over three years the NOSCA/MISR fertiliser recommendations to optimise grain yields, have been revised, and for soils with low, moderate and high N

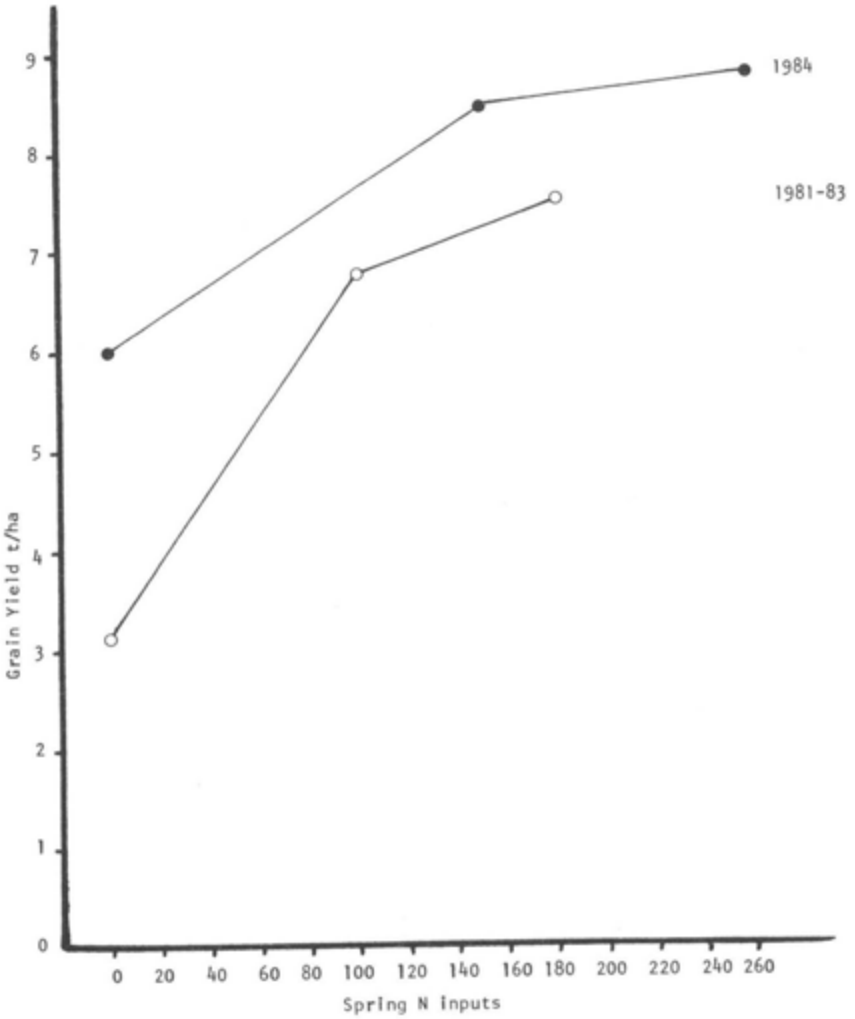

Fig. 7.1
Response of Winter Barley to Nitrogen applied in spring.

status, applications of 200, 150 and 100 kg N/ha are recommended in place of 120, 80 and 40. Some small doubt surrounds the new recommendations because of the drought conditions which prevailed throughout the trial period. Drought may have restricted the lodging of experimental crops to minimal levels and allowed a larger response to nitrogen than in a normal season. However, despite this, yields were good ranging from 7.4 to 10.1 t/ha with an average of 8.8 t/ha of grain (15 per cent moisture) with optimum N. The main effect of drought is to reduce the efficiency of a nitrogen application in terms of grain produced per kg N applied. The relationship between N inputs and grain yield is consistent with a "split line" function as shown in Fig. 7.1. 7048

Nitrogen on Winter Wheat. An increase in the acreage of winter wheat in north Scotland in recent years has created a demand for information on the optimal amount of nitrogen required. A pilot trial with 7N levels ranging from 160-340 kg N/ha applied in spring and summer has shown that the best yield of 10.6 t/ha was obtained with 190 kg N/ha, and decreased slightly probably due to smaller grain, to 10.1 t/ha at highest N inputs. High N rates gave marginal increases in ear no/m^2 and in total dry matter production throughout the season. Further field trials have been planned for 1984/85 and over the next few years the emphasis will be transferred from barley to wheat. 7048

N Transformations. Since nitrogen fertilisers are expensive, it is essential that efficient use and accountability is made of field applications. To measure this an experiment to study the nitrogen balance on a spring barley (Golden Promise)/grass rotation at a long term field site (Cross of Jackston, Ann. Rep. No. 53) has been started. Particular emphasis is being placed on the transformations of soil and fertiliser nitrogen during and after the growing season using ^{15}N. Throughout the summer of 1984, soil and crop samples were collected at regular intervals for measurement of nitrate and exchangeable ammonium ("available N") and non-exchangeable ammonium and organic N ("unavailable N") in soil, and total nitrogen in crops. ^{15}N analysis will be carried out on an SIRA 9 mass spectrometer for which sample handling and operating procedures have been developed in conjunction with staff from the Department of Mineral Soils. Work will continue throughout the winter to monitor nitrogen changes which occur during the post harvest and winter periods, so that any carry over into next year can be assessed. Similar work on nitrogen transformations with potatoes and spring barley are planned for 1985. This work will help our understanding of the dynamics of nitrogen in soils as affected by climatic variations in north Scotland, and enable a more accurate prediction of the nitrogen requirement of a crop to be made. 7039

Nitrogen for Potatoes. The effectiveness of nitrogen applications on potato yields was measured in field experiments in 1983 which showed that the optimal N dressing for potatoes was 150 kg N/ha, and that yield benefits at this rate were only apparent at later harvests due to an increase in light interception by the crop at the end of the growing season. Drought conditions however, caused a severe check in growth and decreased the yield by an estimated 10.1 t/ha. The experiment was, therefore, repeated in

1984 at two sites, one in Aberdeenshire with no irrigation and an irrigated site at Dundee in collaboration with SCRI. The highest yield without irrigation was 56.8 t/ha again obtained with 150 kg N/ha, while the irrigated site yielded a maximum of 81.1 t/ha with 240 kg N/ha, see Fig. 7.2. The increase at the latter site was due partly to irrigation, but also to a longer growing season, and showed that N applications in excess of 150 kg N/ha are only justified if irrigation facilities are available. Analytical and photographic monitoring of the crop provided data on nutrient composition and an estimate of light interception by the canopy, and the data are being assessed to determine whether yield increases with N applications are the result of increased light interception or an increase in the efficiency with which intercepted radiation is used for dry matter production. Leaf analyses have shown that total N concentrations were similar regardless of their stem

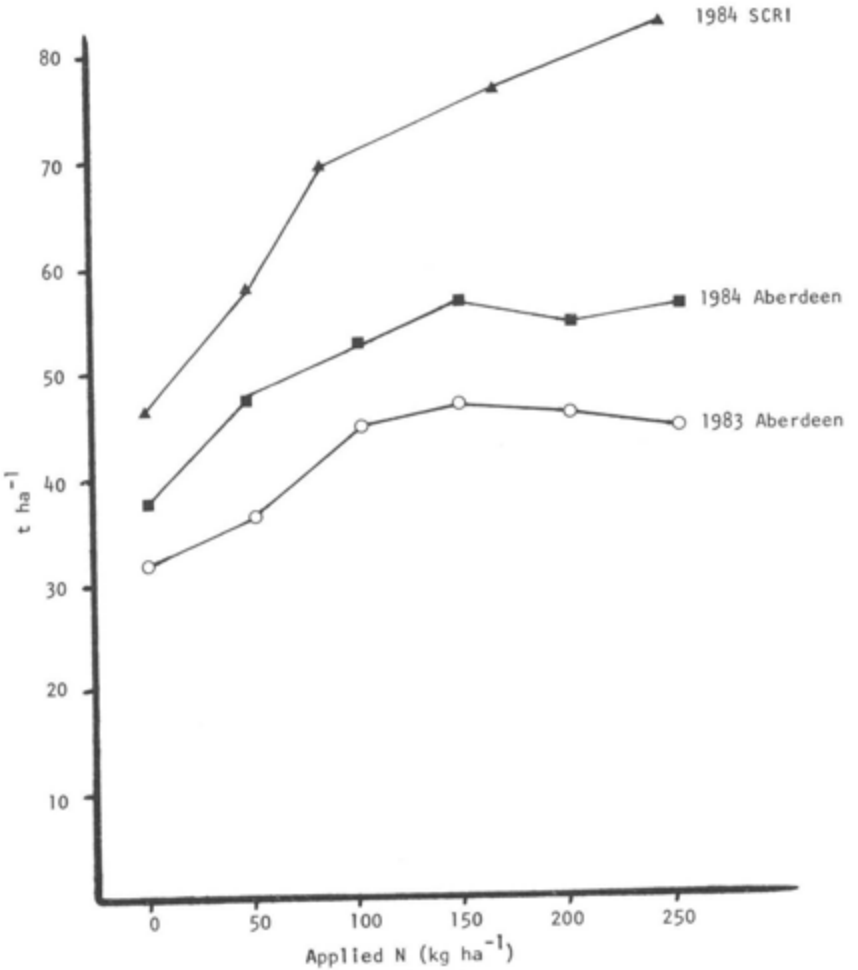

Fig. 7.2
The effect of nitrogen application on the fresh weight yield of potatoes.

position during early stages of canopy growth, and only at leaf senescence was there a marked difference. Senescence occurred with base leaves first which gave lower N levels resulting in a gradation in concentration to upper leaves of the stem. The pattern was the same irrespective of N treatments although concentration depended on N applied. Leaf nitrate concentrations were very small in N untreated plants, but a gradation occurred in N treated plants with the highest concentrations in the lowest leaves. It appears that excess N taken up by the crop is stored as nitrate in the shaded or photosynthetically inactive leaves at stem base and in a reduced form (protein and amides) in upper leaves. These differences could be useful as a tissue test for diagnosing the nutritional status of a crop. 7047

Overwintering of Swedes. Work on the changes in the chemical composition and hence the nutritive value of nine varieties of Swede of differing winter hardiness over the winter, detailed in the last Annual Report No. 53 has been published.[1] An experiment to investigate the pattern of sugar accumulation over the autumn and winter in two contrasting varieties, Ruta Øtofte and Melfort, is currently under way. Four nitrogen rates (ranging from nil to 150 kg/ha) have been used to produce differing levels of canopy growth to allow an assessment of the importance of the canopy in providing protection of the root against frost, and determine whether this is influenced by nitrogen application. 7047

Effect of Applied Nitrogen on Cereal Straw Digestibility. Collaborative work with the Rowett Research Institute described in Annual Report No. 53 has continued and digestibility measurements on Oat as well as Barley Straw samples are in progress. Cellulose measurements taken before and after the digestibility trials have been used as a marker for the cell wall content of samples. The results suggest that spring nitrogen application, while altering the N content of the straws has no effect on the digestibility of the cell walls themselves. Changes found in the straw digestibilities produced by N application were, therefore, due to changes in the soluble sugar levels. Analysis of further samples is being used to confirm this relationship between straw-soluble sugar level and digestibility in both Oats and Spring Barley. 7047

Nitrogen/sulphur interactions. Pot trials with oats showed that grain yield increased with increasing nitrogen when adequate sulphur was available, but in the absence of sulphur excess nitrogen reduced the grain yield. In 1984, field trials with winter barley were conducted at four low sulphur sites, on two soils from the Laurencekirk Association and on two Boyndie Association soils. Of the four trials only one site showed a trend for high nitrogen to decrease the yield in the absence of sulphur, but the result was not significant. Further trials have been set up for 1984/85 since 1984 was a drought season which may have affected results. 7038/7039

Ammonia-treated vermiculite. A field experiment in collaboration with the Department of Spectrochemistry to compare the effectiveness of nitrogen supplied to grass from ammonium nitrate and ammonia-treated vermiculite produced interesting results at the second cut. (See Spectrochemistry Section 3). 7039

Soil pH. An experiment started in 1978 to study the effects of soil pH on barley grain yields, was cropped with winter wheat in 1983/84. The yield with a soil pH of 6.2 was 8.6 t/ha. Relative yields with pH of 5.0, 5.6 and 6.2 were 71, 88 and 100 respectively, this compared with relative yields of spring barley (mean of 5 years) of 81, 97 and 100. This result is very surprising in view of the generally accepted belief that barley is much more severely affected by low pH than wheat. Further investigation of this result will be carried out on another site, with a greater range of soil pH, in 1984/85. 7040

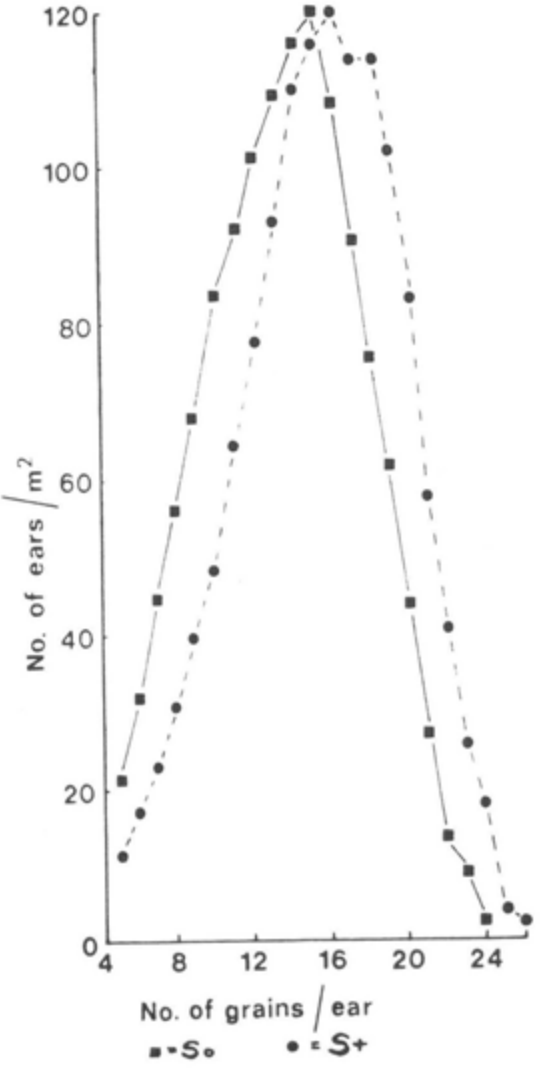

Fig. 7.3
Grain Distribution Diagram.

Sulphur. Sulphur deficiency is a problem in north Scotland due to low atmospheric and fertiliser sulphur inputs and low amounts of available soil sulphate. To obtain further information field trials with sulphur and several crops continued during 1983/84. The results obtained have been reported in several papers,[2, 3, 4, 5] and a paper describing the effect of sulphur on the yield and composition of winter barley has now been published.[6] This showed that a significant overall increase in dry matter grain yield of 0.6t ha^{-1} was obtained due to added sulphur, and crop measurements showed that the response was attributable to an increase in the number of grains per ear, Fig. 7.3.

Two experiments to assess the effect of different sulphur forms on grass were set up on an Old Red Sandstone and an Auchenblae soil (Red fluvioglacial sand and gravel).

The sulphur forms used were elemental sulphur applied as a foliar spray and ammonium sulphate.

Different commercial brands of elemental S were used and applications were made at manufacturers recommended rates. Significant increases were obtained with all forms of applied S after the first cut, particularly on the Auchenblae soil, and both sulphur uptake and crop composition were improved. The same site has been earmarked for a digestibility experiment in collaboration with the Rowett Research Institute in 1985. Material from the fourth cut provided most interesting results in the total amino acid content and clearly illustrates the effect of added sulphur in the yield and quality of crops.

Selenium. Previous work on selenium fertilisers concentrated on selenites since selenates are too mobile and produce excessively high crop selenium levels immediately after application to soils. Recent work in New Zealand used sodium selenate immobilised on pumice granules to provide a

TABLE 7.1
Effects of Selenium treatments on Plant Se content
Plant Se Concentration (μg/g)

Treatment	1st Cut (May)	2nd Cut (July)	3rd Cut (September)
Se 0	0.050	0.023	0.060
N Se 0	0.030	0.017	0.057
Se 1	0.69	0.53	0.144
N Se1	0.73	0.42	0.082
Se 2	1.9	0.57	0.340
N Se 2	2.6	0.60	0.23

Treatment Codes
Se 0 = No selenium added
Se 1 = 17 g/ha Se
Se 2 = 35 g/ha Se
N = 10 kg/ha N as nitrochalk at start of experiment, repeated after each cut (otherwise no nitrogen added)

slow release form of selenium, and this product has been used on a Countesswells soil (granite and granitic gneiss) with grass. Two selenium levels were used 17 and 35g Se/ha and all plots received P and K but only half received N. The results, Table 7.1, show the mean selenium content in the untreated plots was 0.038 μg/g which is below the minimum requirement, while plots receiving the recommended rate of 17g Se/ha gave mean values of 0.7 μg/g at the first cut falling to 0.1 μg/g at later cuts. Both these values are acceptable selenium levels but care must be taken not to apply too much material since plots receiving 35 g Se/ha showed potentially toxic levels. Further trials are planned for 1985 on different soil series although laboratory work suggests that soil type will not play such an important role as with selenites when up to tenfold variations in uptake were noted in different soil series. 7045

Physics

Unconfined compressive strength. The investigation of the relationship between unconfined compressive strength (UCS) and soil matric water potential for a sandy loam and a clay loam soil has been extended to include other soils of different texture. The differences, between UCS values for all soils examined over the complete range of soil moisture tensions, were not significant due to the inherent variability of soil texture and difficulties experienced in obtaining homogenous samples. Further work with disturbed soil samples is planned for 1984/85 when these preliminary problems may be largely overcome 7044

Effect of compaction on spring barley yields. A pilot experiment with spring barley on a soil from the Countesswells association has shown that uncompacted plots (bulk density = 1.30g/cm^3) gave better yields (5.6 t/ha) than compacted areas (bulk density = 1.94g/cm^3) (5.1 t/ha). The difference, although not significant because of the small number of plots used, was sufficient to justify further experiments in 1985.

Potato scab. A field experiment to ascertain the criteria for the development of common and powdery scab on potatoes has commenced at a site already affected by the disease. The moisture regime of the site will be measured, using both manual tensiometers and the neutron probe, as well as the effect of deep loosening cultivation on the moisture content of the topsoil. Preliminary studies in 1984 have shown that this type of cultivation may well reduce the incidence of powdery scab. 7044

Root growth and crop yields in the Spey Valley. A collaborative study with the Department of Soil Survey is under way to study the effect of lowering the water table on soil physical conditions in the Spey Valley. Changes in the physical properties of soils may affect the distribution of roots and yields. Neutron probe access tubes have been installed to measure the moisture requirements of several different crops and extensive root distribution measurements have already been made using 0.5 and 1.0m grid squares laid in profile faces cut perpendicular to the crop rows. Further measurements will be made in 1985, on a different water table level achieved by pumping out a small amount of water, and compared with 1984 values. 7044

Lysimeter Studies. Following preliminary trials using a simplified inexpensive design of lysimeter, root and field experiments are to continue in 1985 to investigate the effect of compaction on nutrient leaching, root and crop growth. Leachate will be collected for analysis, to ascertain the effect of compaction on nutrient leaching and provide data to model N and S input and output balances. 7044

Pot Culture Studies. Interest in sulphur applications to sulphur deficient crops has raised the question as to the form in which sulphur should be applied. Foliar applied elemental S and soil applied S were compared in a pot study with grass and a low S soil. All sulphur applications were labelled with ^{35}S and four cuts were taken. Irrespective of the sulphur form used large responses were obtained over the control (13.9g) with S as ammonium sulphate applied at each cut being highest, (76g). An interesting feature of the elemental S treatments (usually applied as a foliar spray) was obtained when micronised sulphur was mixed into the soil at filling (74g) and when sprayed on to the soil before germination occurred (69g). The latter result has practical implications since it could be used to apply sulphur to sulphur deficient, winter sown crops when growth was minimal. A grass crop sprayed with elemental S three weeks before the first cut gave a total yield of 69g and labelled sulphur could still be detected in the fourth cut. A foliar application of sulphur to a nil treatment before the third cut increased the yield from 1.1g to 3.2g at the third cut and from 1.8 to 15.7g at the fourth cut, and demonstrates that foliar applied sulphur although reacting quickly requires time for its full affect to materialise.

Soil Chemistry

Potassium. A summary account of data comparing soil K and Na fractions released by electroultrafiltration (EUF) with conventional methods of extraction and grass growth, described earlier (Annual Report No. 53, 1983), has now been published.[7] Collaborative work with Rothamsted Experimental Station, comparing rates of release of potassium from soils from two long-term experiments with yield and K offtake by winter wheat, has been published,[8] and this work using Scottish soils, aimed at assessing various release curves to describe the differences in soil K between different Soil Series and between high and low K soils will continue. The curves used are Ca-resin, HCl-leaching, HCl-reflux and K offtake by ryegrass grown in pots. 7041

Field Soil and Crop Studies

Oil seed rape. The effects of soil pH and trace elements on the yield and mineral composition of oil seed rape have been studied in collaboration with the Department of Soil Organic Chemistry and the Department of Soil Science, Aberdeen University. Where soil phosphate levels were moderate or high, the yield of oil seed rape was reduced at pH values below 5.6, but where soil P was low there was a reduction in yield below pH 6.1. Soluble aluminium measurements are being made to establish whether this is an indirect effect of applied P in reducing Al solubility, or is a direct effect of P nutrition on the growth of the crop, similar to that reported with spring

barley (Annual Report No. 53, 1983). The latter is more likely as soluble Al levels are expected to be low at soil pH values greater than 5.6 at sowing. However, the level of soluble Al is greatly increased during the growing season by a substantial reduction in pH of about 1.5 units in May at growth stage 33. This pH reduction is probably caused by the 250 kg N applied in March/April as ammonium nitrate.

Oil seed rape tissue manganese concentration in November ranged from 75 to 8 μg/g dry matter (DM) corresponding to soil pH values of 4.5 to 6.5. Manganese concentration was below 15 μg/g with soil pH values of 5.5 and above, but yield of mature seed was not reduced by Mn deficiency. This was due to the large decrease in pH with a corresponding large increase in Mn solubility. Tissue Mn levels in May at growth stage 33 ranged from 125 to 30 μg/g. Tissue boron concentration ranged from 20 to 10 μg/g DM in November, but had increased to a range of 40 to 15 μg/g in May.

Manganese. Field trials on manganese deficiency in cereals included a seed treatment of spring barley in 1982 and 1983. Soaking the seed with $MnSO_4.H_2O$ solution increased Mn concentration in the crop at the 4 leaf growth stage compared with no treatment, the extent of the increase depending on the method of fertiliser application.

Combine-drilling ammonium nitrate-based NPK fertiliser with the Mn treated seed increased the Mn concentration from 21 to 40 μg/g, whereas the increase was from 14 to 24 where the NPK fertiliser was broadcast on to the soil surface prior to sowing. This is probably due to the lower pH in the rhizosphere soil in the early part of the season following combine-drilling compared to broadcasting, which has held the Mn from the seed treatment in an available form. With untreated seed combine-drilling increased the Mn concentration from 13 to 21 μg/g compared to broadcasting.

The total Mn removed by the crop was increased from about 45 to 65 g/ha by seed treatment and combine-drilling compared to untreated seed and broadcasting the fertiliser, and the corresponding increase in yield of grain was from 4.1 to 5.5 t/ha at 15 per cent moisture content. Manganese sulphate foliar spray (1.5 kg Mn/ha) increased the untreated seed/broadcast fertiliser treatment to 4.8 t/ha, but there was no further significant increase in the seed treatment/combine-drilled plots. 7041

The adequate prediction of plant availability of trace elements based on their chemical extractability from soil samples taken prior to seed sowing is not always possible, and factors responsible are being investigated in collaboration with the Department of Soil Organic Chemistry. Data reported earlier (Annual Report No. 53, 1983) showing changes during the growing season in the concentrations of manganese, zinc and copper in the rhizosphere in soil solutions of spring barley have been submitted for publication.[9] This work has been extended to seven commercial spring barley crops grown on contrasting soil types. During the early period of growth, additional manganese became extractable by $CaCl_2$ from fresh rhizosphere soil where pH ($CaCl_2$) dropped below about 5.5, caused by the acidifying effect of N fertiliser. During June and early July there was substantial mobilisation of $CaCl_2$ — extractable manganese into soil solutions, obtained by a centrifugal method. At sowing, soil-solution

manganese was, in general, less than 5 per cent of the $CaCl_2$ extract, while this increased in the rhizosphere to between 30 and 60 per cent in June and early July, and subsequently dropped to about 10 per cent at harvest. This mobilisation into the rhizosphere soil solution may help to explain why some barley crops grow out of a manganese shortage. The recovery from manganese deficiency may depend critically on the relative rate of Mn mobilisation and the rate of growth of the crop. This work is done in collaboration with the Department of Soil Science, Aberdeen University, and a summary account of the work is to be published.[10] The work has been extended to include winter barley, ryegrass and clover. Moisture release characteristics are being measured to describe pore size distribution and water availability. 7041, 4803, 7044

Development and Advisory Work

A number of sections of the Bulletin on Fertiliser Recommendations, prepared jointly by staff of the North of Scotland College of Agriculture and the Macaulay Institute, have been updated for arable crops grown in the North of Scotland.[11] A Scottish Bulletin on Fertiliser Recommendations is being prepared by staff of the three Scottish Colleges of Agriculture and the Macaulay Institute.

Three papers covering soil fertility and advisory analysis were given at a Course on Soil Management — Principles and Practices for Modern Agriculture, organised by the North of Scotland College of Agriculture,[12, 13, 14] and a review paper on trace elements in soils and fertilisers is to appear in Scottish Farmer.[15] During the year many requests about soils, fertilisers, related crop and animal problems have been dealt with, and a number of talks have been given to farmers' groups organised by the North of Scotland College of Agriculture.

A common system of advisory soil analysis and interpretation of results for major and trace elements at the East of Scotland College of Agriculture, West of Scotland Agricultural College and the Macaulay Institute have been agreed by the Macaulay/COSAC Liaison Group. A Bulletin has been prepared which describes these methods of analysis and the interpretation of results.[16]

"Available" soil P, K and Mg will be extracted with 0.43M acetic acid solution at all three centres in place of ammonium lactate + acetic acid solution as reported earlier (Annual Report No. 52, 1981/82). Different critical values between soil P categories for different soil series have been introduced where this is justified by experimental results. In the meantime, a mixed anion/cation exchange resin method is being evaluated for soil testing. 7041

Advisory Analyses. The recent increase in the number of advisory soil samples from the North of Scotland College of Agriculture has continued and passed 10,000 in the current year. Most of these were for major nutrients, pH and lime requirement, but 1200 included trace elements. 200 forest soil samples from throughout the UK were also analysed. A number of crops and herbages were analysed for major and trace elements in relation to poor crop growth or animal problems. 7043

Soil Fertility Information System. The computerised Soil Fertility Information System for Scotland, which was described earlier (Annual Report No. 53, 1983), is expected to start on 1 January 1985. During the past year a three category scheme for estimating soil N status, based on the ADAS approach, but modified for the Scottish situation, has been adopted and used in the 1984 Fertiliser Bulletin.[11]. It is hoped to obtain information on the trends in soil nutrient levels under different farming systems. Reference to lowland and upland farms has been dropped because of the difficulty in defining these terms. Instead farm types are related to the percentage of grass in the system and the amount of nitrogen used. 7041

Radioactive Services

Radioactive tracers continue to be used extensively in the Institute. ^{75}Se and, for the first time in this Institute, ^{203}Pb are being used to perfect new analytical techniques whilst ^{54}Mn is helping to investigate the uptake of manganese in the plant by spraying with various chelating agents. Influx and efflux studies with ^{56}Co continued as part of the Department of Plant Physiology's trace element programme as is the growth of brussels sprouts in ^{45}Ca labelled nutrient to study the effects of Calcium related disorders. *Lemna* was grown in a ^{14}C-glucose medium to provide a source of labelled soil organic matter whilst further work on the transformation of sugar carries on. Further radioanalysis of ^{14}C labelled potato tubers is being carried out for the Scottish Crop Research Institute. ^{35}S is used to study the uptake and transformation of sulphur applied both in the soil or sprayed on to the plant leaves as a suspension or in solution.

The purchase of a portable dose ratemeter and of a low level contamination meter has considerably improved the radiological safety procedures for the Institute. 0000, 0949, 7049

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8. STATISTICS

R. H. E. Inkson

The activities of the Department are concerned with the provision of services, to colleagues throughout the Institute, in statistics and in computing, including the development of the Institute's Soil Information System. Collaboration has continued in devising appropriate designs for field, glasshouse and laboratory experiments and in the selection of sampling units for surveys. The service continues from the statistical analysis of the data to the interpretation and presentation of results stages. The computing service includes a range of activities from data entry and verification to both hardware and software development and database management. Courses of instruction and supervision continue to be provided for those wishing to use the computing facilities. Members of staff attended meetings of the Biometric Society, the Royal Statistical Society and the AFRC Modellers' Group, demonstrations of computing equipment, database management systems and digital mapping, and training courses on image processing and various aspects of computer software including system programming. The Department has been represented at meetings concerned with the establishment of a Scottish Soil Fertility Information System, standards for access to and exchange of soil data, computing policy in SERC and in AFRS, and the statistical analysis of trace element data.

Computing

The central computing facilities for the Institute are provided in the Department which is responsible for the planning, development, management and operation of the system. In addition to the operator console and disk, diskette, magnetic tape and tape cartridge units, the Data General Eclipse network now extends to 24 VDU and graphics terminals, 10 mini and microcomputers controlling instruments, 4 printers and a plotter. A recent modification has been the provision of lightning protection following the damage caused by a severe electrical storm which affected several computer installations in the city. All lines to remote terminals such as those in Craigiebuckler House had been affected by a transient voltage surge. Convenience back panels, designed by Technical Services, provide more ready access for the network connections. Improvements to the letter quality printer have doubled the printing speed and added facilities for subscripts and superscripts. The system is now regularly available from 8 a.m. till 5 p.m. with overnight running as required. 8059

Modification of the Ordnance Survey's DO9 digital mapping package

J

made it possible to produce contour maps using the D.G. Eclipse and the Benson graph plotter. Maps of the south-west of Scotland from O.S. data and of the Dyce area from our own digitised data were drawn but the program package did not prove sufficiently rugged or flexible for extensive use. Collaborative work with the Department of Soil Survey has assessed the value of GIMMS, a digital mapping package developed at the University of Edinburgh. Since the package is too large for the D.G. Eclipse, all trials have been made at the Aberdeen University Computing Centre and 1:10000 soil maps of the Dyce and Kilmarnock areas have been produced. 8059, 9012

The MIMER and RAPPORT database management systems are being assessed at present. Both packages are too large for the D.G. Eclipse but, as with GIMMS mentioned above, are available for the D.G. MV4000 32-bit computer. As well as experiencing limits on the availability of program packages, the 16-bit memory of the present D.G. Eclipse has proved a limiting factor for many of the Institute's application programs. For example, the multivariate analysis program for the organic matter pyrolysis project cannot accommodate more than 50 mass ions per spectrum which usually contains 100 to 200. Thus time is spent making ion selections and valid data may be lost or ignored. Progress is being made in adapting for the D.G. Eclipse the ISIS 80 program package for modelling dynamic systems. 1018, 8059, 8802

Improvements have been made to a number of statistical programs. A subroutine permits the storing of selected values after the completion of analysis of variance, and additional flexibility has been provided for t-tests. Amendments have been made to routines for sorting, plotting and missing value estimation and to the input sequence for the analysis of dilution series data. Three-dimensional plotting is now generally available. 8057, 8059

Soil Database. The database contains information from two main sources. From the systematic collection of profile descriptions at the 5km national grid intersections, approximately two-thirds of the possible 3,200 have been completed and stored in the database. The horizons of profiles on a 10km grid have been sampled and the results of mineralogical and spectrochemical analysis are also stored. Similar information is stored for selected sites of special interest or for specific investigations such as opencast coal sites. An account of the design of the database is being prepared for publication. On-line interrogation of the data is now possible using a given key, either national grid reference, lab. number or profile title, to identify a record. An example of an interrogation with graphical output showing the distribution of soil drainage categories is illustrated in Figure 8.1. 1802, 8802, 9802

Mineral Soils. A FORTRAN 77 program, entitled FRAME C, written for a VAX 11/780 computer has been adapted to run on the D.G. Eclipse to process results from electron microprobe analysis. 1804, 8059

Spectrochemistry. Several links between the D.G. Eclipse and microcomputers controlling instruments have been established. The d.c.-arc emission polychromator is interfaced to an Apple II which stores data on diskettes prior to transmitting to the D.G. Eclipse for further processing and analysis. This Apple-Eclipse link is also used by the infrared

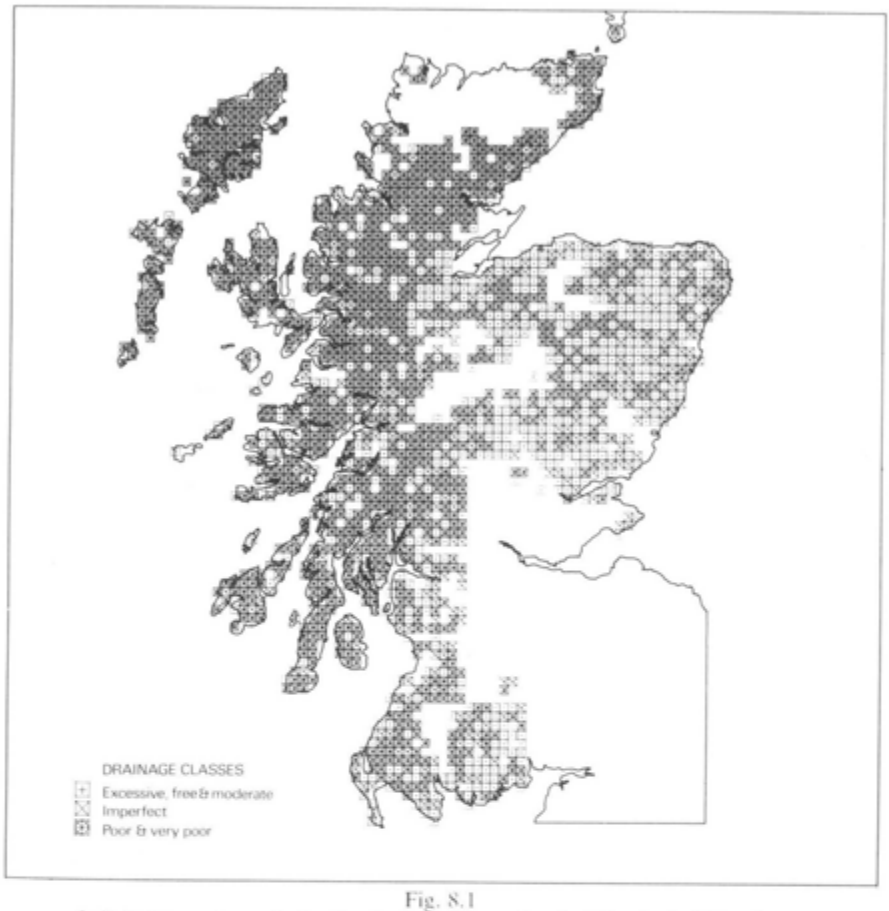

Fig. 8.1
Soil drainage classes in Scotland, plotted from data held in the Soil Database.

laboratory to build up in the Eclipse an extensive library of infrared spectra of clays and minerals in readily accessible form. This provides better facilities for the processing of infrared spectra such as subtraction of spectra to eliminate interfering spectral components. The EPR spectrometer is similarly linked to the D.G. Eclipse via an Apple IIe microcomputer.
3005, 3010, 8059

Soil Fertility. Progress has continued on setting up a database containing the field information and analytical results for advisory soil samples. The link to the D.G. Eclipse from the Commodore 715 microcomputer in the Department of Soil Fertility is now fully operational. 7041, 8059

Soil Survey. The service in the processing and retrieval of results has continued for plant phytosociological data from vegetation surveys.
9015, 8059

Statistical Advisory and Collaborative Work

Peat and Forest Soils. Routine processing of growth assessment and foliage sample data for the series of six experiments of central composite design with controls has continued. Data collection has now ceased at some sites. Forest floor samples were taken to correspond with initial and final whole tree samplings at each site, and calculations for weights have been completed. Analyses of variance were done for dry weight upper (litter) layer, lower (humus) layer and weights of organic matter, and for weights of roots and twigs. 2054, 8057, 8059

Further work has been done on data from birch sites in Yorkshire and Speyside, solving regressions on section area to estimate total weights of tree parts. Data for litter weights have been entered into the computer and await processing. 2054, 8057, 8059

Routine processing of chemical analysis data continues, but the program, PFATD, has been phased out. A new series of interactive programs has been developed to deal with this work as a unit of wider sampling procedures. This includes programs for:— entry of field measurements to give volumes of water and equivalent mm. of rainfall, bulked rainfall, means and analysis of variance where appropriate; chemical analysis data previously done by PFATD plus options related to new equipment and additional elements; assembly of analysis results for matching experiment and date; and conversions of mg/l to micro-equivalents with checks for consistency of the data. These programs are designed for use by staff in the Department of Peat and Forest Soils. The benefits of the new system should be quicker processing of results, early elimination of errors, reduction in manual transcription at intermediate stages and less delay before meaningful conclusions can be drawn from the data. 2054, 8057,8059

Specialised routines to deal with data from an EEC-funded project on mixed stands are included in the water sampling program sequence referred to above. Plots for study under this project were selected from existing experiments at Culloden and Inchnacardoch. Random co-ordinates for siting rainfall and litter collectors, and also for forest floor sampling, were generated by GLIM and RANDOM.SORT. Data processing has been done for forest floor samples on variables such as organic matter, moisture and chemical content, microbial biomass and fungal and bacterial measures. Initial diameter assessments were used to allocate trees to size classes and select sample trees for felling. The first stage of calculations for whole tree sampling data has been completed and work is in progress on other data. 2807, 8057, 8059

Two sites have been selected for the study of acid rain and soil water at Fetteresso and Loch Fleet. Random co-ordinates for the placement of rainfall collectors were generated by GLIM and RANDOM.SORT, and the diameter assessments were used to allocate trees to size classes and select those to be used for collecting stemflow. 2066, 8057, 8059

Data was processed for a study on the effects of reseeding on Lewis, and an account[1] of the work has been submitted for publication. Other work includes the derivation of regression equations for data from the Lon Mor

water table experiment, and analyses of variance by the program, EADAR, for mineral N data. 2055, 8057, 8059

Spectrochemistry. In studies[2,3,4,5] of the distributions of lead and copper concentrations in Scottish soils, the logarithmic transformation has been used to make the distributions more nearly normal and to permit more valid tests of significance to be made. 3007, 8057, 8059

Soil Organic Chemistry. Regression relationships have been tested in a sonication study. The angular transformation was used for data on the percentage persistence of sugars derived from specific activity. 4020, 8057, 8059

Microbiology. Further work was done on soil pore area measurements and a logarithmic transformation eliminated most of the skewness and kurtosis of the distributions prior to the analysis of variance of the data. The logarithmic transformation was also used on counts of aerobes and anaerobes in a study of their distribution in peat. Regular use has been made of the revised program for processing, significance testing and interpreting dilution series data, and analysis of variance done on the logarithms of the estimated counts of various micro-organisms. 6027, 6031, 8057, 8059

Soil Fertility. Close collaboration has been maintained in the design of experiments and in the production of field plans for a range of experiments on different topics. Processing of the data, statistical analysis and interpretation of the results has been done.

4803, 7037, 7038, 7039, 7040, 7041, 7042, 7046, 7048, 8057, 8059

Further work has been done on fitting models to investigate the relationships between crop responses to added fertiliser and different laboratory measurements of soil phosphorus. An account[6] of the effect of depth and type of soil on crop yield has been published. It contains the combined analysis of results of a rotation of crops over a 24 year period. Work has also developed further in studies of the effects of sulphur and have included measurements of amino acids. Correlation analysis has continued in studies of the relationships between different chemical properties in plant parts of a number of species. 7038, 7042, 7047, 7048, 8057, 8058, 8059

Investigation of the pattern of plant growth continues and inverse polynomial response curves have been used. An account of some of this work[7] has been submitted for publication. 7048, 8057, 8059

Soil Survey. Regression relationships were tested in a study of the prediction of bulk density and packing density of soil. The programs, GLIM, RANDOM.SORT and RANDOM.PLOT were used to produce co-ordinates for transparent overlays of random selections of primary and secondary soil inspection sites. 8057, 8059, 9012

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9. SOIL SURVEY

J. S. Bibby

Mr R. Grant retired on 31st October, 1983 having been Head of Department for eight years, a period which saw substantial achievements, both in field survey and in the use of soil maps. Under his direction the 1:250 000 map programme was brought to completion, providing the first overall map of the soils of Scotland and the first complete agricultural land capability assessment of the country based on soil, site and climate data. Mr Grant also presided over additions to medium-scale soil survey of the arable land of Scotland, leaving only two major areas of which one, Sheet 56 (Blairgowrie), has since been surveyed. His services to the Department and the Institute have been loyal and the benefit of his wise counsel is greatly missed.

As forecast in the previous Annual Report, the Department has been undergoing a period of reorganization and consolidation, occasioned principally by the stage that soil survey operations have now reached, but also partly due to the lack of replacements for six staff who have retired or been transferred to other departments in the last two years. The Department has its lowest staffing level since 1968. Over recent years the public have become increasingly aware of the volume and quality of information on the land resource of Scotland offered by the Institute through Department maps and publications, and sales of these show a major increase. Demands for an expansion in the range of publications and for more detailed levels of investigation are also being received and steps are being taken to respond. It is nevertheless a fact that this response is slowed by the reduction in resources, and long-term priority programme commitments mean that the Department will be totally unable to respond to any new initiatives, either from researchers in the Institute or from potential customers during 1985 or 1986.

The Department has been slightly reorganized and operates in three sections: Mr C. J. Bown leads the Field Section and carries responsibility for soil survey methodology, correlation and classification. Field teams are distributed throughout the three regions which correspond to Agricultural College territories and also match Department of Agriculture for Scotland areas. The close working relationships which the Department of Soil Survey has always had with these organizations is strengthened by this correspondence in areas of mutual interest.

Mr D. W. Futty leads a Publications, Cartography and Data Handling Section with responsibility for assessing demand for publications and expanding the range of material offered. Cartography, particularly in relation to automation, and data handling are also in his purview.

Professor J. S. Bibby currently leads the section devoted to Projects, Applications and Contracts. It is directed towards the development of interpretations of soil maps for specific purposes and to undertaking a small number of contracts where these directly forward the programme established with DAFS. He also carries overall responsibility for three project areas; plant ecology, soil moisture and micromorphology studies. Fuller reports on the activities of the three sections appear on subsequent pages.

Members of staff have attended meetings of the British Society of Soil Science, the British Cartographic Society and the Hill Land Ecology Group. For the first time for many years a Departmental Field Course, based at Strathclyde University, was run and allowed members of staff an opportunity of viewing and discussing soils and mapping techniques in Western Scotland. Staff of the West of Scotland Agricultural College, the British Geological Survey and Strathclyde University, as well as several members of staff from other departments of the Macaulay Institute took part. The Departments of Mineral Soils, Spectrochemistry and Fertility also contributed to the Department's winter meeting and the interest stimulated by accounts of their work is expected to pay dividends in increased co-operation in the future.

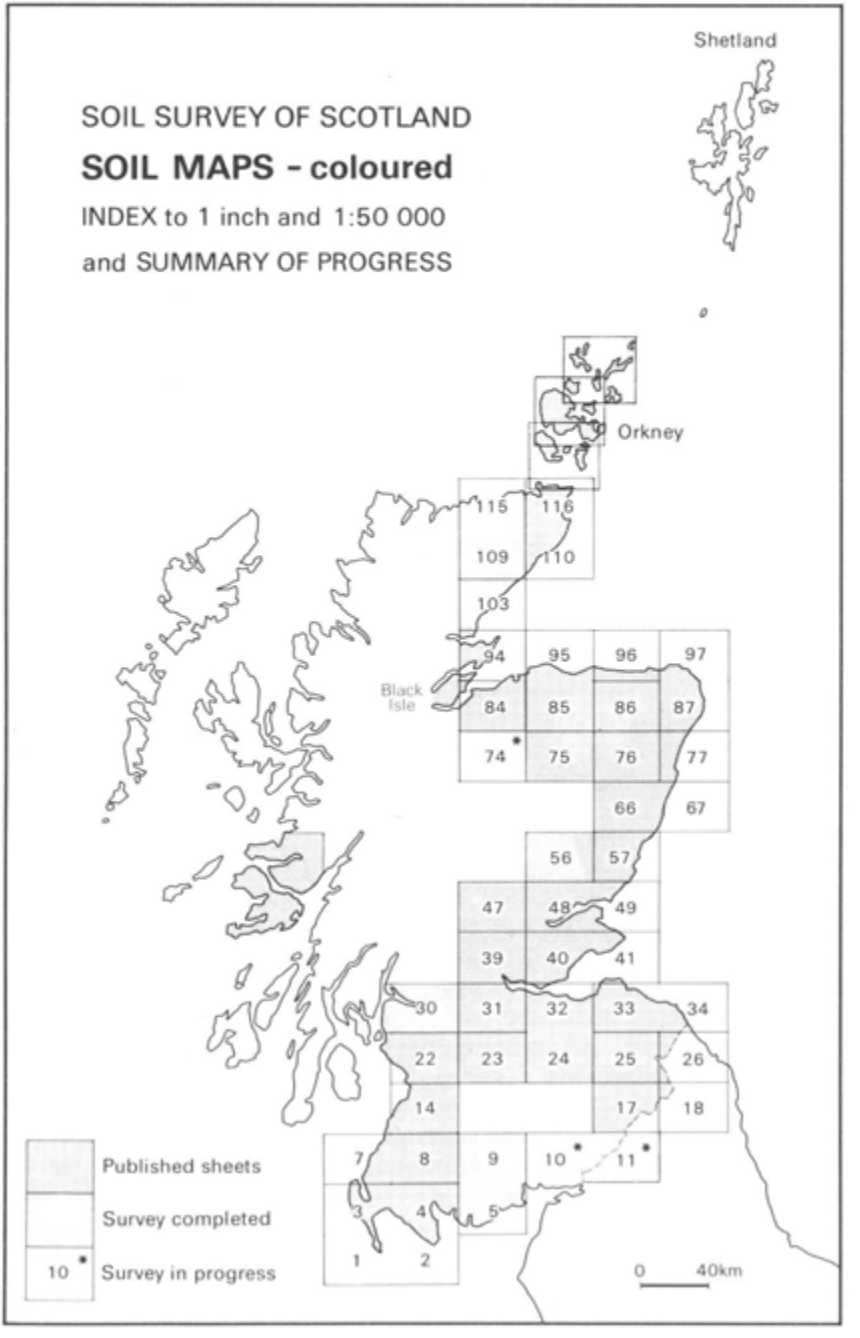
The Department is represented on the AFRC Soil Survey Research Advisory Committee (SSRAC), the SSRAC/NERC Common Interests Group and its subgroups dealing with common databases and projects, the MISR/COSAC Liaison Group and its subgroups, the Ordnance Survey/Public Agencies Consultative Committee, the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

We are pleased to welcome Mr I. A. Williamson to the Cartographic Unit of the Department, where he is assisting to develop the automated cartography programme, and Dr Rolf Tippkötter, a visiting research worker from the University of Hanover. Other visitors during the year have come from Venezuela, Spain, Portugal, Nepal, Papua New Guinea and the People's Republic of China, in addition to those from British Universities and Government Departments.

Field Section

Field survey during the year has focussed principally on Sheet 56 (Blairgowrie) and Sheet 109 (Achentoul), both sheets being completed. Survey was commenced on Sheets 6 and 10 (Annan and Dumfries), the last substantial area of unsurveyed arable land remaining in Scotland, and a small amount was done on Sheet 74 (Grantown). A total area of 1275 km^2 was surveyed during 1984. Sampling was carried out at 105 sites, primarily to assist with characterization of soils of Sheet 30 (Glasgow) where survey was completed last year.

The Annan/Dumfries sheet will be the final sheet published at 1:63 360 scale and will complete the map cover of arable lands with the exception of some minor areas. These will be surveyed during the next two years and published at 1:25 000 scale using the O.S. Pathfinder Series as base maps. It


Shetland
SOIL SURVEY OF SCOTLAND
SOIL MAPS - coloured
INDEX to 1 inch and 1:50 000
and SUMMARY OF PROGRESS
Orkney
Black Isle
115
116
109
110
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11
3
4
5
1
2
Published sheets
Survey completed
10
Survey in progress
0
40km

is intended that revision will start on Sheets 86 and 96 (Banff and Huntly) and Sheets 17 and 18 (Jedburgh and Morebattle) as more data are required from these areas for the land capability programme. The revisions will, however, only be available at 1:25 000 scale.

Three 1:25 000 scale maps have been digitized (NJ 81/91 Dyce, NS 43/53 Kilmarnock/Darvel and NO 20/30 Glenrothes) and an experimental scheme of sampling the major soils has been devised, based on random sampling. It is proposed that this work will supplement the data already held on the soil series and allow estimates of variability of map units to be made in morphological, chemical and physical terms. It will also provide a much needed guide for soil correlation and phased map revision. The increased use of automated field recording linked to data management systems and automated cartography is envisaged. Field-work will start in limited areas next year.

Methodology. Field Handbook

The Soil Survey Research Advisory Committee has recommended that common methods of soil description should be adopted during the soil surveys of Scotland and of England and Wales. Accordingly, therefore, staff representatives of the two surveys have met, reports have been exchanged and a first draft produced for a joint Field Handbook.

A number of features of the soil profile and site are described in common already by the two surveys, as for instance: surveyor, date, weather, locality, slope form, aspect, horizon depth, colour, organic matter status, erosion, relief, flooding, plasticity and stickiness. For many other features, differences in terms in current use are small and, from discussion, modifications to allow common usage have been suggested for the following characteristics: profile title, grid reference, altitude, stoniness and porosity. Minor expansion in the range of terms or categories to describe the following features will encompass the needs of both surveys: deposition by wind and water, rock outcrops, type of sampling point, mottling, moisture state, structure, fissures, roots, calcium carbonate, nodules and crystals, and horizon boundaries. Agreement is anticipated also on revised terms for soil strength, ped strength, cementation, induration and dry and moist consistence.

Recent advances in the recognition and description of plant communities have resulted in modification to the section on land use and vegetation. Categories, based on current Scottish usage, for recording the superficial unconsolidated deposits forming the soil parent materials have been proposed and terms for the lithology of rocks and stones in Britain as a whole have been revised and, where necessary, supplemented. Criteria have been evolved for the recognition and description of induration in soils.

It is anticipated that new or modified terms to describe the structure of cultivated horizons, soil packing density and soil wetness classes, based on newly acquired data for soils in England and Wales, will become available for consideration in relation to Scottish soils.

Differences in particle-size grades and texture classes between the Soil Survey of Scotland and that of England and Wales, dating from when the

latter adopted new criteria in 1973, are at present unresolved and the subject of continuing discussion. Considerations of major importance are the benefits of maintaining consistency with the large body of historically acquired data, of internationally recognized categories, and of textural classes currently familiar to those in agriculture. 9012

Classification and Correlation

A summary of the system of soil classification, used during the soil survey of Scotland, has been included in a handbook[1] describing the organization of and methods used in the 1:250 000 survey. The classification is that used on all published soil maps. Future work will enable comparison of the terms used with those of other classification systems. During 1984 correlation has been carried out in the field in the Blairgowrie area where many soils subject to long continued cultivation and destruction of the naturally occurring upper horizons exemplify continuing difficulties in the classification of profiles subject to such drastic morphological change. Map legends for Sheet 30 (Glasgow) have been reviewed with special attention given to the taxonomy and natural drainage assessment of soils having some gleying and slow permeability to moisture. Consideration has been given also to the map legend for Sheet 103 (Golspie). Following recognition in 1981, during the 1:250 000 scale survey, of the Arkaig Association as a group of soils developed on drifts derived from Moinian schists, gneisses and granulites distinct from those of the Strichen Association, the Bantrach, Derraid, Tombain and Leathain Series names have now been assigned to the Arkaig Association. New names are being given for the soils in the Strichen Association, mapped formerly under these names, as survey proceeds. Throughout, consistence between maps, representing widely separated areas produced at different periods, has been a major concern. 9012

Systematic Survey

Sheets 5 and 9 (Kirkcudbright and Maxwelltown)

Much of the early part of the season was taken up with revision and checking of the systematic mapping at 1:25 000 scale carried out during the period 1968 to 1977, bringing survey of the sheet, suspended during the 1:250 000 programme, to readiness for publication. In addition, 73 soil profiles have been described for the compilation of the National Soil Inventory. The many inventory sites encountered on the Achie Complex, a map unit comprising brown forest soils, brown rankers and rock outcrops, only reflects its wide extent throughout lowland Kirkcudbrightshire. It was a notable feature of these sites that in a high proportion rock lay within one metre of the soil surface. Drumlins of deep, compact clay loam or loam till carrying brown forest soils of imperfect drainage occur scattered throughout the rocky, glacially eroded lowlands, but in the uplands, occupying northern parts of the map area, drifts are again shallow and the predominant map units are soil complexes. 9012, 9013, 9015

Sheets 6 and 10 (Annan and Dumfries)

About 25 km^2 of soil mapping have been completed in the parish of Caerlaverock to the south of Dumfries. The main soils encountered were those of the Kirkcolm, Holywood and Stirling Associations which have been described previously. Two contrasting soils occupy most of the mapped ground, the noncalcareous gley Fordel Series (Stirling Association), developed on estuarine silty fine sands, and a freely drained brown forest soil of the Holywood Association, developed on modified till derived from Permian sandstones. 9012, 9013, 9015

Sheet 30 (Glasgow)

A further 50 profiles were sampled for analysis to characterize more fully the soils of the area. 9012, 9013, 9015

Sheet 56 (Blairgowrie)

In a combined effort involving field parties from Aberdeen, Edinburgh and Perth approximately 870 km^2 have been surveyed and the 1:63 360 soil survey of Sheet 56 (Blairgowrie) is now complete. A further 60 km^2 to the west of the sheet were mapped in order to complete the 1:25 000 sheets NO 06/16, NO 05/15 and NO 04/14. Thirty-five soil profiles were described and sampled.

Sheet 56 provides strong contrasts in soil subgroups and land use, encompassing as it does the highly productive and fertile soils of Strathmore and vast expanses of grouse-moor, deer-forest and forestry.

The principal feature of the solid geology of the area is the Highland Boundary Fault, the zone of which extends north-eastwards from the Loch of Clunie to Cortachy and separates the Lower Old Red Sandstone conglomerates and sandstones of Strathmore from the acid schists of the Dalradian to the north. A belt of metamorphosed granite some 3 km in width occurs by the northern edge of the sheet, extending from Lamh Dearg in a north-easterly direction through Loch Beanie to Broom Hill on the sheet boundary and forming the watershed between Glen Shee and Glen Isla. Other rock types of a more limited occurrence, but with a profound influence on the properties of soil parent materials and on soil genesis, include andesites, epidiorites, quartzites, serpentine and the calcareous schists and limestones of the Wester Bleaton and Soilzarie areas.

The area as a whole was affected dramatically by ice-movements during the Pleistocene. The predominant direction of ice-flow was north-west to south-east, the distribution and composition of the various soil parent materials and the present-day alignments of the major straths e.g. Strathardle, Glen Shee, Glen Isla and Glen Prosen bearing testament to this.

The landscape to the north of the Highland Boundary Fault is dominated by soils of the Strichen Association. A compact, yellowish brown or brown (usually 10YR hue but locally 7.5 YR hue), sandy loam or loam till occurs on undulating lowlands and lower hillslopes. The principal soils are the humus-iron podzols of the Strichen and the Obney Series while brown forest

soils of the Fungarth Series occur on the steeper slopes. The till changes its character on the upper hillslopes, becoming less coherent, more stony, coarser textured and shallower, with rock often occurring within 100 cm. Again, humus-iron podzols dominate, to be replaced with increasing altitude by peaty podzols, peaty gleys and, at the highest levels, subalpine podzols. The subalpine podzols occur on the broader hill summits, often in association with peat, and extend down-slope to approximately 650 to 700 m.

Where there is a discontinuous till cover on rocky hills and where, at lower altitudes, there is a short-range soil variation, a number of soil complexes have been separated. The complexes are determined on the basis of component soils, landform and degree of rockiness, but two, the provisionally named Pitcarmick and Kilbo Complexes, are specific to moundy moraine. In the area around Buzzart Dikes (5 km to the north-west of Blairgowrie), a distinctive landform of nearly parallel, steep-sided till ridges with humus-iron podzols and brown forest soils, and noncalcareous or peaty gleys in narrow inter-ridge channels and flats, has been mapped as the provisionally named Buzzart Complex.

The till of the Strichen Association is sometimes carried south of the Highland Boundary Fault, for example in the Drimmie area north-west of Alyth, where the underlying rocks are andesites and conglomerates. The till contains a minor andesitic or conglomeratic component, but its colour is that of the Strichen tills to the north of the Fault and the influence of the contaminant rocks is not thought sufficient to warrant the establishment of a new soil association or its inclusion in the Gourdie Association.

Soil series and soil complexes of the Countesswells Association have been mapped on the belt of metamorphosed granite. Soils separated as series include peaty podzols, peaty gleys, humus-iron podzols and subalpine podzols. Alpine soils are very local and restricted to broad summits over 750 m. The soil complexes have been separated on the same basis as those of the Strichen Association. The three most extensive are the Ariundle Complex, developed on moundy moraine around Loch Beanie, and the Rait and Moymore Complexes developed on rocky hillslopes.

Soil series and soil complexes of the Tarves Association are developed on mixed tills derived from acid and basic rocks, and on epidiorites, hornblende-schists and other rocks of intermediate basicity. The most extensive area of the Tarves Association occurs at the head of Glen Prosen to the north of Cornmuir. The enhanced base status of these soils is illustrated by the occurrence of brown forest soils in situations where, in the Strichen Association, for example, one might expect to find humus-iron podzols.

In upper Glen Shee and on the slopes of Ben Gulabin, soils of the Foudland Association have been mapped on fine-grained graphite-schists. Soils of the Durnhill Association are not extensive; ranker soils cap Ben Gulabin and a rock-dominated complex occurs on Ben Earb.

The calcareous schists and the limestones give rise to the parent materials of the Deecastle Association. The association is most extensive in the Wester Bleaton area to the east of Kirkmichael. The soils are shallow

brown forest soils and brown rankers. Minor areas have been mapped at soil series level, but the major map unit is the provisionally named Soilzarie Complex, a complex of brown forest soils and brown rankers with flushed gleys, occurring on slightly rocky steep hillslopes.

To the south of the Highland Boundary Fault, the tills of the Strichen Association give way gradually to those of the Gourdie Association. The parent material of the Gourdie Association is a mixed till derived from acid schists, andesites and sedimentary rocks of Lower Old Red Sandstone age. It is generally redder than the Strichen and tends to be finer-textured. As might be expected, the soils of the association occupy much of the area underlain by the andesites, and consequently dominate the zone of the Highland Boundary Fault. The dominant soils are imperfectly drained brown forest soils (Gourdie Series) and freely drained brown forest soils (Snaigow Series); peaty gleys and humus-iron podzols occur locally. There is some local evidence of partial water-modification of the upper layers of the till. Within the fault-zone of the Highland Boundary Fault there occur bands of the Lintrathen "porphyry", a dacite or quartz-andesite having affinities with rhyolite. It is suggested that the soils, mainly brown forest soils and brown rankers developed on parent materials derived from these rocks, might be considered as part of the Bemersyde Association.

The tills of Strathmore are derived mainly from conglomerates and sandstones of Lower Old Red Sandstone age, and three principal soil associations have been mapped, the Stonehaven, Balrownie and Forfar Associations.

The soils of the Stonehaven Association are generally confined to distinctive and isolated hills, for example Broad Moss, Hill of Alyth and Balduff Hill, formed of conglomerate. The till is reddish, with a sandy loam or sandy clay loam texture, and is generally stony. It is patchily distributed and, in some places, colluvial deposits form the parent material. The soils are brown forest soils and humus-iron podzols. North-facing slopes of the Hill of Alyth are rocky and have been mapped as a soil complex within the Stonehaven Association.

The parent material of the Balrownie Association is a reddish (5YR hue) sandy loam or sandy clay loam. Much of the association is cultivated, and freely and imperfectly drained brown forest soils and humus-iron podzols dominate the landscape. On low ground, the till can have partially water-modified upper layers. Where rock is close to the surface and the till is shallow, with abundant angular stones, a separate suite of series, dominated by brown forest soils and humus-iron podzols, has been distinguished.

Where the degree of water-modification of the upper layers of the till is intense, and where the non-modified till of the Balrownie Association is found at depths in excess of 60 cm, soils of the Forfar Association are mapped. As in the Balrownie Association, much of the Forfar Association is cultivated, and the soils, mainly humus-iron podzols and brown forest soils, are some of the most productive soils in Scotland. Under certain systems of management there is, however, a risk of erosion by water (Fig. 9.1).

Fluvioglacial deposits of sands and gravels are widespread, occurring in the major straths and in Strathmore, particularly along the northern

Fig. 9.1.
Erosion on Forfar Series.

boundary of Strathmore between Blairgowrie and Kirriemuir. Three soil associations have been mapped, the Boyndie, Corby and Doune Associations, the two latter associations being the most extensive.

The Corby Association occurs mainly as mounds and terraces in the straths, but also forms an expanse of gently undulating land around Blairgowrie, extending westwards through Kinloch to the Loch of Clunie. The association is dominated by Corby Series, a freely draining humus-iron podzol. The soils are generally cultivated.

To the north-east of Blairgowrie, stones of andesite and of Old Red Sandstone sediments become more apparent in the deposits and it is appropriate to consider such deposits as the parent material of the Doune Association. The soils are cultivated, freely drained podzols or brown forest soils, and occur on a strongly undulating landscape.

Organic soils are not extensive in the area surveyed this year. Blanket peats are restricted to the upper, less-steep hillslopes and summits. The basin and valley peats have a widespread, local distribution with the major deposits occurring on Cochrage Muir and in the Forest of Alyth near Corb.

Tracts of alluvium occur in most of the larger straths, where they form an intricate pattern with the fluvioglacial sand and gravel deposits. In many instances the alluvial deposits are so variable in texture and in drainage status that differentiation into series is impracticable. In Strathmore, however, the alluvial deposits are much more extensive and uniform. Here, dominantly imperfectly drained sandy or loamy alluvial deposits offer land of high agricultural potential. 9012, 9013, 9015

Sheet 74 (Grantown-on-Spey)

Systematic survey of this region has been resumed. An area of 20 km^2 was mapped in an arc stretching north-eastwards from the Braes of Muckrach, near Dulnain, to Auchosnich, north of Grantown-on-Spey. Most of the area is underlain by paragneisses and surrounded by rocks of the more siliceous type of Moine granulite. These paragneisses include minor outcrops of limestone and calc-silicate rocks which give rise to brown forest soils with strong podzolic tendencies and brown rankers; such soils have been assigned provisionally to the Deecastle Association. The majority of the rocks, however, comprise coarsely micaceous gneisses and have given rise to soils of the Strichen Association, whereas the surrounding Moine granulites form the parent material of the Arkaig Association. Both associations are dominated by podzols, although pockets of peaty gleys and humic gleys occur locally on the gentle slopes.

On the lower slopes of the granite masses of Beinn Mhor and Gorton Hill there is an irregular boundary between the pink biotite-granite and the surrounding schists, with the granite containing many inclusions of the schists, and with the country rock veined by granite. On this intricate lithology are developed soils, mainly podzols, of the Aberlour Association.

The parent materials of the Arkaig, Strichen and Aberlour Associations are divisible into stony loamy sand and sandy loam drifts occupying the highest and steepest slopes, and a sandy loam or loam till occupying the lower gentle hill slopes. Induration is widespread, as are soil complexes on terrain with minor rock outcrops.

Fluvioglacial gravels of the Corby Association form both slightly mounds terrain and terraces flanking the River Spey, with the less well-sorted gravelly loamy sands of the Dulsie Association occupying some of the lower hill slopes and the restricted, undulating low ground. The soils are dominantly podzols.

Twenty-five soil profile descriptions for the National Soil Inventory have been collected, mainly from the Monadhliath Mountains. 9012, 9013, 9015

Sheet 109 (Achentoul)

Approximately 300 km^2 were surveyed, and the systematic soil survey of Sheet 109 has now been completed. Fourteen soil profiles were described and sampled, in addition to three National Soil Inventory points.

The area surveyed lies mainly to the north of the Strath of Kildonan and extends as far as Knockfin Heights in the west and Braemore in the east. A smaller tract lies to the west of the Strath of Kildonan in the Borrobol Forest.

Much of the region is underlain by Moinian rocks comprising siliceous granulites, mica-schists and quartzites. The granulites and schists form an undulating non-rocky plateau, whereas the quartzite occurs mainly as long, steep-sided, fairly narrow ridges, the highest of which is Scaraben (626 m). In the north-east, sandstones, conglomerates and mudstones of Lower Old Red Sandstone age occur. The lower ground is again non-rocky and gently undulating, but with prominent hills of conglomerate, including Morven (706 m), Smean (509 m) and Maiden Pap (484 m). The Helmsdale granite, although largely a continuation of the dominant non-rocky landscape, does

contain some rocky, rugged terrain. In the north, rocks of the Strath Halladale injection complex, mainly granite, are almost entirely covered by deep blanket peat.

Soil parent materials are mainly of loamy sand or, less commonly, sandy loam texture and are stony. The notable exceptions are the reddish drifts of silty clay loam or clay loam derived from the mudstones, and the fine sandy loam or loam drifts derived from the mica-schists.

Organo-mineral soils dominate the area: peaty podzols, generally with a strongly gleyed E horizon, are most common, with peaty gleys and peaty rankers rather more restricted. Organic soils are very extensive, whilst subalpine and alpine podzols, lithosols and rankers occur on the higher hills.

Moorland plant communities reflect the range of soil types. Moist and, less commonly, dry Atlantic heather moor occur on the peaty podzols and peaty rankers. Lowland blanket bog is frequent on the organic soils, with the northern and upland forms and mountain blanket bog also occurring with increasing altitude and exposure. Alpine azalea-lichen heath predominates on the subalpine and alpine podzols of the hill summits. The restricted areas of brown forest soils and cultivated podzols usually support herb-rich Atlantic heather moor or bent-fescue grassland, often with bracken.

The most extensive soil association is the Arkaig Association, comprising soils developed on parent materials derived from Moinian granulites and schists. The soils with a high schist content approach Strichen Association, being finer in texture than the more common granulite-derived soils. Pollie Complex and Strathnaver Complex, both comprising peaty podzols and peat, but on different landforms, are two of the most common soil map units. Kildonan Series (peaty podzols) is also extensive, particularly around Suisgill. The steeper slopes of the Strath of Kildonan are occupied by Aberscross Series (brown forest soils); these slopes are often bouldery but the vegetation has a high grazing value. Small areas of cultivated podzols (Gordonbush or Birichin Series) occur on small, previously crofted areas which have long been abandoned.

The Countesswells Association occurs on the Helmsdale granite and very sporadically in the north. Established soil mapping units such as Charr Series, Glutt Complex, Funtack Complex, Sanda Complex and Morvich Complex all occur, often in close association with each other. Other less common units include Countesswells Series, Marail Complex and a complex of peaty rankers and shallow peat on steep, very rocky slopes which is awaiting correlation.

The Kessock Association, consisting of soils developed on conglomerate-derived material, is restricted to the area around Morven. Correlation of map units has still to be completed, but the principal soils found are subalpine podzols, alpine podzols, and peaty rankers. Lunndaidh Complex (subalpine podzols and shallow peat) occurs on Smean. Scree-dominated steep slopes and non-rocky hill summits with a few large prominent tors are the most conspicuous features of the landscape.

The map units of the Durnhill Association (parent materials derived from quartzite) also await correlation, but two main mapping units were found. One consists of alpine podzols, lithosols and rankers which occur on

non-to extremely bouldery, gently sloping hill summits, and the other comprises peaty rankers, shallow peat and scree found on the very steep lower slopes.

The Berriedale and Braemore Association, both established on Sheets 110/116 (Latheron and Wick), are of limited extent. Map units found in the Berriedale Association include Berriedale Series, Ramscraigs Series and Shurrery Complex. The area of Ramscraigs Series at Ousdale Farm represents one of the largest areas of cultivation on the whole sheet, although due to unfavourable climate the land is only marginally suitable for arable cropping. Noncalcareous gleys (Cam-leathad Series) of the Braemore Association occur in a few areas inland from Braemore, but, Marlain Series (peaty podzols) and Braemore Series (peaty gleys) are very restricted.

Organic soils are very widespread, the main map unit comprising deep blanket peat (>100 cm thick). The greatest extent is on Knockfin Heights where much of the peat is eroded and dubh lochans are numerous. Peat is also widespread between the Morven-Scaraben range of hills and on the Caithness-Sutherland border. Many of the soil complexes within soil associations also contain a large proportion of peat.

Alluvial soils occur in the valley bottoms, particularly in the Strath of Kildonan and at Braemore, but there are numerous smaller areas associated with the smaller streams. Soils of the Corby Association are also found in isolated pockets in the Strath of Kildonan. 9012, 9013, 9015

1:50 000 Provisional Soil Maps

This map series has been introduced this year and is based on field-work carried out for the 1:250 000 map series. The 1:250 000 map legend forms the basis of the map key of the 1:50 000 scale provisional maps. Since additional information can be shown at the larger scale, new map units have been created by the use of suffixes, e.g. 26S where a steep slope phase of map unit 26 is encountered. Where suffixes are used, changes to the descriptions of parent materials, soils, landforms and vegetation have been made, as necessary. The enlarged key allows the maps to display increments of information of relevance to land classifiers, agricultural advisers and other users; for example where distinctions within the rock class or slope of some extensive 1:250 000 map units have implications for afforestation or reclamation. The work this year has concentrated on defining these modified map units and entering them into the computer data file for future map key generation: 113 units of this type have so far been defined

9012, 9015

Other Soil Surveys

Department of Agriculture and Fisheries, Thorny Hill, Saline, Fife

The soils and land capability for agriculture of the proposed extension of the Thorny Hill, Saline, opencast coal extraction site were surveyed. A map (1:10 560) and report[2] have been produced.

SOIL SURVEY OF SCOTLAND

SOIL MAPS - provisional uncoloured

INDEX to 1:50 000 SHEETS

This series will be completed during 1985.

1 Shetland - Yell & Unst
2 Shetland - Whalsay
3 Shetland - North Mainland
4 Shetland - South Mainland
8 Stornoway & North Lewis
9 Cape Wrath
10 Strathnaver*
13 West Lewis & North Harris
14 Tarbert & Loch Seaforth
15 Loch Assynt
16 Lairg & Loch Shin*
18 Sound of Harris
19 Gairloch & Ullapool
20 Beinn Dearg
21 Dornoch Firth*
22 Benbecula
23 North Skye
24 Raasay & Loch Torridon*
25 Glen Carron
26 Inverness*
31 Barra
32 South Skye*
33 Loch Alsh & Glen Shiel
34 Fort Augustus
35 Kingussie*
39 Rhum & Eigg*
40 Loch Shiel*
41 Ben Nevis
42 Loch Rannoch
43 Braemar*
44 Ballater*
46 Coll & Tiree*
49 Oban & East Mull*
50 Glen Orchy
51 Loch Tay*
52 Pitlochry & Aberfeldy*
55 Lochgilphead
56 Loch Lomond*
57 Stirling & The Trossachs*
60 Islay*
61 Jura & Colonsay*
62 North Kintyre*
63 Firth of Clyde*
68 South Kintyre*
69 Island of Arran*
71 Lanark & Upper Nithsdale*
72 Upper Clyde Valley*
73 Galashiels & Ettrick Forest*
77 New Galloway & Glen Trool*
78 Nithsdale & Lowther Hills*
79 Hawick & Eskdale*
80 The Cheviot Hills*
84 Dumfries*
85 Carlisle & Solway Firth*

*indicates part sheet

o Fair Isle

There were three objectives:

(i) to map and describe the soils of the area and to assess the land capability for agriculture.

(ii) to comment on the quality and potential availability of topsoils and soil-making materials that might be used to supplement any shortfall encountered during the restoration processes.

(iii) to enable comparison to be made between the present soil and site conditions and those prevailing after restoration.

The soils were mapped and examined by a combination of 100 m grid-survey, free-survey and air photograph interpretation.

Soils of the Darvel and Giffnock Associations, alluvial soils, organic soils and an area of disturbed ground were delineated.

The soils of the Darvel Series, a freely drained brown forest soil developed on fluvioglacial sands and gravels, and soils of the Kennet Series, an imperfectly drained brown forest soil developed on till with partially water-modified upper horizons, provide the best sources of soil-making materials. In the case of the Kennet Series, however, the thickness of the potential soil-making material varies quite considerably over short distances. An initial investigation of the data suggests that both topsoils and soil-making materials will be at a premium if the current specifications, that a minimum of 300 mm of top-soil and 600 mm of subsoil be replaced on the reinstated site, are to be maintained. 9012

Department of Agriculture and Fisheries, Libry Moor, Kirkconnel, Dumfriesshire

A soil survey has been completed of the proposed opencast coal extraction site at Libry Moor, Kirkconnel, Dumfriesshire, approximately 3 km^2 in area.

Soil data are collected on a grid basis, with 100 m intervals between sample points on arable and rotational grassland, and 200 m intervals in areas of rough grazing and forestry. The information is recorded on a computer-compatible card and transferred to the Institute computer for analysis of the data and production of several single-factor maps.

Soils of Rowanhill Association predominate, with noncalcareous gleys (Rowanhill Series) occupying the lower slopes of the Nith valley, and, above 250 m, peaty gleys (Glaisnock Series) associated with shallow peat and deep peat channels. Soils of Giffnock Association occur locally where sandstone is close to the surface.

A considerable shortfall of mineral topsoil for restoration purposes is anticipated, because of the overall thinness of existing mineral topsoils and because of the extent of soils with organic surface horizons. 9012

Hill Farming Research Organisation (HFRO), Hartwood, West Lothian

A detailed investigation of the soils in Minefield, Hartwood, was undertaken. Soil profiles were recorded at the intersects of a 50 m grid and maps constructed to show (a) topography/site features and (b) summaries of the profiles. Results were submitted to HFRO together with a brief report.[3] Presentation of the information, by soil characteristics rather than by soil

series, was considered more appropriate to the purpose of the survey, which was intended to locate areas with high uniformity of soil and site properties, thus facilitating the placement of replicate experimental plots investigating nitrogen mineralization and nutrient losses in drainage waters. 9012

British Geological Survey. Mineralogical and Trace Element Signatures

Where bed-rock is obscured by drift, the British Geological Survey (B.G.S.) is investigating the usefulness of the soil parent materials for predicting the nature of the underlying bed-rock. In a pilot project, the B.G.S. has made traverses across the hills of the Glenbuchat-Blackwater area, mainly on Sheet 75 (Tomintoul), and samples of B and C horizons have been taken. The Department of Soil Survey advised on selection of the study area and, in the field, on sampling procedures and the identification of soil types and horizons. In common with much of Scotland's hill country, the drifts in the study area are mainly locally derived, so that good correlation between C horizons and bed-rock can be expected. Fine sand analyses are being done by the Department of Mineral Soils, and trace element analyses by the Department of Spectrochemistry. 9012

Department of Peat and Forest Soils. Acid Rain

Profiles of the Charr Series (Countesswells Association in Fetteresso Forest, Kincardineshire, were sampled and described for a study of pathways of soil water movements and associated chemical changes by the Department of Peat and Forest Soils. Three profiles were in a lodgepole pine plantation, and three on moorland. 2066

Department of Mineral Soils and Soil Fertility. Soil Physical Conditions

In a co-operative project with the Departments of Mineral Soils and Soil Fertility, selected physical properties of six profiles are being measured. The soils belong to the Boyndie, Countesswells, Peterhead and Stonehaven Series and Associations, and to the Mairlenden Series (Foudland Association) and Thistlyhill Series (Tarves Association). They cover a wide range of parent materials, textures and drainage classes. Samples have been taken for laboratory determinations including stone content and size, particle-size distribution, moisture-release characteristics, bulk density, and consistency limits and index of shrinkage. Field measurements of hydraulic conductivity will be made during the winter. 1001, 7044

Department of Soil Organic Chemistry. Soil Structure

Samples of C horizon material from profiles of the Boyndie, Countesswells, Insch, Laurencekirk and Tipperty Associations were collected for the Department of Soil Organic Chemistry. Sites were chosen by selecting records, including those held in the Soil Database, of soil profile descriptions and analytical data that met specifications of parent material, texture and organic-matter content. The samples will be used for studies of the effectiveness of different groups of organisms in creating a stable soil structure. 4020

Projects, Applications and Contracts Section

Plant Ecology Studies

Much of the year was taken up with preparation of publications and reports[4,5,6,7] based on previously collected data, but some limited field-work was carried out on standard phytosociological survey relating soils to vegetation on Sheets 5 and 9 (Kirkcudbright and Maxwelltown) and Sheets 109 and 115 (Achentoul and Reay), and on CEGB contract work at Loch Fleet connected with the acid rain survey.

In the south-west near Dumfries, sharp-flowered rush pasture (Potentillo-Juncetum acutiflori) is the most widespread and extensive plant community on the gleyed soils of the flushed valley slopes. There are many fine examples of mature oakwood with dense carpets of bluebell *(Endymion nonscriptus)* on brown forest soils along the valley sides; these have been classed as southern oakwood (Lonicero-Quercetum). Many of the small lowland lochs are eutrophic and support marginal plants that are relatively uncommon such as lesser bulrush *(Typha angustifolia)*. Sites of particular interest are a small area of juniper scrub near Tynron (designated an SSSI) and a hill basin with lime-rich rocks and associated shallow brown calcareous soils supporting herb-rich grassland and moorland and flushed humic calcareous gleys carrying sedge mires with broad-leaved cotton-grass *(Eriophorum latifolium)* at Glenswinton.

In northern Scotland, around Achentoul, the uplands are dominated by moist Atlantic heather moor (part of Carici binervis-Ericetum cinereae) on shallow peat, peaty rankers and peaty podzols, and by lowland and upland blanket bogs (parts of Erico-Sphagnetum papillosi) on peat. Exposed summits carry a severely wind-cut vegetation of alpine azalea-lichen heath (Alectorio-Callunetum vulgaris) on alpine soils which gives way abruptly to mountain blanket bog (Rhytidiadelpho-Sphagnetum fusci) on the peat of the gentler summit slopes and cols. The wide straths are the sites of remnant oak and birchwood (Trientali-Betuletum pendulae and Blechno-Quercetum) and the steep faces of the river terraces and mounds carry dry and herb-rich Atlantic heather moor (parts of Carici binervis-Ericetum cinereae). The soils associated with these communities are brown forest soils and podzols. A very narrow, intermittent strip of boreal heather moor (Vaccinio-Ericetum cinereae) occurs on the upper edge of the valley slopes where rock outcrops and exposure are dominant features. The salt-spray community of vernal squill maritime pasture (the *Scilla verna-Festuca rubra* Community) occurrs extensively along the sea cliffs of the northern coast, particularly at Strathy Point. The very dry conditions of the summer months caused even the deepest common cotton-grass pools (the *Eriophorum angustifolium-Sphagnum cuspidatum* Community) to dry out and the peat horizon of up to 1 m deep on the hills of Navidale had developed cracks of up to 15 cm wide and extending down to the mineral horizon. It will be interesting to observe whether this peat blanket will recover its stability or whether the drying out process is irreversible and erosion will set in. The selective and total destruction of the pine trees by the Pine Beauty moth in the mixed coniferous plantations south of Bettyhill was noted.

A paper was presented to the meeting of the British Society of Soil Science at Southampton in September, 1984, on regional trends in Scottish moorland vegetation, which is now being prepared for publication.

Records of two of the most extensive moorland associations, Atlantic and boreal heather moors, have been assessed. Although the communities are usually dominated by ericaceous shrubs, principally heather *(Calluna vulgaris)*, the presence and relative abundance of other species varies considerably. These variations have been correlated with a number of factors, among which are climate, soil type, parent material, topography, flushing and management.

Atlantic heather moor is the association of the more oceanic climates of Scotland, and is replaced by boreal heather moor where oceanic influences are least effective, the largest area being the Grampian Highlands.

The dry forms of both associations are found most often on humus-iron podzols. Moist moorland is related to peaty podzols and peaty gleys, and the herb-rich subassociations to brown forest soils, often on steep slopes, and to the more base-rich parent materials such as limestones and gabbros. As rainfall and flushing increase towards the west, so flying bent *(Molinia caerulea)* increases in abundance.

Periodic burning of moorland stimulates new growth of heather and maintains a valuable grazing resource for grouse, red deer and hill sheep. Overgrazing can result in suppression of the heather and an increase in the abundance of grass species. 9015

A preliminary investigation into biomass production of plant species and communities on a range of soil types has been initiated with a view to refining the method of assessing grazing value of vegetation. 9016

Soil Moisture Studies

This new project centred on soil moisture studies has its main research objectives currently set out as monitoring the soil moisture status of a number of the principal soils of Scotland to check (i) the accuracy of morphological assessments and (ii) the seasonal and annual variation within soil moisture classes.

Lack of staff assistance, due to other departmental priorities, has meant that the project has been slower in establishment than is desirable, but a start has been made.

A visit was paid to the Soil Survey of England and Wales soil physics unit at Shardlow to examine facilities and discuss methods of analysis. Laboratory facilities required as the basis of an Institute service may not be available until next year.

A pilot scheme of monitoring water-table levels in one of the principal soils in Strathmore (Balrownie Series) has been set up. Balrownie Series extends across the Midland Valley from near Montrose in the east to Loch Lomondside in the west. Of necessity the monitoring has to be done by interested and willing farmers or their staff and the method used simple and trouble-free. The help of the Colleges of Agriculture advisers in Forfar, Perth and Stirling has ensured that sufficient enthusiastic farmers were found to service the pilot scheme. These farmers were briefed and the

necessary dip-wells installed during the early summer and early autumn as time and harvest allowed. Some 33 sites have been established on Balrownie Series soils from the Brechin district in the east to the Buchlyvie district in the west.

In Caithness a limited scheme to monitor water-table levels in the principal soil (Thurso Series) has been established with a view to providing more specific information on periods of waterlogging in these soils which will enable the consistent and more precise application of the guidelines of the Land Capability Classification for Agriculture over the area. The help of the College of Agriculture adviser in Thurso ensured sufficient farmer monitors to establish seven sites spread across Caithness. 9063

Micromorphology Studies

During the year, laboratory work has been reduced considerably because of pressure from other commitments (mainly related to the Systems Analysis and Data Processing Section) and staff shortages. Nevertheless, soil thin sections have been prepared at the prior request of the British Antarctic Survey and the Institute of Archaeology, and various samples of both soil and rock materials have been, and are currently being, processed at the request of the Departments of Mineral Soils and Soil Fertility. This unfortunate decrease in departmental micromorphological investigations has in some respects been balanced by increased consultation with other departments, and the increasing interest being shown by them in the possible application of micromorphological techniques to their own and inter-departmental projects is being encouraged wherever possible.

A co-operative project involving the Departments of Soil Survey, Mineral Soils and Soil Fertility is under way, to assist in the characterization of soil materials derived from selected soil series, with particular emphasis being placed on physical and structural properties. Undisturbed material from selected soils of the Foudland, Boyndie, Tarves, Stonehaven, Countesswells and Peterhead Associations, in the Aberdeen area, has been collected, and soil thin sections prepared from these samples will be examined, using micromorphological and scanning electron microscopy techniques.

Early in the year, representatives of the Departments of Soil Survey and Mineral Soils visited the Scottish Institute for Agricultural Engineering (SIAE), Edinburgh, to discuss possible collaborative projects. (See also under Department of Mineral Soils.)

One of the plot experiments being conducted by SIAE at their site at Cowpark (NT 238628) involves assessment of the variation of crop yield caused by differing minimum cultivation techniques and wheel compaction treatments. It was clear that these variations were indirectly related to soil structural stability, and it was felt that it would be profitable to examine soil material from this site in detail, using micromorphological techniques.

Uncompacted topsoil from the site was supplied by SIAE and standard volume subsamples of the material, at different moisture contents, were subjected to a range of compaction pressures in the laboratory, prior to impregnation.

This initial experiment was carried out (a) to ascertain if severely compacted material would retain sufficient pore space to make subsequent impregnation and thin sectioning possible, and (b) to enable a very general qualitative assessment of the changes in pore distribution to be made, and to assess the degree of intra- and inter-ped damage caused by such treatments.

The treated samples were dried by acetone replacement and impregnated under reduced pressure with crystic resin. As expected, impregnation proved to be rather variable, with the wet samples subjected

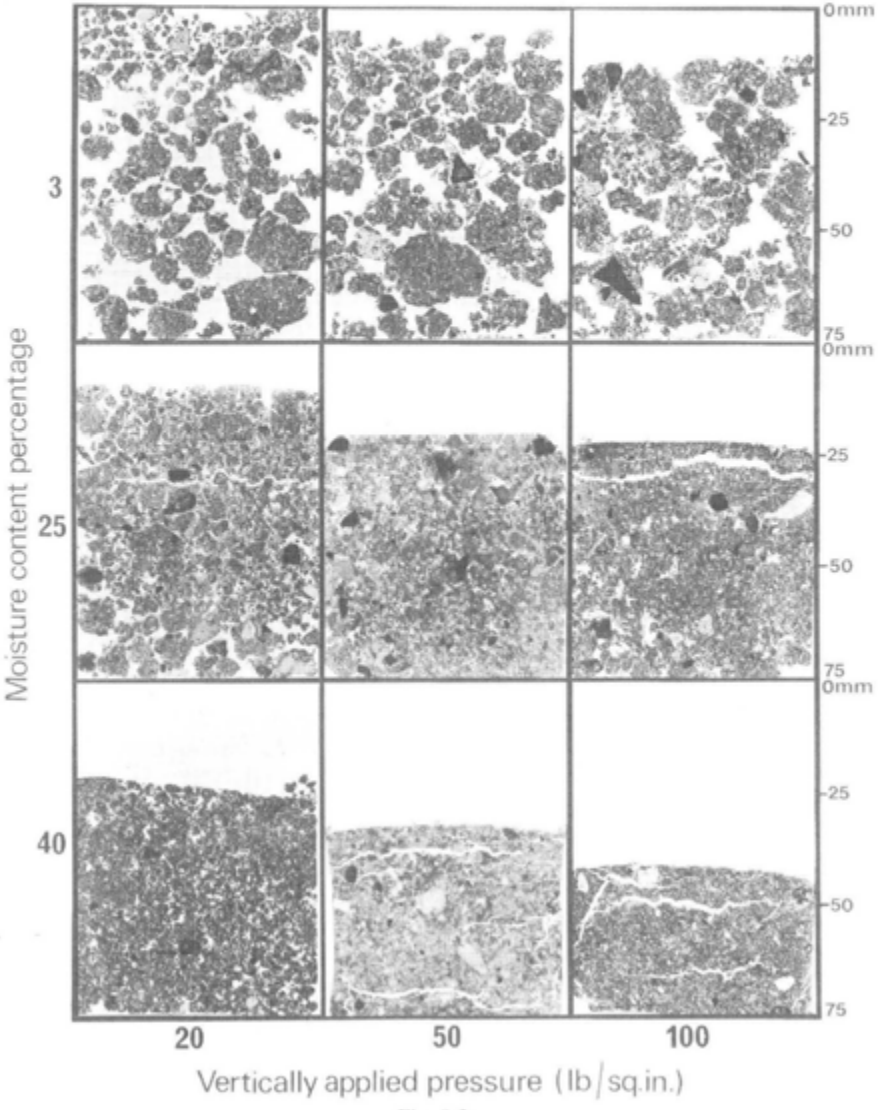


Fig. 9.2
Soil thin sections of progressively compacted topsoil at a range of moisture contents.

to the greatest pressures being least well impregnated. However, it was possible to prepare thin sections from all the samples, and the resultant changes in pore distribution patterns and pedal morphology were clearly visible (Fig. 9.2).

This preliminary work suggested that examination of the actual experimental plots should be undertaken and these were subsequently subsampled selectively after consultation with SIAE representatives.

Undisturbed samples were collected in aluminium frame boxes, to a depth of up to 30 cm, from plots which had undergone minimum tillage cultivation (both direct-drilled and chisel-ploughed), and also from plots which had been subjected to zero, one- and six-pass wheel compaction treatments. In all, six plots were sampled, and these samples are presently being processed.

It is hoped that future optical and scanning electron microscopical examination of thin sections prepared from these samples will give some insight into the structural variation resulting from the various treatments, and that semi-quantitative assessment of pore distribution variations may be possible using image analysis techniques.

At the request of the Department of Spectrochemistry, soil thin sections were prepared from Bs horizon material derived from a peaty podzol of the Tarbothill Series, enabling detailed micromorphological and scanning electron microscope examination of grain coatings and pore linings within this cemented material to be carried out. These coatings can be interpreted as allophanic deposits, associated with varying amounts of clay and iron oxide, impregnated with fulvic acids. They occur in thin section as isotropic or weakly anisotropic, transparent, yellow, commonly fluorescent, gel deposits, which line pores, bridge sand and silt grains and form pseudomorphs of root structures. A paper describing these coatings in detail and suggesting that they have been deposited from solution, has been accepted for publication in the Journal of Soil Science.[8] The joint paper on proto-imogolite in Australian soils described in Annual Report No. 53, is now published[9].

In collaboration with the Department of Microbiology, undisturbed soil samples, pretreated to preserve the structure of incorporated organic materials, were impregnated with crystic resin containing a fluorescent dye. Polished surfaces of these blocks were examined optically and using backscattered scanning electron microscopy methods. Measurement of soil microporosity was carried out using microcomputer areal measurement and image analysis techniques, and estimation of the soil pore network available to protozoa was assessed. A paper[10] describing these micromorphological techniques has been accepted for publication, as has one[11] detailing the microcomputer-based areal measurement methods used in the study.

This work is being extended to investigate further improvements in the field of thin section preparation with particular emphasis on the preservation of biological tissue, and to examine the importance of biopores in relation to soil microstructure and as a habitat for soil protozoa. These investigations will form part of the work of Dr R. Tippkötter, a visiting research worker from the University of Hannover, who will be working in

the Soil Micromorphology Section for 12 months, in collaboration with the Department of Microbiology.

A report[12] on sites of the third millenium BC to the first millenium AD at North Mains, Strathallan, Perthshire, prepared by G. Barclay (Central Excavation Unit, Scottish Development Department), has now been published. This report contains an appendix describing the micromorphological features of the contemporary soil profile of a substantial barrow dated to the early/mid second millenium BC at North Mains. The buried, prehistoric cultivated soils below the barrow, and those at a nearby henge are described, and an interpretation of the soil developmental sequence based on the micromorphological evidence is presented. 9804, 1804

Applications

The Macaulay Institute Land Capability Classification for Agriculture (LCA) is to be adopted by the Department of Agriculture and Fisheries for Scotland as one of the principal elements of advice given to planning authorities throughout Scotland on land use policy. Work has continued on the priority areas established during 1983 round most of the major cities of Scotland and a schedule of mapping has now been produced (Table 9.1) which, when completed in 1987, will alow DAFS and SDD to develop revised planning guidelines. Initial drafts of the maps, produced from soil, site and climatic data by the field surveyors, are subjected to detailed discussion by DAFS and College of Agriculture staff, following which amended drafts are prepared for cartography. It has been decided that, in order to reduce confusion with the system currently used during planning enquiries, no LCA maps will be issued until the series is completed in 1987.

Substantial interest has also been shown in this map series by the Scottish Land Court, the National Farmers' Union of Scotland and various farmers and land agents dealing with land sales.

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

April 1985	July 1985	October 1985	July 1986	December 1986
12 Thurso & Wick	30 Fraserburgh	21 Dornoch Firth	28 Elgin	26 Inverness
38 Aberdeen	54 Dundee	27 Nairn	37 Strathdon	29 Banff
59 St. Andrews etc.	63 Firth of Clyde	45 Stonehaven	53 Blairgowrie	57 Stirling etc.
64 Glasgow	72 Upper Clyde	58 Perth & Kinross	73 Galashiels	78 Nithsdale etc.
65 Falkirk etc.	82 Stranraer etc.	71 Lanark etc.	76 Girvan	83 Kirkcudbright
66 Edinburgh		74 Kelso	84 Dumfries	85 Carlisle & Solway Firth
67 Duns & Dunbar				
70 Ayr & Kilmarnock				

Attention has also been given to the production of maps of land suitability for specific crops and practices. It is intended that European systems of land evaluation methodology should be used but the choice of limiting values is crucial and so far few satisfactory limits have been determined. For example, limits of accumulated temperature used in England and Wales for spring barley bisect the areas in Scotland where this crop is grown successfully. Consultation with the Maximum Yield Constraints subgroup of the MISR/COSAC Liaison Group and through it with other Institutes is being sought and may facilitate this project.

Assistance has been given to the Scottish Institute of Agricultural Engineering in the development of an advisory handbook on minimum cultivation requirements, by grouping soil series on the basis of criteria produced from SIAE experimental data.

Following consultation between the Departments of Soil Survey, Spectrochemistry and Soil Fertility, work has proceeded on a series of ten maps at 1:625 000 scale designed to show the Soil Associations of Scotland and their average trace element contents (B horizon totals). The soil association map, which is basic to the exercise, has now been scribed. 9013

Contracts

Contracts are currently 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 special expertise and national overview. Four such contracts have been undertaken during late 1983 and 1984.

Aonach Mor, Highland Region

Aonach Mor, a mountain of 1200 m in the Nevis range, lies to the north-east of Ben Nevis in the Lochaber District of Highland Region. Its northern slopes have been recognized as a possible area for the development of skiing since the early 1970s. The Department of Soil Survey was approached to contribute to a survey seeking to assess areas of erosion risk, and in particular to identify soil type, drainage status and risk of breakdown of vegetation cover. Field survey was carried out late in 1983 using combinations of free survey and a grid with a spacing of 400 m, which was considered adequate for the feasibility study. It is desirable, should development of the ski complex proceed, to carry out more detailed soil and vegetation surveys and to use these to monitor the environment in the long term. Reports[13] were presented to the consultant engineers, Sir William Halcrow and Partners, early in 1984 and submitted to the clients, a consortium of Lochaber District and Highland Regional Councils, Highlands and Islands Development Board, British Alcan Aluminium Ltd. and the European Regional Development Fund in July 1984. Although the soils of the ski area were typically alpine and subalpine, the proposed approach roads will traverse a variety of soil types, primarily peaty gleys, peaty rankers and peaty podzols developed on material ranging from moraine and till through colluvium and hill-wash to scree and frost-shattered

rock. Plant communities were Atlantic and boreal heather moor and bog heather moor, accompanied by the more widespread heath-rush-fescue, stiff sedge-fescue and deer-grass-white bent grasslands and blanket bog, the latter associated with deep peat deposits. 9012, 9015

Loch Fleet, Dumfries and Galloway Region

In association with the Departments of Mineral Soils and Peat and Forest Soils, the Department of Soil Survey is assisting in site investigations within the catchment of Loch Fleet aimed at discovering the causes of the gradual acidification of the Little Water of Fleet. The experiment, which is administered by the South of Scotland Electricity Board on behalf of the North of Scotland Hydro Electric Board, the Central Electricity Generating Board and the National Coal Board, will eventually proceed to investigate the results of different land and water management techniques on the water chemistry of the loch and the Little Water of Fleet, with the aim of establishing a self-sustaining trout population. Water-transfer through or over different soil types and vegetation communities is an essential element in the studies. The Department is involved in base-line investigations to produce an inventory of soil and vegetation based on a grid inspection at 50 m interval. Soil profiles from approximately one third of the 1 km^2 catchment have been described to date, mainly in the eastern sector. The catchment is dominated by peaty soils, mainly peaty rankers and peaty gleys of the Dalbeattie Association, peaty gleys of the Creetown Association on till derived from a mixture of granite and greywacke, and shallow and deep peat. The absence, or presence and intensity of flushing at the sites appears to be an important factor in assessing water movement through and over the catchment. Initial results suggest that, because of the small number of plant species present, a quantitative approach based on the relative abundance of individual species might provide the most meaningful results. For example, the abundance of flying bent *(Molinia caerulea)* might be related to degree of flushing. Records will be entered on a microcomputer data file to facilitate analysis. 9012, 9015, 2066

River Spey Abstraction Scheme, Grampian Region

Grampian Regional Council proposed to abstract some eight million gallons of water daily from a series of tube-wells sunk in the lowest terrace gravels of the River Spey. These wells will be sited mainly between Mains of Dipple and Orton, south of Fochabers.

In conjunction with the Consulting Engineers, Sir M. MacDonald and Partners, soil studies are being undertaken to determine the impact of this abstraction and its effect upon the surrounding arable area. These have included the installation of 16 dip-wells to a maximum depth of 4 m to establish the location of the ground-water table; fluctuations in levels are being closely monitored. Severe and rapid flooding, allied to the collapse of the dominantly bouldery, coarse sandy gravels of the subsoil, caused major problems during the installation; most dip-wells reached about 3 m. To help to elucidate the interrelation of crop root development, soil structure and texture, and soil water movement, 174 trial pits were excavated to a depth of

about 1.5 m by the Kubota excavator. (Fig. 9.3). Approximately 170 samples from the tube-wells and profile pits have been analysed for particle-size distribution. In addition, the detailed examination of root distribution in 58 of the profile pits is being made by staff of the Department of Soil Fertility, who are also engaged in the interpretation of the results of a weekly monitoring programme of soil moisture levels recorded by neutron probe in six bores established in grass and root crops to a depth of 1 m.

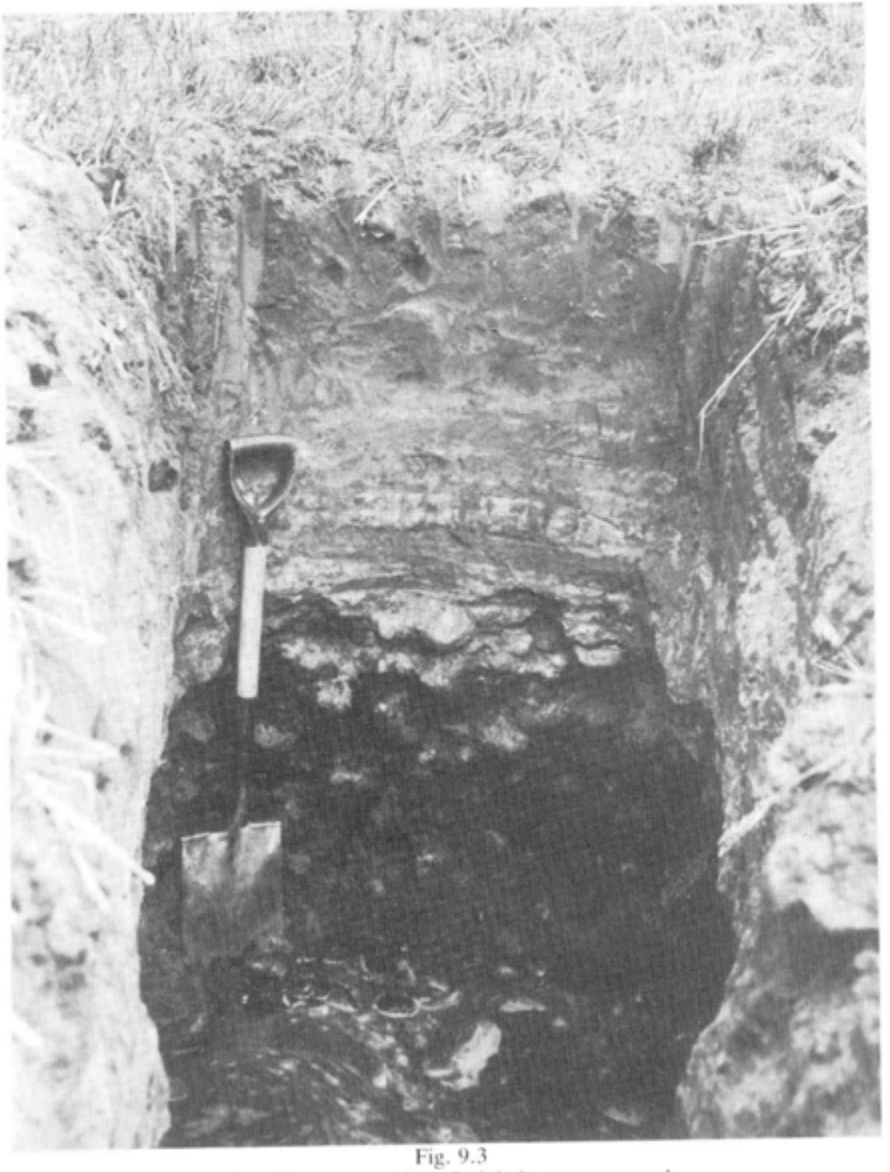


Fig. 9.3
Alluvial soil : topsoil underlain by coarse gravel.

In collaboration with the Department of Peat and Forest Soil Remote Sensing Unit, the investigations were extended to establish whether differences in soil moisture would be reflected in crop-stress patterns. Infra-red photography of the command area has been flown and results are being evaluated.

About a quarter of the area under review awaits investigation. This will involve the installation of another six dip-wells and some 50 to 60 profile pits. Access to this area is still being examined by Grampian Regional Council.

A report summarizing the results of these investigations and the monitoring programmes is scheduled for October 1985. 9012, 2032, 7044

Susceptibility to acidification of the soils of Scotland

A project funded by the Central Electricity Research Laboratories provided them with information for a study of the susceptibility of Scottish soils to acidification. The aim was to present data on the predominant textural class and the levels of exchangeable cations, base saturation and pH of the surface horizons of Scottish soils.

The 1:250 000 soil maps provided a framework for the project. Data were compiled for the dominant soil type within each map unit from analyses of representative soils held in card and computer files, and were presented as an extended map unit key.[14]

The predominance of soils with organic surface horizons showed clearly and accounted for 56 per cent of the total land area; the percentage includes the area of blanket peat, nearly 10 per cent.

It was stressed that, when interpreting the data, attention must be paid to the description of the map units in the key and particularly to their description in the accompanying handbooks. There, much information is given about soil type and variability, slope, rockiness, vegetation, extent of cultivation and management practices, all of which affect the susceptibility of the soils to acidification. 9012

Publications, Cartography, Data Handling Section

Publications

The two remaining handbooks[15, 16] to accompany the series of 1:250 000 soil and land capability for agriculture maps have been published.

A further bulletin[7] on plant communities has been published.

The page proofs of a key to common plant communities[4] have been checked and returned to the printers.

The galley proofs of a memoir[5] to accompany the Black Isle soil map (parts of Sheets 83, 84, 93 and 94) have been corrected and returned to the printers.

The manuscript of a handbook[1] describing the organization of the 1:250 000 soil and land capability for agriculture survey, and the methods used, has been completed.

The manuscripts of the following memoirs are nearing completion: Kinross and Elie (Sheets 40 and 41), Forfar, Banchory and Stonehaven (Sheets 57, 66 and 67), and Orkney.

A review of Soil Survey publications has been made and a number of possible additions to the current range have been identified. The provision of simplified descriptions of soil series is one important item to which the Department is giving priority, and through the Soil Survey Literature Working Party of the MISR/COSAC Liaison Group, a format has been developed. For each soil series there are two sections, each covering one page of A4 size. The first section, compiled by Department of Soil Survey staff, describes the soil map unit under headings covering environmental factors and soil attributes, and the second section, produced by Colleges of Agriculture staff with assistance, where appropriate, from Soil Survey staff, deals with soil management for agriculture.

Memoirs to accompany published 1:63 360 or 1:50 000 coloured soil maps will, in future, contain chapters only on the soil map units and environmental factors. Chapters on agriculture, forestry and land capability classifications will no longer be included, but will form the basis of separate publications.

As an interim measure, short general accounts are being produced to accompany all those published soil maps for which a memoir is not yet available. These accounts are based on the summaries contained in past MISR Annual Reports. One report,[17] on the soils of Easter Ross, has been produced.

Maps, Memoirs and Cartography

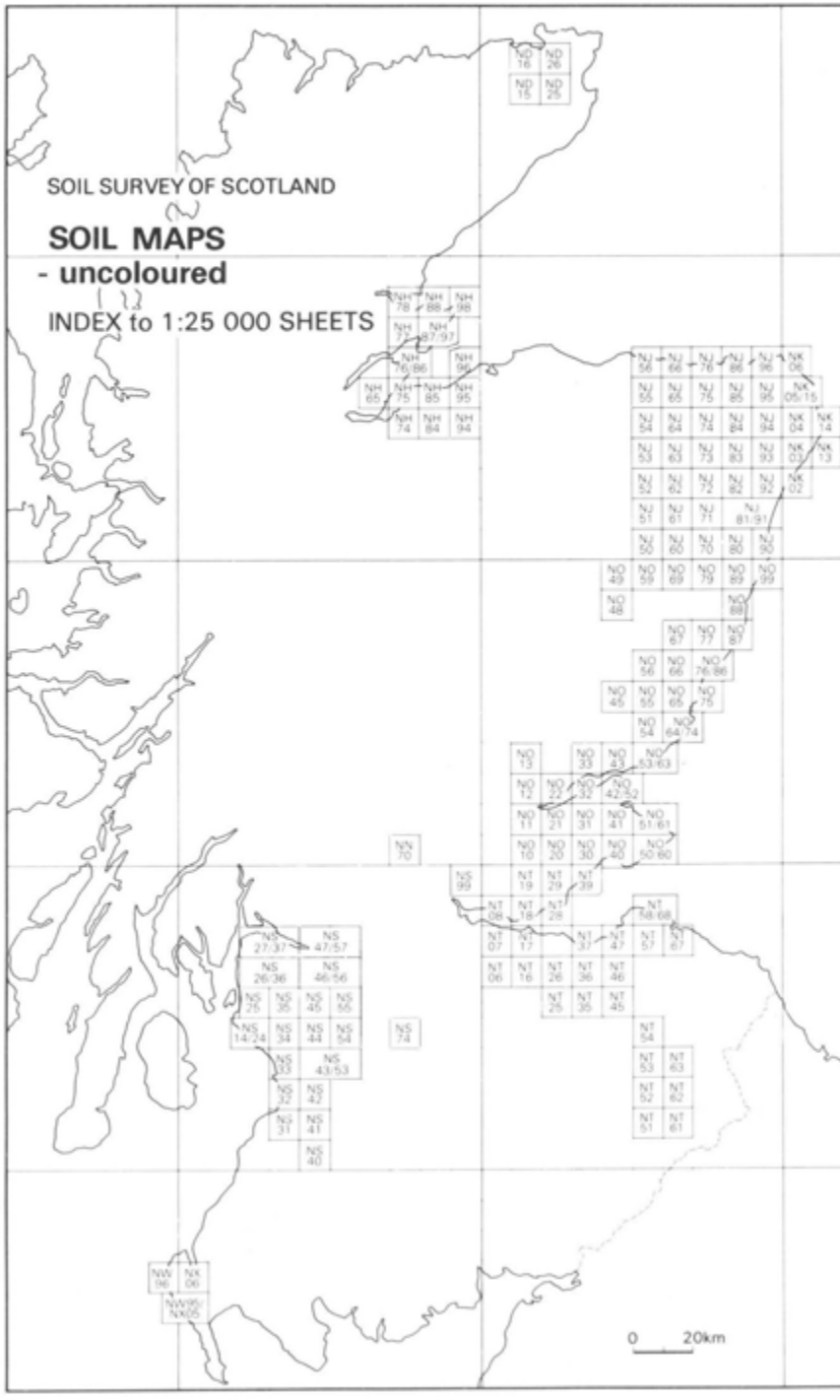
The 1:63 360 soil map Sheet 23 (Hamilton)[18] has been published in both flat and folded version. Sheet 30 (Glasgow) and Sheet 103 (Golspie) have been despatched to Ordnance Survey and colour proofs are awaited.

Drafting has been completed on the following 1:50 000 Land Capability for Agriculture (LCA) maps: Sheets 38 (Aberdeen), 59 (St. Andrews and Kirkcaldy), 65 (Falkirk and West Lothian), 66 (Edinburgh), 67 (Duns and Dunbar) and 70 (Ayr and Kilmarnock). Much of the pre-press work involved in the production of the LCA maps will be undertaken in the Cartographic Section. New photographic processing equipment has been installed in the extensively renovated darkroom suite and the larger film sizes required for the Ordnance Survey Landranger format can now be handled in-house. It is intended that the LCA sheets be printed in batches at Ordnance Survey. The plate-ready map components will be stored and a single plastic-based colour proof of each sheet will be held for reference until the printed paper copies are published.

Investigations into the digitizing of the 1:50 000 LCA maps have been discontinued. Work in this area has been transferred to the 1:25 000 and 1:250 000 scale soil maps.

Production continues on 1:50 000 provisional dye-line soil maps. Fifteen of them have now been published,[19-33] covering areas of north-east Scotland, the Firth of Clyde and the Inner Hebrides. The remaining sheets in this series should be completed in 1985.

In MISR Annual Report No. 49 it was reported that work had been suspended on the 1:25 000 soil map series. The total number of maps then published was 153, all of them based on Ordnance Survey Provisional


SOIL SURVEY OF SCOTLAND
SOIL MAPS
- uncoloured
INDEX to 1:25 000 SHEETS
0 20km

Edition base maps with a 10 x 10 km format. They were available free of charge to interested parties on a restricted circulation basis. Work has restarted on 1:25 000 scale soil maps. All new publications will be produced on Ordnance Survey Pathfinder base maps with a 20 x 10 km format and will be freely available for purchase from the Soil Survey of Scotland at this Institute. Six new sheets have been published,[34] five in the area west of Glasgow, NS 26/36 (Bridge of Weir), NS 27/37 (Greenock and Port Glasgow), NS 43/53 (Kilmarnock and Darvel), NS 46/56 (Glasgow (West)), NS 47/57 (Milngavie) and a re-issue of a sheet north of Aberdeen, NJ 81/91 (Dyce).

An important objective of the year has been to investigate the application of digital techniques to the production of single-factor maps. Work in this area has been concentrated on three 1:25 000 soil maps. The soils information for sheets NJ 81/91 (Dyce) and NS 43/53 (Kilmarnock and Darvel) has been digitized by Laser-Scan Laboratories, Cambridge and sheet NO 20/30 (Glenrothes and Falkland) has been digitized by Ordnance Survey. In addition the soils information of the seven 1:250 000 soil maps of Scotland has been digitized and un-formatted files are being held at Laser-Scan Laboratories whilst alternative systems of digital manipulation are being investigated. The MISR Computer, a Data General Eclipse, is not yet equipped to handle software packages like GIMMS. Preliminary work has therefore been carried out at the University of Aberdeen Computing Centre where GIMMS has been implemented on a Honeywell 66/80 computer. It is unlikely that GIMMS will be entirely suitable for the Department's requirements and the Department of Statistics are developing software to assist in the manipulation of the soil series-based datafiles. Other software packages are being investigated in collaboration with Laser-Scan Laboratories and Ordnance Survey. The experience gained with GIMMS will be valuable in assessing Soil Survey requirements.

A map showing the distribution of soil associations is being scribed. The base map is the Ordnance Survey 1:625 000 Routeplanner which shows all of Scotland on a single map-sheet. 9012, 9013

Systems Analysis and Data Processing

The efficient collection, organization and subsequent analysis of soil and soils related data is an essential requirement for the continuing research and development programme of the Department of Soil Survey and bears directly on many aspects of work being conducted by other Departments within the Institute, and by our colleagues in the Colleges of Agriculture, and other outside bodies.

One very important aspect of this future development programme, involving directly and indirectly the Field, Applications and Contracts, Publications and Cartographic Sections, will concentrate on the detailed characterization of Scottish soils at the soil series level. Particular emphasis will be placed on the systematic collection of pedological, agricultural, environmental and soil physical data, using statistical map unit analysis methods, with the aim of enabling regional inter- and intra-series variability

limits to be more clearly defined, and in the longer term, national overview trends in such soil characteristics to be assessed.

The storage of such large volumes of data, with a subsequent need to access, manipulate and display data subsets quickly and efficiently, in both textual and cartographic form, can only be carried out effectively using modern computer-based storage and information retrieval techniques.

Unfortunately, the infrastructure of the Department of Soil Survey differs from that of other Departments in that many of its field-based operations are conducted from Regional Offices throughout Scotland, which lack direct access to mainframe computing facilities.

However, a diverse range of data-processing applications have benefited greatly since the introduction of departmental microcomputer-based data handling techniques, and such facilities have proved to be ideally suited in many respects for handling various forms of Soil Survey data. It has been decided, therefore, to extend the use of microcomputerized data-handling techniques to the Regional Offices, as a matter of some priority, and to create an integrated data collection and processing system which will be compatible with existing Institute mainframe database facilities, and fulfill the specific requirements of both the Field and the Applications and Contracts Sections of the Department.

To initiate and supervise this project, and to maintain and strengthen the very important links with the Departments of Statistics and Mineral Soils, a Systems Analysis and Data Processing Section has been instigated within the Department of Soil Survey, with responsibility for:

(a) setting up and controlling the various microcomputer-based data processing functions specific to the Department of Soil Survey and its Regional Offices

(b) co-ordinating and overseeing bi-directional data flow between the Soil Survey Department, its Regional Offices and Institute mainframe computer files

(c) fulfilling an advisory and control function between the Department of Statistics and other Institute departments and outside bodies, with an interest in Soil Survey data and digital databases

(d) assisting in developing direct links between such databases and the automated cartography project, and

(e) using relational and heirarchical database management techniques in an attempt to assess regional and national trends exhibited by such soil characterization data, in collaboration with the leader of the Field Section.

Although at a fairly early development stage, much of the basic groundwork involved with the setting up of such a system has been completed, and progress during the reporting year can perhaps best be described with reference to hardware and software facilities currently available.

A dedicated terminal and Epson MX100 dot matrix printer, linked to the Data General mainframe computer in the Department of Statistics, has been installed. It is used extensively in connection with data entry to the National Soil Inventory and related files, and for interrogation of the Institute Soils Database.

Four Apple microcomputers have now been purchased. Two units are installed in the Systems Analysis and Data Processing Section within the Department of Soil Survey, and the other two are in the Regional Offices at Auchincruive and Perth respectively. Although all four machines are essentially configured in a similar manner (twin 5¼ inch floppy disc drives, dot matrix printer, CP/M capability), the main microcomputer within the Department has additional features. This machine is linked directly to the Data General mainframe computer and is capable of being used as a remote terminal. Firmware is installed to enable data to be transferred from mainframe files to Apple floppy discs and vice versa. Although the relational database management system (d-Base II) chosen for use within the Department and its Regional Offices is not directly compatible with standard Apple DOS files, software is now available which enables such files to be converted to CP/M format and then transferred directly into pre-defined d-Base files. Such selected subsets of data are then in a form which can be used independently of the mainframe computer, either within the Department or, when required, by staff in the Regional Offices using their own microcomputing facilities.

In a similar manner, data prepared in the Regional Offices may be transferred without subsequent data entry and extensive verification procedures to mainframe files, via the Systems Analysis and Data Processing Section.

This latter facility has considerable implications as regards future field-data collection methods, and serious consideration is being given to the use of direct digital data capture methods in the field, using self-contained hand-held data-loggers.

Although it will be some time before suitable microcomputing equipment can be installed in all the Regional Offices, and planned data flow techniques fully implemented, considerable progress has been made.

During the reporting year, a range of microcomputer-based databases have been or are in the process of being compiled, and software has been written to enable post-processing functions to be carried out on the data where required, to yield textual or graphic output. In general terms, these databases are specific to the internal requirements of the Department of Soil Survey and its Regional Offices, but derived reports will be of considerable value to staff in other departments within the Institute, and have been used extensively in relation to specific external contractual work undertaken during the year. Such databases include 1:250 000 scale soil map unit definitions, soil association/series definitions, catalogues of archival material relating to soil profile information, Soil Survey literature references, micromorphological data and ecological data of a vegetation and phytosocological nature. 9070

Agricultural Shows and Displays

The Macaulay Institute display caravan has been present at the Royal Highland Agricultural Show, Edinburgh, and at agricultural shows at Ayr, Turriff and the Black Isle. On each occasion the soil maps and displays of soil

monoliths provided a focus of attention for farmers and other members of the public.

Soil maps were also exhibited at the Annual Conference of Scottish Geography Teachers at Jordanhill College, Glasgow, where discussion centred around the value of soil maps in environmental projects in schools.

Assistance was given at a West of Scotland Agricultural College Demonstration entitled "Increasing Output from a Hill Farm", at Minnygap Farm, Dumfries. A number of soil pits were included in a tour of the farm to show a range of hill soils. Maps and publications were also on display at an East of Scotland College "Farm Fair" held in Forfar, when many farmers attended to discuss the input made by agricultural science to practical farming.

Soil maps of Scotland were part of a European exhibit "Cartography in Western Europe" at the Spring convention of the American Congress for Survey and Mapping in Washington D.C., and were selected for display at the Seventh General Assembly of the International Cartographic Association in Perth, Western Australia. A display of land capability maps was mounted at the Easter meeting of the British Society of Soil Science in London.

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10. TECHNICAL SERVICES

A. W. STUART

All four sections of Technical Services have again experienced a heavy work-load this past year. A summary of the work undertaken by the individual sections is given in the following paragraphs.

Instrumentation

Peat and Forest Soils On a Department of Environment grant, further work was carried out in connection with the acid rain project, *viz.* the prefabrication of 120 tilting bucket sampling devices from Styrene sheet.

Soil Organic Chemistry Further development work on the Video Image Analysis project was necessary so that a new ciné camera could be incorporated into the system. A further growth chamber is to be constructed in the near future.

Spectrochemistry A nebulizer head and chamber was developed for the Inductively Coupled Radio Frequency Plasma Spectrometer and an electro-pneumatic, manually controlled carbon rod cutting saw. A computerised microdensitometer was also made for Dr M. J. Adams.

Electronics

There is an increasing interest in the use of computers, not only for statistical analysis of data from experiments, but also for the control of laboratory equipment, and this interest has been reflected in the nature of the tasks undertaken during the past year.

Although routine repair and maintenance continues to be the most time-demanding part of the workload, the Section's staff have assisted in various computer orientated tasks, including the provision of remote computer terminal facilities in Craigiebuckler House for the Soil Survey Department, and the provision of computer terminal facilities in the new offices of the Remote Sensing Unit. Special purpose interfaces have been constructed for equipment connected to the Institute's main frame computer, and additional cabling installed.

Collaborative work on laboratory equipment automation is continuing with the staff of the Soil Fertility and Soil Organic Chemistry Departments, and further automation projects for other Departments are under consideration.

Photography

The services of the Photographic Unit continues to be in great demand along the usual lines of Diazo slides for lectures, linework and black and

white prints for publications and colour prints and transparencies for record and display purposes.

Field work this year was undertaken mostly for the Department of Soil Fertility to record the manganese effect on root development and tiller growth of spring barley. Also photographed were the effects of sulphur applications on grass plots at Mains of Fordoun.

Slides for farmer discussion groups on soil fertility and crop growth were also prepared.

Photography in the field for the Department of Soil Organic Chemistry of the iron ochre problem resulted in some spectacular "down the hole" photographs.

The planning of a proposed new suite for the Photo Unit, to be built on top of the existing Workshop was undertaken and it is hoped that work on the proposed project will start in 1985.

Joinery/Building Maintenance

Due to the ever-increasing demand for extra space and the continuing acquisition of capital equipment throughout the Institute, this Section has again had a busy year refurbishing various rooms and laboratories.

Mineral Soils Rooms 243A/B and 241A/B were refurbished to provide more laboratory working space and to up-date dark-room facilities.

Remote Sensing Unit The installation of five Multi-Purpose Mk II 9.6m x 2.6m prefabricated sections supplied by R. B. Farquhar of Huntly on a prepared site in the west quadrangle was overseen and afterwards individual office areas were prepared and services (water and electricity) were installed.

Room 348 was refurbished to provide an air conditioned area for housing the Prime computer used for Image Processing work carried out by the Unit.

General Maintenance

With the work load being so great this past year, very little progress has been made with resealing and painting the external windows. However, the rewiring programme for the lighting circuits throughout the Institute is continuing as is the installation of control thermostats for the underfloor heating in individual rooms.

11. LIBRARY

A. H. W. DICKIE

The Library was very busy throughout the year, with regular use of it being made by visiting research workers as well as the permanent staff. The reduced number of books which were bought — 388 — reflected the steep rise in costs of academic books, while a record number of 1,116 items were borrowed, of which 583 came from British Library. The use of Union Lists, compiled both locally and nationally, has enabled us to borrow more from libraries outwith the British Library Lending Service. In this way, the increased requirements of readers can be met while keeping within current costs. A total of 146 items were lent to other libraries.

Lists of Available Publications are obtainable from the Librarian. In response to the last list circulated 440 reprints were sent out, and an additional 846 in reply to direct applications.

Two Current Awareness Bulletins have continued to be produced — a weekly Periodicals Bulletin and a less frequent Book Bulletin. Both are circulated internally, and are also sent to other Scottish Agricultural Research Institutes and to local research establishments.

An APPLE IIe, an Epsom Fx-80 Printer and a modem were bought so that the facility for on-line information retrieval *via* DIALOG is now available.

APPENDIX I

NINTH

T. B. MACAULAY LECTURE

22nd November, 1984

by

Sir Leslie Fowden, F.R.S.

Chairman:

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NITROGEN, FROM SOIL TO SEED

By Sir Leslie Fowden, F.R.S.
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INTRODUCTION

In accepting your Director's invitation to present the Ninth Macaulay Lecture, I was greatly honoured and conscious that I would join a band of distinguished agricultural scientists or administrators who had spoken previously in this series. My own background lies in biochemistry, the specialism of the Chairman of your Institute's Governing Council, but of greater probable relevance is the fact that I am Director of a sister Institute having much in common with the Macaulay. Rothamsted and the Macaulay each owe their existence to the vision of individuals determined to advance the cause of agricultural science, especially the knowledge of soils, their chemistry and fertility in relation to crop production. Rothamsted of course is much older than the Macaulay, and your first Director, Sir William (Gammie) Ogg, later became the fifth Director of Rothamsted in our centennial year 1943. With its greater longevity, the scientific programme of Rothamsted has become broader than that of the Macaulay, so that soils work now represents somewhat less than a third of the total effort, and is complemented by programmes in crop physiology and agronomy, biochemistry and the various facets of crop protection. In seeking a topic for this lecture, I was mindful of the broad scope of my Institute's research and in choosing to trace the importance and course of nitrogen in soil-plant systems, I shall range over several scientific disciplines contributing importantly to current agricultural research. Nevertheless, the final emphasis is likely to be biochemical, though I have to my credit one publication in the Journal of Soil Science in 1953 describing an investigation, employing the then recently developed technique of paper chromotography, that provided the first evidence for the presence of free amino acids in soils.

SOIL FERTILITY AND CROP PRODUCTION

General Considerations

Successful crop production requires that an optimum relationship between a soil and the crop it nurtures should exist. The soil acts as a matrix

in which root systems develop to provide an anchorage for the aerial parts of the plant, and to take up all nutrients essential to the plant, with the exception of carbon. (As a digression, we may note that the present atmospheric CO_2 levels of 330-350 ppm may limit photosynthesis under some light or temperature conditions, and that enhancement of CO_2 concentrations within glasshouses is often practical to give higher yields of protected crops. Man's pollution of his aerial environment by increased burning of fossil fuels is gradually raising CO_2 levels and in direct consequence an increase in photosynthetic carbon fixation of almost 5 per cent per decade may be anticipated, provided it is not offset indirectly by coupled changes in climate). The ability of a soil to sustain plant growth and allow the full potential of a crop to be achieved depends upon both the physical characteristics of the soil and subsoil and its chemical properties. Without amendment, few natural soils permit a crop to attain its maximum potential: growth may be retarded by physical constraints on root proliferation within soils, by soil structural factors conducive to adverse water regimes (water-logging or water stress), or by chemical factors limiting the fertility and the soil's ability to provide adequately for the nutrient requirements of crops. Modern cultivation practices and fertilizer treatments seek to overcome the limitations associated with particular soils to the maximum extent possible, having regard for the efficiency with which different inputs are utilized. In this respect, efficiency must be evaluated using at least two yardsticks — the economic return per unit of input should be as favourable as possible, and adverse environmental effects should be kept to an absolute minimum.

The Importance of Nitrogen Fertility

A wealth of field experimentation in the UK, commencing with Rothamsted's Broadbalk wheat experiment, established that crops generally are much more responsive to N applications, than to those of P or K, *ie* withholding mineral–N fertilizer normally results in a greater reduction in yield below a crop's potential than does a similar deprivation of P– or K–fertilizer. This high dependency on nitrogen is linked with the dynamic behaviour of the element in agricultural systems, for unlike P and K, N is quite mobile in soils (both by physical transport and chemical metabolism) and mineral–N residues do not accumulate significantly by comparison with those of P and K. Whilst NH_4^+ can undergo cation exchange and be held at surface exchange sites on soil particles, the activities of nitrifying micro-organisms in soils normally effect a fairly facile conversion of NH_4^+ to the mobile NO_3^- form, which can leach from soils especially during winter rains. Thus, N–fertilizer practices seek to supplement mineral–N, at levels within the soil profile principally explored by plant root systems, by amounts, and at times, designed to elicit optimum crop performance, leaving little non-absorbed mineral–N to escape ultimately to the environment.

As an approach to this goal, a computer-based model simulating the movement of N within the soil profile is under active development: it would seek to predict mineral–N concentrations likely to be encountered at

different points down a soil profile in spring on the basis of autumn soil–N measurements, and a knowledge of simple soil and weather (temperature and rainfall) information. The model includes factors for mineralization of organic–N and crop N–uptake. Soon farmers may be able to adopt such a model and, with their own computers, introduce parameters descriptive of their local situation and target yields to predict optimum spring–N applications for individual fields.

Nitrogen Inputs and Crop Performance

UK farmers now apply nearly 1.5 Mt fertilizer–N to their crops, with somewhat more of this total being given to grass than to arable crops. The cost of this N in 1983/4 was about £600M. This added N supplements other inputs to cropping systems by natural phenomena, i.e. wet and dry precipitation from the atmosphere, and biological N fixation. The Broadbalk continuous wheat and wilderness experiments have provided estimates of these natural N inputs. On the wheat plot receiving no added fertilizer since 1843, some 25-30 kg N seems to be available annually to the wheat, contributed as ~10 kg wet and ~5 kg dry deposition, ~5 kg in seed, and ~5 kg fixed biologically by near-surface algae. Some 40 kg N enter the undisturbed wilderness area annually, yet deposition must be similar to that on the adjacent wheat, and no N is added with seed; fixation then must contribute significantly more, perhaps because the surface microbial flora is undisturbed, in contrast to the situation on the cultivated wheat plots. Overall, no more than 50 per cent of the added fertilizer–N is recovered by crops, but the exact efficiency of N use varies from crop to crop, and from season to season, and depends also on the level of husbandry and intuitive experience of individual farmers. Average applications of N nevertheless have increased significantly for many crops grown in England and Wales in the period 1970-83 (see Table 1). The increased applications to winter wheat and grassland are particularly marked, the former to keep N inputs roughly in line with the extra demands of newer, higher potential varieties produced by breeders during this period, whilst that to grassland has served to bring

TABLE 1
Fertilizer use on arable crops and grassland: overall values for England and Wales.

	Applications kg ha^{-1}					
	N		P_2O_5		K_2O	
	1970	1983	1970	1983	1970	1983
Winter wheat	90	182	41	51	35	46
Spring barley	82	107	40	39	44	44
Winter barley	—	150	—	52	—	54
Potatoes	166	199	181	204	250	262
Sugar beet	161	154	117	72	191	160
Grassland						
2-7 year leys	95	182	44	36	36	44
Permanent	51	96	28	21	20	20

applications closer to levels required for good productivity. The fall in N–applications to sugar beet is a consequence of farmers accepting advice that formerly this crop had been over-fertilized with adverse effects on final sugar production and extraction rates. In contrast to N–input levels, applications of P and K to crops during this same period have remained much more constant — again emphasizing the earlier statement that N is the nutrient most strongly influencing crop growth. This quantatative data is derived from the annual "Survey of Fertilizer Practice" conducted by statisticians at Rothamsted for a large sample of fields in England and Wales. Only in 1983 has this type of survey been extended to farms in Scotland, but it is interesting to note that N application to the winter barley crop (184 kg ha^{-1}) is larger than that given south of the border (150 kg ha^{-1}), and almost equal to N provided for winter wheat. Is it that as Scottish farmers who plant approximately equal, but relatively small (compared to spring barley) total areas of winter wheat and winter barley do not wish to differentiate between their N–fertilizations? However, speculation is probably unwise, until such regional differences are confirmed by further annual surveys of fertilizer practices in Scotland.

The Broadbalk experiment has permitted records to be made over long time periods of the response of winter wheat to different levels of N nutrition, and of overall N–balances. Table 2 presents data for the wheat varieties (cvs Cappelle Desprez and Flanders) grown since 1969. Whilst

TABLE 2
Broadbalk Continuous Wheat
(All plots received PK Mg fertilizer)

Years 1970-78: cv Cappelle Desprez

N applied kg ha^{-1}	Grain yield t ha^{-1} at 85% dry matter	N in grain and straw kg ha^{-1}	% N in grain dry matter	Apparent % recovery of each 48 kg N ha^{-1}
0	1.67	30	1.68	—
48	3.48	57	1.66	56
96	4.81	90	1.84	69
144	5.13	115	2.11	52
192	5.49	130	2.20	31
				(mean 52)

Years 1979-82: cv Flanders

N applied kg ha^{-1}	Grain yield t ha^{-1} at 85% dry matter	N in grain and straw kg ha^{-1}	% N in grain dry matter	Apparent % recovery of each 48 kg N ha^{-1}
0	1.31	22	1.72	—
48	3.76	58	1.61	75
96	5.99	107	1.89	102
144	6.41	136	2.21	59
192	7.04	160	2.36	51
				(mean 72)

Flanders is itself now outclassed by yet newer varieties, its genetic potential for yield was considerably greater than that of Cappelle, and this is reflected in mean yields recorded at all levels of N supply (except nil). The table indicates that in this experiment in which the nitrogen balance has attained a dynamic equilibrium, the annual mean off-take of N in Cappelle was 30 kg ha^{-1}, ie a value in line with the estimate of natural input: no satisfactory explanation of why Flanders only removed 22 kg ha^{-1} (mean of 4 values only) is available, but one suggestion is that in the years 1979-82 biological N–fixation was reduced. At higher levels of N–fertilization, Flanders removed more N than Cappelle in line with the higher grain yields. This fact in turn reflected the more efficient use of fertilizer–N; the apparent percentage recoveries of 48 kg stepwise additions of N were always greater when Flanders was grown, as was the calculated overall recovery (72 per cent for Flanders compared with 52 per cent for Cappelle).

This trend hopefully reflects an expectation that in experiment and in farming practice newer cereal varieties can exploit soil mineral–N levels more effectively; there is a need, nevertheless, for a much fuller understanding of the physiological and biochemical mechanisms associated with the uptake of nutrient–N by crop roots from field soils, and of the internal regulatory controls governing the passage of nutrient ions across cell membranes and their transport within plants, because each of these phenomena influences the efficiency of soil–N utilization.

Table 2 also provides clear evidence that higher levels of N–fertilization produce increased N (and protein) contents of cereal grains *ie* the composition of plants, or their organs, may be altered in ways influencing the nutrition of man or his livestock. This theme will be developed in the second part of the lecture: mechanisms regulating the flow of mineral nutrients, here N, into the final products of biosynthesis will be examined, and opportunities for manipulating the control processes assessed.

NITROGEN: ITS BEHAVIOUR WITHIN THE PLANT

An Overview

A general scheme depicting nitrogen uptake and movement, transformation and deposition in plants is presented in Fig. 1.

NO_3^- is the principal form of mineral–N taken up by crop roots, being produced in soil by microbial oxidation of ammonia applied direct or arising by degradation of area fertilizers, by mineralization of organic matter, or as a product of nitrogen fixation by free-living soil micro-organisms. NH_4^+ is usually regarded as a secondary form of nutrient–N absorbed by root systems, but situations and species exist in which its uptake is predominant. Additionally, legumes acquire ammonia following symbiotic N–fixation in their root nodules.

NO_3^- may be reduced to ammonia and assimilated into simple organic–N compounds in crop roots before translocation to the aerial portions of the plant; alternatively NO_3^- may be translocated as such to the foliage before transformation. The balance between these alternative processes is in part species dependent, and may be affected by the

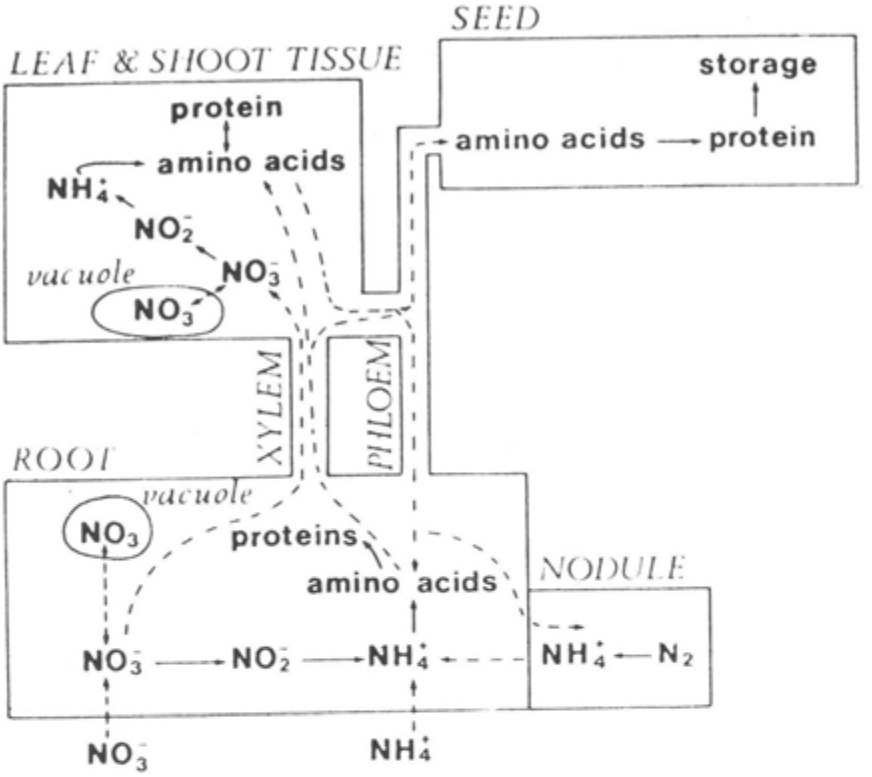


Fig. 1
General diagrammatic representation of uptake, assimilation and transport mechanisms of nitrogen in plants.

physiological status of the plant, *eg* enhanced external NO_3^- supply or reduced photosynthetic activity favour greater NO_3^- translocation. When N is translocated from root to shoot in organic form, the amino acid amides, glutamine and asparagine, are the main transport compounds: however in certain legumes, allantoin and allantoic acid become the principal compounds transporting N out of root nodules. At sites of new growth, N is released or transferred by these transport compounds, and introduced into the full range of nitrogenous constituents forming the essential fabric of plants (ie amino acids and proteins, nucleic acids, chlorophyll, auxin, etc); also into a wealth of secondary products of lesser defined importance and often encountered only sporadically across the plant kingdom. During the period of flowering and seed formation, and the accompanying senescence of leaves, an extensive remobilization of N takes place: some leaf proteins are degraded, and the resulting low molecular weight compounds are transported and used to support biosynthesis in the developing seeds. Since seed proteins differ markedly in composition from leaf proteins, considerable metabolic interchange of N is associated with this final stage in a plant's life cycle.

Within this complex framework of intermediary metabolism associated with N utilization by the developing plant, we may expect to identify points (ie sites of specific enzyme action) of crucial importance in regulating the overall flux of N assimilation, and thereby growth, or in channelling N into different branches of the much ramified pathway. Examples of such sites are considered below, in the belief that a fuller understanding of the properties of key enzymes, and the factors determining the expression of their activities, will be vital to the future successful application of genetic engineering technologies to crop improvement.

Primary Assimilation Steps

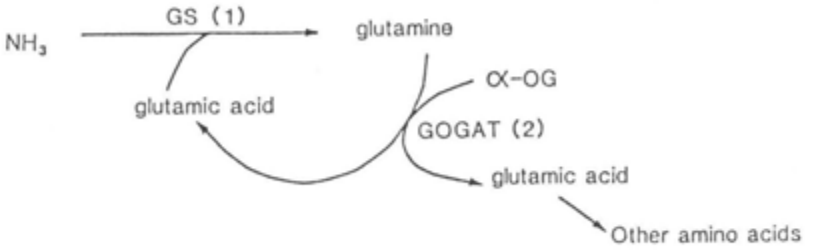
Three enzymes acting sequentially are involved in the introduction of N from NO_3^- into the first organic N–compound; the enzymes are nitrate reductase, nitrite reductase and glutamine synthetase, and NO_2^-, NH_3 and glutamine are their respective products.

Nitrate reductase has been studied intensively: in leaves, it is located in the soluble cytoplasm, where its activity is "induced" by the substrate nitrate, and its action is dependent upon an indirect coupling to photosynthetic electron flow. As the first enzyme concerned with the assimilation of nutrient–N, it has attracted attention as an obvious control point governing the *in vivo* flux of N through intermediates and finally into plant proteins. However, attempts to correlate nitrate reductase activities with vigour and high-protein grain character in cereal cultivars have not been convincing, and so nitrate reductase activity is unlikely to provide a satisfactory diagnostic tool in the early selection of breeding lines: nor can we be convinced that enhancement of this enzyme represents a priority target for genetic manipulation work.

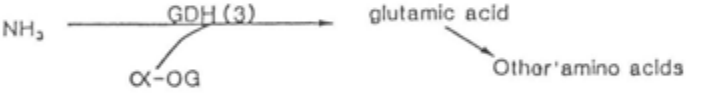
The product of nitrate reductase action, nitrite, passes into the chloroplasts of leaf cells, and there many of the later stages of N assimilation into amino acids occur. In the reaction converting NO_3^- to NH_3, electrons are donated by reduced ferredoxin (FdH_2), itself a direct product of electron transfer from light-activated chlorophyll. This, and several later reactions involved in amino acid synthesis, are then light-mediated processes.

Ideas concerning the pathway of NH_3 assimilation have been revised totally since glutamate synthase (GOGAT) was recognized as an enzyme of higher plants in 1974. It acts sequentially to glutamine synthetase (GS) to provide a two-stage, cyclic mechanism introducing $NH_3^{\wedge}N$ first into the amide–N of glutamine (reaction 1) and then into the α–amino–N of glutamic acid (reaction 2). (Thereafter the amino group may be transferred to other recipient carbon skeletons to form additional amino acids). The earlier view that the primary assimilation of NH_3, present in physiological concentrations, occurred *via* a glutamic dehydrogenase (GDH)-catalysed process (reaction 3) is now largely rejected after consideration of relative enzyme affinities for NH_3, and the results of ^{15}N–labelling and specific inhibitor studies.

The Glutamine Synthetase (GS) pathway



The Glutamate Dehydrogenase (GDH) pathway



(∝-OG; ∝-oxoglutarate, a respiratory intermediate)

From this brief background, glutamine synthetase then emerges as an enzyme whose activity crucially influences the rate at which inorganic–N enters the organic fabric of plant cells. The enzyme plays an additional role in plants exhibiting photorespiration: this process, common to all C_3 –photosynthetic plants, leads to the evolution of CO_2 (and an equimolar amount of NH_3), and so acts counter to photosynthesis reducing net CO_2 fixation. The rate of photorespiratory release of NH_3 can exceed that of its initial production from nitrate by 5-10 fold and so the re-assimilatory function of glutamine synthetase for photorespiratory NH_3 is quantitatively most important.

TABLE 3
Glutamate synthase activity in parent and mutant barley plants

Leaf tissue	Ferredoxin dependent	NADH dependent
Maris Mink	100 (42.2)	100 (1.29)
RPr 82/1	1.3	80.6
RPr 82/9	0.5	103.2
Root tissue	Ferredoxin dependent	NADH dependent
Maris Mink	100 (1.2)	100 (0.7)
RPr 82/1	2.7	105
RPr 82/9	5.6	103.5

Activities expressed as a percentage of those determined for parent.
Values in parenthesis are absolute acitivities nkat g^{-1} FW.

Biochemical lesions in a plant's ability to re-assimilate NH_3, formed as a result of photorespiration, can cause rapid browning and senescence of leaves maintained in normal air. This situation is observed in mutants of barley lacking, or highly deficient in, ferredoxin-dependent glutamate synthase. The mutant plants apparently behave normally if kept in a CO_2-enriched atmosphere, when the initial oxidative step triggering the photorespiratory process becomes inconsequential. Under these circumstances, little if any NH_3 is produced by photorespiration and the residual glutamate synthase activities (ferredoxin- and NADH-dependent, see Table 3) apparently are sufficient to handle NH_3 arising solely from reduction of NO_3^-. The dramatic effect of such mutations on amino acid levels of leaves maintained in air is shown in Table 4, in comparison with the near normal concentrations present in leaves kept in 0.5 per cent CO_2 atmospheres. The mutants' inability to metabolize glutamine is very apparent; asparagine as an alternative compound serving to detoxify NH_3 also accumulates, and NH_3 levels are dangerously high, *ie* assimilatory metabolism backs up.

TABLE 4

Soluble amino acids in leaves of ferredoxin-dependent glutamate synthase deficient mutants of barley

Air	Asp	Ser	$AspNH_2$	Glu	$GluNH_2$	NH_3
Maris Mink	1.4	3.1	2.8	3.9	5.6	0.5
RPr 82/1	0.4	0.3	20.2	0.4	57.0	11.3
RPr 82/9	0.9	0.5	38.5	1.3	41.2	12.7
0.50% CO_2						
Maris Mink	2.0	0.9	1.3	4.4	1.9	0.2
RPr 82/1	1.2	0.3	0.2	2.0	3.5	0.1
RPr 82/9	1.2	0.2	2.2	1.9	1.8	0.1

Data as μmol g^{-1} FW

This strange photorespiratory aspect of nitrogen metabolism that requires a rapid recycling of NH_3 makes it even more unlikely that nitrate reductase serves as a principal regulatory enzyme for assimilation, and recent experimentation has sought correlations between glutamine synthetase levels and hybrid vigour in cereal cultivars. Glutamine synthetase exists in more than one form in plant tissues, and so it will be important to define the role of each isoenzyme, and of the different plant genes directing their synthesis. Genomic clones of glutamine synthetase have been obtained, an advance representing a first pre-requisite for any attempt to introduce foreign or additional glutamine synthetase genes into crop plants.

Later N interchanges

The biosynthesis of other organic–N compounds of plants depends upon the transfer of amide- or amino–N groups from glutamine and glutamic acid to appropriate receptor molecules. Transamination is an important process involved in the synthesis of many amino acids that derive their $-NH_2$ group from glutamic acid: alanine and aspartic acid are examples, the receptor

skeletons being normal intermediates of respiratory carbon metabolism. The amide-N of glutamine is transferred in a versatile way providing N for asparagine, arginine, histidine and tryptophan syntheses, for auxin, and the pyrimidine and purine skeletons of nucleic acids.

The twenty amino acids encountered in proteins can be grouped into biogenetic families. For example, aspartic acid may be regarded as the parent precursor of asparagine, threonine, lysine, methionine and leucine: the last four compounds arise as end-products of multi-step branched pathways. In general, we have a complete knowledge of the intermediary stages of amino acid biosynthesis and good, but still partially incomplete, information regarding the enzymes catalysing each biosynthetic step. Currently, emphasis is devoted to gaining a better appreciation of the control mechanisms regulating the activities of the biosynthetic enzymes, especially those initiating a pathway or functioning at branch-points within it, since they probably represent the most critical points determining the overall rate and direction of metabolite flow.

Plant metabolism must provide all the constituents forming the tissues in a finely balanced manner, such that in the normal physiological state the concentrations of individual metabolites are maintained within narrow limits. Whilst many factors combine to ensure this state of close dynamic equilibrium, the role of end-products as inhibitors of key enzymes within the pathway is of major importance. A generalized situation is represented in Fig. 2: each end-product (D, F and G) derived from precursor A may inhibit

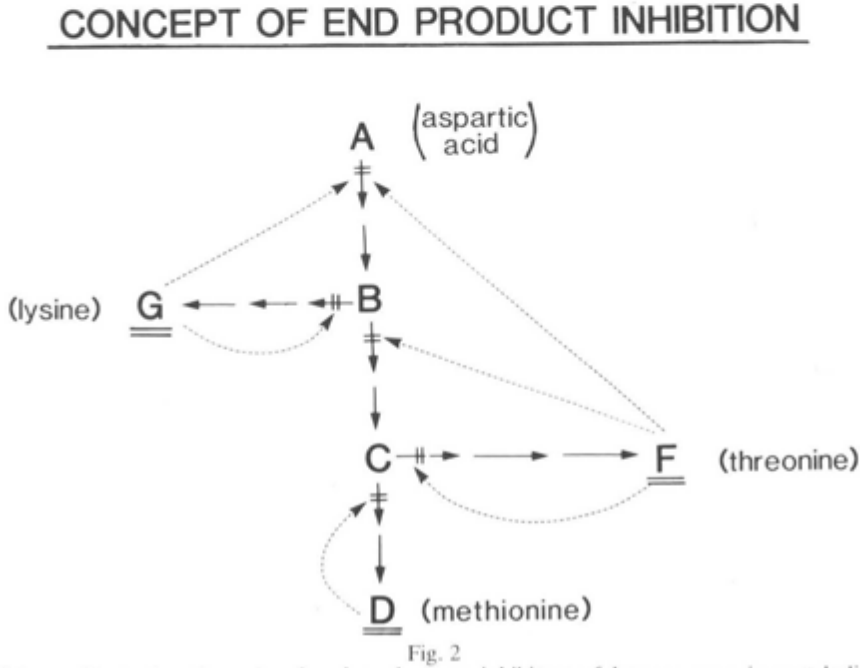


Fig. 2
Scheme illustrating the role of end-products as inhibitors of key enzymes in metabolic pathways.

enzymes concerned in their own synthesis, both at the common initiating reaction and more specifically, at points immediately after a division in a pathway. The scheme also may be viewed as a simplified version of the metabolic conversions producing threonine, lysine and methionine from aspartic acid. At cellular level the situation is more complex, partly because enzymes may exist in isoenzymic forms, that are inhibited differentially by the end products. For example, aspartate kinase, the first enzyme utilizing aspartic acid as substrate, has two isoenzymes in several species studied, one mainly sensitive to threonine, and the other to lysine, inhibition: barley embryos are more complex having three isoenzymes of aspartate kinase. The existence and independent operation of isoenzymes add an extra dimension to plant metabolism and permit the more sensitive control of metabolic fluxes.

In recent years, interest has centred on the possibility of obtaining mutant plant cell lines in which end-product inhibition of a particular enzyme activity has been lost, wholly or partially. At Rothamsted, mutagenized barley embryos have been screened for their ability to grow in the presence of mixtures of lysine and threonine; normal embryos show little or no growth under these conditions because the combination of lysine and threonine inhibits the aspartate kinase isoenzymes and thereby starves the tissue of methionine necessary for its growth. Rare instances of growth are encountered during the screening of mutagenized embryos, and enzymic analysis has indicated that the aspartate kinase isoenzymes in these mutants are either insensitive, or less sensitive, to inhibition by end-products. The continuing biosynthesis of methionine, and hence growth, is then possible. As a corollary, the synthesis of threonine and/or lysine may be unregulated in such mutants and result in their over-production. Some recent data on *free* amino acid levels in seeds produced from two mutant lines of barley derived from the parent cultivar Bomi are given in Table 5. Maximum increases in concentration are: threonine 75-fold, methionine 6-fold, and lysine 20-fold. Although seed protein compositions are not measurably changed, the magnitude of these increases in free essential amino acid levels represents a significant enhancement in the nutritional value of the barley grain, and the mutant lines have been made available to commercial plant breeders. This project provides a nice example of the possibility of selecting and channelling metabolic diversity to provide more desirable products.

A related study using barley embryos sought to select lines that over-produce proline. The selection technique differed slightly in that

TABLE 5
Free amino acid levels in barley grain
(n mol g^{-1} DW)

Cultivar/ mutant	Threonine	Lysine	Methionine
Bomi	118	84	24
R2501	6129	1266	149
R2506	9032	1620	72

structural analogues of proline (rather than proline itself) were employed as a "mimic" end-product inhibitor. Mutant lines selected to date accumulate proline in their leaf tissues to levels 3-6x normal. The interest of these studies does not lie in improved nutritional quality, since proline is abundant in cereal proteins and is not essential for man, but rather in the possibility that enhancement of the free proline content of plant tissues may confer increased drought or salt tolerance — proline accumulates to 10-100x the normal tissue level under stress conditions. However, until greater enhancement of the proline concentration in mutants has been achieved, it is impossible to ascertain whether high proline confers tolerance or is merely a secondary artefact.

Herbicides as Specific Inhibitors of Amino Acid Synthesis

Studies on the mode of action of herbicides in recent years have revealed situations in which lethal effects on plants may be ascribed to specific inhibition of steps in amino acid biosynthetic pathways. For example, the wide spectrum herbicide glyphosate causes an accumulation of shikimic acid, and to a lesser extent shikimic acid-3-phosphate, in treated plants through inhibition of the enzyme 5-enolpyruvylshikimate-3-phosphate synthase which acts in the common metabolic pathway producing phenylalanine, tyrosine and tryptophan. Glyphosate-resistant mutants of *Salmonella* are known and contain an altered insensitive form of this enzyme. If the bacterial gene for the altered enzyme, with the appropriate eukaryotic control sequences could be introduced into a crop plant, it may be expected to confer valuable selectivity among plants to the herbicide. Additionally, glyphosate inhibits the enzyme responsible for the initial activation of phenylalanine necessary for its incorporation into plant proteins.

Another prospective herbicidal compound, phosphinothricin, is a structural analogue of glutamine and behaves as a potent inhibitor of glutamine synthetase: since plants are then prevented from assimilating NH_3, the latter quickly accumulates to toxic levels. Cell lines of alfalfa exhibiting resistance to phosphinothricin have been obtained and appear to possess increased levels (~10-fold) of glutamine synthetase. This preliminary evidence suggests that herbicide resistance may be linked with gene amplification, a mechanism commonly encountered in mammalian cells.

Two chemical companies, American Cyanamid and Du Pont, have developed independently herbicides active at a concentration of a few grams per hectare: the imidazolinones and sulfonylureas, respectively; both potently inhibit acetohydroxy acid synthase, an enzyme catalysing the first key step in the synthesis of valine, isoleucine and leucine. Again, resistant bacteria are known to possess an altered form of this enzyme, but tolerance to sulfonylureas shown by certain higher plant species involves hydroxylation and glucosylation of the herbicides to yield less active or inactive derivatives.

Clearly, intermediary nitrogen metabolism has gained prominence as these newer commercial opportunities have been revealed, and now there is

considerable interest in discovering additional enzyme targets through which regulation of plant growth may be effected more intelligently and precisely.

The Final Phase of Synthesis: Protein Production and Deposition

In leaves and seeds, usually at least 80 per cent of the total N is present in protein. The characterization and description of plant proteins owes much to the work of Osborne, published mainly before 1920, and his classes of protein still provide today's common terminology, ie albumins, globulins, glutelins and prolamins. Recent years have seen a major renewal of interest in the protein complex of commercial grain seeds, and with advanced new techniques a finer resolution and more precise description of the multiplicity of polypeptides constituting seed glutelins and prolamins has been possible. Advances in chemical knowledge of seed proteins have been accompanied by an improved understanding of the genetic basis of seed protein occurrences, and the level of homology existing between protein types in the major cereal species is gradually being documented.

Earlier in this lecture (Table 2), we noted that the protein content of wheat grains was a function of the level of N nutrition provided to the crop. But although higher N fertilizations result in increased total grain protein contents, the major seed protein types are not affected equally: prolamin contents tend to be increased proportionately more than other types of protein, as seen in Fig. 3 for barley hordein. Prolamins generally have low

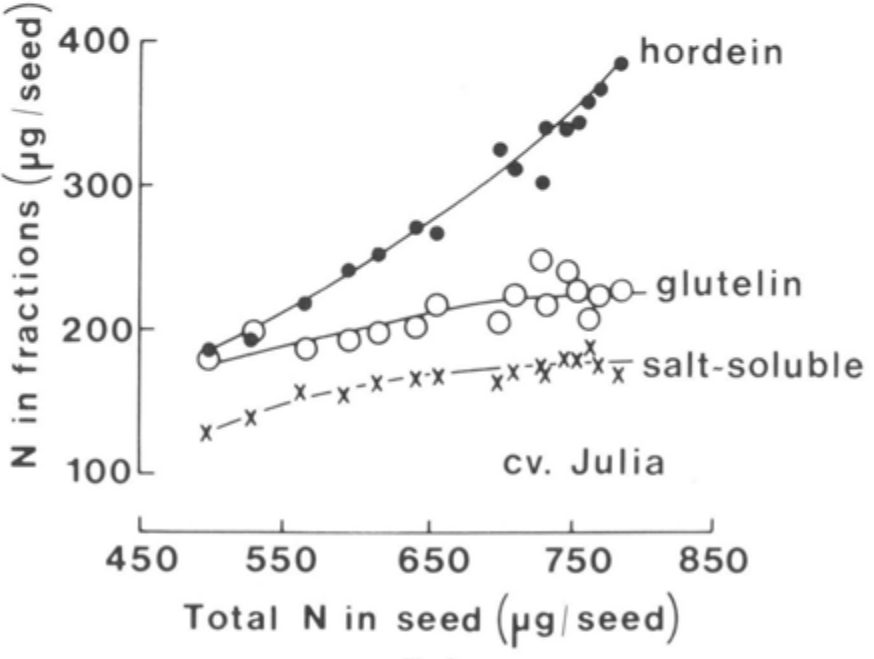


Fig. 3
The relationship between total nitrogen content of barley grains and the amounts of the principal seed protein types.

lysine contents, and since this is the amino acid most limiting in cereal proteins, higher grain protein content is usually associated with a diminished nutritional quality: for the example of barley shown in Fig. 3, the increase from 500-800 mg N per seed was accompanied by a fall in lysine content (expressed as a percentage of total amino acids) from about 4 per cent to less than 3 per cent.

The widespread use of cereal grains both in human and animal foodstuffs stimulated attempts to find cultivars having higher lysine contents, and the recognition of mutants of maize bearing higher lysine is particularly well known. Subsequently, several mutant lines of barley possessing increased lysine contents have been described. The grains of all these high lysine mutants contain reduced proportions of prolamins: the composite Fig. 4 illustrates this for barleys (a wild-type parent cv Bomi and a high-lysine mutant Risó 1508) by depicting the time sequence of deposition of N fractions during seed development and maturity. The end result is that the lysine content of Risó 1508 is 4.9 per cent, whereas in Bomi it is only 3.3 per cent (expressed as mole percentages of total amino acids). However, enhancement of lysine percentages resulting from diminished prolamin

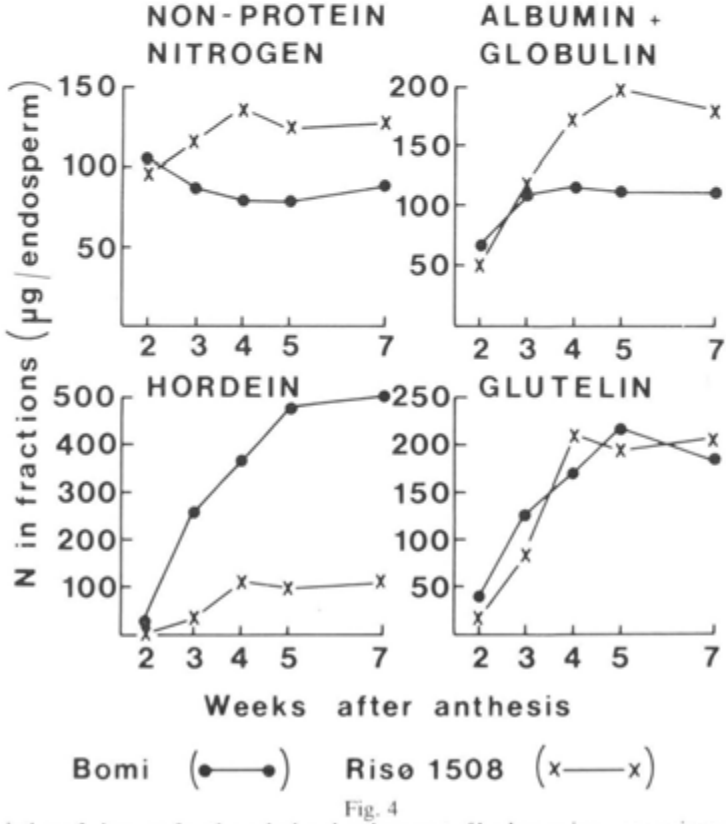


Fig. 4
The variation of nitrogen fractions during development of barley grains: comparison of parent (Bomi) and mutant (Ris 1508) lines.

production is associated invariably with grain yields reduced by 10 per cent or more.

As mentioned above, prolamins are comprised of many electrophoretically-distinct polypeptide species; this is true for hordein of barley whose component polypeptides exhibit considerable variability in lysine content. An option for improvement of grain protein quality may rest in this variability, since genes for specific polypeptides may be identified and cloned; assuming that certain technical problems surrounding gene insertion into monocotyledons can be overcome, it is reasonable to assume that the barley genome could be engineered to contain additional copies of the genes specifying hordein polypeptides rich in lysine. An alternative approach might seek to attach additional lysine codons to cloned hordein genes, prior to genome manipulation. The current "state of the art" requires that many technical problems be surmounted before either of these propositions becomes a reality, but the pace of recent discovery in molecular biology and genetic engineering has been so startling that only a confirmed pessimist would not look to the future with great anticipation.

ADDENDUM

Lawes began his experiments, including the famed Broadbalk, to demonstrate the value to crops of superphosphate, from which he derived much of his income, but with time his fascination with nitrogen increased and his efforts progressively established the greater agricultural importance of this element. I hope my lecture has demonstrated that even today nitrogen still holds many fascinations, not least because its dynamic and versatile behaviour at all stages of plant growth continually poses new challenges for experimental scientists.

Material used in this lecture has drawn heavily on the experiments and ideas of many colleagues at Rothamsted, and I gratefully acknowledge their help.

APPENDIX II

VISITS ABROAD — 1983-84

	Place/Event	*Lectures*	*Date* — 1984	*Financed by*
1. R. V. Birnie	Oberjettenberg (Federal Republic of Germany) Remote Sensing Investigations	—	February/March	Self
2. A. W. Blyth	Dublin (Ireland) 7th International Peat Congress	1	June	DAFS
3. J. M. Bracewell	Wiesbaden (Federal Republic of Germany) 6th International Symposium on Analytical Applied Pyrolysis	2	September	DAFS
4. M. V. Cheshire	Langen (Federal Republic of Germany) Inst. für Wasser, Boden u. Lufthygiene des Bundesgesundheitesamtes	—	May	British Council and German Institute
5. M. V. Cheshire	Ghent (Belgium) NATO Workshop on Soil Colloids	1	September	NATO
6. B. A. Goodman	Goa (India) Magnetic Resonance Conference	1	September	DAFS
7. B. A. Goodman	Ghent (Belgium) NATO Workshop on Soil Colloids	1	September	NATO
8. B. S. Griffiths	(Dijon)/INRA; Nancy/CNRS — University, (France); (Haren/ Inst. Soil Fert; Amsterdam/University; Wageningen/ ITAL Inst (Netherlands) plus Agri. University (Uppsala/ Agri. University, (Sweden).	3	September	DAFS
9. P. D. Hulme	Dublin (Ireland) 7th International Peat Congress	1	June	DAFS
10. D. Jones	Budapest (Hungary) 8th European Congress on Electron Microscopy	1	August	DAFS
11. I. R. MacDonald	Tel Aviv/Weizman Institute; Jerusalem/Hebrew University (Israel)	3	October/ November	DAFS
12. L. Mackie	Amsterdam (Holland) Symposium Water and Solute Movement on Heavy Clay Soils	1	September	DAFS
13. A. E. S. Macklon	Strasbourg (France) 4th Congress, Federation European Societies of Plant Physiology.	—	July/August	DAFS
14. H. G. Miller	Toronto (Canada) Peer review of Government programme for the study of long range transport of air pollutants	1	February	Royal Society of Canada
15. R. A. Robertson	Helsinki (Finland) Meeting of Executive of International Peat Society and visits to research centres	—	March	DAFS/IPS
16. R. A. Robertson	Dublin (Ireland) Meeting of Council of IPS and 7th International Peat Congress	—	June	DAFS
17. R. A. Robertson	Winnipeg, Ottawa and Toronto (Canada) and Sioux Falls (USA) visiting Remote Sensing Centres	—	September	University of Manitoba

	Place/Event	Lectures	Date — 1984	Financed by
18. J. D. Russell	Ghent (Belgium) NATO Workshop on Soil Colloids	1	September	NATO
19. N. M. Scott	Calgary (Canada) Sulphur "84" Conference	1	June	DAFS
20. N. M. Scott	Nantes (France) Sulphur Colloquium	1	June	Sandoz
21. N. M. Scott	Madrid (Spain) Sulphur Colloquium	1	October	Sulphur Institute
22. B. L. Sharp	San Diego (USA) Winter Conference on Plasma Spectrometry and visits to various Universities and National Bureau of Standards	8	January	DAFS
23. A. M. Ure	Ceske Budejovice (Czechoslavakia) 7th Czech Spectroscopic Conference and VIII CANAS.	1	June	Self
24. A. M. Ure	Bratislava (Czechoslovakia) IUPAC Commission V.4 Minimeeting	—	June	IUPAC
25. D. Vaughan	Dublin (Ireland) 7th International Peat Congress	1	June	DAFS
26. T. S. West	Stockholm (Sweden) Oslo (Norway) Royal Society Surface Water Acidification Project Management Group Discussion with Swedish Academy of Sciences, Norwegian Academy of Sciences and Letters	—	February	Royal Society/ SWAP
27. T. S. West	Acid Rain Research Sites in Norway and Sweden SWAP Group discussion — inspection visits	—	June	Royal Society/ SWAP
28. T. S. West	Ottawa (Canada) General Assembly International Council of Scientific Unions	—	September	ICSU
29. R. E. Wheatley	Dublin (Ireland) 7th International Peat Congress	1	June	DAFS
30. B. L. Williams	Dublin (Ireland) 7th International Peat Congress	1	June	DAFS
31. M. J. Wilson	Rodez (France) NATO Workshop on Chemistry of Weathering	1	July	NATO

APPENDIX III

LECTURES GIVEN IN THE U.K. BY MEMBERS OF STAFF

	Place	*Event*	*Date* — 1984
Department of Mineral Soils			
D. C. Bain	London	Clay Minerals Group/Thermal Methods Group, Conference on Clays, Minerals and Thermal Analysis	November, 1983
	London	Clay Minerals Group	November
	Motherwell	X-ray Spectrometry User Group	February
A. C. Birnie	Bangor	International Working Group on Submicroscopy of Undisturbed Soil Materials	September
J. M. Bracewell	Newcastle	Chromotography Discussion Group	March
	London	AFRC Mass Spectrometry Panel	July
	Birmingham	2nd International Humic Substances Society Conference	July
W. J. McHardy	London	Clay Minerals Group/Thermal Methods Group Conference on Clays, Minerals and Thermal Analysis	November, 1983
	Bangor	International Working Group on Submicroscopy of Undisturbed Soil Materials	September
	London	Clay Minerals Group	November
B. F. L. Smith	London	Clay Minerals Group/Thermal Methods Group Conference on Clays, Minerals and Thermal Analysis	November, 1983
M. J. Wilson	London	Clay Minerals Group/Thermal Methods Group Conference on Clays, Minerals and Thermal Analysis.	November, 1983
	Bristol	Clay Minerals Group/Geochemistry Group/Metamorphic Studies Group Conference on Diagenesis and Low Temperature Metamorphism	April
	Bristol	Lichenological Society Conference on Lichen Physiology	April
	Hull	British Geomorphological Research Group Conference on Geomorphology and Soils	September
Department of Peat and Forest Soils			
R. V. Birnie	Silsoe	Remote Sensing in Natural Resource Surveying : Short Course	January
	Haddo House	Scottish Landowners Federation	March
	Edinburgh	Bracken Symposium convened by May and Baker	April
	London and Aberdeen	Remote Sensing Applications for Offshore Industry	May /June
	Dundee	Remote Sensing Summer School	August
	Dundee	MSc Course in Remote Sensing	October/November

	Place	Event	Date — 1984
M. F. Proe	Oxford	Forest Modelling Discussion Group	January
B. L. Williams	York	British Ecological Society	April
	Nottingham	British Mycological Society	September
	Aberdeen	Aberdeen University Department of Soil Science Colloquium	November
Department of Spectrochemistry			
M. J. Adams	Aberdeen	One-day Meeting, Robert Gordon's Institute of Technology	April
	London	Analyticon	September
M. L. Berrow	Stirling	Water Research Centre Seminar — Use of sewage sludge in land reclamation and forestry	December, 1983
	Aberdeen	International Trace Element Symposium TEMA-5	June/July
	London	International Conference Environmental Contamination	July
	Aberdeen	Department of Soil Survey — Autumn Meeting	November
B. A. Goodman	Oxford	Royal Society of Chemistry Mössbauer Discussion Group	July
	Leeds	Biochemical Society ESR applications	July
	Birmingham	International Humic Substances Society, International Meeting	July
	Aberdeen/MISR	NMR Discussion	January
	Aberdeen/RRI	Invited Lecture	March
J. D. Russell	London	Royal Society Surface Waters Acidification Programme	August
	Harrogate	British Crystallography Association (BCA) Industrial Group	November
C. A. Shand	Aberdeen	International Trace Element Symposium TEMA-5	June/July
B. L. Sharp	Strathclyde	Royal Society of Chemistry Atomic Spectroscopy Group	May
	Loughborough	University Department of Chemistry	September
A. M. Ure	London	Analyticon	September
	Aberdeen	International Trace Element Symposium TEMA-5	June/July
Department of Soil Organic Chemistry			
H. A. Anderson	Birmingham	2nd Intern. Meeting of the International Humic Substances Society	July
M. V. Cheshire	Birmingham	2nd Intern. Meeting of the International Humic Substances Society	July
I. R. MacDonald	Edinburgh	Edinburgh School of Agriculture	May
B. G. Ord	Stoneleigh	Royal Agricultural Society Show	July
D. Vaughan	Stoneleigh	Royal Agricultural Society Show	July
Department of Microbiology			
C. E. Alexander	Nottingham	Joint Meeting of British Mycological Society and British Ecological Society	September

	Place	Event	Date — 1984
D. Jones	Edinburgh	11th Scottish Symposium on Electron Microscopy Techniques	November, 1983
	London	"Micro 84"	July
R. E. Wheatley	Nottingham	Joint Meeting of British Mycological Society and British Ecological Society	September
Department of Soil Fertility			
N. M. Scott	London	SCI Symposium Sulphur on Crop Nutrition	October
A. H. Sinclair	London	SCI Symposium Sodium and Potassium in soils and crops	October, 1983
	Aberdeen	NOSCA Symposium "Soil Management"	December, 1983
Department of Soil Survey			
J. S. Bell	St Andrews	Aberdeen University Department of Soil Science Excursion	July
J. S. Bibby	Aberdeen	Aberdeen Institute of Ecology	February
	Ballater	Aberdeen University Department of Soil Science Excursion	April and May
	Black Isle	University of Bonn, West Germany Department of Geography	August
	St Andrews	St Andrews University Department of Geography	October
	Glasgow	Strathclyde University Department of Geography	October
C. G. B. Campbell	Glasgow	Scottish Association of Geography Teachers	October
D. W. Futty	Ballater	Aberdeen University Department of Soil Science Excursion	April and May
J. H. Gauld	St Andrews	Aberdeen University Department of Soil Science Excursion	July
D. J. Henderson	Nairn	Aberdeen University Department of Forestry Excursion	July
R. E. F. Heslop	Aberdeen	NOSCA Soil Management Course	December, 1983
	Aberdeen	Clinterty Agricultural College Course	January and November
	Aberdeen	NOSCA HND Students Course	March
	Aberdeen	Aberdeen University MSc Ecology Course	October
A. Lilly	Aberdeen	Clinterty Agricultural College Course	January and November
	Aberdeen	NOSCA HND Students Course	March
A. J. Nolan	Aberdeen	Aberdeen University Department of Geography	January
	Aberdeen	NOSCA HND Students Course	March
	Southampton	British Society of Soil Science	September
W. S. Shirreffs	Leeds	British Cartographic Society Annual Technical Symposium	September
	Edinburgh	British Cartographic Society	October
W. Towers	Thurso	Department of Agriculture for Scotland	November
A. D. Walker	Inverness	North of Scotland College of Agriculture	November

	Place	*Event*	*Date* — 1984
Director			
T. S. West	Birmingham	University Seminar	May
	London	SCI Agriculture Group	November
	Aberdeen	RSC Grampian Schools Lecture	December

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 which can be bought from the Department of Soil Survey at the above address.

1321 BACHE, B. W. The role of calcium in buffering soils. *Plant, Cell and Environment, 1984,* **7,** 391-395.
Calcium does not take part directly in the proton transfer reactions involved in soil buffering. However, because it is the dominant cation in most soils, it behaves as a complementary cation providing charge balance in many soil processes, including pH-buffering. The presence of free calcium carbonate in soils ensures a very high soil buffer capacity. Non-calcareous (acid) soils have much lower buffer capacities, caused mainly by dissociation of variable charge components, particularly humus acids, and also by precipitation of aluminium ions.

1284 BACHE, B. W. The role of soil in determining surface water composition. *Water Sci. Tech.* 1983, **15,** 33-45.
Surface water (streams and lakes) derive their water from precipitation of rain and snow from the atmosphere. The composition of solutes in these waters is a reflection of both the composition of the precipitation, and the changes that have taken place in it when it flows over or through land surfaces. This review cites a number of examples to show that the main factor determining surface water composition is the composition of the soil or rock through which it flows, but this can be modified by the hydrologic pathway of the water through a catchment.

BACHE, B. W. Soil fertility — major nutrients and lime. *Proc. Soil Management — Principles and Practice for Modern Agriculture, North of Scotland College of Agriculture.* Aberdeen, 1983, 31-38.

1308 BACHE, B. W. Soil-water interactions. *Phil. Trans. R. Soc. Lond.*, 1984, **B305,** 393-407.
This review describes the chemical processes that occur when water flows through and out of soils and rocks. These are mainly cation exchange, mineral decomposition and oxidation-reduction reactions. Water normally reflects the composition of the mineral and organic horizons it has passed through, but its composition is modified by the water flow pattern through the land surface and the contact time with soil and rock. Only detailed soil-water investigations in the field can satisfactorily explain lake and stream water composition at any specific time.

1344 BACON, J. R. and URE, A. M. Computer correction for molecular ion interferences observed in spark source mass spectrometric analysis of non-conducting materials. *Spectrochim. Acta. B.*, 1984, **39,** 1497-1501.
A procedure is described for the routine processing of spark source mass spectrometric data using a microcomputer. Overlapping interferences are identified using a chart recording and corrections are made using a simple interactive computer program.

1334 BACON, J. R. and URE, A. M. Spark source mass spectrometry: a review of recent developments and applications. *Analyst,* 1984, **109,** 1229-1254.
This is a review of developments and applications of spark source mass spectrometry published since 1972.

1340 BERROW, M. L. and BURRIDGE, J. C. Aufnahme, Verteilung und Wirkungen bei Pflanzen. In *Metalle in der Umwelt.* Edited by E. Merian. Weinheim, Verlag Chemie, 1984, 446-454.
A brief description is given of the influence of soil content and factors such as pH and drainage status on plant uptake of trace elements. Variations of plant content with species, plant part and season are illustrated.

BERROW, M. L. and BURRIDGE, J. C. Persistence of metals in sewage sludge treated soils. *Proc. 3rd Int. Symp. Processing and Use of Sewage Sludge, Brighton, 1983.* Dordrecht, D. Reidel, 1984, 418-422.
Some results from two long-term field experiments with sewage sludge are reported. Considerable uptake of Zn and Ni in particular were found and also of Cu, but not Cr, by grasses and clovers some ten years after sludge application. Changes in the extractable levels in soils at both sites suggest that the forms of Zn and Ni in sewage-sludge-treated soils alter but high levels persist. Good linear relationships between the Zn and Ni contents of grasses and the amounts extractable from the soils were found at both sites. At the one site where equivalent total amounts were applied either as a single application or annually as four successive smaller equal amounts, there was little difference in plant uptake of Zn or Cu. High levels of extractable Zn, Cu, Ni, Cr and Cd persisted at both sites over the period 1968 to 1981.

BERROW, M. L. and REAVES, G. A. Background levels of trace elements in soils. *Proc. Int. Conf. on Environmental Contamination, London, 1984.* Edinburgh, C.E.P. Consultants Ltd., 1984, 333-340.
Total metal contents in Scottish soils range over several orders of magnitude and often show a positively skewed distribution. Log transformation produces a distribution which approaches normality much more closely and this has been used to obtain values for the normal range and a derived mean for each element, the derived mean representing a typical content in soil. From the results of analyses of samples from some 1000 Scottish soil profiles and other published data, typical contents have been derived for several elements viz:— Cr 50, Co 8, Cu 12, Pb 15, Mn 450, Mo 1.5, Ni 25, V 90, Cd 0.4, Hg 0.06 and Zn 40μg/g in dry soil. These values are discussed in relation to the proposed CEC Directive on the use of sewage sludge in agriculture.

BIRNIE, A. C. Morphological, physical and chemical changes occurring within a hydrosequence of soils of the Strichen Association. M.Sc. Thesis, University of Aberdeen, 1984.

BIRNIE, R. V. Mapping bracken *(Pteridium aquilinum)* infestation in Scotland: an assessment of remote sensing based mapping techniques. *Int. Peat Soc. Symp. of Commission I, Aberdeen, 1983.* Helsinki, Int. Peat Soc., 1984, 87-101.
Available hill grazing is greatly reduced by bracken infestation. Some 162,000 ha of hill land in Scotland are thought to be affected. Precise figures on infested area or rate of bracken expansion are not however available. This paper reports on a pilot study to assess the value of aerial photography and satellite imagery for providing such figures.

1314 BIRNIE, R. V. Monitoring crop development in NE Scotland from LANDSAT MSS data: results of the AGRISPINE experiment. *Int. Peat Soc. Symp. of Commission I, Aberdeen, 1983.* Helsinki, Int. Peat Soc., 1984, 115-125.
The AGRISPINE experiment involved the rapid dissemination of satellite data. Delay between imaging time and receipt of data by the user was reduced to 24 hours. This paper summarises the results of an experiment in NE Scotland and discusses the potential role of such fast data relay systems for agricultural monitoring in the U.K.

1280 BIRNIE, R. V. and ADAMS, M. J. Development of a spectrometer for monitoring crop reflectance. *Anal. Proc.*, 1983, **20**, 519-523.
An instrument based on a laboratory monochromator has been developed for collecting reflectance spectra of crops *in vivo*. The instrument and ancillary digitising and spectral analysis routines are described. Examples of corrected crop spectra are given.

1290 BIRNIE, R. V., ADAMS, M. J., RITCHIE, P. F. S. and STOVE, G. C. Thermal infrared survey of Aberdeen City: data processing, analysis and interpretation. *Int. J. Remote Sensing*, 1984, **5**, 47-63.
The survey procedure and subsequent development of a microcumputer processing and analysis system adopted for a thermal survey of Aberdeen city is described. Thermal shadows on the imagery are shown to reflect air mixing

patterns at ground level and the sheltering effects of natural windbreaks, whereas canopy temperatures are related to vertical air temperature profiles and enable identification of frost hollows. Determination of heat-loss from buildings was found to be problematical. On the other hand, the technique allows pollution sources and water-mixing patterns in river estuaries and nearshore zones to be readily identified.

†BIRSE, E. L. The phytocoenonia of Scotland: additions and revision. *Soil Survey of Scotland Bulletin No. 5.* Aberdeen, Macaulay Institute for Soil Research, 1984. £6.

BLYTH, A. W. A mechanical aid for use with peat samplers. *Proc. 7th Int. Peat Congress, Dublin* 1984, **1**, 39-44.
A simple device is described which enables one person to provide all the lifting force necessary in sampling deep peat and lacustrine deposits with standard equipment. A steel levering beam and trestle assembly is connected to the rods by a rope sling tied to form a Prusik knot, which grips tightly when pulled and slips when released. Body weight provides the motive force and very little muscular effort is required. Field trials have shown this apparatus to be very reliable and easy to use, providing a welcome reduction in the heavy physical labour normally associated with this type of sampling.

1294 BOLLINGBERG, H. J., URE, A. M., SPRENSEN, I and LEONARDSEN, E. O. Geochemistry of some eudialyte-eucolite specimens and a co-existing catapleiite from Langesund, Norway. *Tschermaks. Min. Petr. Mitt.* 1983, **32**, 153-169.
A study by optical, x-ray diffraction, spark source mass spectrometry and chemical methods of the eudialyte-eucolite group minerals from the nepheline syenite pegmatite in the Langesund area of Norway. A common structure and major element composition are established but the specific gravity and refractive indices vary in accordance with Ce and Nb and minor element concentrations. Trace element and REE composition is constituent with a nepheline syenite pegmatite origin.

†BOWN, C. J. and SHIPLEY, B. M. South East Scotland: 1:250 000 soil and land capability for agriculture survey handbook. Aberdeen, Macaulay Institute for Soil Research, 1984, £7.50 (with maps).

1293 BRACEWELL, J. M. and ROBERTSON, G. W. Quantitative comparison of the nitrogen containing pyrolysis products and amino acid composition of soil humic acids. *J. Anal. Appl. Pyrolysis,* 1984, **6,** 19-29.
The abundances of a number of major pyrolysis products of soil humic substances provide a useful indication of the degree of humification. Two such nitrogen-containing products, pyrrole and acetonitrile, have been shown, by establishing quantitative relationships with amino acids within a set of standard proteins, to originate solely from polypeptides for a group of three Scottish brown forest soils (Cambisols or Ochrepts). Curie point pyrolysis-gas chromatography was used with polystyrene as internal standard. The aromatic products toluene, phenol and p-cresol were shown to have the same source and all these products were related to individual amino acids.

BURRIDGE, J. C. and BERROW, M. L. Long-term effects of metal-contaminated sewage sludges on soils and crops. *Proc. Int. Conf. on Environmental Contamination, London, 1984.* Edinburgh, C.E.P. Consultants Ltd., 1984, 215-224.
Trace-element analysis of soils and crops from a field experiment, started in 1968 and designed to investigate effects of metal-contaminated sewage sludges, are reported for Cr, Cu, Ni, Zn. Soil and sludge analyses for other elements are also presented. The French bean, celery and red beet crops, grown in the period 1968-1972, had their Ni and Zn contents considerably enhanced by the sludge treatments. Plant Cu contents were also enhanced, but to a lesser extent, while no increase in Cr content was found. The analyses of grass and clover sampled in 1977, and of soils sampled in 1981, showed clearly that several metals originally present in the sludges had not been immobilized by the soil, and that Ni and Zn, in particular, had remained in plant-available forms. A good relation between the Ni contents of ryegrass and clover, and the amounts of Ni extractable from the soils by 0.43M acetic acid, was found.

1283 BURRIDGE, J. C. and HEWITT, I. J. Decreased molybdenum emission in a carbon arc caused by zirconium carbide formation on the sample electrode. *Anal. Chim. Acta.*, 1983, **154,** 301-306.
The possible use of zirconium crucibles for the sodium carbonate fusion of soil and plant ashes was tested. The large amount of zirconium taken up into the acid solution of the fused sample, and precipitated by organic reagents with the other trace elements in the sample, caused a severe depression of molybdenum emission in the subsequent arc analysis. This was attributed to the formation of zirconium carbide (ZrC) during arcing and the interstitial retention of the molybdenum on the cathode in the ZrC, which was identified by X-ray powder diffraction. It was concluded that zirconium crucibles were unsuitable replacements for the platinum crucibles normally used.

1304 BURRIDGE, J. C. and HEWITT, I. J. Isotope shifts in the $N_2(C^3\pi u\text{-}B^3\pi_g)$ second positive system. *Spectrochim Acta.B.* 1984, **39,** 605-608.
Wavelength differences between corresponding $^{14}N_2$ and $^{14}N^{15}$ n band heads were measured in spectra emitted from microwave-excited low-pressure discharge tubes containing ammonia. The spectra were mainly recorded photographically using a large quartz-prism spectrograph (Hilger and Watts). The measured isotopic bandhead shifts were shown to be in good agreement with calculated values, based on molecular constants for $^{14}N^{15}N$ derived from those for $^{14}N_2$ by using the Dunham isotope relations. Shifts were reported for 15 bandheads.

CAMPBELL, C. G. B. Report on a soil survey of Minefield, Hartwood Research Station, Lanarkshire. Aberdeen, Macaulay Institute for Soil Research. 1984 (Restricted circulation).

1302 CHESHIRE, M. V., SPARLING, G. P. and MUNDIE, C. M. Influence of soil types, crop and air drying on residual carbohydrate content and aggregate stability after treatment with periodate and tetraborate. *Plant and Soil.* 1984, **76,** 339-347.
The direct relationship between aggregate stability and polysaccharide content previously observed for a Countesswells series soil has now been established for a number of other soils under various cropping regimes. No consistent effect of particular crops or soil type was detected, and each soil appeared to have its own individual relationship between polysaccharide and soil structure.

CHILDS, C. W., DICKSON, D. P. E., GOODMAN, B. A. and LEWIS, D. G. Moessbauer parameters for ferryihydrites at 4K. *Austr. J. Soil Res.*, 1984, **22,** 149-154.
Moessbauer parameters are presented for five ferrihydrites (one natural, four synthetic) at 4.2K. Two samples contained silicon (atomic ratio Si/Fe = 18% and 21% and one contained aluminium (Al/Fe = 19 per cent). Parameters were calculated from peak positions estimated by a fit of one set of six Lorentzian lines to each spectrum and by judging absorption maxima by eye. Internal magnetic field, H, values were between 50.0 and 51.0T for pure samples and between 48.4 and 49.3T for those containing silicon or aluminium. Such small variations would not prevent ferrihydrite being distinguished from lepidocrocite (H = 46.0±0.5 T for pure well-crystallized material) in Moessbauer spectra of soil samples at 4.2K.

†DRY, F. T. *et. al.* Soil survey map of Hamilton (Sheet 23). Scale: 1:63 360. Southampton, Ordnance Survey, 1984. £3.

DRY, F. T. The soils and land capability classification for agriculture of West Saline, Gartknowie and part of Meadowhill: a proposed extension of the Thorny Hill opencast coal extraction site. Aberdeen, Macaulay Institute for Soil Research, 1984. (Restricted circulation).

EDMONDS, T. E. and COUTTS, G. Flow injection analysis system for determining soil pH. *Analyst.* 1983. **108,** 1013-1017.
A flow injection analysis system is described for the determination of soil pH in filtered 0.01M $CaCl_2$ extracts.

EDMONDS, T. E. and JI GUOLIANG. Carbon fibre micro-electrodes in the differential pulse voltammetry of copper ions. *Annal. Chim. Acta.* 1983, **151,** 99-108.
The analytical performance of micro-electrodes manufactured from several types of carbon fibre is investigated. The reduction of Cu^{2+} in a chloride medium is used to assess this performance. Calibration curves in the 10 to 50 ppm range are linear, and relative standard deviations of 4 to 7 per cent are obtained for the determination of 30 ppm Cu^{2+}. The effect of electrochemical pretreatment on surface ionizable groups is examined with the aid of pH-stat experiments.

1339 EWEN, G. J. and ADAMS, M. J. Microcomputer interfacing: an analogue-digital/digital-analogue converter. *Lab. Practice.* 1984, **33,** 116-117.
A circuit has been designed employing 12-bit analogue-digital and digital-analogue converter units. The device is directly compatible with APPLE 11 microcomputers and can provide a fast and efficient method for data acquisition and plotting in a wide range of laboratory applications.

1329 EWEN, G. J. and ADAMS, M. J. Microcomputer interfacing: an asynchronous serial communications interface. *Lab. Practice.* 1984, **33,** 112-113.
A low-cost, general purpose asynchronous serial communications interface for use with APPLE 11 microcomputers is described. The interface can be operated in RS232C or 20 mA current-loop modes at switch selectable baud rates. The device permits serial data transfer between computers or between the host computer and suitable laboratory instrumentation.

1325 FARMER, V. C. Distribution of allophane and organic matter in podzol B horizons: reply to Buurman and Van Reeuwijk. *J. Soil Sci.* 1984, **35,** 453-458.
The distribution of allophane and organic complexes of Al and Fe in a wide range of types of podzol can be explained by separate migration of (a) positively charged Al-Fe-Si hydroxide sols and (b) negatively charged organic sols and solutions, if account is taken of the contribution of root activity in friable B horizons. An alternative theory, that requires allophane to be formed *in situ,* fails to account for its observed distribution.

1288 FARMER, V. C., ADAMS, M. J., FRASER, A. R. and PALMIERI, F. Synthetic imogolite: properties, synthesis, and possible applications. *Clay Minerals.* 1983, **18,** 459-472.
The unique properties of imogolite are closely related to its structure, which is a tube of 23-27 Å outer diameter and about 10Å inner diameter, with an AlOH outer surface and SiOH inner surface. Acid dispersions contain the long, positively charged tubes as isolated units or small bundles, which form bulky gels in alkali, and flocculate with negatively charged colloids, polyvalent anions, and long-chain anionic detergents. Sorption properties are associated with the 10 Å intra-tube pores and with inter-tube channels of variable dimensions. Surface acidity is less than that of layer-silicate clays. The chemical and mechanical stability, biological activity, film- and fibre-forming characteristics, and conditions of synthesis are reviewed, on the basis of both novel and published findings. Areas of potential application are indicated.

1307 FARMER, V. C., MEW, G., CLAYDEN, B. and LEE, R. Hypothesis on the pedogenesis of the "gley podzols" of the west coast of South Island, New Zealand. *J. Soil Sci.* 1984, **35,** 99-102.
The title podzols typically exhibit permanent water-logging extending from the surface to depths of 1-3 metres. Their formation is explained by a continuation of processes which give rise to peaty podzols with thin iron pan (Ironpan Stagnopodzols; Placaquods). Iron pans initially formed within the upper B horizon are breached by acidic reducing waters and reform at a succession of lower levels down to 3 m or more below the surface.

1315 FARMER, V. C., FRASER, A. R., ROBERTSON, L. and SLEEMAN, J. R. Proto-imogolite allophane in podzol concretions in Australia: possible relationship to aluminous ferrallitic (lateritic) cementation. *J. Soil Sci.* 1984, **35,** 333-340.

The theory that aluminium migrates as a hydroxyaluminium silicate complex (proto-imogolite), first proposed for Scottish podzols, is confirmed by the finding that proto-imogolite allophane forms the cement of concretions in Australian podzols. Micromorphology indicates that the allophanic cement is deposited from solution. Proto-imogolite allophane is a likely precursor of the gibbsite and kaolinite also present. A role for proto-imogolite sols in the formation of ferrallitic cementation is proposed.

FERTILISER recommendations for arable crops in the North of Scotland. *North of Scotland College of Agriculture Bulletin No. 30.* Aberdeen, NOSCA/MISR, 1984.

1333 GOODMAN, B. A. and STUCKI, J. W. The use of nuclear magnetic resonance (NMR) for the determination of tetrahedral aluminium in montmorillonite. *Clay Minerals.* 1984, **19,** 663-667.
NMR spectroscopy can be used to distinguish octahedrally-and tetra-hedrally-coordinated aluminium in montmorillonite. The method is straightforward and requires little sample preparation. The ratios of aluminium in the two types of coordination obtained from NMR spectra are very similar to those derived from chemical analyses of the minerals.

1345 GORDON, D. C., MACDONALD, I. R. and HART, J. W. Image analysis of geo-induced inhibition, compression and promotion of growth in an inverted helianthus annuus L. seedling. *Plant Physiology.* 1984, **76,** 589-594.
A method utilising video-image analysis is described whereby the growth of seedlings can be continuously recorded and automatically computed. The capability of the method is illustrated by following the growth responses in a sunflower seedling subjected to repeated inversion. The information obtained from the study has significant implications for understanding the mechanisms of directional growth.

1301 GUZEL, N. and WILSON, M. J. Chemical, physical and mineralogical characteristics of some Turkish soils derived from volcanic materials. *Trans. R. Soc. Edinb.* 1983, **74,** 153-163.
The chemical, physical and mineralogical characteristics of five soil profiles developed on volcanic material on the Anatolian plateau of Turkey have been studied. The soils are generally shallow, with high pH values, low amounts of organic matter, low available water capacities and low to medium ability to sorb phosphate. Weathering of the volcanic material in the prevailing semi-arid climate results in a smectite-dominated clayfraction with some unusual X-ray diffraction characteristics. The Anatolian soils contrast markedly with Andosols formed on similar parent material in a humid, temperate climate.

1305 HART, J. W. and MACDONALD, I. R. Is there a role for the apex in shoot geotropism? *Plant Physiology,* 1984, **74,** 272-277.
This study of the effect of gravity on seedling growth re-instates the classical view (currently in some disfavour) that the re-orientation of growth in response to environmental forces is subject to apical coordination.

HUDSON, G., ROBERTSON, J. S., LILLY, A. and BIRSE, E. L. Soils and vegetation. *Aonach Mor Ski Development Study. Vol. 3.* Sir William Halcrow and Partners/Macaulay Institute for Soil Research, 1984. (Restricted circulation).

HULME, P. D. and BLYTH, A. W. A classification of the peatland vegetation of the Isle of Lewis and Harris, Scotland. *Proc. 7th Int. Peat Congress, Dublin,* 1984, **1,** 188-204.
The peatland vegetation was recorded in over 200 releves using the Domin scale of cover abundance and computer analysed using a two-way indicator species analysis. The sixteen categories which emerged from the analysis are described and compared with the Braun-Blanquet and the National Vegetation Classification systems.

HULME, P. D. and ROBERTSON, R. A. The peat resources of Orkney. *Report for the North of Scotland College of Agriculture,* 1984. (Restricted circulation).

HULME, P. D. and SHIRRIFFS, J. Notes on the pollen content of soil samples from the Mound and Henge at North Mains Farm, Strathallan. *Proc. Soc. Antiq. Scot.* 1984. **113,** 270-272.
Pollen analysis results are presented for a Neolithic site at Strathallan, Perthshire.

1317 JONES, D. Scanning electron microscopy of *acremoniella atra*. *Trans. Brit. Mycol. Soc.* 1984, **82,** 729-732.
The paper reports on the external morphology of the fungus *acremoniella atra*, as observed in a scanning electron microscope. Some of the features noted have not been recorded previously because of the inability of the optical microscope to resolve the details. The structure is compared with that of a related soil fungus A. velata.

JONES, D. and McHARDY, W. J. Low temperature scanning electron microscopy of mycological specimens. *Proc. R. Microscop. Soc.* 1984, **19,** S91.

1292 JONES, D., McHARDY, W. J. and TAIT, J. M. Low temperature scanning electron microscopy of biological specimens. *Trans. Brit. Mycol. Soc.* 1984, **82,** 164-170.
Specimen preparation techniques used in scanning electron microscopy suffer from the disadvantage that water has to be removed from the material prior to examination. This generally results in some distortion of the specimens due to the dehydration processes. Additionally, chemical fixatives and solvents inevitably complicate matters when elemental analysis is required. In an attempt to overcome some of these problems cryo-fixation has been examined. The specimen under examination is quickly frozen in liquid nitrogen and can be examined in the frozen state on a cryogenic stage in the scanning microscope without any pre-treatment with chemical fixatives etc. This paper describes some preliminary observations on microbiological and plant specimens.

JONES, D. and McHARDY, W. J. Observations on frozen-hydrated biological specimens in the scanning electron microscope. *Proc. 8th Eur. Congress on Electron Microscopy, Budapest,* 1984, 1425-26.

1297 KHOURY, H. N., MACKENZIE, R. C., RUSSELL, J. D. and TAIT, J. M. An iron-free volkonskoite. *Clay Minerals.* 1984, **19,** 43-57.
Volkonskoite, the chromium-bearing mineral of the smectite group, usually contains significant amounts of iron. The present sample, which occurs, admixed with calcite and a silica phase, in the Daba marble of Jordan, contains about 16% $CR_2 O_3$ (thus being higher in chromium than any sample described outside the USSR) and no iron. Chemical and instrumental methods have shown it to be very uniform in composition and, although essentially dioctahedral, to have certain trioctahedral characteristics. A sample from the type locality in the USSR, examined for comparison, proved on the other hand to be a mixture of three smectitic species, one of which was aluminium-rich. Possible reasons for the tri-dioctahedral nature of the Jordan sample are discussed.

1332 LINEHAN, D. J. Micronutrient cation sorption by roots and uptake by plants. *J. Exper. Bot.* 1984, **35,** 1571-1574.
The magnitude of sorption of the trace nutrients Fe, Cu, Zn and Mn by wheat roots and by discs of cellulose filter paper was measured and found to be in the above order. Sorption increased with increasing pH except in the case of Fe where it decreased. It is suggested that the extent of sorption depends on the degree of hydrolysis of the metal ions in solution. It was also suggested that adsorbed metals could be remobilized by organic ligands leaking from the root cells and subsequently translocated from plant roots to shoots.

1326 LUMSDOM, D. G., FRASER, A. R., RUSSELL, J. D. and LIVESEY, N. T. New infrared band assignments for the arsenate ion adsorbed on synthetic goethite (α–FeOOH). *J. Soil Sci.* 1984, **35,** 381-386.
In view of the increasing content in the environment of arsenic, usually in the form of arsenate ion, it is important to know how it might be retained in soil and by which minerals. As a contribution in this field, the adsorption of arsenate by a hydrated iron oxide (synthetic goethite, α–FeOOH) has been studied by infrared spectroscopy. It has been shown that arsenate is adsorbed on the geothite surface

as the acidic $HAsO_4^{2-}$ ion, replacing singly coordinated surface hydroxyl groups. In this respect arsenate is analogous to phosphate, but its larger size causes it to interact more strongly with other types of hydroxyl group that remain on the mineral surface. The observations have led to an alternative assignment for the adsorption bands of these hydroxyl groups.

1299 McBRIDE, M. B., FRASER, A. R. and McHARDY, W. J. Cu^{2+} interaction with microcrystalline gibbsite. Evidence for oriented chemisorbed copper ions. *Clays Clay Minerals, 1984*, **32**, 12-18.
The ability of a high surface gibbsite to adsorb Cu^{2+} was studied using a Cu^{2+} ion sensitive electrode, electron spin resonance, infrared spectroscopy, and electron microscopy. The gibbsite chemisorbed small amounts of monomeric Cu^{2+} (<0.5 mmoles/100g), which was oriented with its z axis perpendicular to the 001 plane of the mineral. The proposed chemisorption sites are at the gibbsite crystal "steps" observed under the electron microscope. At pH values greater than 5, the gibbsite appeared to promote hydrolysis and polymerization of Cu^{2+}, with further adsorption on surfaces.

1286 McBRIDE, M. B., GOODMAN, B. A., RUSSELL, J. D., FRASER, A. R., FARMER, V. C. and DICKSON, D. P. E. Characterization of iron in alkaline EDTA and NH_4OH extracts of podzols. *J. Soil Sci.* 1983, **34**, 825-840.
A standard method of extracting metal ions that are bound to soil organic matter (O.M.) involves the use of ammonium EDTA. This reagent has been used here at pH 9 to extract iron from Bh horizons of iron and iron humus podzols. The greater part of the iron extracted is in the form of a polymeric hydroxyiron-O.M. complex. A combination of Mossbauer, ESR, IR, chemical analysis, dialysis and centrifugation techniques has shown that these complexes range in diameter between 2.4 and 60nm, and that the polymeric iron core may have a structural organization resembling that of geothite and ferrihydrite. Among other more minor components present in the pH 9 extract is a monomeric iron-O.M. complex. Because of the stability of these complexes of organic matter with monomeric and polymeric iron at the extraction pH, and especially of monomeric Fe complexes over a pH range of 2-10, it is suggested that these, or related forms of iron exist as such in the Bh horizon.

1296 McBRIDE, M. B., FARMER, V. C., RUSSELL, J. D., TAIT, J. M. and GOODMAN, B. A. Iron substitution in aluminosilicate sols synthesized at low pH. *Clay Minerals*. 1984, **19**, 1-8.
Iron and proto-imogolite allophane are intimately associated in many podzols Bs horizons, and iron can be incorporated in the stable proto-imogolite sols which are thought to play a role in podzol formations. To investigate the nature of this association, synthetic imogolite and proto-imogolite preparations containing iron have been examined by electron microscopy, infrared spectroscopy, electron spin resonance, and Mössbauer spectroscopy. This has shown that little iron can substitute for aluminium in these structures, but that iron inhibits the formation of imogolite tubes. Aluminium and iron are largely segregated on a molecular scale, the aluminium into proto-imogolite allophane and the iron into ferrihydrite-like structures. The high colloidal stability of mixed $Al_2O_3-Fe_2O_3-SiO_2-H_2O$ sols can be understood in terms of a dispersed phase consisting of a ferrihydrite core with a proto-imogolite surface.

1322 MACDONALD, I. R. and HART, J. W. The influence of adjacent tissue on hypocotyl hook opening. *J. Plant Physiol.* 1984, **115**, 285-289.
Seedlings germinating in the dark develop a hooked configuration to assist their emergence through the soil. The hook remains closed until exposed to light. This study shows that evidence which gave rise to the hypothesis that a hook-maintaining compound is exported from the apex of the seedling has been misconstrued.

MACKENZIE, R. C. De calore: prelude to thermal analysis. *Thermochimica Acta*. 1984, **73**, 249-372.
The prehistory of thermal analysis is traced from the time man first possessed fire (*ca* 500,000 B.C.) up to 1887. Early developments, inferred from archaeological

evidence, and later knowledge, obtained from written sources, show a remarkable understanding of the nature and effects of fire and heat by about 300 B.C. Even at this period minerals were distinguished by their behaviour towards fire. The following alchemical era, which stretched to about the end of the seventeenth century, saw little advance in chemistry, all effort going into that Great Work — which must be regarded largely in a mystical sense. Yet control of heat was highly developed and assaying methods were established, mineralogy became more systematic — although earths (clays) proved highly intractable — and thermometry was established for ambient temperatures. In the phlogiston era that flourished in the eighteenth century there was much emphasis on experiment, many gases were prepared and identified (both evolved gas detection and analysis can be dated to this period), temperature scales developed into those used today, empirical pyrometry was introduced and, towards the end of the century, both calorimetry and thermochemistry were founded. The nineteenth century saw particularly pronounced advances in chemistry (including thermochemistry), in mineralogy, in pyrometry and, with the advent of gas and electricity, in the development of furnaces and heat control. In 1877-1887 these advances led to the introduction of modern thermoanalytical methods by Hannay (modified by Ramsay) and Le Chatelier — the contribution of Regnault is still not clear.

1327 MACKENZIE, R. C. Discovery of volkonskoite. *Miner. Mag.* 1984, **48,** 297-8.
The chromiferous smectite mineral volkonskoite is currently believed to have been first described by Kämmerer in 1831. However, the mineral was in fact described and named in an anonymous paper in 1830 and Kämmerer merely quoted from this. A grass-green chromiferous clay discovered in Sweden in 1782 may well have been predominantly volkonskoite.

MACKENZIE, R. C. Origin and development of differential thermal analysis. *Thermochimica Acta.* 1984, **73,** 307-367.
Differential thermal analysis (DTA) was devised by Roberts-Austen in 1899 to give added precision to studies on thermal transformations in metals. Although only sporadically used until 1920, it nevertheless was employed in several non-metallurgical studies. In 1920-1940 it was used extensively, particularly in specialist centres in France, USA and USSR, but workers in one field appeared to be unaware of activity in others. However, at this time it found application in most fields where it is used today. Only after 1939, when Norton described the first purpose-built apparatus, did it become widely known over a broad range of disciplines. After a rather frustrating period of indiscriminate use, and therefore little success, in the early to mid 1940s, a steady growth in genuine interest became apparent, leading to the availability of commercial equipment and a balanced outlook. Many national societies, one international society, two international journals and one international abstracts journal are now devoted to thermal analysis in which DTA is one of the most, if not the most, widely used technique.

1311 MACKENZIE, R. C., WILSON, M. J. and MASHHADY, A. S. Origin of palygorskite in some soils of the Arabian peninsula. In *Palygorskite-sepiolite: occurrences, genesis and uses.* Edited by A. Singer and E. Galan. Amsterdam, Elsevier, 1984, 177-186.
In earlier studies on Saudi Arabian wadi soils, it was deduced that the palygorskite present represented neoformation, although inheritance could not be entirely excluded. A further set of wadi profiles, taken from areas of igneous and metamorphic rocks, confirm the hypothesis that much of the palygorskite formed *in situ* but also indicate that inheritance can play a part where neighbouring palygorskite-bearing rocks occur. No criteria are currently available for distinguishing the two.

1320 MACKLON, A. E. S. Calcium fluxes at plasmalemma and tonoplast. *Plant, Cell, Environment,* 1984, **7,** 407-413.
An account is given of the characterization of calcium fluxes across plasmalemma and tonoplast membranes of root cortical cells, using compartmental analysis. Some of the assumptions associated with the method are discussed. Recent evidence regarding the concentration of free Ca^{2+} in plant cells, and the mechanisms driving active calcium transport across cell membranes, is reviewed. It

is proposed that the evidence from whole cell studies and work at the molecular level is mutually supportive, and some speculation is ventured about the general pattern of calcium transport in higher plant cells.

1316 McPHAIL, D. B. and GOODMAN, B. A. TRIS buffer — a case for caution in its use in copper-containing systems. *Biochem. J. Letters*, 1984, **221,** 559-560.
The effect of the TRIS buffer on the copper-containing enzyme super-oxide dismutase has been monitored using electron para-magnetic resonance spectroscopy. Results indicate that the buffer can abstract and complex a substantial proportion of the enzyme-bound copper. Care should therefore be exercised when using TRIS in copper-containing systems.

1328 MILLARD, P., BAIN, S. D. and CRESSON, A. The effect of overwintering on the chemical composition of nine varieties of swede root. *J. Sci. Fd. Agric.* 1984, **35,** 982-986.
The composition of nine varieties of swede root of high, medium or low winter-hardiness were compared in samples harvested in November, 1982 or March 1983. Between 52-63% of root dry matter was soluble sugars (glucose, fructose and sucrose), 18-22% cell wall polymers, 10-12% soluble phenolic material and 3-5% inorganic nutrients. The composition and so presumably nutritive value of the low and medium winter-hardy varieties were unchanged over the winter, whereas the high-winter-hardiness varieties increased their soluble sugar levels (particularly glucose) by 20%. Leaving high winter-hardiness varieties in the field over winter, therefore, seems an attractive alternative to storage in a clamp.

1309 MILLER, H. G. Deposition-plant interactions. *Phil. Trans. R. Soc. Lond. B.* 1984, **305,** 339-352.
Available data, both in the literature and from unpublished studies, indicates that acidity is usually removed from rainwater as it passes through vegetation, except beneath old coniferous trees or in heavily polluted areas. This acidity is exchanged for soil-derived base cations; as such it is merely an extension of the soil exchange process and can be regarded as an acid stress upon the soil. Normally cations lost through crown leaching are readily replaced. However, in German forests leaf damage by gaseous pollutants and frost appears to be leading to excessive loss of magnesium with consequent growth decline and death.

1335 MILLER, H. G. Nutrient cycles in birchwoods. *Proc. R. Soc. Edinb. B.* 1984, **85,** 83-96.
Birch has a long-established reputation as a soil-improver, a characteristic often presumed to result from some aspect of the nutrient cycle peculiar to this species. However, models for the cycles of nitrogen, phosphorus, potassium, calcium and magnesium by age in slow-growing birch based on data from the literature for biomass development, nutrient levels and rates of decomposition suggest that nutrient cycling in birchwoods is very comparable to that in forests of other species with similar rates and patterns of growth.

MILLER, H. G. Dynamics of nutrient cycling in plantation ecosystems. In *Nutrition of Plantation Forests*. Edited by G. D. Bowen and E. K. S. Nambiar. London, Academic Press, 1984, 53-78.
The pattern of nutrient cycles in plantations is discussed. It is pointed out that the uptake, accumulation and release of litter of the major nutrients is primarily a function of growth rate, and after taking this into consideration species differences are small, even between coniferous and broadleaved species. Rate of crown leaching, however, may vary between species. For all species, demands on the soil are shown to be greatest prior to canopy closure, thereafter the cycles within the tree and within the ecosystem, coupled with effective capture and retention of nutrients from the atmosphere, supply much of the annual requirements for growth.

MILLER, H. G. Water in forests. *Scott. For.* 1984, **38,** 165-181.
Recent research work is reviewed, and the silvicultural implications discussed, under the headings (i) interception loss from forests, (ii) tolerance of roots to

water-logging, (iii) input from the atmosphere and loss to streams of nutrient and pollutant elements and (iv) acid rain, its effect on forests and streams. Foresters are recommended to ensure that no drain leads directly into a stream so that water can be filtered through the mineral soil along the riparian strip.

1331 NADEAU, P., WILSON, M. J., McHARDY, W. J. and TAIT, J. M. Interstratified clays as fundemental particles. *Science*, 1984, **225**, 923-925.
Interstratified clay minerals are common in soils and sediments but their actual physical nature remains uncertain. In this paper it is shown by transmission electron microscopy and X-ray diffraction that these minerals are composed of aggregates consisting primarily of three types of fundamental particles. This new concept could form the basis for a greater understanding of the physical and chemical nature and behaviour of clay minerals in soils.

1295 NADEAU, P. H., TAIT, J. M., McHARDY, W. J. and WILSON, M. J. Interstratified XRD characteristics of physical mixtures of elementary clay particles. *Clay Minerals*, 1984, **19**, 67-76.
Transmission electron microscopy of the <0.1 μm fraction of montmorillonite and regularly interstratified illite-smectite shows a predominance of particles only one or two unit cells thick. Sedimented aggregates which were made up from mixed suspensions of these clays yield X-ray diffraction (XRD) patterns similar to those from randomly interstratified illite-smectite, but quite unlike the patterns of mixtures of two distinct phases. It is concluded that the interstratification is produced by the sedimentation of elementary clay particles, the resulting XRD phenomenon being here termed inter-particle diffraction. Using XRD data alone, it may be difficult, if not impossible, to distinguish between interstratification arising from intimate physical mixtures of elementary particles and true interstratification within relatively large clay crystallites. These findings may be of considerable interest in the study of soil clays where interstratification is common.

NOLAN, A. J., LILLY, A. and CAMPBELL, C. G. B. Susceptibility of Scottish soils to acidification: basic data. Aberdeen, Macaulay Institute for Soil Research, 1984, (Restricted circulation).

1289 REAVES, G. A. and BERROW, M. L. Extractable lead concentration in Scottish soils. *Geoderma*, 1984, **32**, 117-129.
Recent reports on the effects of low-level lead-exposure on humans, particularly children, have led to renewed interest in lead in soils and other phases of the environment. The levels of extractable lead in soils and the factors which control these may well have an influence on the uptake of lead by plants. The distribution of acetic acid-extractable lead concentration levels in 3764 samples from 751 Scottish soil profiles is reported. The relation of extractable lead concentration to that of total lead and to some other soil variables is also examined. Because the frequency distribution of concentration levels is approximately log-normal, a logarithmic transformation of the data has been performed to provide a more satisfactory means of describing the distribution. The derived mean for the full set of data is 0.24 mg/kg and the normal range 0.016 — 3.4 mg/kg. Total lead concentration was found to be the dominant factor in determining the level of extractable lead in these soils and it was concluded that it would be more meaningful to consider the extractability of lead (i.e. the percentage of total lead extractable by acetic acid), rather than the absolute level of extractable lead in relation to the various other soil variables which are of interest in this connection. There is evidence that extractability is enhanced under conditions of impeded drainage but none to indicate that it is related to clay or ash content or to sampling depth.

1342 REAVES, G. A. and BERROW, M. L. Total copper contents of Scottish soils. *J. Soil Sci.* 1984, **35**, 583-592.
The distribution of the total copper contents of 4179 samples from 946 Scottish soil profiles is reported and the relation of total copper concentration to some other soil variables is examined. The frequency distribution of copper contents is found to be approximately log-normal. This being the case, it is felt that rather than quoting mean and standard deviation the distribution is best described in terms of the derived mean (x^*) and the "normal range" ($L' — L''$) where x^* = antilog x', L' =

antilog (x′−s′) and L″ = antilog (x+2s′); x′ and s′ being the mean and standard deviation of the log-transformed data. The derived mean for the full set of data is 10 mg/kg and the normal range 0.93 — 110 mg/kg. The copper contents of basic and intermediate igneous rocks exceed those of acidic rocks by a factor of about five and among sedimentary rocks copper contents are higher in argillaceous than in arenaceous types. Both of these observations are due largely to the copper contents of quartz, a major constituent of both acid igneous rocks and sands, being low compared with those of other rock-forming minerals. The general trend is for total copper to increase with increasing depth and ash content and to decrease with increasing sand content. On the basis of total copper content the risk of copper deficiency is assessed to be high in twenty-six soil associations in Scotland and moderate in a further ten. Naturally occurring copper toxicity is unlikely to be encountered.

1291 REAVES, G. A. and BERROW, M. L. Total lead concentration in Scottish soils. *Geoderma*, 1984, **32**, 1-8.
The distribution of total lead concentration levels in 3944 samples from 896 Scottish soil profiles is reported. The relation of total lead concentration to some other soil variables is also examined. Because the frequency distribution of concentration levels is approximately log-normal, a logarithmic transformation of the data has been performed to provide a more satisfactory means of describing the distribution. The derived mean for the full set of data is 14 mg/kg and the normal range 2.5 — 85 mg/kg. The lead concentration in organic soils is generally higher and more variable than that in mineral soils. The most prominent feature of the vertical distribution of total lead is the enrichment of surface horizons.

1330 REITH, J. W. S., INKSON, R. H. E., CALDWELL, K. S., WIMPSON, W. E. and ROSS, J. A. M. Effect of soil type and depth on crop production. *J. Agric. Sci.* 1984. **103**, 377-386.
Topsoils from eight different soil series were taken from arable fields and substituted for the local soil in three soil arrangements involving two depths with either local or sand subsoils. A rotation of crops, cereals, swedes and grass, was grown with uniform N, P and K treatments for twenty-four years. Results for yields of dry matter and for P, K, Ca, Mg and Na concentrations in, and uptake by, the crops are reported. Deep topsoil (46 cm) produced higher yields than shallower (23 cm). The concentration of P was higher in crops on peat than on mineral soils.

1298 REITH, J. W. S., BURRIDGE, J. C., BERROW, M. L. and CALDWELL, K. S. Effects of fertilisers on the contents of copper and molybdenum in herbage cut for conservation. *J. Sci. Fd. Agric.* 1984, **35**, 245-256.
Field experiments were carried out on three mineral soils and on a deep acid peat to measure the effects of fertiliser applications, especially N, on the Cu and Mo contents in samples of mixed herbage, grass and clover, taken at the silage stage of growth. The Cu contents in the herbage showed effects of N, P and Cu applications, differences between grass and clover and seasonal increases. With adequate Cu, applying N generally increased the Cu content in grass. The Mo contents were reduced by applying N and showed marked seasonal increases, especially on a mineral soil to which Mo had been applied. Some data are given for Cu and Mo extracted from the soils.

REITH, J. W. S. Soil analysis and fertilizer recommendations. *Proc. Soil Management — Principles and Practice for Modern Agriculture, North of Scotland College of Agriculture*, Aberdeen, 1983, 45-50.

1318 RITCHIE, P. F. S. and STOVE, G. C. Development of an integrated photogrammetric system for digital mapping and interpretation. *Int. Peat Soc. Symp. of Commission I, Aberdeen, 1983*. Helsinki, Int. Peat Soc., 1984, 53-63.
Development at the Macaulay Institute of an automated photogrammetric and image processing system (MAPIPS) is described and examples are given, of its application for the display, analysis, interpretation and mapping of peat survey and remotely sensed data using associated digitising, automated plotting and computer-aided graphics facilities.

RITCHIE, P. F. S. MAPIP system users' guide. Macaulay Institute Internal Report, 1983.

ROBERTSON, J. S. Vegetation, soils and land capability. *AFRC News*, 1984, Summer, 15.

ROBERTSON, R. A. jt.-author. Peat dictionary — Russian — English — German — Finnish — Swedish. Helsinki, Int. Peat Soc., 1984, $50 + postage.

ROBERTSON, R. A. ed. Remote sensing in peat and terrain resource surveys: *Int. Peat Soc. Symp. of Commission 1, Aberdeen, 1983*. Helsinki, Int. Peat Soc., 1984, $25 + postage.

1312 ROBERTSON, R. A. and GODSMAN, N. M. Peat as an energy source in Scotland. In *Energy for Rural and Island Communities, 3*. Edited by J. Twidell, F. Riddoch and B. Granger. Oxford, Pergamon Press, 1983, 395-402.
In terms of unit energy costs, peat is now a highly competitive fuel and many countries are currently assessing or re-appraising its potential as an alternative energy source. Although Scotland has considerable reserves of peat of suitable quality for direct combustion and fuel conversion processes, large-scale developments for the generation of heat and power from air dry milled peat, similar to those in Ireland, Finland, and the Soviet Union, are not regarded as a viable proposition. New techniques for the production, harvesting and utilization of small air dry sod peat, coupled with the high cost of other fuels, particularly oil, do however provide a unique opportunity to develop and diversify the fuel peat industry in Scotland. A considerable increase in the utilization of such peat fuels for domestic and industrial use is envisaged.

ROMANS, J. C. C. and ROBERTSON, L. An account of the soils. In *Sites of the 3rd millenium BC to the 1st millenium AD at North Mains, Strathallan, Perthshire*. By G. Barclay. *Proc. Soc. Antiq. Scotland*. 1983, **113**, 122-281.
The micromorphological features of the contemporary soil profile on the mound at North Mains, Strathallan and the buried prehistoric cultivated soils below the mound and the nearby henge are described and interpreted.

1313 RUSSELL, J. D., LIVINGSTONE, A. and FRASER, A. R. Infrared absorption spectra of the three polymorphs of $Pb_4SO_4(CO_3)_2(OH)_2$ (Leadhillite, Susannite and Macphersonite.) *Miner. Mag.* 1984, **48**, 295-297.
Lead carbonate sulphate hydroxide of composition $Pb_4SO_4(CO_3)_2(OH)_2$ is now known to exist as three polymorphs, Leadhillite, Susannite and Macphersonite. The infrared absorption spectrum of the newly-discovered Macphersonite is reported for the first time and is shown to be distinctly different from those of the other two forms, which in turn are readily distinguishable. In this respect, the infrared technique is more successful than X-ray diffraction, powder patterns of Leadhillite and Susannite being virtually indistinguishable.

1287 SCOTT, R. O. Robert Lyall Mitchell, B.Sc., Ph.D., C.Chem., F.R.S.C. — obituary notice. In *Year Book of R.S.E., 1983*.

SCOTT, N. M. Sulphur in soils and crops in the north of Scotland. *Proc. Sulphur in Western Europe, 1984*. London, Sulphur Institute, 1984.
Low amounts of available soil sulphate and sulphur deficiency can be found with soils from any soil association if a regular sulphate supply is not available, although sandy soils are particularly prone because of leaching. Critical indices derived from soil and plant analysis are useful to diagnose possible sulphur deficiency and the effect of high N applications with low sulphur is discussed.

SCOTT, N. M. and SHARP, G. S. Crop response to sulphur and sulphur research in the north of Scotland, 1984. *Proc. 'Sulphur '84' Conf., Calgary, Canada*. Canada, Sulphur Development Institute of Canada, 1984.
Many Scottish soils have low amounts of plant available sulphate and consequently many crops may suffer reduced yields because of S deficiency. This can be corrected by using either soil applied S, or elemental S as a foliar spray. Both forms have been used in the north of Scotland and responses have been obtained with most crops. Elemental S is particularly useful for autumn sown crops, when S

applied at sowing could be leached from the soil over the winter months. In the absence of adequate S, high N dressings can be wasted and can even depress yields further in conditions of severe S deficiency.

1337 SCOTT, N. M., DYSON, P. W., ROSS, J. and SHARP, G. The effect of sulphur on the yield and chemical composition of winter barley. *J. Agric. Sci.*, 1984, **103**, 699-702.
The application of S to alternate strips of winter barley in field experiments increased the grain yield by 5-28 per cent and also total S, So_4 -S content, and S uptake of plants. Sulphate-S calculated as a percentage of the total S appears a useful guide to the sulphur status of plants when sampled in May and June. Values less than 10% require additional S.

SINCLAIR, A. H. Soil fertility — trace elements. *Proc. Soil Management-Principles and Practice for Modern Agriculture, North of Scotland College of Agriculture*, Aberdeen, 1983, 39-44.

SINGH, K. D., GOULDING, K. W. T. and SINCLAIR, A. H. Assessment of potassium in soils. *Commun. Soil Sci., Plant Anal.* 1983, **14**, 1015-1033.
Potassium was extracted from soils by five methods: two boiling nitric acid extractions, electro-ultrafiltration, Ca-saturated ion exchange resin, and a new procedure using extraction by HCI under reflux. HCI-reflux method gave the closest correlations with yield and K removal by winter wheat. The amount and rate of release of fixed (available but not exchangeable) K estimated by HCI-reflux was also correlated with yield and K removal.

1310 SMITH, B. F. L. The determination of silicon in ammonium oxalate extracts of soils. *Commun. Soil Sci. Plant Anal.* 1984, **15**, 199-204.
A spectrophotometric method for the determination of silicon in ammonium oxalate extracts of soils has been devised and shown to be accurate, reproducible and more sensitive than the conventional flame atomic absorption techniques.

†SOIL SURVEY STAFF. Soil maps of Scotland. Scale: 1:25000. Sheets NS 26/36 (Bridge of Weir); NS 27/37 (Greenock and Port Glasgow); NS 43/53 (Kilmarnock and Darvell); NS 46/56 (Glasgow West); NS 47/57 (Milngavie); NJ 81/91 (Dyce.) £2 + VAT + postage.

†SOIL SURVEY STAFF. Soil maps of Scotland. Scale: 1:50 000. Sheet 9 (Cape Wrath); Sheet 10 (Strathnaver); Sheet 15 (Loch Assynt); Sheet 16 (Lairg and Loch Shin); Sheet 19 (Gairloch and Ullapool); Sheet 24 (Raasay and Loch Torridon); Sheet 46 (Coll and Tiree); Sheet 49 (Oban and Mull); Sheet 55 (Lochgilphead); Sheet 60 (Islay); Sheet 61 (Jura and Colonsay); Sheet 62 (North Kintyre); Sheet 63 (Firth of Clyde); Sheet 68 (South Kintyre); Sheet 69 (Island of Arran) £2.50 + VAT + postage.

†SOILS in Easter Ross. *Technical Report No. 1.* Aberdeen, Macaulay Institute for Soil Research, £1.

1319 STOVE, G. C. Improved peatland classification using principal components analysis based on synthetic variables: a remote sensing methodology for peat resource surveys in Scotland. *Int. Peat Soc. Symp. of Commission 1, Aberdeen, 1983.* Helsinki, Int. Peat Soc., 1984, 75-86.
Production of a medium scale map of the peat and terrain categories of Lewis and North Harris, using a stratified random sampling strategy, has demonstrated that a relatively simple LANDSAT image processing technique can produce 80% of the information required to map ground features at the required scale. Backed by a comprehensive set of ground truth data and photogrammetrically plotted information, principal components analysis based on synthetic variables is shown to improve both areal precision and feature classification particularly in areas where complex topography and atmospheric effects complicate more simple processing techniques.

1323 VAUGHAN, D. and MALCOLM, R. E. Influence of assay conditions on invertase activity in different Scottish soils. Plant and Soil. 1984, **80,** 285-292.
The measurement of soil enzymes such as invertase is important because they are indicators of the soil biomass and ultimately fertility. There is, however, no uniform method for the measurement of a particular enzyme in different laboratories and hence it is difficult to make direct comparisons between soils on a world wide basis. This current investigation takes a critical approach to the determination of soil invertases and a recommendation is made for the adoption of more uniform methods for soil invertase measurements based on biochemical principles.

VAUGHAN, D., WHEATLEY, R. E. and ORD, B. G. Easing the ochre problem. *Drainage Contractor,* 1984, **10,** 28.
Ochre deposition is a serious problem in newly installed drainage systems throughout the UK, particularly in peaty soils or in acid soils close to peat deposits. This paper reports to the layman the results of field trials using weathered coniferous bark to ameliorate ochre deposition.

1306 VAUGHAN, D., WHEATLEY, R. E. and ORD, B. G. Removal of ferrous iron from field drainage waters by conifer bark. *J. Soil Sci.,* 1984, **35,** 149-153.
The blockage of newly installed drainage systems by ochre is a serious agricultural problem, particularly on peaty soils. Removal of ferrous iron from the drainage water using conifer bark ameliorates the problem. The bark, inserted into the drains in loosely woven nylon mesh sacks, absorbs ferrous iron quickly and irreversibly and has a large absorption capacity. Preliminary field trials have shown that the bark which is inexpensive, lasts at least six months before renewal is necessary. In addition conifer bark contains only small quantities of soluble toxic substances and hence does not produce an environmental problem.

VICENTE-HERNANDEZ, J., VICENTE, M. A. ROBERT, M. and GOODMAN, B. A. Evolution des biotites en fonction des conditions d'oxydo-reduction du milieu. *Clay Minerals.* 1983, **18,** 267-275.
Experiments have been performed in order to investigate the relationship between vermiculitization and iron oxidation. IR spectroscopy and XRD were used to follow the vermiculitization process and the degree of oxidation of iron was measured by Mossbauer spectroscopy. The results show that if a certain level of oxidation normally occurs during vermiculitization, then a higher level of oxidation results in iron release from the structure and produces hydroxy iron vermiculites.

†WALKER, A. D., *et. al.* Eastern Scotland: 1:250 000 soil and land capability for agriculture survey handbook. Aberdeen, Macaulay Institute for Soil Research, 1984, £7.50 (with maps).

WHEATLEY, R. E., VAUGHAN, D. and ORD, B. G. Amelioration of the ochre problem in field drainage systems using coniferous bark. *Proc. 7th Int. Peat Congress, Dublin,* 1984, **4,** 96-105.
Iron ochre deposition in field drainage systems is a serious agricultural problem which results from the chemical and microbiological oxidation of soluble ferrous to insoluble ferric iron. Coniferous bark absorbs ferrous iron from solution rapidly and irreversibly. Field trials on the effectiveness of coniferous bark in the prevention of iron ochre deposition in field drains have been carried out. These trials were very successful and suggest that coniferous bark provides an inexpensive method of ameliorating the problem of ochre formation.

WILLIAMS, B. L. The influence of peatland type and the chemical characteristics of peat on the content of readily mineralized nitrogen. *Proc. 7th Int. Peat Congress, Dublin,* 1984, **4,** 410-418.
The content of readily mineralized nitrogen, determined in aerobic and waterlogged incubation experiments, was compared in samples of peat taken from a range of peatland types. Under aerobic conditions, mineral nitrogen correlated with the total nitrogen and phosphorus contents but in waterlogged samples the influence of nitrogen content and pH was predominant. Nitrification was observed under aerobic conditions only in samples of blanket peat with a high inorganic matter content.

1303 WILLIAMS, B. L. and SPARLING, G. P. Extractable N and P in relation to microbial biomass in U.K. acid organic soils. *Plant and Soil*, 1984, **76,** 139-148.
The amounts of carbon, nitrogen and phosphorus contained in micro-organisms in peats and acid mor humus were estimated by measuring the release of these elements from the soil microbial population killed by chloroform fumigation. These amounts were compared with further estimates of the microbial biomass obtained by the Anderson and Domsch test based on respiration and, also, the ATP content. Releases of carbon as CO_2 and nitrogen as mineral−N during incubation of fumigated samples were anomalously low and rather erratic. In contrast, the flush of inorganic phosphate released immediately after fumigation was less variable and may provide a better basis for estimating the size and nutrient content of the microbial biomass in these soils.

WILLIAMS, L. D. and BIRNIE, R. V. Ground-truth measurements of snowcover properties: Oberjettenberg, Federal Republic of Germany, Feb.-March, 1984. *Report prepared for Royal Signals and Radar Establishment, Malvern, under MOD Agreement No. 2116/017*, 1984.

1300 WILSON, M. J., RUSSELL, J. D., TAIT, J. M., CLARK, D. R. and FRASER, A. D. Macaulayite, a new mineral from north-east Scotland. *Miner Mag.* 1984, **48,** 127-129.
Macaulayite is a fine-grained red mineral that occurs in deeply weathered granite near Inverurie, Aberdeenshire. Its ideal composition is $Fe^{3}_{24}Si_4O_{43}(OH)_2$ and it has been fully characterized by X-ray powder diffraction, electron diffraction and infrared spectroscopy. The mineral has a layer structure and is thought to consist of a double ferric oxide unit terminated on both sides by silicate sheets and with water between these sheets. Macaulayite is named after the Macaulay Institute for Soil Research and both mineral and name have been approved by the Commission on New Minerals and Mineral Names of the International Mineralogical Association.

1324 WILSON, M. J. and JONES, D. The occurrences and significance of manganese oxalate in *pertusaria corallina* (Lichenes). *Pedobiologia,* 1984, **26,** 373-379.
An occurrence of manganese oxalate dihydrate associated with a crustose lichen growing on manganese ore is described. It is probable that a range of hitherto-unreported oxalate minerals exist where appropriate substrates are colonized by lichens that secrete exalic acid, a common organic acid in soils.

WROBLESKI, D. A., DAY, C. S., GOODMAN, B. A. and RAUCHFUSS, T. B. Synthesis and characterization of heterobimetallic complexes derived from [o−(diphenylphosphino) benzoyl] pinacolone (HacacP). The structure of $PtCl_2$ $[Cu(acacP)_2]$. *J. Amer. Chem. Soc.*, 1984, **106,** 5464-5472.
Heterobimetallic complexes are of considerable importance in natural systems. The enzymes nitrogenase and cytochrome *c* oxidase are two examples of species of agricultural importance that contain two different metals. This paper reports the laboratory synthesis of a series of complexes of the unsymmetrical ligand o−diphenylphosphinobenzoyl-pinacolone with a first row and either a second or third row transition metal ion. Characterization of the resulting materials has been performed by a variety of physical methods, including IR, UV-visible, NMR (^1H and ^{31}P), EPR (X-band and Q-band), FD and FABMS and in one case single crystal XRD.

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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 of the institutes concerned.

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

State-aided Institutes (Scotland)

Animal Diseases Research Association	Moredun Institute, 408 Gilmerton Road, Edinburgh, EH17 7JH.
Hannah Research Institute	Ayr, KA6 5HL.
Hill Farming Research Organisation	Bush Estate, Penicuik, Midlothian, EH26 0PH.
Macaulay Institute for Soil Research	Craigiebuckler, Aberdeen, AB9 2QJ.
Rowett Research Institute	Bucksburn, Aberdeen, AB2 9SB.
Scottish Institute for Agricultural Engineering	Bush Estate, Penicuik, Midlothian, EH26 0PH.
Scottish Crop Research Institute	Invergowrie, Dundee, DD2 5DA. and Pentlandfield, Roslin, Midlothian, EH25 9RF.

State-aided Institutes (England and Wales)

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Grassland Research Institute	Hurley, Maidenhead, Berks, SL6 5LR.
Houghton Poultry Research Station	Houghton, Huntingdon, PE17 2DA.
John Innes Institute	Colney Lane, Norwich, NOR 7OF.
Long Ashton Research Station	Long Ashton, Bristol, BS18 9AF.
National Institute of Agricultural Engineering	Wrest Park, Silsoe, Beds., MK45 4HS.
National Institute for Research in Dairying	Shinfield, Reading, Berks., RG2 9AT.
National Vegetable Research Station	Wellesbourne, Warwick, CV35 9EF.
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