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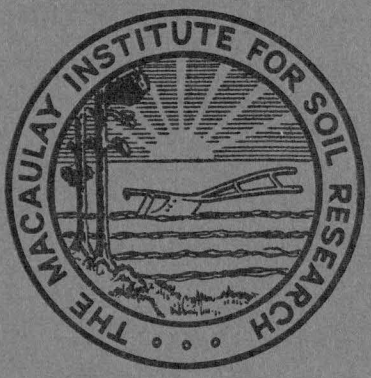
THE MACAULAY INSTITUTE FOR SOIL RESEARCH

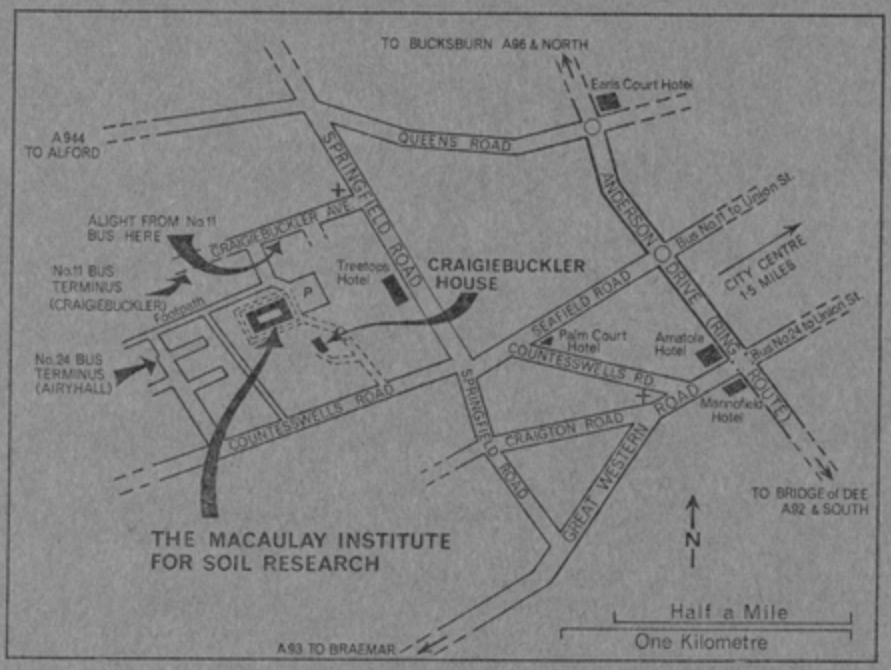


FOUNDED 1930

1976-1977 ANNUAL REPORT

No. 47

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



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The main part of this report covers the period from 1st October, 1976, to 30th September, 1977. The staff list is that current in November/December, 1977, and the Introduction is similarly updated. The report was published in May, 1978.

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

(Founded 1930)

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STAFF

1976-77

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Mrs C.-A. Dawson.
Miss L. E. McIntosh.
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F. F. Warden—retired 29/7/77.
D. Johnston—appointed 11/7/77.

Peat and Forest Soils

R. A. Robertson, B.Sc.
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Mrs A. Milne (née Black).
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Miss G. Kirkton—appointed 16/5/77.
Miss S. M. Simpson—appointed 16/5/77.
Miss G. M. Scott—appointed 1/9/77.
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E. Lawson.

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Miss P. Stewart—appointed 1/6/77.

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Miss M. R. Moir.
I. Smith.
I. D. McFarlane.
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R. E. Wheatley, B.Sc.
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Miss E. B. Sneddon, B.Sc.—appointed 1/11/77.
Miss S. K. Fyfe—1/4/77-22/7/77.
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Miss M. G. Sherriffs—resigned 30/4/77.
Mrs R. H. Easton.
Miss S. Milne—resigned 31/8/77.
Mrs M. M. Justice.

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W. M. Crooke, B.Sc., Ph.D.

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Miss C. Ireland.
Mrs H. R. Booth (née Hutchison).
C. A. Frost, B.Sc.
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Miss E. A. Mackay.
Mrs R. G. McPherson.
Mrs G. Coutts.
Miss E. J. Donald.
Miss A. Birnie.
S. D. Porter.
Mrs H. M. Duncan—resigned 7/6/77.
Mrs C. A. Morice.
Mrs J. Stewart—resigned 28/2/77.
Mrs A. G. Forbes.
Miss E. F. McCourt—appointed 1/7/77.
Mrs V. G. Hay (née Woodburn)—appointed 1/8/77.
Miss A. S. Doig—appointed 12/9/77.
Miss M. E. Watson—appointed 26/9/77.
Miss M. A. McDonald—appointed 10/10/77.
A. G. Gall.
A. R. Douglas.
J. S. Morrison.
J. A. M. Anderson.
W. J. Duncan.

STATISTICS

Head of Department: R. H. E. Inkson, B.Sc., F.S.S., F.I.S.
Miss J. M. Cooper, B.Sc., Dip.Stat., M.I.S.
G. J. M. Stephen, B.Sc.
Miss A. C. Crowther, B.Sc.—resigned 26/9/77.
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Miss A. McDonald.
Miss J. E. Taylor.
Miss L. Stevenson—transferred 1/3/77.
Miss A. Hitz—appointed 16/5/77.

SOIL SURVEY

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J. W. Muir, B.Sc.(Agr.), C.Chem., M.R.I.C., N.D.A., N.D.D.
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J. C. C. Romans, B.Sc.
D. Laing, B.Sc., C.Chem., M.R.I.C.
J. M. Ragg, B.Sc.
C. J. Bown, B.Sc.
B. M. Shipley, B.Sc.
A. D. Walker, B.Sc.
D. W. Futty, B.Sc.
J. S. Bibby, B.Sc.
R. E. F. Heslop, B.Sc.(For.).
J. S. Robertson, B.Sc.
F. T. Dry, B.Sc.
J. H. Gauld, B.Sc., Ph.D.
L. Robertson, B.Sc.
J. Menzies, B.Sc., Ph.D.—resigned 8/7/77.
N. A. Duncan, B.Sc.
G. Hudson, B.Sc.
C. G. B. Campbell, B.Sc.
D. J. Henderson, B.Sc.
G. G. Wright, B.Sc.
W. Towers, B.Sc.
G. McLaren, B.Sc.—resigned 30/9/77.
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A. D. Moir.
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Miss G. Love.
Miss P. R. Carnegie.
C. Halliday.

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Librarian Mrs J. M. D. Alcock, M.A., A.L.A.—resigned 31/12/77.
Mrs L. Garden.
Mrs S. C. Watt.

Information Officer Miss E. M. Watson, B.Sc.

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J. H. Normington.
G. J. Gaskin.
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R. A. Burns.
R. D. Malcolm.
G. Sim.

Photographer J. Mitchell, A.I.I.P., A.I.M.B.I.
D. J. Riley.

Clerk of Works G. Forbes.

STAFF—*continued*

ADMINISTRATION

Secretary and Treasurer	Miss E. A. Piggott. Miss E. J. Cockburn.
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Attendant	E. M. S. Cruickshank—resigned 11/10/77. A. McMann—appointed 31/10/77.
Outdoor Staff	A. Mutch. H. Shaw. W. L. W. Ross. F. B. Adam—resigned 13/5/77. R. A. R. Clarke. J. S. West—appointed 9/5/77.

HONORARY FELLOWS

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Dr A. B. Stewart, C.B.E., M.A., B.Sc., Ph.D., LL.D., C.Chem., F.R.I.C., F.R.S.E.
Dr R. L. Mitchell, B.Sc., Ph.D., C.Chem., F.R.I.C., F.R.S.E.

VISITING RESEARCH WORKERS

D. R. Ascroft, Department of Plant Physiology.

C. W. Childs (D.S.I.R. Soil Bureau, New Zealand).

*S. Cooke, Department of Soil Fertility, Technicon/M.O.D. Research Student.

M. Del Prete (Instituto di Geologia Applicata e Geotecnica, Italy).

A. Federico (Instituto di Geologia Applicata e Geotecnica, Italy).

*S. Forbes, Departments of Soil Fertility and Spectrochemistry, S.R.C. Student.

*Miss E. B.-I. Glass, Department of Soil Fertility, M.O.D. Research Student.

N. Guzel (Department of Soil Science, Cukurova University, Turkey).

Miss M. P. Hernandez (Department of Analytical Chemistry, University of Murcia, Spain).

S. Kaunisto (Parkano Research Station, Finland).

*J. Khalighie, Department of Spectrochemistry, Research Student.

J. H. Kirkman (Department of Soil Science, Massey University, New Zealand).

J. V. Lagerwerff (Agricultural Research Centre, Beltsville, Maryland, U.S.A.).

M. Levesque (Soil Research Institute, Central Experimental Farm, Ottawa, Canada).

D. G. Lewis (Waite Agricultural Research Institute, Adelaide, Australia).

*D. A. P. Mackay, Department of Statistics, A.R.C. Student.

*P. G. Monks, Department of Soil Fertility, M.O.D. Student.

*A. R. Morrisson, Department of Spectrochemistry, A.R.C. Student.

S. Murayama (Department of Soils and Fertilizers, National Institute of Agricultural Sciences, Tokyo, Japan).

*Miss K. Murphy, Department of Spectrochemistry, Chemical Society Research Student.

S. A. Rahim (Department of Chemistry, University of Mosul, Iraq).

J. M. Stewart (Department of Botany, University of Manitoba, Winnipeg, Canada).

Miss M. I. Tejedor (Department of Analytical Chemistry, University of Murcia, Spain).

D. J. Terrell (Neutron Activation Analysis Laboratory, Geophysics Institute, National University of Mexico).

*D. I. Welch, Department of Soil Organic Chemistry, A.R.C. Student.

*Miss R. M. West, Department of Microbiology, A.R.C. Student.

*Miss S. G. Williams, Department of Plant Physiology, A.R.C. Student.

H. L. Yeung (Department of Geography and Geology, University of Hong Kong).

**Ph.D. Student.*

CONTENTS

INTRODUCTION

The year reported on has been a busy one for the Institute. Fifty-four scientific papers have been published and another 54 had been submitted for publication by the 30th September, 1977. Members of the Institute's staff have delivered lectures in places as far afield as Saudi Arabia and Japan. Many distinguished overseas visitors from 22 countries, including the U.S.S.R., U.S.A., South America and the Far East, have paid short-term visits to discuss problems, etc. During the year, grants for capital equipment from the Department of Agriculture and Fisheries for Scotland have enabled us to add several useful items of equipment to our armoury, but four items of capital equipment that we might normally expect to have had granted for three departments could not be provided due to shortage of funds. The main instruments acquired included an X-ray Diffractometer, an Inductively Coupled Radiofrequency Plasma Source, an Atomic Absorption Spectrometer, two Gas-liquid Chromatographs, Autoclaving Equipment, an Electroultrafiltration Unit and a Surface Grinder for the preparation of thin section specimens for microscopy.

In the Department of Pedology the new X-ray Diffractometer will supplement existing X-ray equipment and allow more fluorescence work to be done on the older instrument while in the Department of Spectrochemistry the Atomic Absorption Spectrometer will supplement the A.A.S. equipment which is rather overworked at present. The Inductively Coupled Radio-frequency Plasma Unit will be linked to optical dispersion/detection equipment and will provide an alternative source to the d.c. arc for emission spectrography for some elements such as molybdenum, cobalt and boron, with gains in sensitivity. The Gas-liquid Chromatograph in the Department of Soil Organic Chemistry should allow a greater throughput of its work which is now more heavily dependent on gas liquid chromatography. The Department of Microbiology is having part of its ailing autoclaving equipment, first installed in 1962, replaced by more modern and compact steam generating devices and this will incidentally also liberate some laboratory space for other work. The same department has also acquired a Gas Chromatograph to facilitate its work on gaseous products of soil microbial activity. Soil Fertility's Electroultrafiltration apparatus will be used in studies of the rates of release of nutrients from soils and is complementary to other electrochemical developments recently initiated within that department. Lastly, the Surface Grinder for the Department of Soil Survey is a replacement for present obsolescent equipment and is capable of working to finer tolerances in the production of soil thin sections, etc.

As will be seen, apart from the equipment for the Department of Soil Fertility, this year's capital budget has gone largely on replacing obsolescent instruments or in expanding existing facilities. In the present difficult circumstances we have thought it mostly worthwhile to stabilize and maintain our capabilities rather than to venture out into new fields.

During the year an extension of some 1404 sq. ft. was provided to the buildings for the Institute's Technical Services Unit. This has given some

much needed room for electronics, plastics, photographic services and for a new paint spray shop. Some of the rooms previously used by Technical Services are now being used temporarily to house the dye laser equipment and the newly purchased R.F. Plasma Source Unit. Whilst the construction of this extension to the buildings went according to plan we are still awaiting completion of the new 1500 sq. ft. Pot-Culture building for the Department of Soil Fertility though it was started and should have been completed in the previous year.

Macaulay Visiting Group (front row, left-to-right): Prof. D. H. Whiffen, Prof. E. A. Vincent, The Director, Prof. J. H. Harley, Sir William Henderson, Prof. J. F. Sutcliffe, Prof. D. J. Greenland. (Back row, left-to-right): Dr J. V. Lake, Dr G. W. Cooke, Mr D. C. M. Corbett, Mr G. S. Murray, Mr J. G. Brotherston, Dr J. K. R. Gasser, Dr J. Ingle, Mr J. Mason and Dr R. N. Crossett.

ARC Visiting Group

Although, strictly speaking, a Visiting Group from the Agricultural Research Council was not due until 1978, we welcomed a group of six consisting of Professor J. L. Harley (Chairman), Oxford; Professor D. J. Greenland, Reading; Professor J. F. Sutcliffe, Sussex; Professor E. A. Vincent, Oxford; Dr C. C. Webster, formerly ARC, and Professor D. H. Whiffen, Newcastle-Upon-Tyne, for a four day visit from Monday, 14th, to Thursday, 17th November. The Group was accompanied by the following staff from the Agricultural Research Council: Sir William Henderson (Secretary of ARC), Dr G. W. Cooke (Chief Scientific Officer to the Council), Dr J. V. Lake (Head of Research Division I (Plants and Soils)), Mr J. Mason

(Research Branch, Division I), Dr J. K. R. Gasser, Mr D. C. M. Corbett, Dr J. Ingle (Scientific Advisers to the Secretary) and, from the Department of Agriculture and Fisheries for Scotland, Mr G. S. Murray with Mr J. G. Brotherston and Dr R. N. Crossett (Scientific Advisory Unit).

The greatest majority of our staff in the Band I/Band II HSO, SSO, PSO and SPSO grades were interviewed in Craigiebuckler House and visits were paid by the Group to a selected number of laboratories in the main building, including the Technical Services Unit. A series of receptions was organised (by department) on the three available evenings to allow all staff in the HSO and higher grades to meet members of the Group and the Secretariat on an informal basis. Local members of the Council of Management were able to meet the Group for lunch on the first day of the visit.

Links with Other Agricultural Research Stations

During the year two conferences have been held in the Institute to examine the possibility of inter-institute collaboration on topics of mutual concern. The first such meeting on 18th November was with visitors from the Letcombe Laboratory of the ARC and the Rothamsted Experimental Station. Discussions took place on soil-root relationships and it is hoped to maintain contact during the coming year and to set up collaboration where this is thought to be of mutual benefit to the stations concerned and to the well-being of the Agricultural Research Service. The meeting was attended by the Agricultural Research Council's Chief Scientific Officer, Dr G. W. Cooke.

The second of these meetings was held on 30th November with the Director, Sir Kenneth Blaxter, and a group of staff from the Rowett Research Institute on the subject of trace metals at the soil-plant-animal interface. Many mutual interests were discovered and some concerted work is likely to develop in this area between the two Institutes in the following year.

Visitors from the ARC and the DAFS

During the year the staff were very pleased to have visits from several members of the Agricultural Research Council, including the Chairman, The Hon. J. J. Astor, The Rt. Hon. the Earl of Selborne, member of the ARC and Chairman-designate of the Joint Consultative Organisation Horticultural Board, Visits were also received from Sir William Henderson, Dr G. W. Cooke and Dr J. V. Lake at other times as well as from the Scientific Advisers, Mr D. C. M. Corbett, Dr J. K. R. Gasser and Dr J. Ingle. Visits were also welcomed from several members of the staff of the Department of Agriculture and Fisheries for Scotland, including Mr G. S. Murray, Mr G. G. Lyall, Mr J. G. Brotherston and Dr R. N. Crossett.

Amongst our distinguished overseas visitors we were particularly pleased to welcome Professor V. D. Pannikov, Vice-President, and Professor V. G. Mineev, Director of the All Union Research Institute of Fertilizers and Soil (Vaskhnill), USSR, and Dr Pierce Ryan, Deputy Director of the Agricultural Research Institute of Ireland.

Group visits to the Institute included members of the DAFS Lands Branch Staff, Advisory Staff from the North of Scotland College of Agriculture and members of the Analytical Division of The Chemical Society upon the occasion of The Chemical Society Autumn Meeting, during the course of which lectures were given by one of the Institute's Honorary Fellows, ex-Director Dr R. L. Mitchell, by Dr M. L. Berrow and by Mr B. F. L. Smith.

Research Programmes

Some aspects of the work of the various departments of the Institute are outlined in the following paragraphs. It must be stressed that only *selected* items are discussed briefly here. The individual reports for each department should be consulted for a full account of the work done during the year.

PEDOLOGY

The aim of the work of the Chemistry and Mineralogy Section of the Department is to elucidate the processes active in soil formation and to establish the properties of soil components in order to appreciate and to evaluate differences in soil behaviour, potential nutrient status, etc. In particular the relative contributions of crystalline and non-crystalline inorganic (and organomineral) components to soil properties are being assessed principally by physical and selective chemical methods. The characteristics of particle surfaces, the reactivities of different types of surfaces and the elemental distribution on surfaces of synthetic and naturally occurring particles are being investigated by a number of physical, physicochemical and electron-optical techniques. The results, along with those from X-ray diffraction, X-ray fluorescence spectroscopy and thermal analysis highlight changes occurring during soil formation and mineral weathering. Since greater emphasis can now be given to surface characteristics, the studies are moving much closer to soil in the field condition. Background information on these projects is also being accumulated from a recently initiated study of the seasonal variation in major element content of drainage waters from the principal soil associations of north east Scotland.

Chromatographic and mass spectrometric examination of the volatile pyrolysis products of soil organic matter has proved most valuable in distinguishing soil types and the potentialities of the technique are being further developed. Gas chromatography techniques have also been successfully employed in soil atmosphere-root environment studies.

The profile samples currently stored, dating back to the early 1930s and characterized both in the field and laboratory provide an extremely valuable source of soils for all departments of the Institute. Successful development of the soil data bank project, currently at the pilot stage, will greatly improve the task of logging and retrieval of data and also enable a comprehensive study to be made of relationships between laboratory and field characteristics.

The Peat and Forest Soils Section is largely concerned with the survey and evaluation of Scottish peat resources, which cover some 800,000 ha (2 million acres) of the land area and contain reserves estimated to be in excess of 1,000 million tonnes. Peat is not only a highly organic soil that could be

more intensively developed for agriculture or forestry, but is also an important raw material that can be extracted, processed and utilized for horticultural substrates, soil conditioners and a variety of industrial purposes. Survey techniques are, therefore, designed to provide information on site characteristics, including drainage, and on the quality and quantity of peat in deposits with potential for industrial development. To accelerate evaluation of resources in the Highlands and Islands and to meet a growing demand for information from national and other development authorities, satellite imagery is now being successfully employed as an adjunct to ground survey and air-photo interpretation. Establishment of the European Space Agency Earthnet Programme, in which the Institute is to collaborate, will greatly assist development of this technique, which has considerable application in recording and monitoring changes in site conditions and land use. Identification of plant remains and pollen grains preserved in deep peat provides a valuable means of assessing local and regional changes in climate and vegetation over the past 10,000 years. The results also provide useful information on soil-forming processes and on the relationship between environmental conditions and the rate of peat development.

Although deep peat contains a vast store of nitrogen, 5000 to 10,000 kg ha^{-1} in the upper 30 cm, more than 99% is present in organic forms unavailable to plants. Consequently special attention is being given to the physical and biological factors that control the rate of conversion of this element to its inorganic forms. This work is being carried out in association with field and glasshouse investigations designed to study the effect of soil moisture conditions on aeration, microbiological activity and plant growth. Work is also in progress on the nutrition of trees and nutrient cycling in forest-soil systems. Recent investigations have shown that atmospheric aerosols trapped by trees represent an input of some elements several times greater than that supplied by rainwater. Information on the total input is necessary for an understanding of soil development and the effects of pollution.

SPECTROCHEMISTRY

The work of the Department of Spectrochemistry can be broadly divided into three fields: studies of the distribution and the amounts of trace elements in soils, soil profiles and plant materials, the development of analytical methods for widening the coverage and lowering the limits of determination of significant elements, and the characterization of inorganic and organic components of soils. Many of these projects are carried out in collaboration with other Departments. Besides these research activities the Department provides an analytical service to other departments, especially for the determination of trace elements in soil extracts, soils and plant materials.

Much of the effort during the year on the soil-plant relationships of trace elements has been related to the application of sewage sludge to land. A first assessment has been made of the extensive analysis of plants and soils, from the ADAS long-term experiment in which urban sewage sludges were disposed on soil at Luddington Experimental Horticulture Station. These

analyses confirm that the amounts of copper, chromium, nickel and zinc in the sludges added have had a marked effect on the total contents of the soil. Treated soils sampled in 1976, some 8 years after the sludges were applied, demonstrate the persistence of very high levels of extractable copper, nickel and zinc, readily taken up by plants. There is no indication yet that chromium is being taken up into the above-ground part of plants or is having any deleterious effects on their growth. Monitoring of these long-term experiments is continuing at this site and another at the Lee Valley Experimental Horticulture Station.

Spark Source Mass Spectrometry has emerged from the analytical development stage to the extent that comprehensive, quantitative analysis of soils and rocks is now practicable on a routine basis and is being applied both to topsoils and soil profiles. Soils can be characterized, by their composition for 62 elements, in the form of a computer-drawn finger-print convenient for inter-soil comparison. The methods of evaluation, standardization and interference correction evolved for these sample types are beginning to be adapted and applied with some success to other materials, such as concentrates of soil extracts and ashes of plants and biological tissues. The high sensitivity of the technique brings new elements, including non-metals, metalloids, and the rare earths to the focus of interest and investigation, while the wide element coverage offers new insights into multifactorial trace element problems.

In the course of infrared studies on the highly reactive amorphous alumino-silicates that are so important in soil chemistry, a completely novel type of synthetic inorganic polymer has been prepared in the laboratory. It is similar in structure to the natural tubular hydrated aluminium silicate, imogolite, which is now known to be widely distributed in Scottish soils. Apart from its value as a model for natural amorphous soil clays, the synthetic imogolite has attracted interest because of the many unusual properties, associated with its high surface area, high porosity, and remarkable gel-forming characteristics. It is the subject of a provisional patent by the National Research and Development Corporation.

Mössbauer spectroscopy, along with infrared, has shown that some clay minerals with appreciable contents of tetrahedral iron may be broken down by reducing agents with the production of a phase with an intense blue colour. This colour is very similar to that observed in some Scottish soil profiles and the reaction may, therefore, be relevant to the situation which exists in poorly-drained soils containing ferruginous smectites. By using a combination of electron paramagnetic resonance (EPR) and Mössbauer spectroscopy it has been possible to identify very small amounts of an iron-rich phase in some clay minerals of low total iron content; the presence of such unrecognised phases may be the cause of misinterpretation of results from Mössbauer and some other spectroscopic techniques. Work is also in hand on the characterization by EPR spectroscopy of the bonding of several transition metals, such as copper, manganese and molybdenum, with soil organic materials and the chemical and physical changes which occur on their uptake by plant roots.

SOIL ORGANIC CHEMISTRY

Only a very small proportion of the soil organic matter occurs in a form readily soluble in water, and consequently the soluble components have not, in the past, received as much attention as the remainder. However, some of the water-extractable components are known to have a physiological effect on the growth of plants or plant tissues and investigations are now being carried out on a number of these substances. A large part of the brown material that occurs in the soil solution has already been shown to bear a striking resemblance to a synthetic polymer, polymaleic acid, which has an aliphatic or alicylic structure and contains many acidic groups. Using a radioactive tracer technique it has now been shown that wheat and tomato plants (the only plants tested) can absorb polymaleic acid through the roots and translocate it to the shoots. This is of particular interest because both the natural and synthetic polymers affect the activity of certain plant enzymes and stimulate the growth of excised tomato roots. In addition, they readily form complexes with cations and could influence the availability, uptake and translocation of nutrient trace elements. The amounts of the water-extractable polycarboxylic acids that occur in soils are influenced, in some cases at least, by the soil drainage status and are highest when the drainage is very poor. Well-drained soils usually contain much higher amounts of active aluminium than their poorly-drained counterparts and this is the agent thought to have the greatest effect on the sorption of these polymers from solution.

Other soluble compounds receiving attention are a number of simple phenolic acids. Their effects, too, are interesting because at low concentrations they stimulate the growth of wheat plants in a solution containing nutrients, but not when the nutrients are absent. At higher concentrations they have an inhibitory effect on growth. It has been shown that they act as substrates for respiration in the soil, but are presumably being replenished continuously from plant and microbial sources. Investigations are now beginning into the factors influencing their amounts in the soil and data will be collected from laboratory, pot and field experiments. Monitoring of their amounts under different cropping systems or with different fertilizer treatments should provide information about the possible effects that residues of one crop will have upon another.

Chemical studies comparing the properties of natural and synthetic humic substances have continued and some observations have been made with regard to the products obtained on oxidation. Various aromatic structures have been proposed in the past for the natural materials, as a result of degradative studies, particularly oxidative degradation which yields aromatic acids among its products. Aromatic nuclei undoubtedly occur in some of the humic substances, but is has now been shown that polymaleic acid, with an aliphatic or alicyclic structure, also yields several benzene polycarboxylic acids on oxidation with nitric acid. A number of aliphatic acids are also produced.

PLANT PHYSIOLOGY

Work on abscisic acid has shown that this growth regulator induces increased amounts of calcium and iron and a loss of potassium as dormancy

is induced in the tissue, such that the ratios of phosphorus to iron and potassium to calcium are decreased, while the growth-promoting substance benzyl-adenine, which will reverse the effect of abscisic acid, causes the amounts of potassium, calcium and iron to revert to normal values.

Work is being done on the uptake of selenium by certain plants in an investigation to study the effects of selenium deficiency on grazing stock *via* plants grown in the selenium deficient areas that are a prominent feature of the soils of Northern Scotland. Experiments in the Department confirm the findings of other Departments in this Report that selenate is much more easily taken up by plants than selenite.

MICROBIOLOGY

Glasshouse experiments in 1975 and 1976 have confirmed earlier field observations that the addition of ammonium rather than nitrate nitrogen fertilizer encourages the incidence of take-all disease of spring barley. The application of similar levels of nitrogen as foliar sprays of urea did not promote the disease as much as either nitrate or ammonium nitrogen.

In collaboration with Dr K. M. Old of the Department of Biological Sciences, Dundee University, a wide range of soil microbes have been successfully fed to a giant soil amoeba, which was recently isolated from Scottish soils. A number of fungal and nematode pathogens of British crop plants can be destroyed by this amoeba. Apart from the possibilities of biological control that are suggested by these observations, this amoeba is the only known soil microbe which can attack pigmented fungal spores.

SOIL FERTILITY

The main objctive of the Department of Soil Fertility continues to be the study of crop production and soil management through research on soil-nutrient-crop relationships and the application of results through the agricultural advisory services. Increasing importance is being attached to advisory soil testing and associated consultative activities for practical application of results and identification of problems for experimental investigation.

Experiments during the year have shown the importance of taking account of the influence of weather on fertilizer effects, e.g. lower yields and responses and uncharacteristic inferiority of placed fertilizer, for swedes, due to abnormally dry and warm conditions during July to September, 1976. Some very interesting results have been observed in relation to the time of destruction of foliage in relation to the absolute and relative yield of seed- and ware-size potatoes. It is generally the custom to burn off the foliage around the third week in August on the assumption that the yield of seed has by then maximized and will thereafter decrease whilst the ware yield subsequently increases. Experiments on the cultivar Record over four season have shown that the yield of seed maximises around mid-August and remains constant thereafter, whilst the ware yield increases in the following month by *ca.* 10t/ha. Obviously in the absence of blight, later destruction of foliage is indicated for this cultivar at least.

Cultivation experiments on barley revealed difficulties in the chemical control of grass weeds under the prevailing conditions of Northern Scotland

in unploughed, direct drilled and chisel ploughed plots, thus indicating the importance of soil conditions and climatic factors in relation to husbandry techniques that are much more successful elsewhere. The reduction in yield due to weeds was much less marked in traditionally ploughed plots and the beneficial effects of phosphate on crop yield were much less evident on the plots that did not use traditional ploughing. It appears from these experiments that for Northern Scotland normal ploughing, despite its higher cost, is more effective in weed control, including wild oats, than direct drilling, etc.

Studies on soils treated with copper-containing wastes, *e.g.* pot ale, show that the copper remains accumulated in the surface (plough) layers even after several years. Even when the Cu content of the surface soil had been increased 50 times above normal no increase in copper could be found at levels 300 mm below the surface irrespective of whether or not the plot had been cultivated. Studies on selenium treatment show that selenate is taken up much more effectively by the plants so far studied than selenite. This finding stresses the need for caution in the use of selenium salts to increase the selenium contents of herbage in connection with attempts to overcome deficiency problems. Deficiency of manganese in barley is being increasingly found in the examination of crop samples from areas where the soils show low exchangeable manganese levels or rather high lime status. Work of potential importance in relation to environmental considerations is being done on the possibilities of progressive acidification of soil profiles due to acidified rainfall. The latter is a matter of concern in some quarters at the present, but the differing exchange (H-Ca and Al-Ca) capacities of the different horizons requires much more work to be done before any significant interpretation may be drawn.

STATISTICS

The creation of a soil data bank is a process of centralizing results and records at present kept in a number of departments dealing with different biological, chemical and physical properties of soil. The records of any single department cannot be readily scanned to investigate inter-relationships between the many soil properties without resort to computer processing and multivariate statistical methods. Consequently a working group was established in September, 1976, under the chairmanship of Mr R. H. E. Inkson, to plan a unified system of data storage on all aspects of soil. The group includes one or more representatives from all departments in the Institute.

Considerable progress has already been made on a pilot study involving four soil associations and 430 profiles. A system of cross-referenced files has been established and programs written to store, retrieve, summarize and display the data. Coding forms were designed for dealing with the descriptive Soil Survey information so that the input to the computer is in numerical form. A typesetting program routine was devised to improve the quality of the English text output. The data bank may be searched for profiles whose properties satisfy certain conditions. Statistical summaries can be produced such as maximum, minimum or mean values of a variable

and its standard deviation. Histograms can be drawn, scatter diagrams plotted and correlation coefficients calculated. Work is already in progress to test the use of multivariate statistical methods and members of the Working Group are asking specific questions of the data.

SOIL SURVEY

The primary objective of the Department of Soil Survey continues to be to carry out systematic soil and land use capability surveys aimed at the production of soil and land use capability maps at a scale of 1:63,360 or 1:50,000, and, in collaboration with other Departments, the description, characterization and classification of the soils identified during the survey.

During the current season a further 1035 km² (400 square miles) have been surveyed, with concurrent land use capability assessments, 1800 km² (700 square miles) of the backlog of published maps have been assessed and extensive revision carried out on completed sheets. One hundred and sixty profiles have been described and sampled for analysis. Four maps have been published and nine others are at various stages of processing for publication.

The Department is represented on a number of Committees and Working Parties, sponsored by, amongst others, the Department of Agriculture and Fisheries for Scotland, the Scottish Agricultural Development Council and the Agricultural Research Council. Arising from these, a report with proposed guidelines for the division of LUC Class 3 has been accepted and they are now being applied. A scheme for a rapid survey of the hill land in Scotland has also been accepted and the preparations necessary for a start to be made on this next year have been put in hand.

There has been an ever-increasing demand for soils and land use capability information from a wide range of map users, including Regional and District Planning Authorities, the Scottish Colleges of Agriculture and the Highlands and Islands Development Board. Assistance has been given to the Environmental and Medical Division, AERE, Harwell, in the selection of sites for a UK Survey of radioactive fall-out accumulation and to the Northern Constabulary, Inverness, in an investigation, which involved aerial photograph interpretation and the supply of soils and terrain information. Several special surveys on larger scales have been carried out.

The mapping of the vegetation of Cairnsmore of Fleet is nearing completion and the collection of phytosociological records continued. The survey of the soils of the Mainland of Orkney has also been completed during the year. The survey of the Isle of Mull's land use capability has now been completed. Only 1·5% of the land surface is classified as having potential for arable use; 21% is suitable for reclamation for grassland and 71% is suitable only for rough grazing. A technique for estimating the percentage occurrence of the more widespread plant communities in an area has been investigated, as has a method for assessing relative grazing values. In micromorphological studies some preliminary work has been done in connection with soil problems arising from intense application of cattle court slurry on strip grazed grassland.

Studies on climatic factors have shown that while rainfall increases with elevation from about 900 mm in the lower valleys of the Spey, Don and Dee to about 1150 mm on the Ladder Hills and to above 1150 mm on the highest ground it may be as high as 2250 mm on the Cairngorm summits. Other work and calucations show that, whereas on the lowest ground in the area the mean monthly temperature rises from 2°C in January to 14°C in July, with a growing season of 200-210 days, on the highest ground near Braemar the corresponding data are −4°C, 8°C and 90 days.

Presentation of the Scroll of Honour to Professor E. W. Russell.

EVENTS AND PEOPLE

Second T. B. Macaulay Lecture

The origins of the T. B. Macaulay Lecture were given in the Introduction to the 46th Annual Report of the Institute and need not be repeated. This year's talk entitled " Soil Survey Methodology and Agriculture " was given by Professor E. W. Russell, C.M.G., D.Sc., F.Inst.P., F.I.Biol., F.I.Agr.E., Professor Emeritus of the University of Reading, before an audience of over 200 Institute staff, members of the Council of Management and visitors from other agricultural research institutes and the University, in the Marine Suite of the Amatola Hotel on 24th November, 1977. Professor T. C. Phemister, Chairman of the Council of Management, took the Chair and the vote of thanks and presentation of the memorial scroll was undertaken by the Director. The citation on the scroll, which was specially produced by the Institute cartographer, reads:

> " Presented to Professor E. W. Russell in recognition of his outstanding services to agricultural science and in commemoration of

the occasion of the Second T. B. Macaulay Lecture delivered at the Macaulay Institute for Soil Research, Aberdeen, Scotland, on 24th November, 1977 ".

The scroll bears the Seal of the Institute and the signatures of the Chairman of Council and the Director.

Professor Russell's lecture is printed in full as the Appendix to this Report. Speaking entirely without visual aids, Professor Russell gave a fascinating account of the origins and development of soil survey in the U.K., in his own inimitable style, revealing his mastery of the subject and some of his thoughts on its future development. It is a pleasure here to record our appreciation of his visit and the opportunity to meet him again. Following on the First Lecture by Sir William Henderson in 1976, the very high standard already set has been maintained in a totally different sphere of our interests.

Meetings and Lectures

The research colloquia continued this year with many excellent talks from external and internal speakers. Amongst the former were Dr D. R. Williams*, Chemistry Department, University of St Andrews, on " Trace elements in human health and disease "; Dr C. Dickinson, Department of Plant Sciences and Dr A. J. McLachlan, Department of Zoology, University of Newcastle-Upon-Tyne, on " Peat Micro-organisms and Chironomids "; Professor D. J. Greenland, Department of Soil Science, Reading University, on " Charge characteristics of soils and clays "; Professor H. M. Reisenauer, Soils and Plant Nutrition Section of the University of California, Davis, U.S.A., on "Ammonium effects on yield and ion uptake by plants "; Professor S. St J. Warne, University of Newcastle, New South Wales, Australia, on "Aspects of Quantiative Mineralogy "; Dr S. Kaunisto, Finnish Forest Research Institute, Parkano, Finland, on " Peatland Forestry Research in Finland "; Professor J. M. Stewart, University of Manitoba, Winnipeg, Canada, on " Peatland Erosion "; Dr N. Guzel, Cukurova University, Turkey, on " Soil Research in Turkey "; Dr C. F. Mills, Rowett Research Institute, Aberdeen, on "Aspects of soil-plant-animal relationships in trace element diseases in animals ".

Internal speakers were Mr M. S. Davidson (Microbiology) on " Chemostat and Coulter Counter Techniques "; Dr B. W. Bache (Soil Fertility) on " Soil and Soil Solution "; Mr E. Paterson (Chemistry and Mineralogy, Pedology) on " Differential Scanning Calorimetry "; Mr J. S. Bibby (Soil Survey) on " Land Use Classification "; Dr B. A. Goodman (Spectrochemistry) on " Electron Paramagnetic Resonance Spectrometry"; Mr G. C. Stove (Peat and Forest Soils, Pedology) on " Remote Sensing and its Use in Peat and Land Surveys "; Dr A. M. Ure (Spectrochemistry) on " Spark Source Mass Spectrometry ".

Whilst these research colloquia are of interest principally to the senior staff of the Institute, a need was felt to provide a similar facility for junior staff and consequently a start was made on a series of talks of a more

* Now Professor of Bioinorganic Chemistry at U.W.I.S.T., Cardiff.

general nature. Mr R. Grant gave an account on the Institute's work on Soil Survey; Mr B. D. Mitchell talked on the work of the Section on Chemistry and Mineralogy of the Department of Pedology; Dr J. W. S. Reith on Soil Fertility and Crop Production and Mr J. S. Robertson discussed the work of his department on Vegetation Survey. These talks on the various aspects of Departmental work will be continued in 1978 and the series will also deal with selected techniques and special topics of general interest to the junior staff.

T.V. Broadcast

The T.V. programme " The World About Us " screened some of Dr J. F. Darbyshire's work (Microbiology) on leaf decomposition, fungal invasion and protozoa, in September.

Honours and Appointments

The Director was awarded the 12th Gold Medal of the Analytical Division of the Chemical Society for his work on chelate chemistry and atomic spectroscopy. The Macaulay Institute thus became the first Institute to receive this award on separate occasions, following the award of the 10th Medal to Dr R. L. Mitchell in 1975. The Director also became one of the first three recipients of the newly instituted Spectroscopy Medal of the Czechoslovak Spectroscopy Society. The medal was presented to him at the meeting of the Spectrochemistry Commission of IUPAC at its Warsaw meeting in August. The other two recipients, Sir Alan Walsh (Australia) and Professor T. Ch. Alkermade (Netherlands) received their medals in Prague at the September meeting of the Colloquium Spectroscopium Internationale. The Institute was particularly pleased by the award of one of Her Majesty's Silver Jubilee Medals to Mr J. Logan of the Department of Pedology in recognition of his outstanding services to members of the Agricultural Research Service.

The Director was elected President of the Analytical Division of the International Union of Pure and Applied Chemistry at its General Assembly in August, 1977, for the period 1977/81 and Chairman of the Division Presidents Group within IUPAC. He also becomes *ex officio* a member of the Bureau of IUPAC. Dr R. O. Scott (Spectrochemistry) was elected to Associate Membership of the Spectrochemistry Commission of IUPAC at the General Assembly in Warsaw. Dr M. J. Wilson (Pedology) was elected to the Field Excursions Committee of the International Clay Conference 1978. Dr W. J. McHardy (Pedology) was appointed to the ARC Electron Microscope Advisory Group. Dr H. G. Miller (Pedology) became vice-chaiman of the Committee of the Sylvicultural Group of The Royal Scottish Forestry Society. Dr V. C. Farmer (Spectrochemistry) is acting as Associate Editor of the Proceedings of the International Clay Conference 1978, to be held in Oxford in July. Dr J. F. Darbyshire (Microbiology) accepted an invitation to join the U.K. Organising Committee for the 2nd International Symposium on Microbial Ecology in 1980/81. Mr J. M. Ragg (Soil Survey) was appointed to the DAFS working Party on Rural Land Use Information Systems and also to the ADAS/ARC/Soil Survey Working Party on

Suitability for Direct Drilling. Mr L. Robertson (Soil Survey) has been elected a member of the Organising Committee of the 6th International Working Meeting on Soil Micromorphology.

Lectures and Visits Overseas by Institute Staff

Professor T. S. West (Director) attended a meeting of the Executive Committee of the IUPAC Analytical Division in Oak Ridge, Tennessee, U.S.A., in May, and presided over the affairs of the Analytical Division of IUPAC at its General Assembly in Warsaw during August in the absence of the President who was unable to attend due to illness. Dr R. C. Mackenzie (Pedology) accepted an invitation to participate and give a lecture at the Scandinavian Symposium on Thermal Analysis in Trondheim, Norway, in June. This invitation was issued by the University of Trondheim and the Norwegian Section of the Nordic Society. He has also accepted an invitation to visit the Soil Department, Faculty of Agriculture, University of Riyad, Saudi Arabia, for two weeks in December, 1977. Dr W. J. McHardy (Pedology) was an invited speaker at the Second National Congress of the Association Internationale pour l'Etude des Argiles, University of Bari, Italy, in October. At the invitation of the Highlands and Islands Development Board, Mr R. A. Robertson (Pedology) accompanied five of their representatives at a meeting in Helsinki, Finland, in June, to advise on peat matters. Mr J. M. Ragg (Soil Survey) accepted an invitation from the University of Sulaimanya, Iraq, to spend two weeks with them for consultations regarding the soil survey of the University Farm. Mr N. A. Duncan (Soil Survey) has been seconded to Huntings Technical Services Ltd., for six months to assist in the soil survey of Saudi Arabia.

Several members of staff made very useful visits to various research establishments and scientific conferences abroad with the aid of funds made available by the DAFS. The Director accepted an invitation to speak as principal lecturer on atomic spectroscopy at the IUPAC Congress in Tokyo in September. Mr R. A. Robertson (Pedology) attended a meeting of the Presidium of the International Peat Society, Bremen, Germany, in June. Mr L. Robertson (Soil Survey) attended the Fifth International Meeting of the International Society of Soil Science Working Group on Soil Micromorphology in Granada, Spain, in May. Dr D. C. Bain (Pedology) attended the Third Meeting of European Clay Groups, Oslo, Norway, in June, as did Dr V. C. Farmer and Mr J. D. Russell (Spectrochemistry). Mr R. Grant (Soil Survey) visited the Centre de Cartographie des Sols, University of Ghent, Belgium, in June. Dr A. H. Sinclair (Soil Fertility) visited two Dutch research centres, at Groningen and Wageningen, and two German institutes at Hanover and Göttingen in June. Dr R. C. Mackenzie (Pedology) attended the Fifth International Conference on Thermal Analysis, Kyoto, Japan, in August. Dr R. O. Scott (Spectrochemistry) attended the meeting of the International Union of Pure and Applied Chemistry, Warsaw, Poland, in August. Dr A. M. Ure (Spectrochemistry) attended the XXth Colloquium Spectroscopium Internationale and 7th International Conference on Atomic Spectroscopy, Prague, Czechoslovakia, in September. Dr D. Jones (Microbiology) attended a Joint Royal Micro-

scopial Society/German Electron Microscopy Society Meeting on Biological Microanalysis, Munster, Germany, in September, and Dr B. W. Bache (Soil Fertility) attended the International Seminar on Soil Environment and Fertility Management in Intensive Agriculture under the auspices of Commission IV (Soil Fertility) of the International Society of Soil Science, Tokyo, Japan, in October.

New Postgraduate Research Students

During the year several research students have joined the Institute staff. Miss Karen Murphy (Spectrochemistry), supported by a Chemical Society grant, is working on spark-source mass spectroscopy. Mr D. I. Welch (Soil Organic Chemistry) is studying the examination of the structural properties of polymeric substances in soil. Miss Sarah G. Williams (Plant Physiology) is working on selenium metabolism and translocation in plants. Both Mr Welch and Miss Williams are supported by Agricultural Research Council grants. Miss Elaine B.-I. Glass (Soil Fertility), supported by a Ministry of Defence grant, is studying piezoelectric crystal monitors for trace atmospheric gases. With the addition of these four students the total number of postgraduate Ph.D. researchers in the Institute is now 11.

Overseas Research Workers

As well as the postgraduate research students listed above, several other long-term research workers have visited the Institute from Australia, Canada, Finland, Hong Kong, Italy, Japan, Mexico, New Zealand, Spain, Turkey and the U.S.A.

Deaths

It was with regret that we learned of the death, on 12th September, 1977, of Dr John V. Lagerwerff of the Agricultural Research Centre, Beltsville, Maryland, U.S.A. Dr Lagerwerff had returned to his laboratory in Beltsville at the end of November, 1976, after having worked for one year in the Department of Spectrochemistry. It is also regretfully recorded that Mr J. A. Robbie, who served as a member of the Council of Management from 1969 to 1975, died on 19th May, 1977.

Institute Events

The Institute's news magazine Profile, launched in February, 1976, has continued to be produced throughout the year and has now become a feature of the life of the Institute. By December it had reached its 21st issue and it is again a pleasure to record thanks to the Editor and the Editorial Advisory Board for maintaining a continuing high quality and focus of interest.

The first issue of " Health and Safety at Work " has now been in operation for *ca.* one year and its operation was reviewed during the year by the Departmental Safety Committees and the Institute Safety Committee. Few serious faults have been found with it and a second edition in a more suitable format will be produced during 1978. Pressure of events did not allow the production of the introductory pamphlet for new staff and visitors in 1977 as anticipated, but is is hoped to have it available during the coming year.

The Consultative Committee met twice during the year. Matters discussed included the operation of the flexible working hours scheme. Following these discussions the flexibility was increased in April to allow staff to begin work earlier or to work later. A further slight modification was made in November to ease the situation for junior staff attending official evening classes. At the second meeting in October various matters relating to safety, colloquia, management training courses for staff, etc, were discussed and action was subsequently taken as appropriate.

The Council of Management met twice, on 27th May and 25th November. On both occasions members of Council were able to visit some of the Departments of the Institute. During the year, the Council also provided copies of its agenda to the Institute Section of the I.P.C.S.

T. S. WEST.

The departmental responsibilities for individual research projects are discussed in the Report as follows:

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

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

PROGRAMME OF WORK

RESEARCH PACKAGES AND ASSOCIATED PROJECTS

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

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

(a) Characterization of Minerals and Major Constituents

Projects

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

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

104 Minerals: alteration during weathering and soil development.

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

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

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

(b) Trace Element Characterization

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

204 Geochemical distribution and pedological behaviour of trace elements.

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

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

703 Development of computer techniques and programs.

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

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

Projects

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

106 Surface characteristics of soil particles.

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

304 Nature, distribution and properties of humic soil substances.

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

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

Projects

801 The systematic survey of Scottish soils.

804 Studies of soil structure and genesis.

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

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

Projects

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

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

305 The synthesis and degradation of polysaccharides and related constituents of soil organic matter.

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

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

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

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

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

Projects

301 Chemical and biochemical investigations of organic material of microbial origin.

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

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

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

508 Soil-borne fungal parasites.

510 Investigation of soil protozoan populations.

512 Microbial degradation of soil organic matter.

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

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

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

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

Projects

110 Organic soils: moisture retention and root development.

111 Organic soils: site capability and amelioration.

112 Scottish peat deposits: survey, classification and characterization.

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

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

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

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

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

(a) Soil-Nutrient Relationships

Projects

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

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

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

602 Organic phosphorus and sulphur in relation to soil type and nutrient supply.

603 Available nitrogen in soils.

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

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

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

614 Electrochemical studies on soil-nutrient-plant relationships.

(b) Soil-Plant Relationships

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

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

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

610 Assessment of lime and nutrient status of soils.

612 Soil physical conditions and crop growth.

701 Theory of experimental design and statistical analysis.

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

PACKAGE 8: The study of factors affecting crop composition.

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

Projects

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

401 Iron and copper metabolism of plants.

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

407 Salt absorption: physical and metabolic aspects.

408 Nitrate reductase and molybdenum-copper interactions in plants.

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

613 Development and application of radioactive techniques.

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

Objective: To study the nutrition of conifers and other non agricultural crops on forest soils, peats and other soils of limited capability. To

study the natural vegetation in relation to soil type and to consider means of improving the utilization of marginal land.

Projects

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

117 Nutrient deficiencies in conifers: diagnosis and amelioration.

802 Plant communities and their relation to genetic soil types.

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

SERVICE PROJECTS

Non-Departmental

Projects

901 Provision of Instrument Workshop facilities.

902 Provision of Photographic facilities.

903 Provision of specialized materials and equipment.

Departmental

Projects

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

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

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

5313 Provision of analytical facilities employing special equipment.

5314 Supervision and maintenance of general glasshouse facilities.

5613 Provision of radioactive facilities.

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

5703 Data preparation and computer processing.

1. PEDOLOGY

DR R. C. MACKENZIE

The work of the department has progressed along the previously established main lines with a view towards elucidation of the origin and properties of the soil and the better utilization of poor, highly organic soils.

All three phases present in the soil—solid, liquid and gas—are now under investigation with the result that the information being obtained is more comprehensive and better integrated than previously. The sorption of ions and gases on solid particles—where their properties may be quite different from those exhibited in the solution and gas phases, respectively—is also being examined and should help to fill in some of the lacunae. Consequently, having started with systems consisting of only pure materials, the department is now at the stage where progressively more complex systems can be tackled. It is difficult to ascertain how far this work is from dealing with soils as they occur in the field: certainly, some investigations can be made on the " whole soil " but the material so called has been dried and sieved and the divergence between this and the undisturbed soil, although clearly variable, has still to be gauged. Nevertheless, indications are that, with mineral soils, the information being elucidated is becoming increasingly relevant to the soil in the field.

So far as highly organic soils are concerned, great strides have been made in the mapping of peatlands by use of remote sensing and photogrammetric techniques with limited ground traverse and the rate of survey is likely to be transformed should plans to maximize use of the computer in mapping come to fruition. Moreover, many types of Scottish peat have been shown, in glasshouse experiments, to be suitable for " loamless culture ", whilst forest nutrition experiments have revealed that unexpectedly large amounts of nutrients are supplied to crops by rain water and dust. Although the importance of this to agricultural crops has still to be assessed, there is no doubt that the information on moisture/aeration relationships, nitrogen mineralization and on the above aspects should eventually result in improved management practices being devised for peat and related organic soils.

Specialized techniques have been employed to examine samples from other departments and from outside bodies—e.g. to determine the sulphur content of feeding stuffs for the Rowett Research Institute and to examine some soil clays for the University of Riyadh, Saudi Arabia. Close collaboration has been maintained with the Forestry Commission, the Highlands and Islands Development Board (HIDB), the Scottish Development Department, ADAS, Regional Councils and other organizations, particularly on the survey and utilization of peat. Information and advice on peat resources and their development have been supplied to many individual researchers and organizations.

During the year the department has been pleased to welcome several visiting workers, all of whom contributed in some way to the department's programme. Dr N. Güzel, Cukurova University, Adana, Turkey, completed

a study on potassium reserves and their origin in selected Turkish soils; Dr M. Isabel Tejedor Tejedor, University of Madrid, Spain, has investigated synthetic manganese oxides and is presently studying buserite, a mineral that may be a precursor of some soil manganese oxides; Prof. S. St J. Warne, University of Newcastle, N.S.W., Australia, returned to the Institute after some seven years to carry out further studies on carbonate minerals; Dr J. H. Kirkman, Massey University, Palmerston North, New Zealand, also returned to discuss allophanic soils with members of staff and to study literature on allophane for a review he is compiling; Prof. M. Del Prete and Dr A. Federico, University of Bari, Italy, spent some time becoming familiar with electronoptical techniques and Dr S. Kaunisto, Finnish Forest Research Institute, has been comparing techniques used in studying nitrogen mineralization.

Members of staff have attended meetings of, *inter alia*, the Mires Research Group of the British Ecological Society, the Forest Soils Discussion Group, the Mineralogical Society and the Chemical Society. Papers have been presented at meetings of the Analytical Division of the Chemical Society and the Clay Minerals Group of the Mineralogical Society, at the Second X-ray Powder Diffraction Conference in Exeter and at a UNESCO-ITE Workshop on Acid Precipitation in Edinburgh.

Dr R. C. Mackenzie lectured, by invitation, at a Thermal Analysis Course at the Norges Tekniske Hogskole in Trondheim and subsequently participated in the 5th meeting of the Nordic Society for Thermal Analysis. He also presented a paper at the 5th International Conference on Thermal Analysis, Kyoto, Japan[1], and subsequently delivered two lectures in Tokyo —one at the University of Tokyo and the other to the Clay Science Society of Japan. Brief discussions were also held with soil science staff at the National Institute of Agricultural Research, Tokyo. Mr R. A. Robertson attended a meeting of the Presidium of the International Peat Society at Bremen and participated in the Centenary Celebrations of the Peat Research Institute, Bremen. At the request of HIDB, he acted as adviser on peat science and technology to HIDB staff during a visit to Finland to study methods of peatland exploitation. Dr W. J. McHardy delivered an invited lecture on the use of scanning electron microscopy and microanalysis in the study of soil mineralogy at the Second National Congress of the Gruppo Italiano dell'AIPEA at Bari, Italy, and Dr D. C. Bain attended the 3rd Meeting of European Clay Groups in Oslo, Norway.

CHEMISTRY AND MINERALOGY

Despite the close linkage between the disciplines of chemistry and mineralogy and the close interweaving of the two within the department, it is necessary at times to consider separately those aspects of the work that are predominantly analytical in nature.

Soil Analysis

Chemical Studies. Systematic chemical and physical examination of all profile samples collected in 1974 and of samples from a number of high-priority profiles collected in 1975 and 1976 have been completed. More-

over, all the 1976 samples have been prepared for analysis. A chapter dealing with laboratory characterization has appeared in the Soil Survey Memoir on the area around Wick (Sheet 110/116,/part 117). Soils and allied materials from, *inter alia*, Turkey, Italy and New Zealand, as well as samples supplied by departments of the Institute, have also been subjected to systematic analysis. 101, 105, 801

The pilot study for the Institute soil data bank, being carried out in the Department of Statistics, has involved the assembly and preparation of analytical data for computer processing. In this study, the data for 430 profiles from 4 soil Associations (Countesswells, Ettrick, Rowanhill and Strichen) are being processed. When complete, the bank should enable (a) more ready correlation of field/field, field/laboratory and laboratory/laboratory results and (b) easier retrieval of profiles or samples with desired characteristics. 101, 703, 801

The various selective chemical techniques employed for determining the presence of non-crystalline inorganic materials in soils—namely, extractions with sodium carbonate, sodium dithionite and potassium pyrophosphate and treatment with sodium fluoride—have been assessed and compared. The results were incorporated in a paper presented to the Analytical Division of the Chemical Society at their Autumn meeting. 101, 105, 801

In addition to its solid components, the soil also contains liquid (soil solution) and gaseous (soil atmosphere) phases. Since plant growth depends upon all three, it is unjustifiable to characterize soils on their solid phase alone. For this reason, systematic studies are now in progress on all three phases. Seasonal variation in the soil solution is being assessed by major-element analysis of stream water from the principal soil Associations in north-east Scotland. To avoid the effects of agricultural operations, the streams being sampled are in high land areas of semi-natural vegetation. Present results indicate that, in all samples, silica, bicarbonate, sulphate, potassium and sodium predominate, whereas phosphate concentrations are low (<0·03ppm). As might be expected, the aluminium content of stream water from soils developed on basic igneous parent material is also low (<0·1ppm). Extension of soil atmosphere studies to peat deposits shows that these are well aerated except for a narrow zone just above the fluctuating water table where methane and other hydrocarbons, as well as carbon dioxide, accumulate. In mineral soils a 1 per cent increase in carbon dioxide is generally associated with about a 1.5 per cent decrease in oxygen content, but in peat the decrease is approximately doubled. Evidence of denitrification in anaerobic soil and peat environments is provided by the higher nitrogen:argon ratios observed. Methods for field sampling have been improved by the use of pre-evacuated containers: a method for determining dissolved gases in the soil solution has also been developed. A chromatographic system for monitoring incubation atmospheres has been designed for the Department of Microbiology. 101, 108, 110, 512

The value and accuracy of X-ray fluorescence spectroscopy in total analysis has been amply demonstrated during the year and a pressed powder method has been found satisfactory for potassium determinations. Deposits

collected on filter papers in rain gauges at four forest experiment sites in different parts of Scotland contain mainly potassium, silicon, aluminium and iron with variable amounts of titanium and chlorine and traces of phosphorus and zinc. Despite a site-to-site variation in the amounts of iron and titanium, the deposits are remarkably similar chemically and probably represent wind-blown soil material mainly. Samples of feeding stuffs are being analyzed for sulphur at the request of the Rowett Research Institute: most contain 0·1-0·4 per cent sulphur. 104, 107, 5107

Electron probe microanalysis combined with scanning electron microscopy provides both chemical and morphological information on surfaces and, therefore, enables observation of compositional changes across sections or surfaces and during weathering. The technique is also applicable to biological materials as is evidenced by the collaborative study with the Department of Microbiology on the elemental composition of, and distribution in, cell walls of *Cunninghamella echinulata*[2]. 107, 109, 507

Thermoanalytical Studies. Differential thermal analysis (DTA) and thermogravimetry (TG), although not methods of chemical analysis, can be regarded as methods of phase analysis. Along with other themoanalytical techniques such as differential scanning calorimetry (DSC), they are finding increasing use in pure and applied chemistry[55] and are widely used within the department to study both mineral and organic materials[56]. In a study of the development of thermal analysis from earliest times[1, 57] it was found that heat treatments were in use to distinguish minerals over 2000 years ago. However, there have been rapid developments in recent years leading to problems of nomenclature that are only now being solved[58]. Power-compensation DSC has revealed that part of the water sorbed on the iron oxyhydroxide goethite is so strongly held that it is probably bound to the surface by hydrogen bonds. An aluminium iodate complex, examined by DTA and X-ray diffraction, contains hexa-aquo aluminium cations[3]—an observation of interest in relation to aluminosilicate formation.
103, 104, 105, 106, 107

Soil Mineralogy

The lithogical nature of the parent material is one of the main criteria used in the field classification of Scottish soils—a natural consequence of the fact that this to a large measure determines the profile morphology and the inherent fertility of the soil. Thus, weathering of the primary minerals of the parent material not only releases plant nutrients, but also forms secondary minerals that can retain nutrients in available or unavailable forms. In order to interpret results for such a complex system, it is frequently necessary to fractionate the soil and examine the individual fractions. It must be remembered, however, that the information obtained, even when suitably integrated to represent the whole soil, refers to an artificial system and may not tally with that from undisturbed soil. In order to minimize this factor it is customary now to examine the whole soil wherever possible—although even here the effect of drying and sieving may be far from negligible. Field tile drains, particularly those with little fall in areas of heavy soils, frequently become blocked after a period of use.

Mineralogical and particle-size examination of two such blocked drains, one in the Tipperty Soil Association in Aberdeenshire and the other in the Stirling Soil Association in Stirlingshire, has revealed the mechanism of blocking. This would appear to be sedimentation and sorting within the tile, with complete elution of very fine particles, of material eroded internally from the soil profile and washed in through joints[59]. 103, 106, 109, 801

An examination of the relationship between the potassium status and the mineralogy of some Turkish soils indicated that most of the non-exchangeable plant-available potassium was associated with an interstratified mica-montmorillonite clay mineral rather than with the mica present as a separate phase[60]. This has led to an investigation of the potassium reserves in Scottish soils in relation to their mineralogy. The results for some 20 soil Associations developed on widely different parent materials suggest that potassium-bearing minerals in the non-clay fractions may well play an important role. Concurrently, the microbial weathering of potassium-bearing minerals is being examined in collaboration with the Department of Microbiology. During weathering studies on Scottish rocks the micaceous mineral stilpnomelane has been detected in fresh and weathered gabbro from Crinan, Argyllshire: its possible conversion to vermiculite on weathering is being investigated. In such investigations the device, mentioned in last year's Report, for obtaining X-ray powder diffraction patterns from very small areas of thin sections[61] is proving invaluable.

101, 103, 104, 107, 506, 801

In general, chloritic minerals appear to be fairly stable in Scottish soils[4], but the ferruginous chlorite in one podzolic profile was absent in surface horizons[5]. This is attributed to decomposition by the organic acids, particularly those in the fulvic fractions, arising from the mor humus surface. The occurrence of halloysite[6] and gibbsite[7] in Scottish soils, under conditions where they would not be expected to form during pedogenesis, is considered to reflect the influence of preglacial weathering. Some podzolic soils contain large amounts of EDTA-extractable titanium and vanadium in their surface horizons. A collaborative study with the Department of Spectrochemistry has shown that both elements concentrate in the clay fraction and scanning electron micrographs reveal surface corrosion of titanium-bearing minerals in the coarser fractions. All evidence suggests that titanium may, to a limited extent at least, be mobile in certain soils.

101, 103, 104, 107, 204, 801

Mineralogical examination of a red air-borne dust deposited on the Isle of Skye showed the coarse fraction to contain predominantly stained quartz with smaller amounts of calcite, halite, sylvine and several other minerals. The clay fraction contained palygorskite in addition to quartz, calcite, illite and felspar. The mineralogy taken together with meteorological evidence indicated that material from a dust storm in North Africa had been carried westwards over the Atlantic Ocean whence it had travelled north-eastwards to Skye[8]. The ammonium-bearing phosphate mineral from Elephant Island, British Antarctic Territory, described in last year's Report, has been accepted by the International Mineralogical

Association as a new mineral and, in view of its formation from reaction of soil minerals with bird manure, has been named spheniscidite after the penguin order *Sphenisciformes*. 103, 104, 109

Clay Fraction. The fine minerals in the clay fraction of soils exert a disproportionate effect on soil properties because of their large area of highly reactive surface: they are also indicative of the processes active in soil formation. It is, therefore, customary to perform a systematic clay mineralogical examination of profile samples collected by the Department of Soil Survey and during the year under review such an examination has been initiated on soils from the Orkney Islands (Sheets 118, 119, 120, 121, part 117). Preliminary results reveal the dominance of inheritance in determining the clay mineralogy of soils derived from sedimentary rocks. For comparative purposes, the clay mineralogy of soils from Egypt, Iran, Italy, New Zealand and Saudi Arabia has also been investigated: these soils derive from a wide variety of parent rocks under widely differing climatic conditions. 101, 103, 105

The dehydration characteristics of monoionic smectites and vermiculites are being compared at different temperatures. Results so far indicate that the smectities dehydrate in discrete steps, the temperature of the step depending on the nature of the saturating cation. X-ray diffraction examination of a series of analyzed nontronites, in collaboration with the Department of Spectrochemistry, has shown that their 060 spacings—frequently used to distinguish dioctahedral and trioctahedral minerals—fall within the region usually associated with trioctahedral species. These large spacings for a dioctahedral mineral are attributed to iron-for-silicon substitution in the tetrahedral sheet[62]. 103, 207

The mineral imogolite, which occurs naturally in the form of extremely fine, hollow, long fibres, has been observed in many soils throughout the world and is generally believed to result from the weathering of pyroclastic materials. However, its occurrence in the B horizons of Scottish soils[63] and the fact that it can readily be synthesised from dilute solutions[9] suggests it may be much more widespread than was previously considered. Both allophane and imogolite are affected by sodium carbonate solutions[64]: while extraction at room temperature does not affect composition, hot extractions cause the formation of a silica-rich solid phase giving infrared absorption spectra resembling those of zeolites. These studies are collaborative with the Department of Spectrochemistry. 105, 107, 109, 207

Surface Properties of Soils and Clays. Low-temperature nitrogen adsorption studies have revealed that allophane, in addition to having pores in the 2-10 nm radius region, also contains micropores <1 nm radius[10]: this suggests that the results of specific surface area determinations on allophanic materials must be treated with caution. The fact that the specific surface area of Scottish soils developed on till derived from Old Red Sandstone (Devonian) sediments is about one hundred times that calculated from electronoptical evidence is accounted for by the presence of porus aggregates of clay size material. The effect of oven-drying on the cation-exchange and

surface properties of several freely and imperfectly drained Scottish soils is currently being examined, but no clear trends have yet been observed.
103, 106, 107, 109, 801

The manganese oxide buserite has a layer structure with, possibly, easily exchangeable cations between the layers. Various monoionic forms have been prepared and characterized with regard to X-ray and electron diffraction, thermal behaviour and morphology. This oxide may be a precursor of secondary manganese oxides in soils and could perhaps also be used as a model substance for assessing the mechanism of cation adsorption. Specific surface-area measurements and pore-size distribution determinations, supported by high-resolution electron micrographs are consistent with the occurrence of the iron oxyhydroxide akaganéite as solid rods rather than hollow tubes[11]. Work on the conditions of formation of this iron oxide is continuing. 105, 106, 109

Organic and Biological Materials. Rapid pyrolysis of soils followed by gas chromatographic separation and mass spectrometric identification of the volatile products, which has proved particularly valuable in identifying humus types in freely drained soils[12] on the basis of the relative amounts of the various products formed (see last year's Report), has been extended to poorly drained soils. The pyrolysis products of poorly drained surface horizons resemble to some extent those of the B horizons of freely drained podzols, showing abundant acetonitrile, benzonitrile and naphthalene with only small amounts of furfural derivatives; poorly drained B horizons tend to yield large amounts of acetonitrile and benzene products. In general, the A and B horizons of poorly drained soils resemble each other more closely than do those of freely drained soils, but when gleyed surface horizons have been cultivated the humus becomes very like that in the cultivated horizons of freely drained soils and indeed is indistinguishable at the level of accuracy obtainable. A study, in collaboration with the Department of Soil Survey of brown forest soils has shown that examination of pyrolysis products can assist in distinguishing podzolized brown forest soils and that differences in pyrolysis products correlate well with soil pH, base saturation and climatic variables[65]. 101, 108, 801

In collaborative studies with the Department of Soil Organic Chemistry, partially methylated derivatives are being used to establish the structures of, and bond-linkages in, soil polysaccharides. A service is also being given in the identification of aliphatic and alicyclic carboxylic acid derivatives related to fulvic and synthetic polymers. 108, 303, 305, 5107

Since complexes of metal salts with monocyclic polyethers are valuable in studying ionic transfer through cell membranes, the structure of a calcium crown-ether complex has been determined[13]. 105

PEAT AND FOREST SOILS

Peat Survey and Evaluation

Survey, classification and evaluation of Scottish peat resources, estimated to cover some 800 000 ha or 10 per cent of the land area, provide information of practical as well as of scientific importance. Increasingly, remote

sensing and photogrammetric techniques are being developed and employed to support and supplement close-grid topographic, stratigraphic, hydrologic and vegetation surveys that not only contribute to the general inventory, but also provide basic information for projects concerned with peatland drainage, afforestation, peat utilisation, the establishment of site capability classes and vegetation history[66]. Results of this work are incorporated in appropriate Soil Survey Memoirs[14] and in more detailed maps and reports for areas scheduled for development. 110, 111, 112, 113, 114, 801

At the request of the Highlands and Islands Development Board, a detailed survey of some 4000 ha of deep blanket bog in Caithness has been carried out to establish the distribution and nature of extractable reserves, to provide working plans for drainage and production processes and, in particular, to investigate the spatial variation, both laterally and with depth, in the chemical composition of the peat and to relate this to the strict requirements imposed by the development envisaged. In collaboration with Soil Survey, most of the major peat deposits in mainland Orkney and in the larger islands have been examined and characterized. Field work in the Wigtownshire area (Sheet 1/2/3/4) has been completed. 112, 801

The application of photogrammetric techniques to peat survey is currently concerned with the interpretation, design and compilation of thematic maps related to specific peat survey projects. At present, hydromorphological and vegetation maps at the 1:5000 scale are being compiled for the North and South Arnish areas of Eastern Lewis, in conjunction with the general peat survey of the Outer Isles. 112

Evaluation of a variety of remote sensing techniques is still in progress. This includes assessment of the resolution of different scales of aerial photography and satellite imagery, the value of different types of film for specific mapping projects and image analysis studies, and the role of digital imagery in the form of computer-compatible tapes for image interpretation, classification and numerical mapping. A software computer program for the numerical solution of photogrammetric mapping problems is being developed together with specific programs for spatial representation and statistical analysis of topographic and thematic map data in digital form. 112, 5703

Special ground-truth sites have been established for monitoring seasonal changes in ground conditions with respect to the interpretation of space-satellite imagery and multi-band photography. During 1977, seasonal aerial reconnaissance surveys, taking true colour and infra-red false colour obliques by a turn camera system, were conducted along pre-selected flight paths in the Laurencekirk-Cairn o' Mount area, one of the special ground-truth sites. 112, 902

As part of a joint survey in collaboration with the Grampian Planning Authority, the University of Aberdeen and other bodies, aerial photography of the Grampian Region is now in the second year of its proposed three-year programme. Virtually all the vertical panchromatic photography planned for the year has been completed, including 1:11 000 photography of the Cairn o' Mount area. Ground-truth surveys of peat erosion and

vegetation reflectances have been undertaken in conjunction with simultaneous multi-level true colour photography of the same area. 111, 112

As a basis for classifying peatland systems, three principal types of deposit—namely, confined mire, unconfined mire and partly-confined mire—have been distinguished. The first two categories generally correspond to basin and blanket mire, respectively, while the third has been created for those deposits that combine the features of both. Sub-division is based on such characteristics as hydromorphology, phytosociology and soil-nutrient status. Whether one or a number of these characteristics are employed in the classification of a particular area depends on the scale of mapping, the charateristics distinguishable within the area and the user requirements specified. 111, 112

Information gathered in connection with peatland classification is now being assembled in the computer to facilitate easy and efficient retrieval and sorting. A programme of vegetation data analysis using advanced computer techniques has been initiated. 112, 5701, 5703

Pollen Analysis and Quaternary Research

Investigation of the vegetational and environmental history of Shetland is continuing and sample cores from selected sites on the Mainland and Unst are in preparation. These sites include a shore peat at Sandwick partially exposed at low tide, a 6m-deep basin peat at Brindister and a basin peat at Saxaford, Unst. 112, 113

Pollen analysis is in progress on undersea and shore samples of peat and organic silts obtained by sub-aqua techniques from the Sound of Harris and North Uist in the Outer Hebrides and submitted by the Department of Geography, University of Aberdeen. Results should assist the study of sea-level changes and related vegetational history of the Western Isles. 113

Since pollen counts by traditional methods are based on percentages of an arbitrary total sum, the rise and fall of the numbers recorded for each taxon represented in this total must inevitably affect the values calculated for the other contributors and may lead to a false interpretation. In the Absolute Pollen Count method, which is currently being assessed, the exact numbers of pollen grains of all taxa are separately determined for a unit weight or volume of the sample material used. The procedure is, however, somewhat laborious and will be reserved for the study of specific problems. 113

A number of isopollen and trend surface maps have been produced using stored computerised data. Detailed spatial and multivariate techniques of statistical analysis are being used to clarify and classify the distribution of the more important units of vegetation. 113, 5701

Root and Moisture Studies in Peat

The experiment at Lon Mor, Inverness-shire, where water levels in ditches surrounding plots are held at fixed levels, continues to provide information on factors influencing the growth and development of coniferous trees on blanket peat[15]. Under lodgepole pine particularly, the percentage air volumes in the upper horizons of the peat have been much increased

compared with those under natural vegetation within the same drainage treatment[67]. Sitka spruce, initially held in check by competition from vigorous heather growth in the drier plots, is now responding to the different water-table levels[16] following suppression of the surface vegetation by a chemical spray. Collaborative work with the Department of Microbiology to relate seasonal microbiological activity and chemical variations (mainly in nitrogen and phosphorus) to water-table levels and oxygen concentrations has indicated that there is a greater seasonal variation in the drier than in the water-logged environments. 110, 111, 116, 503

The glasshouse work on organic substrates for plant growth has been extended to include a study of bark compost which has been used as a mono-ingredient substrate and in mixture with different peat types. Whereas bark seems to have limitations as a horticultural soil when used alone, its value as a substrate can be improved by admixture with even poor quality peat. Laboratory studies of the physical properties of horticultural substrates have included collaboration with the International Peat Society in a multi-national project designed to identify and quantify the principal criteria for assessing the quality of horticultural peat and peat products. 114

Nutrient Uptake from Forest Soils

Nutrient input, cycling and accumulation are being studied in untreated and fertilized plots of Sitka spruce at six sites in widely different climatic regions. Nutrients in litterfall and rainwater beneath these crops are being monitored using litter bowls, throughfall gauges and stemflow recorders developed for the purpose[17]. During the first few years of the study, stemflow has ranged from 2·9 to 16·2 per cent of the annual gross rainfall, the values increasing with increasing rainfall ($P<0{\cdot}001$) and decreasing with increasing crop height ($P<0{\cdot}05$). The concentrations of elements in stemflow, however, are inversely related to its volume. Input to these sites is being monitored both in standard rain gauges surrounded by aerodynamic (Nipher) shields, and in gauges surmounted by cylindrical wind filters constructed from polyethylene-coated wire mesh. Both types of gauge are mounted about 6m above ground level in a nearby open area. The presence of the inert wind filter has varying effects on the concentrations of elements in the water collected, ranging from a five to six-fold increase for magnesium and sodium to virtually no change for phosphorus and organic nitrogen. Comparison of the results from the " filter gauges " with those for throughfall and stemflow suggests that much of the calcium, magnesium and sodium gained by water passing through the forest represents a net input to the site, rather than an internal cycle through crown leaching.

A series of regression equations developed to describe growth and nitrogen levels in fertilized Corsican pine has been used to show that continued growth response after cessation of fertilizer application can be explained solely in terms of excess nitrogen stored within the tree tissues[18]. At moderately low rates of fertilizer application all the nitrogen applied is retained within the ecosystem. The possibility of diagnosing nitrogen deficiency from the species composition of the ground vegetation or from humus nitrogen levels has been explored[68]. 115, 5703

The interrelationships of growth, climate and nitrogen deficiency have been studied in Scots pine on upper Deeside and in Corsican pine on the coast of the Moray Firth. In Deeside, the important features of climate were rain during both May and June, rain in the latter month apparently influencing growth through an effect on nitrogen uptake[69]. On the Moray Firth, however, the operative factor appears to have been the effect of late summer drought on needle retention. 117, 5701, 5703

In an experiment with lodgepole pine growing on peat, foliar nitrogen and phosphorus levels are broadly related to depth of water-table, but the levels of both elements and of potassium declined with time and showed no improvement as a result of the drying and the increased rooting volume that followed canopy closure[15]. 110, 111, 117, 5701, 5703

The nutrition advisory service provided to forest nurseries has been been extended to include some Forestry Commission nurseries in England. 117, 608

Nitrogen Mineralization in Peat and Mor Humus

In a continuing study of the effects of afforestation with lodgepole pine on nitrogen mineralization, and on the related chemistry of peat, changes due to the tree crop have been assessed by comparing samples from contiguous planted and unplanted areas. More detailed investigations of the higher acidity of planted peat, mentioned in last year's Report, have revealed that concomitant increases occur in the exchangeable hydrogen ion content and in the cation-exchange capacity with a consequent decrease in percentage base saturation[70]. Recent comparisons, using samples from peat varying in depth from <600 mm to >3 m from Naver Forest (Sutherlandshire), suggest that the changes in rates of nitrogen mineralization due to planting are different in shallow and in deep peat. 110, 116, 5701, 5703

Long-term effects of liming and of nitrogen and phosphorus fertilizers on acid mor humus beneath pole-stage Scots pine are being studied at Culbin (Laigh of Moray Forest). Humus from limed plots continues to show higher pH values, calcium content and percentage base saturation eight years after treatment, but, despite these differences, rates of carbon dioxide evolution and nitrogen mineralization in incubated samples are similar both for limed and unlimed humus. 115, 116, 117

2. SPECTROCHEMISTRY

DR R. O. SCOTT

The work carried out in the department can be divided into three interrelated categories: the investigation of the distribution and mode of occurrence of trace elements in soils, soil profiles, clay minerals and plant materials; the provision of an analytical service for the determination of elements in samples from other departments; and the examination of the composition, reactivity and structure of inorganic and organic components of soils. The installation during the year of an electron paramagnetic resonance spectrometer will facilitate the investigation of the forms in which metal-organic complexes occur in soils and will supplement information obtained by infrared and Mössbauer spectroscopic methods. In the Mössbauer technique work at liquid helium temperature has been made possible through the courtesy of the Department of Natural Philosophy of the University of Aberdeen.

Several visiting research workers have used the spectroscopic facilities of the department. Dr Maria P. Hernandez, Department of Analytical Chemistry, University of Murcia, Spain, developed the application of a carbon-filament atomizer to the analysis of agricultural samples, and Miss Jilla Khalighie, a former student of the National University of Iran, Teheran and of Imperial College, London, is working on atomic absorption techniques of analysis; Mr S. Forbes, an SRC research student working conjointly in the Departments of Soil Fertility and Spectrochemistry towards the degree of Doctor of Philosophy of the University of Aberdeen, is continuing his investigations of the potentiality of electrodeposition-concentration and microwave emission spectrometry for the determination of selenium. Other visitors include Dr C. W. Childs, DSIR, Soil Bureau, Lower Hutt, New Zealand, who is using Mössbauer and electron paramagnetic resonance, and Dr D. G. Lewis, the Waite Agricultural Research Institute, Adelaide, Australia, who used the infrared and Mössbauer spectroscopic facilities, for the characterization of inorganic soil components; experience was gained of the spark-source-mass-spectroscopic technique by Mr D. J. Terrell, Geophysics Institute, National University of Mexico, and of the spectrochemical analysis of soils by Mr H. L. Yeung, Department of Geography and Geology, University of Hong Kong.

Mr J. D. Russell presented a paper at the Third Meeting of the European Clay Groups in Oslo, Norway, and Dr V. C. Farmer also attended. Dr A. M. Ure presented a paper at the XX Colloquium Spectroscopicum Internationale in Prague, Czechoslovakia. Dr R. O. Scott attended in Warsaw, Poland, the 29th General Assembly of the International Union of Pure and Applied Chemistry as the British National Representative appointed by the Royal Society to the V4 Spectrochemistry Commission. Contributions were made by members of staff at meetings of the Fourth SAC Conference on Analytical Chemistry in Birmingham; the Autumn meeting of the Chemical Society in Aberdeen; the Infrared and Raman Discussion Group in London; and the Analytical Division of the Chemical

Society in Pitlochry. Papers were also presented at a seminar, organised by the Department of the Environment, on Research into the Effects of Metal Contaminants in Sewage Sludge, London, and to a conference of the Soil Scientists of the Agricultural Development and Advisory Service on Inorganic Pollution and Agriculture, London. Meetings of the Analytical and Faraday Divisions of the Chemical Society; the DOE Standing Committee of Analysts (Group 8.0; soils and sewage sludges); the Clay Minerals Group of the Mineralogical Society; the Association of Scottish Industrial Analysts; and the Interservices/DTI Panel on Spectroscopy were also attended.

Trace Elements in Soils, Plants and Biological Materials

Preliminary analyses of the ten large samples (Ann. Rept. No. 45, 1974/75) from different soil series throughout Scotland have been made, and results for extractable trace elements obtained at the Institute, the East of Scotland College of Agriculture and the West of Scotland Agricultural College are being compared to check the analytical procedures used at the three centres. Examination of surface and soil profile samples using different extractants including DTPA and 2-ketogluconic acid have continued. In subsoils of poorly drained soils, 2-ketogluconic acid extracted only slightly less copper than either DTPA or EDTA but in the organic upper horizons it extracted less than one-tenth. 201

Soils and Soil Parent Materials. Investigation into the high contents of titanium and vanadium extracted by EDTA from the A horizons of podzols (Ann. Rept. No. 45, 1974/75) has continued. The A horizon soils from profiles developed on widely differing parent materials were separated into particle size fractions and the total and EDTA-extractable titanium, vanadium and iron determined in the total soils and their fractions. The fine sand fraction accounts for 50 to 80 per cent respectively of the total and extractable amounts of all three elements in the total soil. In general, both the total and extractable titanium and vanadium concentrations increase with decreasing particle size, the clays containing extractable amounts up to 420 ppm Ti and 27 ppm V. The main titanium minerals in the soils are anatase, rutile and ilmenite and observations by scanning electron microscopy of the surfaces of the minerals show clear evidence of chemical, and possible physical, weathering processes that may lead to the accumulation of titanium in fine fractions, but not to downward translocation. Vanadium released by weathering is subsequently absorbed by the clay fraction. Electron paramagnetic resonance spectra confirm that most of the vanadium extracted from the soils and their clay fractions by EDTA is in the vanadyl, $(VO)^{2+}$, form. 104, 201

A paper on the use of Mössbauer spectroscopy for the characterization of the secondary iron in pans formed in Scottish podzolic soils has now been published[19]. 201, 203

The determination of trace elements in selected soil profiles sampled by the Department of Soil Survey has continued. Work on soils from the areas covered by Sheets 32 and 24 (Edinburgh and Peebles), Sheet 84 (Nairn and Cromarty) and Sheets 40 and part of 41 and 32 (Kinross, Elie

and Edinburgh) has continued. In addition to total contents and amounts extractable by acetic acid and EDTA from all the soils submitted by the Department of Soil Survey for trace element analysis, trace elements extractable by M ammonium acetate are also being determined in selected horizons of the profiles chiefly to identify soils in which excess molybdenum may be a problem. 101, 201

The distribution of the total and acetic acid-extractable lead in over 200 soil samples from 41 profiles, sampled by the Department of Soil Survey, has been investigated. The profiles represent six soil Associations in Wigtownshire, a rural area remote from any source of pollution. The overall mean total lead value was 30 ppm, modal value 15 ppm and median value 20 ppm. The highest degrees of correlation at the 0·1% level were between total lead and loss-on-ignition, the acetic acid extractable lead content, and the reciprocal of depth. The ratios of total lead in the uppermost horizons of the profiles to those in the corresponding C horizons show that the intensity of lead enrichment is highest in profiles with organic surface horizons, suggesting that the surface lead accumulation is due, at least in part, to biological cycling. 101, 201

A paper reporting work carried out in collaboration with the Department of Soil Organic Chemistry on the distribution of trace elements in humic and fulvic acids and their subfractions, combined with electron paramagnetic resonance studies on the form in which they occur, has been published[20]. Further studies have shown that the total amounts of Co, Cu, Fe, Mn and Ni in the fulvic acid separated from an Insch Association soil are very similar to those extractable from the whole soil by 0·05 M EDTA. This was confirmed by the almost complete extraction (90 per cent or more) of the Al, Co, Cr, Fe, Mn, Ni and V from the fulvic acid by 0·05 M EDTA. In the humic acid, however, which is present in lesser quantity than the fulvic acid, lower proportions of Al, Co, Cr, Cu, Fe, Mn and V were extractable. 201, 203, 307

Collaborative studies with the Department of Pedology on trace elements in peat profiles have continued. In some profiles from the Caithness area high molybdenum contents of up to 18 ppm have been found in the lowest peat horizon close to the parent mineral material. 112, 201

Soil Status and Plant Uptake. During the year the number of requests by the Department of Soil Fertility for the analysis of soils where cobalt and copper deficiencies have been suspected has increased, this upward trend being noticeable over the past three to four years. Requests for the determination of other trace elements, including molybdenum, have remained about the same. Other samples, from the Department of Soil Fertility experiments, have also been analyzed. In collaboration with the Department of Pedology, background information is being obtained on the naturally occurring copper and manganese contents of the leaves, twigs, etc. of conifers, chiefly Sitka spruce. 115, 201, 202, 609, 610

Soil profiles sampled last year (Ann. Rept. No. 46, 1975/76) in areas where distillery wastes have been disposed of for many years have been examined for 0·05 M EDTA-extractable copper, manganese and zinc. Upper

horizons (0-10 cm) of some of the treated soils contain over 200 ppm Cu extractable by EDTA, compared with less than 8 ppm in comparable horizons of untreated soils. In all the profiles examined the highest EDTA-extractable amounts of copper, and to a lesser extent zinc, were within the top 30 cm. Similarly in soils treated with copper-rich pig slurry, elevated Cu levels do not appear below a depth of about 25 cm. 201, 609

In collaboration with the Agricultural Development and Advisory Service of the Ministry of Agriculture, Fisheries and Food the analysis of sewage sludges, sludge-treated soils and pasture herbage from sludge treated plot experiments has continued. The results obtained over an eight-year period from a field experiment at the Luddington Experimental Horticulture Station, where abnormally high trace element additions were made, indicated that there was little decrease in the extractable amounts of such potentially deleterious trace elements as Cd, Cr, Cu, Ni or Zn eight years after application of sludge. The relative amounts of these elements extracted from the treated soils by either acetic acid or EDTA have shown considerable changes although the readily-extractable amounts have remained high. There appears to be a tendency for the ratio between acetic acid- and EDTA-extractable contents of some elements in the treated soils to reach a constant value irrespective of the levels initially present in, or the sources of, the sludges; for zinc and nickel, after a period of about eight years the ratios approach those found in untreated surface soils. Four annual applications had effects similar to an equivalent single application and it would appear that the cumulative total amount added determines the possible long-term supply of these elements. The two main effects noted with plant samples from this experiment were firstly, increases in the plant contents of copper, nickel and zinc but not chromium and secondly, that a good relationship was found in 1976 between the zinc content of timothy grass and the amounts of this element extractable by either acetic acid or EDTA from soil samples taken earlier in the same year. Reports of this work have been submitted for publication[71, 72] 201, 202

A small number of the samples from the field experiment started in 1976 on selenium uptake by plant materials have now been analyzed. It is already discernible that plant uptake (ryegrass, clover, mixed herbage) of added selenate is several times greater than of added selenite and that the natural available selenium in most of the soils involved is probably much less than the lowest rate of application i.e. less than 0·04 ppm in the soil. 202

Miscellaneous samples analyzed have included soils from St Helena sent by the Ministry of Agriculture, Fisheries and Food; liver ashes and feedstuffs from the Rowett Research Institute; a phosphomolybdate complex from Northwick Park Hospital, Middlesex; and, in order to help diagnose a problem of poor tree growth on Dartmoor, some Sitka spruce leaves from the Forestry Commission. 201, 202

Spectrochemical Methods of Analysis

During the year two programmable desk calculators have been acquired to speed up calculations especially for the evaluation of data from both

emission and mass spectrographic plates. Kodak SA-1 plates have been brought into regular use for some of the arc emission work to replace Ilford Chromatic plates which are no longer available. The ORWO WT2 plate has emulsion properties suitable to substitute for the Ilford Long Range Spectrum, but, the $10'' \times 4''$ size needed for Hilger Spectrographs is not yet available. The nearest metric size (24 cm × 9 cm) would provide fewer exposures per plate or, for semiquantitative work, necessitate a smaller image of the source on a shorter entrance slit. An historical account of some British contributions to spectroscopy has been submitted for publication[73]. 205

Conversion of the Institute's gas supply to natural gas caused considerable difficulty where sodium carbonate fusion was needed. A reasonably satisfactory Meker-type burner has now been designed using a quartz burner tube with a perforated top made from machinable ceramic. Ways of speeding up the standard chemical concentration procedure are being investigated. With the co-operation of the Department of Soil Fertility, tests using radioactive ^{99}Mo have indicated that this element is rapidly precipitated with 8-hydroxyquinoline and that leaving the sample to equilibrate overnight may not be necessary. 205

Arc Emission. No changes have been made in the cathode layer arc procedure during the year. Further work with the high-current arc is awaiting modification of the stabilized high-current power supply. 205

Direct Photometry. Following the suspected changes in EHT supply to the E789 Polychromator photomultipliers reported last year, an accurate digital voltmeter has been incorporated to monitor this EHT supply. In order to study arc emission variations with time, a 6-channel pen-recorder is being interfaced to the Polychromator. Information gained may enable lower limits of determination to be achieved for some of the volatile elements by shortening the integration times and thus improving their signal-to-noise ratios. 205

Flame Emission. The existing flame emission technique continues to be used without modification. Determination of calcium, potassium and sodium by flame photometric methods, carried out as a service to other departments of the Institute, continued at the same level as last year. 5206

Atomic Absorption: Flame Techniques. The number of samples analyzed for copper, manganese and zinc has increased by about 50 per cent compared with last year. The laboratory atomic absorption instrument constructed in 1962 for the determination of cobalt in soil extracts has been taken out of operation to make space for an IL751 twin-channel, double-beam atomic absorption/emission spectrometer about to be installed. This instrument will be used for cobalt determination as well as for major element analysis in small mineral samples following dissolution techniques at present being developed. 206, 5206

In order to assess possible losses of cadmium and zinc, and also of copper and manganese, during the ashing of sewage sludges overnight at 450°C, aqua regia digestion followed by atomic absorption analysis were

carried out on both ignited and unignited samples of 42 sewage sludges from England and Wales. There was no evidence to suggest loss of any of the elements during the ashing procedure. 201, 206

The Varian Techtron AA6 atomic absorption instrument installed last year has been devoted to research on methods of concentration by "atom-trapping." In this technique a water-cooled silica tube mounted in the flame collects and concentrates elements from solutions nebulized into the flame in the normal way. By switching off the cooling water a rapid release and atomization of the collected element is produced and the enhanced atomic absorption signal measured. Significant improvements in sensitivity are obtained for copper, lead and cadmium. 206

Atomic Absorption and Fluorescence: Electrothermal Atomization. The development of this analytical technique for the simultaneous determination of lead by atomic absorption and cadmium by atomic fluorescence spectrometry previously reported (Ann. Rept. No. 46, 1975/76), has now been completed and a description has been accepted for publication[74]. A new design of carbon rod which is suitable for atomic absorption spectrometry[21], but has improved performance for atomic fluorescence, has also been developed. A review of some recent developments in atomic fluorescence spectroscopy has been submitted for publication[75]. 206

Microwave Plasma Emission. Studies are being carried out on the determination of nitrogen isotope ratios, using the emission spectra from a microwave discharge of nitrogen/argon mixtures under reduced pressure. The preliminary work is being made using a large quartz spectrograph with a view to evaluating the resolution required to enable the various isotopic band-heads to be measured accurately and to investigate possible spectral interferences. A recently acquired Optica Monochromator is now being evaluated for this work. 205

The determination of selenium by the use of a microwave plasma is also being investigated. By volatilizing selenium from an electrically heated metal filament into a free-flowing argon plasma and by employing a vacuum monochromator, 5ng Se can be detected using the line at 2062·79Å. 206

Radio-frequency Plasma Emission. Preliminary studies on the determination of boron, cobalt and molybdenum by inductively-coupled radio-frequency plasma emission spectroscopy have provided evidence that this technique can make a valuable contribution to the analysis of agricultural materials. Detection limits are adequate for the determination, without further pretreatment, of cobalt in acetic acid extracts and boron in water extracts of soils, but improvement is needed to permit molybdenum to be determined in ammonium acetate extracts at very low levels. The results obtained agree well with those obtained by conventional methods and, although interferences occur because of matrix effects on the plasma characteristics, these can be overcome. 201, 206

Laser Spectroscopy. The laser equipment provided by the Science Research Council, the Agricultural Research Council and the Royal Society

is being incorporated into a laser remote-sensing system for the determination of SO_2 and NO_x in agricultural atmospheres, the back-scattered radiation from these species being collected by a reflecting telescope. For remote sensing techniques it has been necessary to modify the dye laser (Electrophotonics, Model 23) to allow computer selection of the output wavelength and control of laser pulsing. The control system is based on an Intel SBC 80/10 microcomputer, the data acquired being stored on a 250 kilobyte floppy disc. The construction of the remote sensing system is nearing completion and preliminary testing will begin soon. 206

Other Methods of Trace Element Analysis

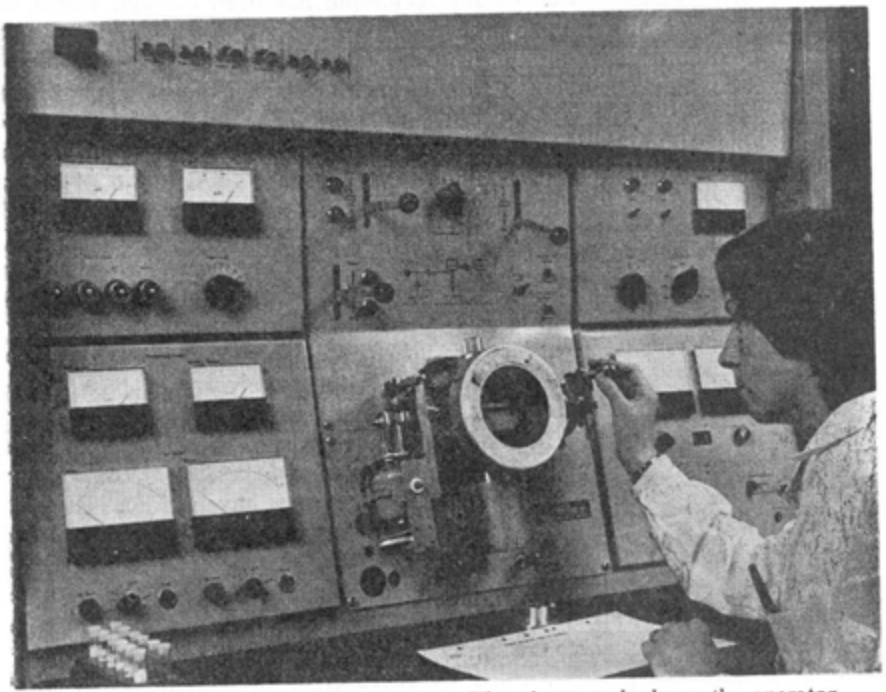
Fluorescence Spectroscopy. The use of the molecular fluorimetric method described in last year's report has been investigated for the determination of selenium in soils. The oxygen-flask combustion technique, however, gives poor recovery of selenium and a nitric acid/sulphuric acid digestion procedure is being developed which gives both better recovery and a more rapid sample throughput. Interference effects in the digestion procedure are being investigated. 206

Cathodic Stripping Voltammetry. The method for the determination of selenium by cathodic stripping voltammetry, worked out conjointly with the Department of Soil Fertility, (Ann. Rept. No. 46, 1975/76) has been applied to the analysis of soils and plant materials[22], the lowest amount determinable being 0·005 ppm in the dry sample. Results obtained electrochemically are in good agreement with those determined by the spectrofluorimetric technique mentioned above. A method using differential pulse polarography for the determination of selenium has also been developed[76]. 206

Spark Source Mass Spectrometry. The analytical techniques for the SSMS determination of over fifty elements in soils and rocks have now been consolidated. Mathematical correction procedures have been devised and tested for most of the mass-overlap interferences occurring and the refinement of Relative Sensitivity Coefficients to improve the accuracy is continuing. A report on these techniques with particular reference to interference correction methods was presented at an International Conference on Mass Spectrometry in Florence[23]. The precision of determination is now $\pm$ 10% to $\pm$ 15%. The analysis of standard rock samples and comparisons of SSMS with spectrographic, atomic absorption and neutron activation analysis indicate that for many elements an accuracy of about $\pm$ 20% is being achieved. This accuracy is, however, capable of improvement as the analytical information, on which the Relative Sensitivity Coefficients are based, accumulates. Unlike most current work in other laboratories, in which only the heavier elements are usually determined, the methods developed have a comprehensive element coverage including the lighter and biologically more important elements. A description of these techniques of comprehensive quantitative analyses, presented at the SAC Conference in Birmingham, 1977, is now being prepared for publication. Detailed accounts are also in preparation of the application of SSMS to the analysis

of ten Scottish top-soils derived from different parent materials and of the determination of all the rare earth elements directly in soils and rocks. A short note has been accepted[77] on the rare earth element content of water lily (*Nuphar Lutea*) and the NBS Orchard leaf, SRM 1571 which shows that, in contrast to the findings of an American study, there is no evidence of rare earth element accumulation in water lily grown in Scottish conditions. 202, 205

The methods developed for soils and rocks are now being extended to the analysis of concentrates of soil extracts prepared by co-precipitation of



The Spark Source Mass Spectrometer. The photograph shows the operator making an adjustment to the electrodes in the sample chamber of the Instrument.

trace elements with alumina using an 8-hydroxyquinoline/tannic acid/thionalide concentration procedure. Excellent agreement has been obtained with spectrographic analysis of concentrates for the elements Co, Cr, Mo, Ni, Pb, Sn and V and, with atomic absorption spectrometric analysis of soil extracts directly for Cd, Cu and Zn. Other elements such as As, Nb, Se, Th, U and W have been determined by SSMS in the concentrates and investigations are continuing. A report of this work was given at the XX Colloquium Spectroscopicum Internationale in Prague and an extended abstract published[24]. 205

The performance of the electrical detection systems has been investigated and, while these are very rapid and sensitive, the resolution and precision

are poor. The instrument, as designed, is severely limited in these modes by magnetic hysteresis effects, and by the sequential nature of the measurement which, together with the highly variable production of ions by the spark, make it very difficult to make precise measurements of ion intensity or of isotope intensity ratios. An examination of lead isotope ratios although feasible for the major 208/207/206 isotopes by photographic detection becomes very difficult for ratios of these to the 204 isotope because the ratios either exceed (208/204) or are only slightly less (207/204, 206/204) than the linear dynamic range of the photographic plate. 205

An alternative electrode-pressing technique has been evolved which is particularly suitable for plant ash and for concentrate samples. This uses polythene moulds prepared by Technical Services by injection-moulding. These are also more suitable for making tipped electrodes for small 5-10 mg samples than the PTFE mould currently used. The instrument has also been modified by fitting digital panel meters to monitor accurately the magnet current and accelerating voltage and assist the selection of mass range in the electrical detection modes. 205

Molecular Spectrometry of Soil Constituents

Optical Absorption Spectrometry. The tubular aluminosilicate, imogolite, has a molecular structure fundamentally different from that of any other known inorganic compound (Ann. Rept., No. 43, 1972/73) and its successful synthesis[9] at the Institute during the past year has now made this novel material available in pure form in substantial quantities for further study. Apart from its interest as a component of natural soils, the material has potential applications as an adsorbant, coagulant, molecular sieve, gel former and catalyst, and these possibilities have led the National Research and Development Corporation to patent the new material. The successful synthesis was greatly assisted by the finding that the infrared spectrum of natural imogolite exhibits an absorption band which was absent or weak in the spectra of most allophane samples[25]. This distinctive absorption band was then found to be given also by soluble synthetic alumino-silicate complexes formed by reaction of monomeric silica with hydroxy-aluminium cations in acidic solutions. The work, therefore, opens a new field in the solution chemistry of aluminium and silicon in a pH region ($<4{\cdot}5$) where reaction was not previously suspected. 109, 207

It has been common practice to fractionate and classify the hydrous oxides of aluminium and silicon that occur in clays, either alone or in combination, by use of progressively more aggressive alkaline extractants, *i.e.* cold sodium carbonate, hot sodium carbonate, and hot sodium hydroxide. A collaborative examination by several techniques of the residues from the extraction of homogenous samples of allophane and imogolite has shown that hot sodium carbonate leaves an altered product with a higher silica-alumina ratio[64]. Cold sodium carbonate and hot sodium hydroxide are, however, confirmed as useful extractants, the first for highly reactive materials, and the second for the total extraction of allophane and imogolite, leaving only the better crystallized silicate clays. 105, 109, 207

A survey of a number of celadonite and glauconite samples, in collaboration with workers at the British Museum, has shown that these closely related micas are clearly distinguishable by infrared spectroscopy, the hydrothermally-formed celadonite being always better ordered than glauconite, which forms at ambient temperatures[78]. 207

Infrared spectroscopy has provided important insights into the mechanism of interaction between agriculturally important chemicals and soil components. Work previously reported on the adsorption of various anions, including fulvate and humate, on goethite and gibbsite has now been published[26, 27, 28, 29]; these papers considerably clarify the extent and nature of the reactive surfaces of these hydroxides. Work at this Institute elucidated the reactions between anhydrous ammonia gas and smectites and vermiculite some years ago (Ann. Repts., No. 36, 1965/66 and 42, 1971/72), and showed that the ammonium ions formed were much more deeply placed and uniformly distributed within vermiculite crystals than was possible by cation exchange processes. The expected slow release properties of the ammonium in ammonia-treated vermiculites has now been confirmed under standard leaching conditions, and related to particle size[79]. Collaborative work with the Department of Soil Fertility, comparing its effectiveness for various crops with that of conventional nitrogen fertilizers has been completed and will be published in due course. 207, 603

Infrared spectroscopy has revealed a novel reaction between alkali metal hydroxides and ferruginous smectites which may be similar to those that occur when soils are stabilized by applying such bases. Results presented at the 3rd Meeting of the European Clay Groups in Oslo suggest that a partially reversible deprotonation reaction takes place, associated with a major deformation of the silicate framework; the reaction also causes dramatic changes in Mössbauer spectra and cell *b* dimensions. In the course of this work it was found that the *b* dimension of many untreated nontronites were significantly higher than any published figures, and a short paper[62] has been submitted relating these high values to the effect of Fe^{3+} replacing Si^{4+} in tetrahedral layers. A new formula is proposed relating the *b* dimension of smectites to tetrahedral and octahedral Fe^{3+} contents only. 105, 201, 207

The considerable insight into the nature and reactivity of soil mineral surfaces that has been gained at the Institute by the application of infrared spectroscopy and other techniques has led to a request to prepare a chapter on Water on Particle Surfaces for a treatise on soil chemistry. This task has now been completed in a radically new treatment utilizing modern theories of the structure of liquid water and aqueous solutions[80]. 207

Continuing collaboration with the Department of Soil Organic Chemistry has led to the preparation of a paper on the characterization of various organic matter fractions from a podzol, and the identification of fulvic acid fractions able to complex and translocate metal ions[81]. The interpretation of infrared spectra of organic matter fractions plays a key role in their characterization, but, unfortunately, unrecognised sample contamination continues to lead to erroneous conclusions in published

literature. As these faulty conclusions are likely to mislead both specialist and non-specialist readers, a critical note on these topics has been published[30] and a second submitted[52]. 208, 303, 304

Mössbauer Spectroscopy. Investigations of relevance to Scottish soil-forming minerals have been continued and a paper on the characterization of the secondary iron in pans formed in Scottish podzolic soils has now been published[19]. Work has been started in collaboration with Dr C. W. Childs, a visiting research worker, on a study of the iron-containing weathering products of some New Zealand soils, and in order to obtain further background information for both of these studies, the iron oxyhydroxides, goethite (α-FeOOH) and akaganéite (β-FeOOH) are being extensively investigated. In the study of goethite, samples containing up to 33 mole per cent aluminium have been prepared (by Dr D. G. Lewis,, a visiting research worker) and the effects of both aluminium substitution and particle size are being investigated. Results indicate that soil goethites may not always show the usually-characteristic 6-peak spectrum at 77 K. The work with akaganéite has revealed the presence of two types of iron environment which had not previously been suspected by other workers. The nature of these iron-containing sites is currently being investigated. Work on nontronites and the products of their reactions with various reagents has been further extended. It has been demonstrated that, whereas the effect of the reduction with hydrazine is reversible, reduction with dithionite may lead to decomposition of the structure by dissolution of tetrahedral iron. The product resulting from a reoxidation of this species bears little resemblance to the original nontronite and this reaction may be significant in the procedure normally employed in the pre-treatment of clays for analysis which uses a citrate-buffered dithionite solution. Treatment of nontronite with alkali has also been investigated and this produces a dramatic increase in magnitude of the electric field gradient, presumably as a result of deprotonation of hydroxyl groups. A paper on the effect of lattice substitutions on the electric field gradient at octahedral sites in layer silicates has been published[31] and papers on a consideration of alternative assignments of the Mössbauer spectra of nontronites and on the reduction of nontronites are currently being prepared. 201, 203, 207

Further work on the effect of pH on the reduction of Fe^{3+} by humic acid has been carried out in collaboration with the Department of Soil Organic Chemistry. It has now been shown that Fe^{2+} enters the solution phase in an uncomplexed form at low pH values. Raising the pH leads to oxidation of the iron and complexation by the organic matter. 203, 307

In collaboration with the Department of Microbiology work has started on a study of iron-rich deposits in field drains. Preliminary results indicate that the iron in these deposits, which are believed to be of microbial origin, has a strong resemblance to the iron in podzol iron pans described earlier. 203, 503

The work, previously reported (Ann. Rept., No. 45, 1975/76), in collaboration with the Department of Plant Physiology on the uptake of iron,

as ^{57}Fe, by various plant species has been further extended. By using Mössbauer spectroscopy, a magnetically-ordered component has been observed in a spectrum of *Lemna gibba* at 4·2 K. This corresponds to either a storage or transport protein, but specific identification has not yet been made. Evidence has also been obtained for the presence of Fe^{2+} in pea leaves, but not in any other part of the plant. This Fe^{2+} may, therefore, be involved in photosynthesis. 203, 401

Electron Paramagnetic Resonance Spectroscopy. The results of the work carried out in collaboration with the Department of Soil Organic Chemistry on the nature of some copper, manganese and vanadium complexes in soil organic matter fractions has been published[20] and investigations have begun on the effects of extraction and fractionation methods on the types of metal complex which can be observed in soil organic matter. The way in which conditions during and after extraction affect the nature and concentration of organic radicals in humic acids is also being investigated. The work commenced last year, in collaboration with the late Dr J. V. Lagerwerff, a visiting research worker, on the bonding of copper with fulvic acid has been extended to include the effects of the additional presence of minerals such as gibbsite and montmorillonite. Interpretation of the spectra has so far proved difficult largely because of the presence of considerable amounts of Fe^{3+} in the minerals used. 203, 304, 305, 307

A study of some montmorillonites of low iron content has, in combination with results from Mössbauer spectroscopy, led to the conclusion that in some samples a considerable proportion of the iron may be present on the clay surface, whereas in other specimens the Fe^{3+} appears to be mainly substituted in octahedral sites in the structure. A paper on this work is currently being prepared. 203

In collaboration with the Rowett Research Institute work has been started on the reaction of copper and thiomolybdate with albumin, since there appears to be a direct relationship between copper, sulphur and molybdenum in animal nutrition. So far, Cu^{2+} complexes with albumin have been observed and these are completely destroyed by thiomolybdate when the thiomolybdate:copper molar ratio is greater that 1:1. No paramagnetic molybdenum species have been observed. 203

To aid the investigation into the high contents of vanadium extracted by EDTA from the A horizons of podzols (reported in Soils and Soil Parent Materials), a method has been developed which is both rapid and has a low limit of detection (about 0·01 ppm) of vanadyl vanadium in the extracts. 201, 203

3. SOIL ORGANIC CHEMISTRY

DR G. ANDERSON

The work of the department has continued along the lines described in previous reports, and is concerned with the chemical nature and origins of the organic components in soil, their distribution in different soil types, and their effects on plant growth and nutrition. Increasing attention is being paid to the effects of readily soluble organic components, including substances of low molecular weight which, although rapidly broken down, are continually being replenished from root exudates and by microbial action. A number of long-term field plots have now been established to monitor the levels of some components which are known to be physiologically active and to study the changes that occur under different cropping systems or with different fertilizer treatments. Most of the department's investigations involve chromatographic methods of analysis, particularly gas chromatography, and during the year a third chromatograph, a Perkin Elmer F17-3, was put into operation.

Mr S. Murayama, a visitor from the Department of Soils and Fertilizers, National Institute of Agricultural Sciences, Tokyo, has now completed his studies on the use of radioactively-labelled substrates for examining the metabolism of carbohydrate in soil.

Members of the department attended meetings of the British Society of Soil Science, the Association of Applied Biologists and the Society for Experimental Biology. Dr M. V. Cheshire has been appointed to the Advisory Editorial Board of the Journal of Soil Science.

A paper dealing with soil organic matter research at the Macaulay Institute was presented to the Soil Science Committee of the Arable Crops and Forage Board of the Joint Consultative Organization for Research and Development in Agriculture and Food.

Soil Polysaccharide

Investigations have continued on the nature, origins and stability of soil polysaccharide and a review of work in this field has been published[32].

Collaborative studies with the Department of Microbiology have earlier shown that a polysaccharide rich in xylose is synthesized at low soil temperatures (about 5° C) probably due to the activity of yeasts (Ann. Rept., No. 46, 1975/76). It has now been shown that another condition required for the xylose production is that the soil should have been through a drying cycle, and the predominance of the growth of yeasts over that of bacteria and fungi in cold conditions with predried soil has been confirmed. A paper describing these effects has been submitted for publication[53].

305, 506, 5613

Further comparisons have been made of the breakdown of radioactively-labelled plant material and glucose in the soil during incubation. The distribution of labelled sugars in various physically and chemically separated fractions was determined at intervals and with both substrates the light

fraction of the soil, separated by flotation in a liquid of density 2·06, contained a greater proportion of the sugars than the heavy fraction, even after lengthy periods. Where plant material had been added, the highest specific activities also occurred in the light fraction, but in the glucose-treated soil they occurred in the heavy fraction. The greater part of the labelled glucose in the plant-treated soil occurred in cellulose-like material, but this was not the case in the glucose-treated soil. 305, 5613

A study of the chemical structure of soil polysaccharide has been initiated, in collaboration with the Department of Pedology. Isolated polysaccharide is methylated and hydrolysed, and the nature of the partially methylated sugars that are released is being established by gas chromatography-mass spectrometry. Ideally such methods should be applied to single polysaccharides if the data is to be fully interpreted, but much useful information should still be gained from mixtures of the kind found in soil. Attempts to fractionate the polysaccharide and characterize the fractions are also continuing. 108, 305

Chemical Taxonomy of Podzolic Soils

An investigation into the distribution of organic matter and associated inorganic components in profiles of a wide range of podzols and acid brown earths has now been completed and the results are awaiting statistical analysis. 304, 804

A paper dealing with the chemistry and infra-red spectroscopy of fulvic acids isolated from horizons of a podzol in Glentanar, Aberdeenshire, has been accepted for publication[81]. 208, 304

Soil Organic Nitrogen and Sulphur

Amino acids have been analyzed in acid hydrolysates of humic acids recovered from the various horizons of soil and peat profiles. In general, the percentage of the total nitrogen released as amino acids decreases steadily with depth, but there are notable exceptions. For example, in podzolic soils under natural vegetation, 60 to 80 per cent of the humic acid nitrogen is released from the surface organic horizon products, with a decrease to 30 to 40 per cent in the A horizons, followed by an increase to 50 to 70 per cent in the B horizons. Also, in agricultural soils with deep A_p horizons (>30 cm), amino acids are released in greater proportions from the humic acids in the base of this layer compared with those from higher levels. In peat, the largest proportion of amino acids is released from the layer immediately beneath the living plant community. Within profiles, these points of protein or peptide accumulation may represent foci of microbially immobilized organic nitrogen. Further studies are in progress on the transformations of this type of organic nitrogen and a more detailed examination is also being carried out of the as-yet uncharacterized nitrogen that is not released on acid hydrolysis. A paper concerning the fractionation of humic acids by gel chromatography, with particular reference to their oxidation products and amino acid contents, has been accepted for publication[84]. 303, 804

Collaborative studies have continued with the Department of Soil Fertility on the distribution of sulphur-containing amino acids in soils.
303, 602

Comparison of Synthetic and Natural Humic Substances

Two papers dealing with the phenolic compounds liberated from natural humic substances by acid hydrolysis have been accepted for publication[85,86]. Structural studies have continued, comparing polymaleic acid, noted in Ann. Rept., No. 46, 1975/76, as a useful soil organic matter model, and soil organic fractions. Soil humic and fulvic acids give rise to oxidation products containing low amounts of propane-1, 2, 3-tricarboxylic (tricarballylic) acid and butane-1, 2, 3, 4-tetracarboxylic acid. More abundant oxidation products such as α, ω-alkanedioic acids and benzene polycarboxylic acids (certain of which would contain hydroxyl substituents), have been assumed by previous workers to arise from long-chain hydrocarbons and humified lignin, respectively. Synthetic polymaleic acid can be oxidised by dilute nitric acid to yield a homologous series of aliphatic products, succinic to pentane-1, 2, 3, 4, 5-pentacarboxylic acid and, tentatively, hexene-hexacarboxylic acid, accompanied by a series of benzene polycarboxylic acids akin to those arising from the natural polymers. The yields of the aromatic products from polymaleic acid are lower, and those of the aliphatics higher, than the corresponding yields from typical humic acids. However, acid treatment of the synthetic polymer gives a highly condensed water- and acid-insoluble dark coloured residue and this gives oxidation products containing greater amounts of the benzene polycarboxylic acids and diminished yields of the aliphatic acids compared with polymaleic acid. Further comparative work of this kind is in progress.
108, 208, 304

A note commenting on a paper dealing with the contamination of humic acid by silica gel and sodium bicarbonate has now been published[30].
208, 304

Metal Complexes of Humic Substances

In collaboration with the Department of Spectrochemistry, the distribution of metals between the classical humic acid, fulvic acid and the alkali-insoluble residue of a soil has been examined and an attempt made to characterize organic complexes of some transition elements by EPR Spectroscopy[20]. About 15 per cent of the total copper was associated with the soluble organic fractions, 8 per cent of the aluminium, 4 per cent of the vanadium and 3 per cent of the cobalt and nickel. Less than 1 per cent of the total manganese, iron, titanium, chromium, barium or strontium was extracted with alkali. The copper appeared to be present as a porphyrin complex in the humic acid, but as some other complex in the fulvic acid. A large proportion of the extracted vanadium was observed in the fulvic acid as a vanadyl complex having EPR parameters somewhat different from those of complexes made by adding vanadyl sulphate to humic acid. Most of the manganese in the soluble fractions occurred in the fulvic acid and was always observed in a predominantly ionic form. The small pro-

portion of iron and titanium in the soluble fractions was mainly concentrated in the humic acid fraction. 201, 203, 307

Effects of Humic Substances on Plant Growth and Nutrition

Further comparisons have been made of the effects of soil organic matter fractions on the activities of enzymes, associated with growth, in several plant species. Humic acid, and the insoluble residues remaining after humic acid is boiled with water or with acid, inhibited the activities of invertase, peroxidase and phosphatase in wheat, peas, mung beans and carrots, but had no effect in beetroot. The most active fraction was the acid-insoluble "core" material, virtually devoid of carbohydrates, proteins and mineral salts, and with a large amount of phenolic material removed. The water-soluble and acid-soluble materials were less inhibitory than the corresponding insoluble residues and actually stimulated the activity of pea-root invertase. A study of the enzyme kinetics revealed that these fractions produce non-competitive inhibitions. They do not affect the affinity of the enzyme for its substrate, but reduce the maximum velocity of the enzyme reaction. It is suggested that the soil fractions combine with the enzyme, but not at the sites most active in forming the enzyme-substrate complexes. 311, 317

Investigations have continued on the interaction between humic acid and plant growth regulators, and between the regulators themselves. The finding referred to in Ann. Rept., No. 46, 1975/76, that the synthetic cytokinin 6-benzyladenine can counteract the inhibitory effect of supplied abscisic acid on the growth of wheat seedlings has been further investigated and its effectiveness in this respect compared with that of gibberellic acid. The results show that the inhibitory effect of abscisic acid on the growth of seedlings, as reflected by fresh weight and dry weight increases, is particularly marked in the light-grown seedlings compared with those grown in the dark. This inhibition can be very largely overcome by benzyladenine and by gibberellic acid, the former being especially effective in counteracting the inhibitory effect of abscisic acid on the increase in dry weight of the growing seedling. 309

Wheat seeds labelled *ab initio* with ^{45}Ca are being used to study the movement and distribution of calcium in the seedling root system. This has revealed an unexpectedly high loss of calcium from the root to the external medium. The possible interaction of humic substances with calcium in the root is under investigation. An interesting effect of radiation on germination has been observed with the radioactive seed which produced a relatively high proportion (about 2 per cent compared with a normal 0·1 per cent) of twin seedlings. 309

A paper describing a modified Petri dish that has proved particularly useful in plant growth studies has now appeared[33]. 309

Water Extractable Organic Matter

Work has continued on the effect on plants of the water-soluble soil components p-hydroxybenzoic, vanillic, p-coumaric and ferulic acids, all of

which are extracted with cold water and comprise some 0·01 per cent of the total soil organic matter. Earlier tests have shown that these phenolic acids stimulate the growth of wheat roots in full nutrient solution, when present at the levels that occur in the soil solution (about 10^{-5}M) (Ann. Rept., No. 46, 1975/76). Now it has been found that the growth of wheat, pea or mung bean seedlings in pure water is not stimulated by the phenolic acids, nor is there any effect on the activity of invertase or peroxidase, enzymes closely associated with plant growth. At higher concentrations, about 10^{-3}M, the phenolic acids inhibit growth of the seedlings and the enzyme activity. 311

A collaborative investigation has been initiated with the Department of Microbiology on the effects of phenolic acids on soil microbial activity. Preliminary data show that p-hydroxybenzoic, p-coumaric, ferulic and cinnamic acids stimulate microbial activity for two days after addition, measured in terms of CO_2 evolution and invertase activity. The phenolic acids appear to act as microbial substrates and indeed some soil micro-organisms are able to use p-hydroxybenzoic acid as the sole carbon source. A note on these findings is being prepared for publication. 301, 512

Papers showing the close similarity between the water-soluble poly-carboxylic acids in soil and the fulvic acids extracted with alkali have appeared[34, 35] and investigations are now being carried out to establish the amounts of these acids which occur in different soils. An important factor influencing their water-solubility appears to be the drainage status of the soil. A comparison of soils selected from two associations[87] has shown that relatively small amounts are extracted from the well-drained soils whereas much larger amounts are removed from the very poorly-drained soils of the same association. The amounts dissolved are not related to the total fulvic acid contents of the soils, but are inversely related to the amounts of acid-oxalate extractable aluminium, suggesting that the solubility is being controlled largely by the extent of adsorption at sites containing active aluminium. As well as their possible influence on root physiology, these polycarboxylic acids might have other effects on plants if they are absorbed and translocated. Direct evidence of translocation is very difficult to obtain because the amounts involved are extremely small. However, it has been possible to synthesize ^{14}C-labelled polymaleic acid, similar in chemical characteristics and physiological activity to the natural material (Ann. Rept., No. 46, 1975/76), and demonstrate its uptake and translocation to the shoots of wheat and tomato plants[88]. The label had been incorporated only into the chemically stable " backbone " of the molecule and not into the more reactive carboxyl groups. It seems likely, therefore, that polymers of the type found in the soil solution will be physiologically absorbed by plants. Considerable adsorption also occurred at the root surface. 304, 309

Effects of Light and Gravity on Root Growth

The inhibitory effect of light intensity on the growth of seedling roots has been further investigated in relation to the application of a force field. In the case of cress roots growing on the horizontal plane, growth is an

inverse function of light intensity. Inhibition due to increasing light intensity can be relieved by the application of an increased axial force. These results, indicating that growth is a function of two opposing forces, support the theory that root growth is regulated by a basipetal flow of growth-inhibitory compounds from the root cap and an acropetal flow of growth-promoting compounds from the older regions of the root.

The experiments on the effect of gravity on root growth revealed a marked tonic effect on the growth of mustard seedlings. Geotonic effects have received very little attention, mainly because of the experimental difficulty of clearly separating tonic effects of gravity from tropic effects. The demonstration that the application of an axial force can stimulate the synthesis of chlorophyll and anthocyanin pigment in mustard seedlings is, therefore, of particular interest; the more so because it provides good experimental evidence that there is a direct link between enzyme activity and the gravity-sensing system in plants. A preliminary account of this work has been submitted for publication[89]. The possibility that gravity affects phytochrome activity in mustard seedlings is being investigated in collaboration with the Botany Department of the University of Aberdeen. 309

4. PLANT PHYSIOLOGY

Dr P. C. DeKock

Work on calcium metabolism has continued to be the main interest of the department; its relations with nitrogen and translocation within the plant receiving special attention. Investigations on the selenium metabolism of plants have been initiated.

Dr P. C. DeKock presented a paper at the S.C.I. Agricultural Group Symposium in London in April 1977 on calcium metabolism[36] and a further paper on nitrogen at the Long Ashton Symposium on Nitrogen Metabolism in Plants in September 1977[90].

Mr R. Ascroft, University of Aberdeen, spent three months in the department and Miss S. G. Williams has been awarded an A.R.C. studentship to work in the department for three years from September 1977 on selenium problems in plants.

Calcium

Further work on blossom-end-rot in tomatoes has been carried out; emphasis being placed on the effect of water regime as well as the form of nitrogen. The results showed that the over-riding factor was the form of nitrogen presented to the plant. As previously reported, ammonium nitrogen caused severe BER while with nitrate nitrogen BER was negligible whether the plants were kept dry or given an excess of water. An experiment in which the number of fruits allowed to develop on each truss was varied, showed again that the form of nitrogen determined the appearance of BER and no effect of fruit number was found.

Work on potatoes with the plants set in peat plus or minus added calcium, but with the roots descending into tubs containing complete nutrient solution with either ammonium nitrogen or nitrate nitrogen, showed that the developing tuber was indifferent to the nutrient solution as far as calcium was concerned; drawing its calcium directly from the surrounding peat. In the instances where there was no calcium amendment to the peat, only small tubers of low calcium content were formed, even though the nutrient solution below contained calcium. Experiments are being continued to study the effects of supplying calcium to the leaves. 402

Studies on the enzyme nitrate reductase in tomato leaves fed either nitrate or ammonium showed that there was very low activity in the ammonium fed plants and higher activity in the nitrate fed plants. There was also a fairly well marked relationship of activity to calcium status, as had been found for cauliflower leaves. 408

Selenium

A programme of research into selenium metabolism in plants has been instituted with the acquisition of an A.R.C. studentship to the department. The interest stems from suspected selenium deficiency in ruminant animals in Scotland. Although the methods being used for estimation of selenium

are not satisfactorily proven and dubiety on analytical techniques must be resolved, it is already evident that selenate is more available to plants than is selenite. Studies on translocation have been initiated using the convenient radio-isotope of selenium (^{75}Se). 401

Growth Hormones

Following work of others on the induction of dormancy in the fronds of the duckweed, *Lemna gibba*, by abscisic acid (ABA) and its reversal by benzyl 6-amino purine (BA) it has been shown that the mineral contents of the fronds are in accordance with the ageing sequence so that the dormant fronds are low in potassium and phosphorus and rich in calcium and the reversal by BA brings about a lower level of calcium and a gain of phosphorus and potassium. The ABA-treated fronds also contain great amounts of starch and resumption of growth induced by BA causes the starch to disappear. In view of the close parallel in metabolism between the growth hormones and the essential elements, it is clear that some close metabolic link exists between them.

Ion Flux Studies

Previous work with onion root segments, using a complete nutrient solution containing 1mM Ca^{2+}, has shown that Ca^{2+} enters the root cortical cells by diffusion down an electrochemical potential gradient, while a simultaneous efflux of Ca^{2+} is maintained at the plasmalemma and the tonoplast, by means of a metabolically driven pump. The possibility remained, however, that at lower external concentrations of Ca^{2+}, the efflux pump may cease to be operational or detectable, or may be replaced by an influx pump. We have now, therefore, examined by compartmental analysis, the fluxes of Ca^{2+} occurring over a ten thousand fold range of external Ca^{2+} concentrations with all other constituents of the nutrient solution, except the Ca^{2+} counter-ion, being maintained at the same level as used in the 1mM Ca^{2+} experiments. The results show that the efflux pump at the plasmalemma of onion root cortical cells is evident at outside concentrations of Ca^{2+} in the range found in soil solution, 1 to 10mM. Below that level, in the range 0·01 to 0·1mM Ca^{2+} in the external solution both influx and efflux appear to be passive. It is only when the external concentration of Ca^{2+} falls as low as 0·001mM that calcium absorption occurs against the electrochemical potential gradient revealing the activity of an inwardly directed pump. At all the external Ca^{2+} concentrations examined (0·001 – 10mM) Ca^{2+} activity in the vacuole appears to be limited by an outwardly directed metabolic pump. It is concluded that Ca^{2+} nutrition is entirely dependent upon diffusion from the soil solution into the root cells and that it is only at Ca^{2+} concentrations well below the minimum necessary to avoid deficiency that an inward Ca^{2+} pump can be detected in the roots.

Ca^{2+} fluxes in wheat leaf are also being studied. It appears that there is a light-stimulated fraction of Ca absorption and this suggests that a more significant Ca^{2+} influx pump than that occurring in onion roots may operate in leaves. 407

Calcium Uptake and Transport in Tomato Plants

Preliminary solution culture experiments have confirmed that the Ca content of leaves from plants grown solely on ammonium nitrogen is lower in absolute terms compared with Ca in leaves from plants supplied with nitrate alone, or together with ammonium. The content of calcium in the stem is also lower in ammonium grown plants than in those fed with nitrate. The content of Ca in the roots, which is generally low (3-5μmoles/g f. wt.) does not vary much between treatments. The calcium concentration in xylem sap, collected in exudation experiments, is much lower in ammonium-fed plants than in plants to which nitrate is available. The work is continuing. 407, 402

Aluminium

A paper on aluminium uptake by lucerne has been submitted for publication[91].

5. MICROBIOLOGY

Dr J. F. Darbyshire

The research programme of the department is mainly concerned with microbial interactions with plant roots and the significance of soil microbes in the decomposition of soil organic matter. Close collaboration is maintained with the other departments and with other research centres with allied interests.

During the year six members of staff attended scientific meetings or instructional courses. Dr J. F. Darbyshire — Symposium on aspects of elemental and image analysis in biological microscopy at Glasgow University, organised by the Royal Microscopical Society (R.M.S.) and a joint meeting of the British Ecological Society and the Microbial Ecology Group of the Society for General Microbiology (S.G.M.) at University College, London, on ecological aspects of the nitrogen cycle; Dr J. F. Darbyshire and Mrs C. M. Macdonald—Annual meeting of the British Section of the Society of Protozoologists (B.S.S.P.) at Edinburgh University; Dr D. Jones — the R.M.S. international meeting on low temperature biological microscopy at Cambridge University and the international conference on microprobe analysis in biology and medicine organised by the R.M.S. and the German Society for Electron Microscopy at Münster University, Federal Republic of Germany; Mr M. S. Davidson — Photomicrography course organised by the R.M.S. at Brunel University; Dr G. P. Sparling—Course on the principles of electron microscopy organised by the R.M.S. at Leeds University and the A.R.C. meeting on the effects of mycorrhizal infection on the growth of white clover, at Leeds University; Mr R. E. Wheatley—Aquatic Microbiology group meeting of the S.G.M. at Aberdeen University. A 16 mm ciné film of a giant soil amoeba digesting fungal spores was shown at the B.S.S.P. meeting and a paper was read at the A.R.C. meeting at Leeds University. Drs T. Nicolson and K. M. Old, Department of Biological Sciences, University of Dundee showed the same ciné film at the International Symposium on Microbial Ecology at Dunedin, New Zealand and at the 2nd International Mycological Congress in Florida, U.S.A. Some film sequences of the microbial decomposition of leaves on soil, originally filmed at the Institute, were also included in a BBC TV programme produced by the Bristol Natural History Unit.

Interrelationships of Plant Roots and Microbes

The results of a study of the microbial population and nitrogen status of the rhizosphere soil around the roots of spring barley grown in fields in the Kincardine district in collaboration with the Department of Soil Fertility and the Plant Pathology division, North of Scotland College of Agriculture are in press[92]. Glasshouse experiments in 1975 with sieved soil from the same fields with different levels of either aqueous ammonia with the nitrification inhibitor " N-serve " or potassium nitrate added to the soil showed that within the first two months after germination the largest incidence of take-all disease occurred on those barley plants receiving

ammonia rather than nitrate. Nevertheless, there was no statistically significant correlation between the incidence of take-all and the ratio of ammonium nitrogen to nitrate nitrogen in the barley rhizosphere. A further glasshouse experiment in 1976 has confirmed that the addition of aqueous ammonia rather than nitrate to the soil causes the largest incidence of take-all both in terms of numbers of infected plants and infected roots. The application of similar levels of nitrogen as foliar sprays of urea did not promote the disease as much as either nitrate or ammonia applied to the soil. The application of either ammonia or nitrate to the soil also increased the rhizosphere population of denitrifying bacteria, but foliar applications of similar levels of urea did not stimulate this group of bacteria. The results of these glasshouse experiments are being prepared for publication.
513, 603

Recently, a study has been started of the role of plant roots and rhizosphere microorganisms in the weathering of soil minerals in collaboration with the Department of Pedology. 513, 104

Studies on the decomposition of ^{14}C labelled plant roots and shoots are in progress in conjunction with the Department of Soil Organic Chemistry. The roles of some groups of soil fauna e.g. earthworms and a wide range of microorganisms in root decomposition are also being studied. 512, 513

Fungi

Ultrastructure. A paper dealing with electron-probe microanalysis of cell walls of *Cunninghamella echinulata* has been published[2]. 109, 507

At the request of the Division of Plant Pathology, North of Scotland College of Agriculture, flowering stems and leaves of narcissus plants were examined in the scanning electron microscope. In some instances the epicuticular wax was altered where these plants had been invaded by pathogenic microorganisms and mites. Several preparative methods for preserving this wax were tested. Although the wax was evident on air-dried material, these preparations were unstable in the electron beam. The wax was removed when the material was immersed in a graded series of ethanol and Freon 113 and then dried from Freon 13 by a critical-point method. The wax was preserved in material which had been pre-fixed in glutaraldehyde and osmic acid and subsequently freeze-dried. A paper incorporating these observations has been accepted for publication[93].
507

Powdery scab disease of potatoes is caused by the fungus, *Spongospora subterranea* and can cause severe damage to potato tubers. Microscopic spore balls of cystorsori of the fungus are found in the lesions and consist of many spores or cysts stuck together in sponge-like structures. These cystosori can remain viable in the soil for many years and can thus provide a source of infection for healthy tubers. The surface morphology of these resting structures has been studied in the scanning electron microscope and the results are in the press[94]. 507

Sclerotia of Plant Pathogens. A local survey of the incidence of *Sclerotinia sclerotiorum,* particularly in vining peas, has continued. In

June, many quite large apothecia (up to 2 cm diam.) of *S. sclerotiorum* were seen on the soil surface beneath giant hogweed at Lonmay. These apothecia had developed from many sclerotia which had fallen from diseased plants in previous years. Seven farms with a total area of about 80 ha of vining peas were visited during July and August. Typical symptoms of the disease were only found on one farm and the damage was not very significant. Diseased peas were readily found on three farms, however, after a weekend of heavy rain in late August. Black sclerotia had developed by this time within the stem cavities and the typical white cotton-like growth of the fungal mycelium was seen on the stem surfaces. *S. sclerotiorum* has been found on vining peas on 14 farms during the last few years and it is significant that it has been recorded this year on a farm, which had not previously grown peas. Examination of a small sample of peas from the seeds sown this year failed to reveal any signs of *S. sclerotiorum*, so the origin of the disease on this farm is unknown. Infra-red aerial photography of one of the pea fields with diseased patches, in this case not associated with *S. sclerotiorum*, gave promising results. A 16 mm ciné camera was also used to photograph diseased patches of peas due to *S. sclerotiorum* in August. 508

A paper describing the fine structure of pea stem lesions, caused by *S. sclerotiorum*, and the manner in which the fungus penetrates potato leaves has ben published[37]. 507, 508

Protozoa

Systematics. A paper describing an unusual amoebo-flagellate, previously isolated from 19 Scottish soils has been published[38]. A new genus has ben proposed for this amoeba. A redescription of the colourlesss soil flagellate, *Heteromita globosa*, has been published[39]. Another similar paper dealing with the flagellate *Spiromonas angusta* has been accepted for publication[95]. This flagellate possesses a buccal cavity and a food canal analagous to those structures found in other soil flagellates of the genus *Bodo*. One important difference between these two genera is the absence of a discrete kinetoplast in *Spiromonas*. Instead of a kinetoplast there is a series of DNA—positive swellings on the mitochondrion of *S. angusta*. 510

Ecology. In collaboration with Dr K. M. Old, Department of Biological Sciences, University of Dundee, a study has been made of a giant soil amoeba of the family Vampyrellidae. This amoeba occurs in a wide range of soils and can digest the spores of many fungi, as well as many bacteria, blue-green algae, diatoms, flagellates and plant pathogenic nematodes. A paper describing the results of several feeding trials with this amoba is in the press[96]. 512

Organic Matter

Microbial Decomposition and Synthesis. Further investigations in collaboration with the Department of Soil Organic Chemistry of the microbial synthesis of soil polysaccharides showed that the pre-drying of soil samples markedly affects the development of the yeast microflora and alters the

type of polysaccharide formed. Polysaccharide with a high proportion of xylose residues was detected only when the soil had been dried, remoistened and then incubated at 5°C. These conditions favoured the growth of soil yeasts. A paper reporting this investigation has been submitted for publication[83]. 512, 305

Soil Phenolic Acids. The effects of water-soluble phenolic acids on plant and microbial growth have been investigated in collaboration with the Department of Soil Organic Chemistry. The yields of these acids from axenic and non-axenic barley have been measured. The role of microorganisms in the turnover of selected phenolic acids has been investigated using soil respiration and enzyme assays as indicators of microbial activity. A paper dealing with the effects of different phenolic acids on soil respiration and invertase activity is in preparation. 301, 512

Peat. A survey of the anaerobic bacteria in a local basin peat at Lyne of Skene is nearly complete. The anaerobic population decreases in size with increasing depth in a similar manner to the aerobic bacteria. At all depths the number of anaerobes is smaller than the size of the aerobic population at the same depth. 503

In collaboration with the Department of Pedology the interrelationships between microbial numbers and water content in peat is being investigated in more detail at the Lon Mor experimental site near Fort Augustus. The water levels in the experimental plots at this site have been maintained at a range of depths for 14 years. Preliminary results suggest that there are inverse correlations between microbial numbers and water contents at different depths in the peat. In addition the populations of ammonifying, nitrifying and denitrifying bacteria are being estimated at different depths in the experimental plots and an attempt will be made to correlate these data with concurrent chemical analyses of the peat, particularly with regard to nitrogenous compounds. 110, 116, 503

A microbiological study of peat composts has been continued in collaboration with the Department of Pedology and has been extended to include tree bark as a compost for horticultural crops. One of the aims of these studies is to follow the microbial changes in the peat and peat/bark composts after successive crops to determine if root pathogens eventually become established in these media. 114, 503

A study of triterpenoids in peat deposits in collaboration with the Organic Geochemistry unit at Bristol University has continued. Significant amounts of these compounds have been detected in species of *Sphagnum*, *Eriphorum*, and *Calluna* as well as in some pure and mixed cultures of aerobic bacteria from peat. 503

6. SOIL FERTILITY

Dr E. G. Williams

The soil fertility programme continues to be directly aimed at improvement of manurial practices, soil management and crop production, through research on soil-nutrient-crop relationships and practical application of results through advisory soil testing and associated consultative activities.

The overall experimental approach, therefore, remains the concurrent development and integration of field, pot culture and laboratory investigations in three main areas: (a) nutrient relationships, properties and productivity of selected contrasting soil series in north Scotland, (b) effects of fertilizers, soil conditions, husbandry practices, environmental factors and physiological characteristics on the growth, development and chemical composition of crops, and (c) development, calibration and practical application of laboratory methods for assessing the lime and nutrient status of soils for advisory purposes.

This approach, including the gearing of all studies to soil series, has been systematically developed over more than 30 years, and continues to fulfil two basic purposes. The contrasting behaviour of the different soils is a major aid to identification and measurement of the soil properties and processes which regulate nutrient supply and crop growth, and which underlie effects of pedological factors, especially differences in parent material and drainage status. The results also provide quantitative information on the agricultural performance of the different soil series, especially the nature, influences and amelioration of factors restricting crop production.

The fertility programme is accordingly designed to be a logical quantitative complement to, and extension of, the broader characterization of soil series provided by the Soil Survey. Blanket coverage of all series, however, is not envisaged. On the contrary, clarification of the pivotal soil properties and processes governing the behaviour of the different series should enable findings to be extrapolated to others without full additional experimental coverage, as well as promoting better understanding of the behaviour of soils in general. The emphasis is on the principal agricultural crops and the behaviour of the soil as a whole. In both respects, the fertility investigations are complementary to, and dovetail with, studies on soil and plant constituents and processes in the other departments of the Institute. Interdepartmental liaison is well established. Where appropriate, collaborative work is undertaken, and advice and assistance are frequently given in the selection and provision of soil samples for various purposes.

Major effort continues to be devoted to external consultative activities, especially advisory soil testing in collaboration with the North of Scotland College of Agriculture. Increasing importance is attached to these activities not only as the main channel for continual filtration of research findings into practice, but also as a means of eliciting practical problems requiring investigation. To these ends, liaison is maintained with other research organizations, especially the Rowett Research Institute, and the department continues to be represented, usually by Dr J. W. S. Reith, on various tech-

nical committees. The latter are mainly under the auspices of the Department of Agriculture and Fisheries for Scotland (DAFS) and the Scottish Agricultural Development Council (SADC), and currently include: the Scottish Standing Committee for the Calculation of the Residual Values of Fertilizers and Feeding Stuffs (DAFS), the Scottish Farm Waste Committee (SADC), the Working Group on the Disposal of Sewage Sludge on Agricultural Land (DAFS), the Study Group considering the Report of the Working Party on Land Use Capability Classification (DAFS), and the Consultative Committee for the Development of Spectrochemical Work.

Dr P. W. Dyson contributed a paper[40] on Nitrogen Requirement of Barley at a meeting of the Agriculture Group of the Society of Chemical Industry on Progress on Plant Nutrition, held in London, April, 1977. Two papers[41, 42], one on Effect of Fertilizers and Date of Sowing on the Rates of Growth and Nutrient Uptake of Swedes, by Dr P. W. Dyson, and the other on Effects of Fertilizers on the Yield and Mineral Composition of Swedes, by Dr J. W. S. Reith, were presented at a U.K. conference on Brassica Fodder Crops, organised by SADC in Edinburgh, February, 1977. Dr B. W. Bache gave a review paper on Acid Precipitation and Soil Acidity Development at a Meeting of the N.E.R.C. Air Pollution Research Liaison Committee, held in Edinburgh, April, 1977. Dr N. M. Scott also attended this meeting. Dr Bache also prepared a paper on Cation Equilibria in Soils with respect to their Availability, for a joint meeting of the Plant Science and Soil Science Committees of the Arable Crops and Forage Board of the Joint Consultative Organization for Research and Development in Agriculture and Food.

At the invitation of the Organizing Committee, Dr B. W. Bache gave one of the invited papers[43], on Practical Implications of Quantity-Intensity Relationships at a special seminar on Soil Environment and Fertility Management in Intensive Agriculture, in Tokyo, in October, 1977, under the auspices of Commission IV (Soil Fertility) of the International Society of Soil Science. This paper illustrates how the amount of available nutrient can be deduced from the quantity-intensity (Q-I) curve and discusses the interrelationships and implications of Q, I, soil buffer power, nutrient mobility and the rooting pattern of crops. The implications of Q-I curves are also discussed in relation to calibration of soil test methods and interpretation of their results, and to general principles of efficient use of fertilizers.

Dr W. M. Crooke visited the Indian Agricultural Research Institute, New Delhi, in March, 1977, and, by invitation, addressed the staff and students of the Divisions of Agronomy, Soil Science and Agricultural Chemistry on the use of plant composition parameters as early indices of final yield.

During a study tour in the Netherlands and Germany to appraise current research activities on the potassium and magnesium relationships of soils and crops, Dr A. H. Sinclair visited the Institute of Soil Fertility at Groningen, the Agricultural University at Wageningen, the Agricultural Research Station of the Kali and Salz AG, Büntehof, Hannover, and the

Institute of Soil Science and Forest Nutrition at Göttingen. A specific objective of this tour was to study the use of Electro-Ultrafiltration in investigations on release of potassium and magnesium from soils. An apparatus of this kind has been acquired during the year, and should also be a valuable tool for studying release of non-labile forms of other nutrients, especially phosphate and some of the trace elements.

At the invitation of the President and Directors of the International Potash Institute, Dr E. G. Williams attended the Thirteenth Colloquium of the Institute, at the University of York, in July, 1977, on Fertilizer Use and Production of Carbohydrates and Lipids.

During the year the department was also represented at the following meetings: Development Seminar organized by SADC; a conference on Crop Production—The Way Ahead, organized by the East of Scotland College of Agriculture; an ADAS Conference on Inorganic Pollution and Agriculture; a meeting on the Inter-relations between Agriculture and Forestry in the Uplands of Scotland, organized by the Royal Society of Edinburgh; a Meeting of the Scottish Arable Crops Group in the Aberdeen area; the Easter and Autumn meetings of the British Society of Soil Science; a meeting of the Chemical Society on Soils, Geochemistry and Exploration of Mineral Resources; a seminar on Soil Structure at Rothamsted; and an Exhibition in London organized by the Royal Society. Members of the staff also visited several Research Centres in England, including Rothamsted Experimental Station, the National Institute of Agricultural Engineering, the Glasshouse Crops Research Institute, the Letcombe Laboratory, the National Vegetable Research Station, and the Universities of Leeds, Reading, Nottingham and Oxford.

The principal research topics are reviewed below. Electrochemical studies are now well established, enabling a start to be made in applying physicochemical concepts, especially quantity-intensity relationships, in studies on trace elements. Investigations on soil physical properties and factors in relation to crop growth have also been initiated.

Fertilizer Responses of Crops

The field experiment programme and supporting soil and crop analyses continue to provide practical information on the nutrient status and productivity of different soil series, on fertilizer requirements for optimum yields, and on factors influencing nutrient uptake and mineral composition. To cover differential effects of seasonal variations, especially in climate, experiments are normally continued over a number of years.

601, 603, 608, 5206, 5701, 5703

NPK Requirements of Swedish Turnips. This crop has continued to be extensively grown in Scotland, especially in the north, and there are signs of return to favour in other areas. An account[42] of effects of fertilizers on yield and mineral composition was presented at the conference on Brassica Fodder Crops, mentioned above. Average N, P and K requirements for satisfactory yields were assessed from the results of 55 experiments carried out between 1965 and 1974. The responses at different sites showed

large differences depending on the differing abilities of the soils to supply the three nutrients. Compared with findings from earlier experiments over 15 years ago, there has been practically no change in the average response to K, but the corresponding response to N is now larger and that to P slightly smaller. Even so, there are no grounds for suggesting any major change in the N, P and K dressings normally recommended. There were also appreciable variations between sites in the N, P, K, Ca, Mg and Na contents of the swede roots produced with normal fertilizer treatment. These differences could be of some significance in relation to animal nutrition 608, 5206, 5701, 5703

Fertilizer Placement for Swedish Turnips. Placement information is being up-dated to cover changes in fertilizer composition. Comparisons of broadcast fertilizers with dressings placed in a narrow band 5 cm directly below the seed have, therefore, been continued. The results obtained in 1976 differ from corresponding findings in 1975, which showed that placement was at least as good as broadcasting. In 1976, however, placed dressings of ammonium nitrate (" Nitram ") supplying 50, 100 and 150 kg N per ha produced lower yields at both the experimental sites compared with the same dressings broadcast. In two other experiments a granular fertilizer with an $N:P_2O_5:K_2O$ ratio of 1 : 1 : 1 was placed at rates supplying 25, 37·5 and 50 kg P per ha and compared with broadcast dressings of a normal turnip fertilizer with a ratio of 1 : 2 : 1, supplying 50, 75, and 100 kg P per ha. As in 1975, this ensured that the corresponding treatments of the two fertilizers supplied practically the same amounts of N and K, whereas the placed treatments supplied only half as much P as the broadcast dressings, in the expectation from earlier work that the effectiveness would be at least doubled by the placement. Unlike the outcome in 1975, however, the latter expectation was not realised. The 1976 yields were below normal, the fertilizer responses were small, and placement was inferior to broadcasting. In both sets of comparisons, there is little doubt that the main factor responsible for poor yields and for uncharacteristic inferiority of the placed treatments was the abnormally dry and warm conditions during July, August and early September, 1976. As indicated earlier, this illustrates the susceptibility of fertilizer effects to weather conditions, the necessity for seasonal replication of experiments, and the inherent limitations of generalized fertilizer recommendations. 603, 608, 5701, 5703

Comparison of Granular and Liquid Fertilizers on Barley. Three further experiments in this series were carried out in 1976 to compare granular and liquid forms of fertilizers with an $N:P_2O_5:K_2O$ ratio of 2 : 1 : 1, frequently used for barley. Three methods of application, broadcasting, combine-drilling with the seed and placing 5 cm to the side of the seed, were studied, and the fertilizers were tested at rates supplying 60, 80 and 100 kg N per ha. At one centre, where there was only about 25 mm rainfall during the five weeks following sowing, the crop in the plots with liquid fertilizer combine-drilled, especially at the highest rate, had a yellowish appearance during early growth. At the other two centres there was about 75 mm rain during the same period and no yellowish symptoms were

observed. There were clear responses at all three sites, but irrespective of method of application the yields produced with 60 kg N were pracitcally as good as those obtained with the two higher rates. As in 1975, there were no significant differences in the yields obtained with the two forms, but there was a tendency for the best yields to be produced by either combine-drilling the granular form or placing the liquid 5 cm to the side of the seed. Three more experiments with the same range of treatments were laid down in 1977. 608, 5701, 5703

Time of Application of Nitrogen to Barley. The effects of 50 and 100 kg N as " Nitro-chalk " applied at seed-time and six to eight weeks later, just after the crop had brairded, when the plants were at the two to three leaf stage, were examined in three experiments. As in previous years, there were no yield differences attributable to the time of application, despite rainfall of 70 to 105 mm between the seed-time and later treatments. The N content of the grain was also not affected. 603, 608, 5701, 5703

Effects of Minimum Cultivation Methods for Barley. The experiment started in 1975 is being continued to investigate the effects of three cultivation techniques, normal ploughing, chisel ploughing and no ploughing, on the effects of superphosphate applied broadcast or combine-drilled. Despite treatment with appropriate weedkillers in autumn 1975 and spring 1976, grass weeds adversely affected growth, especially in the chisel ploughed and no ploughing treatments, reducing grain yields by about 0·5 t per ha. On the unploughed plots, broadcasting 20 kg P per ha did not increase yield, but combine-drilling produced an increase of 0·3 t per ha barley grain. With normal ploughing, broadcasting and combine-drilling 20 kg P per ha produced increases of 0·6 and 0·7 t per ha, respectively, while the corresponding increases with chisel ploughing were 0·4 and 0·8 t. Phosphate was, therefore, less effective in the absence of ploughing. At harvest there were about 200 more fertile tillers per m^2 with normal ploughing than with no ploughing and chisel ploughing, and the bulk density of the soils at 150 mm tended to be slightly higher with no ploughing than with the other two cultivation methods. Another interesting observation was that the number of wild oat plants was considerably less in the ploughed plots than in all the others. The weedkiller treatments to control grass weeds were continued during autumn 1976 and spring 1977, but it was found necessary to substitute normal ploughing instead of chisel ploughing. Although better control of grass weeds has been obtained in 1977, they are still at an unsatisfactory high level in the no-ploughing treatment. In 1977, obvious effects of the phosphate treatments were visible during growth.
601, 608, 5701, 5703

Nitrogen, Phosphate and Potassium Requirements of Grass on Deep Peat. An area of deep peat with adequate drainage was reseeded in 1972 using a mixture of ryegrass, timothy and white clover, and dressings of 10 t ground limestone, 40 kg N, 50 kg P and 100 kg K per ha. In subsequent years, the effects of various rates of N, P and K on yield and mineral composition of the herbage have been studied, three cuts at the silage stage of growth being taken each year. In 1974 and 1975, the yield without fertilizer N was

about 7 t dry matter per ha, but in 1976 it fell to just over 4 t, mainly due to the abnormally low summer rainfall. N dressings with adequate P and K have produced large increases in yield, the average increments from 60 kg and 120 kg N per ha per cut being nearly 50 and 100 per cent, respectively. With these two rates of N, the results for various rates of P and K suggest that optimum yields have been obtained during 1973 to 1976 with P and K dressings approximately equivalent to their uptake in the herbage. This amount of P appears to maintain the average P content of the herbage at about 0·3 per cent in the dry matter, but appreciably higher dressings seem necessary to raise the content above this level. The results for K confirm, as would be expected, that peat, unlike mineral soils, releases practically no reserve K. 608, 5206, 5701, 5703

Crop Growth and Development

Detailed studies on the effects of fertilizers, environmental factors and husbandry practices on the progressive accumulation of dry matter and nutrients by barley and swedes or potatoes have been continued at four contrasting centres. In addition, a more intensive study has been made of the effect of nitrogen on the growth of barley and oats, in an experiment in which the crops were sampled twice a week until ear emergence and at weekly intervals thereafter. Effects of fertilizers and date of sowing on the rates of growth and nutrient uptake of swedes were summarized in Ann. Rept. No. 45, 1974-75. A fuller account of this work has now been published[43] in the proceedings of the conference on Brassica Fodder Crops mentioned above. The effects of date of sowing require further investigation to check the indications that late sown crops require less N fertilizer and have only a limited capacity to grow faster than early sown crops in the latter part of the growing season. Unfortunately, it was not possible to make this comparison in 1977 because adverse weather conditions caused late sowing of all the swede experiments. All the three sites concerned were, therefore, used to compare the growth of two cultivars, Doon Major and Wilhelmsburger. 607, 5206, 5701, 5703

The results of four years experiments with potatoes are now available for one site. The most interesting conclusion from these data concerns the changes with time in the yields of seed (32-57 mm) and ware (>57 mm) sized tubers. It is normal practice to burn off the foliage around the third week in August in the belief that the yield of seed will have reached a maximum and will then decrease. The subsequent increase in tuber size is then assumed to increase the yield of ware to the partial detriment of the yield of seed sized tubers. The evidence for the cultivar Record in the present experiments, however, is that the yield of seed reached a maximum by about mid-August, but then remained constant, even though the yield of ware sized tubers increased markedly in the following month by about 10 t/ha. The results are based on only one cultivar and one centre, but the pattern was the same in all four seasons. This suggests that, in the absence of blight, there is a need to consider later foliage destruction in potato crops, even when grown primarily for seed. Because of its practical

importance, this question deserves wider investigation for other cultivars and growth conditions. 607, 5701, 5703

The paper quoted in last year's report, on relations between some growth parameters and yield of barley, has now appeared[44]. 607

Chemical Composition of Crops

The work in this area is complementary to the field experiment activities summarized above and is being closely integrated with the studies on crop growth and development. There are two main objectives. One is better understanding of the effects of lime, fertilizers and growth conditions. The other is examination of the usefulness of plant composition parameters at early growth stages as indices of nutritional status, yield and fertilizer requirements, especially nitrogen. 606, 607, 608, 5703

Barley. The account, summarized in last year's report, of relationships between nitrogen and excess base (organic acids) content of young barley plants and final grain yield has now been published[45]. An examination has been started of plant constituents involved in loss of dry matter from straw during grain filling. Measurements of the reducing sugar and fructosan contents of barley straw from field plots showed that the former remained at about 10 per cent for the first 100 days of growth, but during the 20 days before harvest the value fell to about 2·5 per cent. In contrast, the fructosan level rose steadily to about 40 per cent at 85 days and thereafter fell sharply to 20 per cent at 100 days and about 5 per cent at harvest. The combined decreases, however, were insufficient to account for the total dry matter loss from the straw. This suggests that starch may also be involved and this possibility is being examined 606, 607

Swedish Turnips. Relationships between yield and nitrogen and excess base contents of young plants have also been examined for swedes. In this case, however, sampling had to be based on appropriate numbers of fully expanded leaves, rather than whole plants, and the choice of leaf has proved much more critical than was anticipated, due to very rapid changes in nutrient concentrations with increasing leaf age. Excess base was highest in old leaves, indicating the site of nitrate reduction, and lowest in the young leaves, whereas total nitrogen gave the opposite picture, suggesting transfer from old to young leaves. Changes in total cation content paralleled those of excess base. The differences in content between adjacent fully expanded leaves averaged about 5 per cent for N and about 10 per cent for excess base. Since the percentage differences in these constituents between cultivars average only about 15 per cent it is hardly feasible to use these parameters to characterize varieties. For swedes, unlike barley, inclusion of N as a variable factor did not improve the relationship between yield and composition. An account of the results is in preparation. While good relationships between leaf composition and root yield occasionally occur, the generally small N response coupled with sampling uncertainties and seasonal variations probably preclude establishment of any practically useful general relationship. It is unlikely, therefore, that plant analyses can be of much help in adjusting fertilizer treatments of swedes. 606, 608, 5206, 5703

Cation-Anion Balance. An account of earlier collaborative work on cation-anion balance in plants and the recycling of potassium has been published[46]. 606

Trace Elements

Effects of Boron and Cobalt on Swedes and Turnips. The paper[42] presented to the conference on Brassica Fodder Crops, mentioned earlier, also reported experimental work on application of B to prevent brown heart disease (raan) in swedes and on the Co content of swede and turnip roots in relation to animal nutrition. Comparisons of different rates of B on swedes on deficient soils indicate that the normal rate of 2·5 kg B per ha is not always adequate and that double this amount may often be advantageous. On soils where the Co content in the dry matter of the roots was low and similar to that in deficient herbage, the normal treatment with 2·2 kg cobalt sulphate per ha produced appreciable increases in content, especially in yellow turnips. 609

Accumulation of Added Soil Copper. Soil samples were collected from profile pits in fields that had received considerable quantities of copper from pot ale or similar waste from distilleries over many years, for comparison with corresponding samples from relatively untreated adjacent areas. Irrespective of whether land had been cultivated or not, analyses by the Department of Spectrochemistry show practically no increase in EDTA extractable Cu in samples below 300 mm, even where the content in the surface soil had been increased to over fifty times the normal amount. This was found also for profile samples from a cultivated field which had received regular dressings of pig slurry high in Cu for about 15 years, compared with an adjacent field which had received none. 609, 201

Effect of Copper, Cobalt and Zinc on Grass on Deep Peat. The experiment started in 1973 and mentioned in last year's report is being continued. In 1976, with 120 kg N per ha per cut, the 6 kg Cu per ha treatment applied in 1973 increased the total yield of dry matter from three cuts by about 1 t per ha, compared with the no Cu treatment. Where no N or 60 kg N per ha per cut was applied, the corresponding increase from Cu was only about 0·5 t. As in previous years, the 0·5 kg Co and 6 kg Zn treatments did not increase yield. The herbage samples are being analyzed by the Department of Spectrochemistry for trace elements. The limited data so far available indicate that in the absence of applied Cu the content in the herbage dry matter is normally less than 2 ppm Cu. 609, 5206, 5701, 5703

Relative Effectiveness of Copper Amendments. An experiment started in 1976 to compare copper sulphate, copper oxychloride and a commercial copper slag is being continued. All three sources produced a significant increase in the yield of barley grain in 1976 and there was no difference between them. 609, 5701, 5703

Selenium. Four experiments started in 1976, in collaboration with the Department of Spectrochemistry, are in progress to compare the effectiveness of sodium selenite and sodium selenate in raising the Se status of the soils and of herbage cut three times annually at the silage stage of growth.

Preliminary results for some of the first cuts in 1976 show that 0·1 kg Se per ha as sodium selenite increased the Se content in ryegrass from below 0·03 to about 0·2 ppm, compared with about 0·6 ppm where 0·3 kg Se was applied. The sodium selenate was much more effective, the increases from corresponding dressings being usually about five times greater. The values for clover and mixed herbage are similar to those for ryegrass.
609, 201, 202, 5703

With the aid of recently developed electrochemical methods of estimation, mentioned later, detailed studies have been started on the selenium relationships in selected contrasting soil series. This work is part of a wider study on the anion sorption and desorption characteristics of soils. A major objective of the experimental approach is to examine the applicability to trace elements of physicochemical concepts, especially quantity and intensity measurements and relationships, which have proved so fruitful in studies on major nutrients, particularly phosphate. To this end, the sorption and desorption characteristics of selenate and selenite in soils are being studied and radioactive ^{75}Se is being used to investigate the feasibility of measuring labile Se (L Values) in pot cultures and exchangeable Se (E Values) in laboratory suspensions. The implications and inter-relationships of Se values by more conventional extraction methods are also being examined, in relation to forms of occurrence. 609, 614

Nitrogen

Soil Nitrogen Measurements. Results for ranges of soils cropped in series of pot cultures in different years are being processed to examine relationships between various measurements of available soil N and the yield, N uptake and N responses of oats. The indications are that several of the soil N values, especially measurements of mineralizable N and of carbohydrate extracted with 0·05 M barium hydroxide, give significant relationships. Even under the controlled pot conditions, however, the correlation coefficients seldom exceed about 0·7 and the outlook in relation to possible adoption of a soil N measurement for advisory purposes is not promising. Complementary pot culture work has, therefore, been continued to examine the usefulness of plant N measurements at different stages of growth as alternative and supplementary indices of nitrogen status and requirements. 603, 606, 607, 5703

Further information has been obtained on changes during the season in inorganic soil N in field plots under different crops, with particular reference to vertical distribution of applied N and to removal in drainage. In keeping with the high rainfall during the winter of 1976-77, soil samples collected from experimental sites in March and April, 1977, contained lower amounts of extractable inorganic N than at the corresponding time in 1976. 603, 608

An account has been submitted for publication of joint work with the Department of Microbiology on nitrate and ammonium nitrogen in soil from around the roots of barley plants, in relation to incidence of take-all disease[92]. 603, 504

Gaseous Loss of Added Soil Nitrogen. This question has not hitherto been investigated under the conditions in north Scotland. A preliminary pot culture experiment in which potassium nitrate, enriched with ^{15}N as a tracer, was added to a typical agricultural soil of the basic igneous Insch series, has, therefore, been carried out to examine the effects of maintaining a high moisture level of about 60 per cent, compared with a normal level of about 30 per cent, and of stimulating microbial activity with heavy additions of straw, glucose or both. The ratio of ^{15}N to ^{14}N is being measured in the soil before and after cropping with oats, and in the harvested plant material. Coupled with the corresponding total N contents, this enables any loss of added fertilizer N to be detected. Since the culture system precludes any removal in drainage, any such loss has to be in the gaseous form. The added glucose severely depressed growth and final yield, but water level and straw had little effect. Duplicate cultures without ^{15}N were set up for sampling by the Department of Microbiology to follow the total bacterial population and the numbers of ammonifers, nitrifiers and denitrifiers.

603, 513

Effect of Applied Nitrogen on Soil Acidity and Calcium Content. In a grassland experiment started in 1973 on a freely-drained soil of the Foudland series, three cuts of herbage have been taken annually for three years at N levels of 0, 95 and 190 kg per ha per cut, added as ammonium nitrate. At the end of the third year the 190 kg N treatment had increased the acidity and decreased readily soluble Ca compared with the other two treatments. The mean soil pH values in 1:2·5 water suspensions, were 6·2, 6·1 and 5·6 for the 0, 95 and 190 kg N treatments, respectively. The corresponding acetic-soluble Ca values were 250, 240 and 180 mg per 100 g air-dry soil <2 mm. In 1976 the 190 kg N plots were subdivided. One half was given no lime and the other a dressing of ground limestone, averaging 4·2 t per ha, to raise the pH to about 6·2. Barley was then grown and the limed portions produced 3·33 t oven-dry grain per ha, compared with a significantly lower yield of 2·94 t from their unlimed counterparts. 603, 608

Phosphorus

Interactions with Goethite. Thermodynamic studies have been continued on the interaction of phosphate and other anions with goethite, αFeOOH. The surface charge characteristics of the goethite were determined using potentiometric titration, and adsorption enthalpies of the anions were measured with a microcalorimeter. The enthalpy of the initial high energy adsorption at pH 4 was approximately 43 kJ/mol for OH^- and 20 kJ for $H_2PO_4^-$, but the values dropped with increasing coverage of the surface. The design of the calorimeter cell is being modified to provide better mixing of added solutions with the suspensions, rather than relying on diffusion 605

Desorption Isotherms. The effects of a number of anions occurring in soil solutions on the phosphate desorption isotherms of a slightly acid granitic soil of the Countesswells series have been studied. Compared with 2mM $Ca(NO_3)_2$ solution alone, bicarbonate and sulphate at a concentration of 10^{-4}M had virtually no effect while fluoride and p-hydroxybenzoate had

little effect, but oxalate and polymalate brought considerable amounts of phosphate into solution. Dowex 21K anion exchange resin, in chloride form, produced moderate desorption while maintaining a low phosphate concentration in solution. The results should help to clarify the roles of chemisorbed interactive and non-interactive anions in soil phosphate release under natural conditions. 605

Evaluation of Soil Phosphate Status. The results of work on the phosphate status of some chernozem and luvisol soils from Alberta, Canada, mentioned in Ann. Rept., No. 45, 1974/75, have been prepared for publication. This work was carried out by Professor J. A. Robertson while on sabbatical leave from the Department of Soil Science of the University of Alberta, Edmonton. Detailed phosphate sorption isotherms were measured on samples from six sites that had been enriched with phosphate in the field and cropped with barley in the glasshouse. Phosphate uptake by the barley test crop was highly correlated with any pair of the following measurements: equilibrium P concentration, isotopically-exchangeable P and the P buffer capacity. Four measurements of the latter factor were examined and proved equally appropriate. Analysis of the sorption isotherms enabled the reaction constants and adsorption capacities of three differing adsorbing surfaces to be calculated. Phosphate uptake was very low from the soils in which the high-energy surface was under-saturated. At low concentrations, quantity-intensity curves obtained from the adsorption isotherms were very similar to those found by enrichment and cropping of the field soils, but at higher concentrations they deviated considerably. The capacities of the adsorption surfaces correlated with the clay and extractable Al contents of the soils, but not with extractable Fe. 605

Progress is being made in processing the results of a comprehensive reappraisal of the significance, interrelationships and usefulness of different types of P extraction values as indices of the phosphate status of Scottish soils, with particular reference to the influences of soil type and soil properties. The programme extended over six years and included field measurements of crop responses with swedes and potatoes, response and L value measurements with oats in pot cultures, and laboratory evaluations of extractable P and soil properties, on over 100 soils representing a range of contrasting soil series. The main objective is to assess what improvements may be feasible, either by modification of methods or of interpretation of results, in laboratory evaluations of soil phosphate status for advisory purposes. 601, 608, 610, 5703

Sulphur

Status of Soil and Crops. The analytical survey, mentioned in last year's report, of the sulphur status of representative agricultural soils from north Scotland is complete. Determinations of total inorganic sulphate show that many of the soils examined have values less than 12 ppm S. This level is quoted in the literature as a limit below which responses to added sulphur might be expected, but field tests are necessary to check its significance under the conditions in north Scotland. The sulphate status of soils is also being studied in pot cultures. In one series, radioactive ^{35}S

is being used to evaluate the pool of available sulphate (L Value) in a selection of contrasting soils and to assess the amount contributed by rainfall. In another series, exhaustive cropping with ryegrass is being used to study sulphur depletion in a range of soils with different sulphate contents and sorption characteristics. Work is also continuing on the S content and N:S ratios in different crops from field experiment centres on different soil series. 601, 608

Organic Soil Sulpher. A collaborative study with the Department of Soil Organic Chemistry on the amounts of sulphur-containing amino acids in a selection of five contrasting soils, comprising four mineral soils and a peat, has been completed. The proportion of amino-acid S in the peat is considerably lower than in the mineral soils, amounting to only about 15 per cent of the C-bonded S in the former compared with 20 to 30 per cent in the latter. 602, 303

Soil Acidity and Cation Exchange

Removal of calcium with attendant development of acidity in soils has been investigated by slow leaching of soil columns with solutions of different composition. For solutions adjusted to a common pH value of 4·4, the effectiveness of acids in displacing Ca decreased in the following order: carbonic>acetic>sulphuric, thereby varying inversely with dissociation and increasing with amount of undissociated acid in solution. As might be expected, this shows that the total acidity of the solution, as well as the free hydrogen ion content, is important for acidity development. The inclusion of salts, even at such low concentrations as 1mM, to give a solution nearer that found in the field, when percolating acids are diluted by the soil solution, markedly decreased the effectiveness of the acids. These results indicate that it should be possible to treat acidity development by combining the principles of cation exchange and acid dissociation. 604

The possibilities of progressive acidification of seminatural soil profiles is being examined in relation to current concern over acidified rainfall. Determinations of pH and soluble and exchangeable cations indicate very different exchange coefficients for H-Ca and Al-Ca exchange for different horizons. These horizons have presumably come to equilibrium with the acid percolates from the F layer, but they show different H/Al ratios, a feature which merits more detailed investigation.

A review of acid precipitation and soil acidity development, incorporating the above results, was given to a meeting of the N.E.R.C. Air Pollution Research Liaison Committee, mentioned above.

Pot culture experiments on Ca/Al ratios and the response of barley (cv. Golden Promise) to acidity have been continued, using peat as a growth medium and loading it with different ratios of H, Ca and Al. The detailed soil chemical and statistical analyses remain to be completed, but although high Ca improved growth, the reduction caused by low pH and high Al was less than expected.

As mentioned earlier, a paper on " Cation equilibria in soils with respect to their availability " was prepared for a joint meeting of the Soil Science

and Plant Science Committees of the Arable Crops and Forage Board of the Joint Consultative Organization for Research and Development in Agriculture and Food.

Publication is still awaited of five articles[97, 98, 99, 100, 101] mentioned in last year's report, which were prepared for an Encyclopedia of Soil Science. 604

Potassium and Magnesium

Soils with contrasting mineralogical composition representing five Scottish series have been characterized by K adsorption-desorption isotherms. The isotherms of soils of the same series are reassuringly similar, whereas K sorption and buffering capacity decrease in the series order: Caprington > Insch > Strichen ≃ Foudland > Countesswells. K removed in ryegrass tops after two years of cropping to exhaustion in pots varied from 1 to 12 meq per kg oven-dry soil. Release of K over this two year period from soils of similar initial K status decreased in the order Caprington > Insch ≃ Strichen > Foudland > Countesswells. This removal resulted in changes in the K intensity in the soil solution, as measured by the equilibrium activity ratio AR_0^k, from initial values of $0{\cdot}5\text{-}15{\cdot}0 \times 10^{-3} M^{\frac{1}{2}}$ to a narrow range of final values of $0{\cdot}1\text{-}0{\cdot}4 \times 10^{-3} M^{\frac{1}{2}}$. These final values increased to between 0·5 and $0{\cdot}8 \times 10^{-3} M^{\frac{1}{2}}$ on air drying, but did not change significantly on freezing and thawing. Exchangeable K in the soils was reduced by cropping from initial values of 1·5-8·5 meq/kg oven-dry soil to a narrow final range of 0·6-1·4 meq/kg. Non-exchangeable K was released from soils of satisfactory K status in the order: Caprington ≃ Strichen > Insch ≃ Foudland > Countesswells. After two years of continuous cropping with ryegrass in pot cultures, the soils from all five series have been severely depleted of plant-available Mg. The resulting changes in the Mg intensity in the soil solution, measured by AR_0^{Mg}, have been followed. Since Mg uptake is affected by K, satisfactory assessment of K-Mg interactions is essential for evaluation of the Mg status. A study of relationships between Mg uptake in perennial ryegrass and cation activity ratios in the equilibrium solutions of soils with different contents of exchangeable Mg, Ca and K has, therefore, been started, with the view to suggesting values for Mg activity ratios necessary for satisfactory growth and composition of the ryegrass.

As mentioned earlier, an Electro-Ultrafiltration (EUF) apparatus, combining electrodialysis and ultrafiltration, has been acquired. The underlying principle is extraction of nutrient ions from soils under an external electric field. The immediate objective is clarification of the K and Mg supplying power of soils in terms of quantity-intensity relationships and rates of release and forms of occurrence of reserves. 611, 5206

Electrochemical Techniques

Nitrate Determination. Two papers mentioned in last year's report have now appeared, one[47] on the development of a solid state reference electrode for use in soil pastes and the other[48] on the direct determination of nitrate in moist soil with an ion selective electrode. 603, 614

Selenium Determination. Methods of determining selenium in soil and plant extracts have been investigated. One paper[22] covering these develop-

ments has already appeared and another[76] has been accepted for publication. Both differential pulse polarography and cathodic stripping voltammetry are being used. Differential pulse polarographic analysis has the advantage of suffering fewer interferences. The detection limit of 0·025 ppm in soil extracts is not sufficient for analysis of saturation water extracts of soils low in selenium, but the method has been successfully applied to study selenium adsorption characteristics of soils. Though more susceptible to interference, especially by Cu, Fe and Pb, cathodic stripping voltammetry has proved to be a reliable and sensitive method, with a detection limit of 0·005 ppm. For both soil and plant extracts it has given results virtually identical with those obtained by a fluorimetric method. Close contact is maintained in these investigations with the Department of Spectrochemistry. 614, 206

Molybdenum Determination. Several polarographic and voltammetric methods have been studied for the determination of Mo at concentrations around 10^{-8}M. The most promising technique appears to be differential pulse polarography in a concentrated nitric acid electrolyte. The method is free from interference from the majority of the common inorganic anions and cations found in soil extracts. The detection limit is 3×10^{-8}M, and has enabled Mo to be determined in a saturation water extract of a typical acid topsoil from the Insch series. 614

Instrumentation. A digital storage oscilloscope has been incorporated into the polarographic system as a versatile instrument for signal acquisition. Techniques of background subtraction have already been implemented and further analogue and digital processing techniques are envisaged. 614

Soil Physics

As indicated in last year's report, studies are being started on soil physical properties and conditions in relation to crop production. The department also continues to be responsible for standard characterization of moisture release curves, pore-space relationships and hydraulic conductivity of soil series mapped throughout Scotland by the Department of Soil Survey. 612

Soil-Crop Relationships. Investigations have been initiated on the pattern of soil moisture extraction by crops. Using a neutron moisture probe, the progressive development of moisture profiles under barley, grass and bare soil is being studied on a granitic soil of the Countesswells series. In this soil the rooting zone is restricted by an indurated subsoil layer, and difficulties encountered in installing access tubes indicate marked physical variability, even within the relatively small confines of the experimental plots. Computer programs have been written for the analysis of the water balance equation, providing estimates of actual evapotranspiration and soil moisture deficit during the growing season. Due to the wet spring in 1977, the soil remained at field capacity until about mid-May. Maximum soil water deficits of about 100 mm under barley were recorded in mid-July, at the end of two weeks of drought coinciding with the early grain filling stage. 612

Since stones and gravel, all coarser than 2 mm, are major components of many Scottish soils, it is intended to study their effects on thermal and moisture conductivity in the bulk soil and on the energy balance at the soil-atmosphere interface. Computer models are being used in preliminary work on the latter aspect, and exploratory field and laboratory studies are being planned, both for the determination of parameters used in the models and for comparison of experimental results with model predictions. 612

Bulk density measurements in field patches with poor growth of barley on a soil of the Foudland series revealed compacted soil with densities varying from 1·8 to 2·3, with a mean of 2·0, at a depth of 300 mm, compared with 1·2 to 1·8, and a mean of 1·5, in places where growth was satisfactory. 612, 610

Characterization of Soil Series. Moisture characteristic measurements have been made on 42 more profiles representing 12 series. To standardize the derivation of hydraulic conductivity from these curves, values calculated from them by different methods are being compared with direct measurements on a range of soils. In freely-drained agricultural land in Scotland, however, the traditional well methods for measuring hydraulic conductivity are of limited applicability because the water tables are normally too deep. The simple flow-in method previously used has been found to be too empirical to enable reliable conductivity values to be calculated from the measurements. An air-entry permeameter is, therefore, being tested, which promises to be both reliable and relatively simple to use. 612, 801

Surface Tension of Capillary Liquids. The surface tension of liquid-gas interfaces is a parameter important to many aspects of the study of porous media, including soils, such as water retention by small pores, mercury porosimetry, and capillary condensation. It is, therefore, important to understand the effect of curvature, among other factors, on the surface tension. This effect is mediated by at least two principal mechanisms, a free energy effect and a geometric factor. A theoretical analysis of the question has been made and an equation describing the influence of changes in free energy (suction or pressure) of the capillary fluid on the surface tension has been derived. 612

Radioactivity

Collaboration, services and advice in this field continue to be provided throughout the Institute. As indicated in the sections above on selenium, phosphorus and sulphur, radioisotopes are being increasingly used in soil fertility studies for laboratory measurements of exchangeable nutrients in soils (E Values) and for corresponding pot culture measurements of labile pools (L Values). Whole wheat plants labelled with ^{14}C and seed from plants grown with ^{45}Ca have been provided for the Department of Soil Organic Chemistry, and assistance has been given to the Department of Spectrochemistry in an analytical investigation involving use of short half-life ^{99}Mo. An effect of radiation in the wheat seed appears to be higher incidence of twinning, in the form of germination of two seedlings from one seed. Of three papers mentioned in last year's report one, on tracing magnesium, has appeared[49], and publication is awaited of the other two, cover-

ing production of labelled plant material[102] and joint work with the Department of Pedology on the use of tritium for water tracing[103]. An account of collaborative work with the Department of Soil Organic Chemistry on transformation of ^{14}C glucose in soil has been submitted for publication[83]. 613, 5613, 601, 605, 614, 305, 309

Advisory Work

During the year, nearly 6000 soil samples were submitted by the Advisory Officers of the North of Scotland College of Agriculture, of which all except about 150 horticultural samples were from agricultural land. This total represents a decrease of about 1600 compared with the previous year, probably due mainly to restriction of sampling by bad weather during December, January and February. The lime, phosphate and potassium status was assessed in all the samples, and magnesium in 750. In a number of samples from areas where crop growth, mainly barley, was poor, inorganic nitrogen extracted with potassium chloride solution was also estimated. A large proportion of the horticultural samples came from greenhouses and the electrical conductivity of water extracts of these soils was measured to assess the level of soluble salts. The trace element contents, normally cobalt, copper and molybdenum, of nearly 700 soil and 63 crop or herbage samples were assessed in collaboration with the Department of Spectrochemistry in relation to problems of either crop growth or animal health. An increasing number of cases of suspected manganese deficiency in barley continue to be reported and soil samples from some of these areas show either low exchangeable manganese or rather high lime status. 610, 5205 5206

Eleven samples of sewage sludge from towns in the Grampian Region were analyzed. Except for copper, which was relatively high in samples where distillery effluent was discharged into the sewage system, the contents of major nutrients, including nitrogen, phosphate and potassium, and of potentially injurious or toxic elements, including boron, cadmium, mercury, nickel, lead and zinc, were within the range normally found in sludge from non-industrial towns. 609, 610, 5205, 5206

In collaboration with the Peat and Forest Soils Section of the Department of Pedology, 73 samples of soil from forest nurseries were analyzed to assess their lime, phosphorus, potassium and magnesium contents. 608, 117, 5206

7. STATISTICS

Mr R. H. E. Inkson

One of the most important activities of the department is collaboration with others in the planning of experiments. This involves the choice and production of the appropriate experimental design and consequent method of statistical analysis. Similar considerations apply whether the experiment is in the field, forest, glasshouse or laboratory. In addition to the analysis of variance of sets of observations from designed experiments, other methods of statistical analysis such as multivariate methods and model-building are applied to the results of sample surveys and the accumulated records of series of experiments. The large number of projects referenced below shows that collaboration and service have been provided for all project packages and all departments.

Mr D. A. P. McKay, an ARC postgraduate research student working towards the degree of Doctor of Philosophy of the University of Aberdeen, has completed the first year of a research project on the establishment of an information system for the computer storage, retrieval, analysis and presentation of soil data.

Members of staff have attended meetings of the Biometric Society, the Royal Statistical Society, the Institute of Information Scientists, the ARC Crop Science Model-Builders' Group and of ARC statisticians. The department has also been represented at the fourth ARC data logging symposium, at a Royal Statistical Society conference on graphical methods in statistics, and at courses of the Institute of Statisticians on multivariate analysis and experimental design.

Computing Service

The department contains the Institute computer system and is responsible for its programming and operation. At present the system consists of an IBM 1130 computer with facilities for reading and punching cards, reading punched paper tape, plotting graphs and printing. An IBM System/7 computer is attached to the 1130 to provide additional disk storage and the two can work independently or as one system.

A soil data bank working group, under the chairmanship of the Head of Department has begun to plan a unified system of data storage on all aspects of soil. Considerable progress has already been made on a pilot study involving four soil associations and 430 profiles. A system of cross-referenced files has been established and programs written to store, retrieve, summarise and display the data. Work is also in progress to test the use of multivariate statistical methods and members of the working group are asking specific questions of the data. 701, 703

Pedology. Vegetational data from sites in peatland areas is punched and stored on computer data files for subsequent retrieval, processing and plotting. Ordination and clustering techniques are being assessed for subsequent

classification of the accumulated data. The continuous system modelling program (CSMP) for the IBM 1130 computer has been used in a study of peat erosion. 112, 701, 703, 5703

The IBM numerical surface techniques and contour mapping package is being used to produce isopoll maps for individual pollens depicting contours of equal percentages based on data from 92 sites covering the whole of Scotland. 113, 5703

The punching and processing by the program OXIDE of data from X-ray silicate analysis continues on a regular routine basis. The processing of data from the auto-analysis of rainfall, foliage and other samples is also

The Institute Computer. The photograph shows the interactive computer operation at the console.

a regular service. However, changes in the presentation of the data made it necessary to revise input routines. The new arrangement is more convenient for the punch operators and saves punching time as well as cards. 103, 104, 107, 112, 114, 115, 116, 117, 703, 5703

Spectrochemistry. The processing of data from Mössbauer and electron paramagnetic resonance (EPR) studies continues on a regular basis. A program has been developed to display in the form of a histogram the element content fingerprint of soil samples. 201, 203, 703, 5703

Soil Organic Chemistry. Problems with the laboratory apparatus and the choice of suitable sampling rates have delayed progress in the development of a program for the identification of amino acids and the calculation of peak areas and percentage composition of samples 303, 703

Microbiology. Alterations and improvements have been made to the program for solving equations to determine the most probable number (MPN) of organisms in a sample and the probability of occurrence of the numbers of fertile tubes in the dilution series. Coulter Counter data on ragweed pollen have been processed by the dual threshold program CCPML. 513, 703, 5703

Soil Fertility. Regular use is made of the programs that have been developed for the input and processing of data, analysis of variance and correlation and regression analysis. 703, 5701, 5703

Soil Survey. Regular use is made of the revised version of the program for the processing of plant sociological data. 802, 703, 5703

Advisory and Collaborative Work

Pedology. Two new programs have been written to complete the group for processing rainfall data from Sitka spruce experiments of central composite design in the study of the relationship between tree growth and nutrient uptake. Regular processing and statistical analysis of the annual basal area increments, foliar analysis and rainfall data is carried out on the six experiments in this series. Summaries of foliage profile results have also been produced. 115, 701, 703, 5701, 5703

A joint account of a study of nitrogen mineralization in peat from planted and unplanted sites, referred to in last year's report, has been accepted for publication[70]. 116, 5701, 5703

In an investigation of the effects of type and rate of nitrogen supplied on the growth of conifer seedlings in glasshouse experiments, growth rates and net assimilation rates have been computed. The data have been examined by analysis of variance for individual harvests and related to time by regression anlysis. 117, 5701, 5703

A number of field trials concerning the growth of sphagnum shoots in different environments provided data for analysis from several harvests and growth increments were derived. An examination of the variability of the percentage of dry weight in peat samples provided estimates of the numbers of replicate quadrats required in a peat erosion investigation. 112, 5701, 5703

Spectrochemistry. An examination of the relationship between total and extractable lead and various properties of soils from six associations used logarithmic and reciprocal transformations in regression analysis to establish linear relationships. Correlation and regression analysis were also used in a study of the trace element contents of top soils on parent materials derived from rocks of different types, in relating b (A°) to type of iron, and in comparing three sets of calculated values with the observed data from X-ray 060 spacing. 201, 207, 5701, 5703

Soil Organic Chemistry. Polynomial regression equations have been used to investigate the relationship between carbohydrate-carbon and the percentage of carbon in soils. Quadratic equations were found to give no significant improvement compared with straight lines in a method of inverse estimation of sugar concentration. Standard methods of analysis of variance were used in a series of factorial experiments to test the effects of various media and inhibitors on growth of wheat plants. 305, 309, 5701, 5703

Plant Physio'ogy. Factorial and randomized block experiments have been designed and analysis of variance, correlation and regression analysis carried out for various studies dealing with nutrient contents and ratios in tomatoes, cabbage, cauliflower, maize, alfalfa, brome grass and potatoes. For data expressed as percentages the angular transformation has been used. A joint account of experiments on cabbage and cauliflower with nitrogen, calcium and molybdenum factors was presented at the 6th Long Ashton Symposium—Nitrogen Assimilation of Plants[99]. 401, 402, 5701, 5703

Microbiology. Analysis of variance, linear regression and logarithmic transformation have been used in studies of CO_2 evolution and of the effect of different substrates on microbial respiration in soil. Further work has also been done on physical and chemical measurements and on MPN solutions from dilution series from an experiment where barley has been grown continuously for a number of years. 512, 513, 5701, 5703

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

Two series of field experiments, 107 on swedes and 26 on potatoes, have provided yield, uptake and response to added phosphorus data, six different soil phosphorus values and other soil properties. Linear regression methods have been used to relate the crop performance variables to the soil variables. separately for the different soil types in the set of experiments.
601, 702, 5701, 5703

Regression methods have also been used with pot experiment data relating response and uptake of P to soil P values, and relating soil P values to each other and to other soil properties, and in relating temperature, pressure and surface tension. 601, 603, 605, 612, 5701, 5703

For a number of different crops in the field and for a range of pH levels in pot experiments, the relationship between yield, nitrogen and excess base values has been examined. In a series of swede variety trials the percentage variation due to different causes (site, year, etc.) was also determined.
604, 606, 5701, 5703

The detailed study of the pattern of growth and development of barley and swedes continues and further experiments planned with factorial, con-

founded factorial and split-plot designs. Linear and quadratic regression equations have been used to relate grain size to grain number per ear in barley and wheat. 607, 5701, 5703

Soil Survey. Analysis of variance has been used to test differences in canopy development for several areas over a period of years for a number of tree species. Three similarity indices have been compared in a study of changes with time in the forest floor vegetation of 20 areas. 802, 5701, 5703

8. SOIL SURVEY

MR R. GRANT

The primary objectives of the department continue to be the systematic soil and land use capability surveys aimed at the production of coloured soil and land use capability maps at a scale of 1:63 360 or 1:50 000, and, in collaboration with other departments, the description, characterization and classification of the soils identified during the survey.

During the current season a further 1035 km² (400 square miles) have been surveyed, on a scale of 1:25 000, in 10 areas: 90 on Sheets 118, 119, 120, 121 and part 117 (Orkney); 220 on Sheets 115 (Reay), 109 (Auchentoul) and 103 (Golspie); 130 on Sheet 74 (Grantown); 50 on Sheet 65 (Braemar); 160 on Sheet 47 (Crieff); 30 on Sheet 45 (Oban); 30 on Sheets 28 (Jura) and 29 (Rothesay); 100 on Sheet 23 (Hamilton) and 225 on Sheets 5 (Kirkcudbright) and 9 (Maxwelltown). In addition, correlation and revision have been carried out on Sheet 75 (Tomintoul) and Sheet 52 (Tobermory), which are now completed, and four special surveys on larger scales have been made.

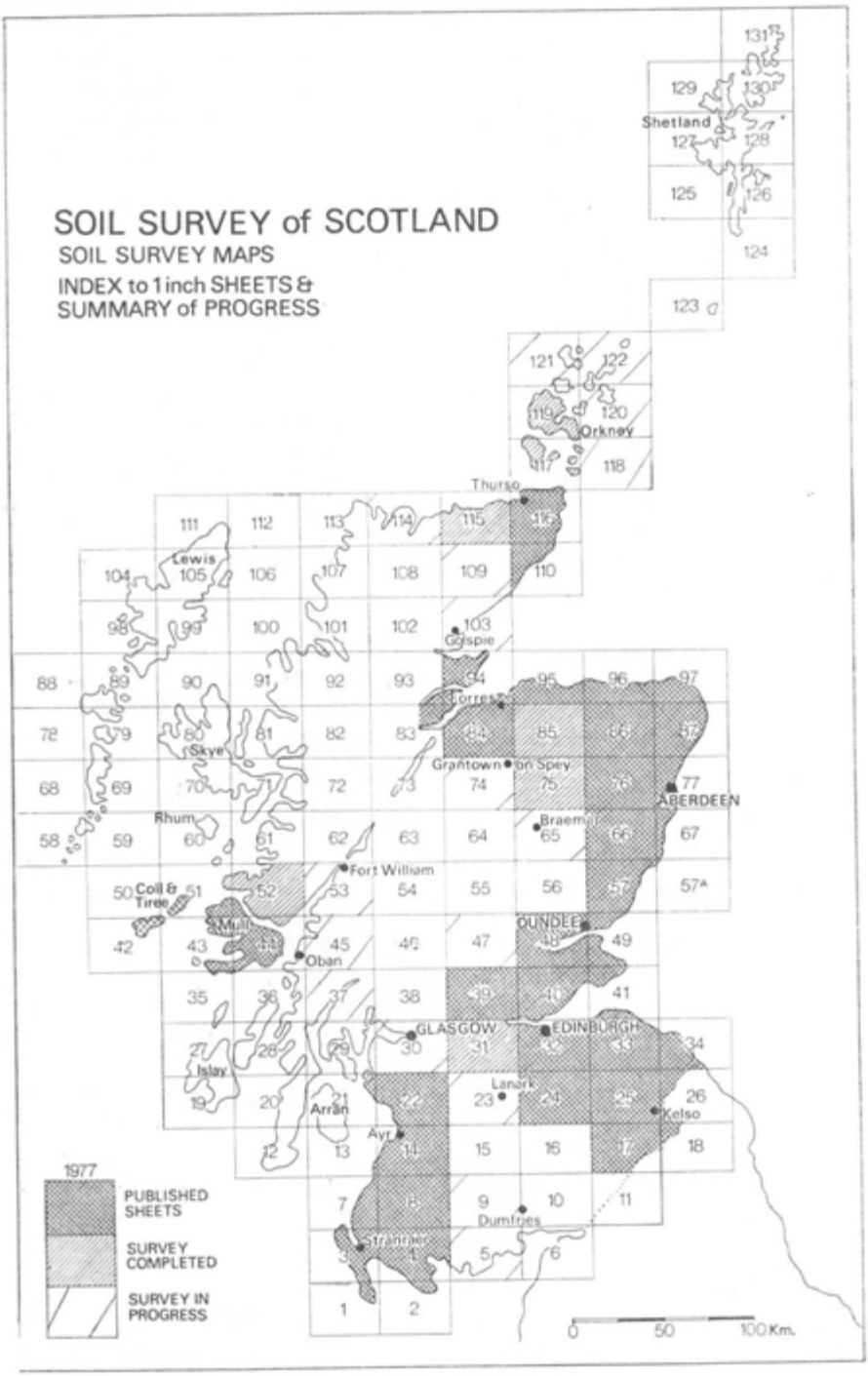
Land use capability assessments have been made concurrently with all new soil mapping and progress continues with the back-log of assessments for published soil maps, with 440 km² to complete Sheets 76 (Inverurie) and 77 (Aberdeen), 500 km² to complete Sheets 87 (Peterhead) and 97 (Fraserburgh) and 890 km² on Sheets 43, 44 (Island of Mull).

One hundred and sixty profiles have been described and sampled for analysis.

A report with proposed guidelines for the sub-division of Class 3 has been prepared for and accepted by the Department of Agriculture and Fisheries for Scotland Working Party on Land Use Capability Classification of the Low Ground. The DAFS Working Party on Land Classification of the Hill Areas has accepted a proposed scheme for a rapid survey of high lands submitted by a technical group (J. S. Bibby, Chairman), which will be presented to the Standing Committee on Rural Land Use.

A scheme for improving the climate guidelines in Technical Monograph No. 1, Land Use Capability Classification, has been finalized and maps of assessment of climatic limitations in Scotland have been prepared.

Members of staff have attended meetings of the British Society of Soil Science, the Scottish Ecological Group and the Land Reclamation Conference held at Thurrock, Essex. Mr R. Grant visited the Correlation Centre, University of Ghent in connection with the F.A.O. Soil Map of Europe; Mr J. M. Ragg accepted an invitation to visit the University of Sulaimaniya, Iraq, to advise on soil mapping, classification and reporting, and Mr L. Robertson attended the 5th International Working Meeting on Soil Micromorphology in Granada, Spain, and participated in the post-meeting excursion. He was subsequently appointed to the organizing committee of the 6th Meeting to be held in the U.K. in 1981.


SOIL SURVEY of SCOTLAND
SOIL SURVEY MAPS
INDEX to 1 inch SHEETS &
SUMMARY of PROGRESS
Shetland
Orkney
Thurso
Lewis
Golspie
Forres
Grantown on Spey
Skye
Rhum
Braemar
ABERDEEN
Fort William
Coll & Tiree
Mull
Oban
DUNDEE
GLASGOW
EDINBURGH
Islay
Lanark
Arran
Ayr
Kelso
Dumfries
Stranraer
1977
PUBLISHED SHEETS
SURVEY COMPLETED
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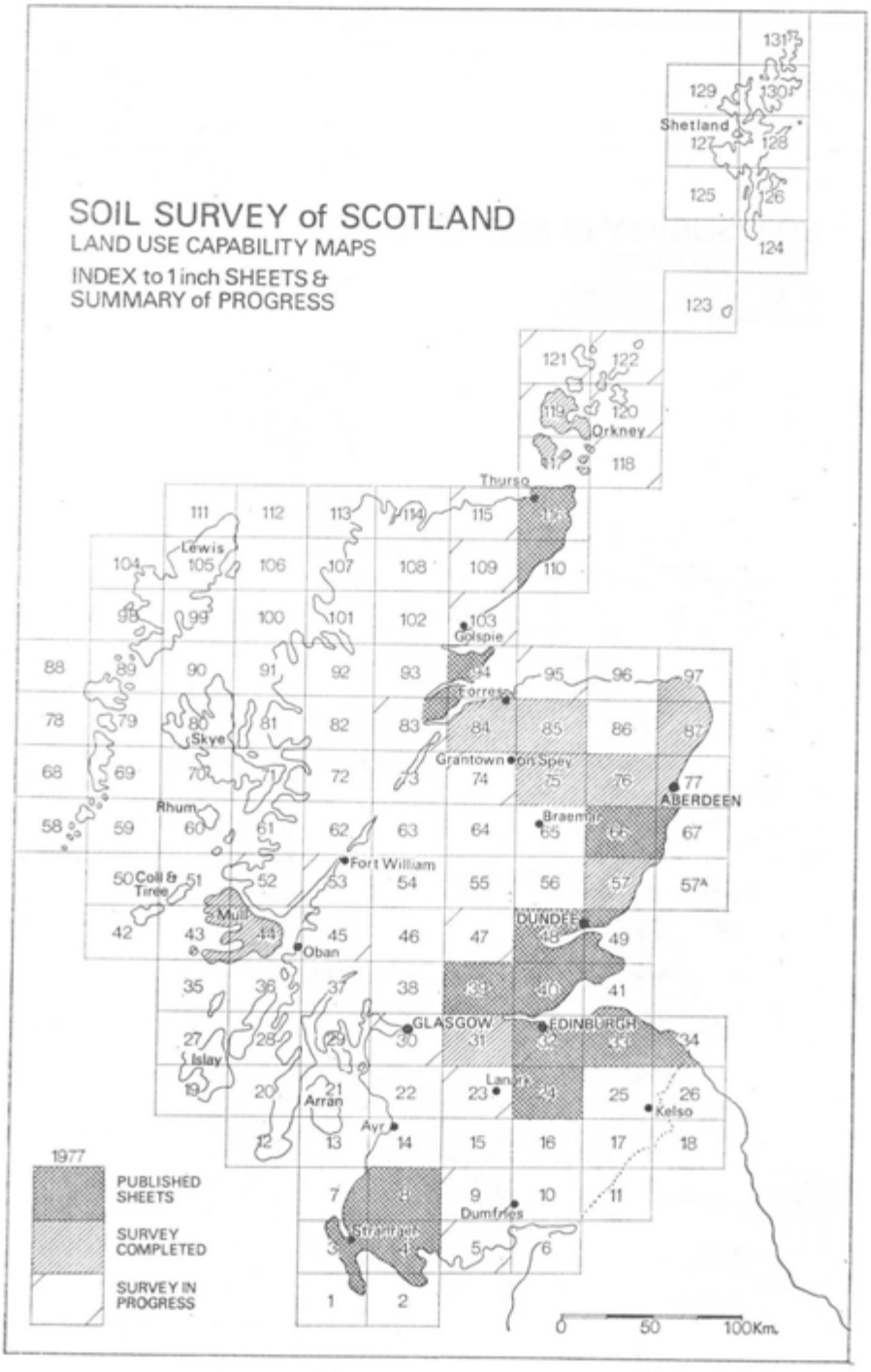
SOIL SURVEY of SCOTLAND
LAND USE CAPABILITY MAPS
INDEX to 1 inch SHEETS &
SUMMARY of PROGRESS
Shetland
Orkney
Thurso
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DUNDEE
GLASGOW
EDINBURGH
Islay
Arran
Ayr
Lanark
Kelso
Dumfries
Stranraer
1977
PUBLISHED SHEETS
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SURVEY IN PROGRESS
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The department continues to be represented on the Ordnance Survey Advisory Committee, the Scottish Agricultural Development Council Field Drainage Group, the DAFS Working Parties on Hill Land Classification and Rural Land Use Information Systems, the ADAS/ARC/Soil Survey Working Party on Suitability for Direct Drilling and the MAFF/ADAS Working Party on Land Use Capability Classification. 801, 802, 804

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

With the surveying of approximately 25 km² in the parishes of Sandwick and Birsay the soil survey of the Mainland of Orkney was completed. As in previous years, soils of the Thurso Association dominated the landscape with shallow podzols of the Bilbster series the most frequently encountered; areas of the Thurso series and Olrig series were also mapped while a further area of the salt-affected soils, named provisionally the Mousland series, was mapped along the western seaboard between Yesnaby and Bay of Skaill. These soils, formerly referred to as " the maritime phase of the Thurso series " have now been given series status and are presently considered as saline gleys. The mapping of the soils of the Fraserburgh Association around Bay of Skaill was completed, the mapping of deep-topped freely or imperfectly drained soils continued and further small basins of peat-alluvium complex, usually with marl deposits, were met. In view of the high degree of exposure, much of the arable ground was mapped as L.U.C. Class 4, with soil shallowness the principal limitation; in areas sheltered and more removed from the westerly influences of climate Class 3 land was recognized.

A further 65 km² was mapped on the Islands of Eday and Stronsay. Much of Eday is blanketed in peat, the bulk of it thin (50-100 centimetres) and eroded and cut-over phases were mapped; a number of well-defined basins of deep peat were also encountered.

Cultivated podzols, the provisionally named Ocklester series, and gleys, the Canisbay and Tresdale series of the Canisbay Association, constitute much of the arable ground. Peaty gleyed podzols, the Warth series and peaty gleys, the Canisbay series of the Canisbay Association and an unnamed peaty gleyed podzol developed on drift derived mainly from the Eday Sandstones were mapped on the hill ground. A large area of Links was mapped around Loch of Doomy and it was found possible to differentiate imperfect and poor drainage classes on the blown sand. The arable ground was placed in L.U.C. Classes 3 and 4 with shallowness and wetness the principal limitations.

Two major associations were mapped in Stronsay; soils of the Canisbay Association, particularly gley soils of the Tresdale series, dominate the south of the island, while generally shallow soils of the Thurso Association occur in the north. Small areas of soils of the Fraserburgh Association have been mapped skirting the larger bays. Hill ground in Stronsay is minimal, confined to the Rothiesholm headland where thin peat and peaty gleyed podzol (Warth series) with occasional peaty gleys (Canisbay series) were mapped. As in Eday, the arable ground was placed in L.U.C. Classes 3

and 4 with wetness the chief limitation in the south and shallowness and wetness the principal controlling factors in the north of the island.

Revision and correlation of the Mainland soils commenced with a particular emphasis being placed on the reddish brown sandy clay loam to clay loam tills of the East Mainland and South Ronaldsay. Graemsay was revisited for revision and profiling. Nine profiles were described and sampled throughout the county. 801

Sheets 103 (Golspie), 109 (Achentoul) and 115 (Reay)

Approximately 218 km² (83 square miles) were surveyed and 14 soil profiles described and sampled. Mapping was carried out in 4 districts.

The first district lies to the north of Golspie between Dunrobin Glen and Strath Brora and consists of an inland plateau and a coastal range of hills. The plateau, underlain by Moinian granulites, has a general altitude of between 120 and 270 m (400 and 900 feet) and is dissected by the valleys of the River Brora and the Blackwater. The soils belong to the Strichen Association and are predominantly peaty podzols, peaty gleys and peaty fragogleys. Mostly they occur in soil complexes with deep and shallow peat. Noncalcareous gleys (Anniegathel series) occur in a small area of formerly cultivated land. A complex of humus-iron podzols and brown forest soils, together with some gleys (Dalvina complex), is commonly present on the lower slopes of the valleys.

The hilly area nearer the coast is composed of Middle Old Red Sandstone conglomerates and sandstones, and reaches an altitude of 520 m (1706 feet) on Ben Horn. Shallow and deep blanket peat covers much of the ground, the remaining soils belonging to the Berriedale Association and comprising peaty podzols usually in a complex with peat or peat and rock, humus-iron podzols on areas of moundy moraine, and oroarctic soils on the summits of the higher hills. Soils of the Corby Association are present on terraces above Loch Brora.

The second district mapped lies between Brora and Helmsdale. The land is predominantly hilly, rising to 628 m (2060 feet) on Ben Dhorain, and underlain by the Helmsdale Granite and Middle Old Red Sandstone sandstones and conglomerates. Soils of the Countesswells Association occur on the granite hills, Countesswells series being present on the lower, steeper slopes with Charr series above. Deep and shallow peat are extensive on the higher, more gently sloping ground, together with a small patch of oroarctic soils on the highest hill. Soils of the Berriedale Association are present on the hills composed of Middle Old Red Sandstone rocks, and comprise peaty podzols at lower altitudes and peaty lithosols and oroarctic soils on the higher ground. Shallow blanket peat is common. Mudstones present on the lower ground in Glen Loth give rise to soils of the Braemore Association. A narrow strip of arable lowland along the coast, underlain by Jurassic rocks, is covered with fluvioglacial and raised beach sands and gravels on which freely drained soils have developed.

The third district lies between Strath Fleet and Strath Brora and includes the area around Rogart. The land lies mainly between 120 and

210 m (400 and 700 feet), is dissected by valleys in the south, and is slightly higher in the north. The district is underlain by the Rogart igneous complex, a zoned tonalite-granodiorite-granite body with an outer migmatite complex. Brown forest soils and humus-iron podzols occur on the lower ground and peaty gleyed podzols and peat are present on the higher land. The soils have been included meanwhile in the Countesswells Association, although they may eventually be placed in a new association. Coarse-textured freely drained soils occur on the lower alluvial terrace of Strath Fleet and Corby series on the upper.

The fourth district mapped lies to the north of the Dornoch Firth and extends from Spinningdale to Dornoch. Freely and imperfectly drained soils developed on raised beach sands and gravels are common in the Dornoch area, together with some Corby series on fluvioglacial materials. The rest of the district, rising from about 30 m (100 feet) above the raised beaches to over 270 m (900 feet) in the west, is underlain by Moinian and Old Red Sandstone rocks. The soils mainly belong to the Strichen Association, comprising freely and imperfectly drained podzols on the lower and peaty podzols, peaty gleys and peat on the higher ground. 801

Sheets 87 (Peterhead) and 97 (Fraserburgh)

The land use capability of about 500 km² (200 square miles) of this area has been assessed. Most arable land has been included in Class 3. Areas of peaty gley and shallow soil have usually been assessed as Class 4, and most of the basin peats as Class 5. Although inland districts below about 120 m (400 feet) often have a suitable climate for Class 2, only a few areas, mainly around Tarves, have been so assessed because of soil limitations. 801

Sheet 76 (Inverurie) and 77 (Aberdeen)

The land use capability assessment for this district is now nearing completion and 444 km² (171 square miles) were classified this season. In the light of experience gained in other areas and following discussions with other surveyors, a reappraisal has been made in a number of areas of the previous land use capability assessment. 801

Sheet 75 (Tomintoul)

After revision and correlation this season, mapping of the soils and land use capability of Sheet 75 has now been completed.

Most of the revision was carried out in the north-western part of the Sheet where some of the soils previously included within the Strichen and Corby Associations have now been mapped as Dulsie Association. The parent materials of these associations are formed from acid schists and their derived drifts, gravels derived from acid rocks, and rudely-stratified loamy sand drift derived mainly from acid schists, respectively.

Correlation of the boundary between Sheets 75 and 74 has also been carried out, aided by viewing a number of complexes mapped on Sheets 74 and 84. Most of these complexes are rocky, with scree as only a minor

component, whereas on Sheet 75 many complexes are scree-dominated. The scree often forms a cover only 50-100 cm thick, overlying a much less stony drift in which well-developed B horizons can occur. It was agreed to separate scree-dominated from rock-dominated complexes.

A visit to the Strontian area (Sheet 52) confirmed that correlation of soil complexes mapped in the area with those of Sheet 75 was seldom possible, a consequence of the great difference between the rugged relief and wet soils of western Scotland and the rounded hills and drier soils of the east. A match was, however, established with two granite complexes of the Countesswells Association: the corrie walls of the Cairngorms can be accommodated within the Kingairloch complex, and the alpine soil and rock mapping unit of the Cairngorms, provisionally named the Avon complex, occurs in the Strontian area.

Two mapping units have been used for peat on Sheet 75: blanket peat, and basin, valley and terrace peat. The units are usually easy to distinguish, but collaboration in the field with Peat Survey (Department of Pedology) has been helpful where separation is more difficult. 801

Sheet 74 (Grantown-on-Spey)

Approximately 130 km² (50 square miles) have been surveyed and 24 profiles described and sampled. Another 25 pits were excavated to determine the nature of parent materials.

Due to adverse weather conditions during April and the prolonged convalescence of one surveyor, the survey programme was slightly restricted.

Following the completion of the correlation along the eastern boundary with Sheet 75 (Tomintoul), mapping was concentrated east of the A9 trunk road. With the exception of minor areas, the survey of 1:25 000 sheets NH 80, 91 and 92 together with the western sectors of NJ 01 and 02 is complete.

Much of the area between the River Spey and the flanks of the Cairngorm plateau consists of a rolling outwash plain stretching from the Moor of Alvie in the south to Abernethy in the north. The freely or excessively drained gravel soils are predominantly iron podzols (Forres series) and iron-humus podzols (Corby series) of the Corby Association. Characteristically, the kettle holes are either infilled by basin peat or occupied by lochs, e.g. Garten, Mallachie, etc. The maximum thickness of peat recorded in such situations to date is 5.5 m.

Occasionally flash-flood gravels, associated with fast-flowing streams draining the Cairngorms, form fans traversing the outwash plain, as at Allt à Mharcaidh. Although the drainage of soils on these varies considerably the profile is immature and thin buried A horizons are frequently encountered.

Projecting above the general level of the plain are several isolated 'whale-back' hills, such as Ord Ban and Kennapole Hill, which reflect the trend of the Strathspey glaciation. Except on the steep northern slopes where schist rock complexes belonging to the Strichen Association have

been identified, the remaining slopes are covered with a varying thickness of gravelly loamy sands. These form the parent material of the Dulsie Association. Similar freely drained podzolic soils are widespread on the southern footslopes of the Kincardine Hills. Peaty gleys (Culfern series) have also been mapped on flushed concave sites near Badaguish. Hill-wash in this area has been extensive and up to a metre of redistributed soil now overlies a basin peat at the foot of the slope. As many as four buried A horizons have been identified within the one profile.

The parent material of the Dulsie Association has also been identified within the glens and embayments in the western flanks of the Cairngorm Plateau to a height of about 530 m. Elsewhere on the plateau the soils are mainly derived from granitic 'mountain detritus' and belong to the Countesswells Association. Such soils form a distinctive altitudinal sequence, viz. peaty podzols, subalpine podzol and alpine podzol and have been described previously.

The scree-dominated slopes between Creag Mhigeachaidh and Cadha Mor, which have been mapped within the Kingairloch complex, contain some of the highest surviving remnants of the Caledonian pine forests. Although the upper limit is around 520 m isolated trees occur up to nearly 600 m. 801

Sheet 65 (Balmoral)

About 50 km² (20 square miles) have been mapped in the country between Braemar and Ben Avon. The soils are derived from acid schists, granites, diorites, dark schists, quartzites, limestones, and gravels formed from acid rocks, and have been mapped within the Strichen, Countesswells, Tarves, Foudland, Durnhill, Deecastle and Corby Associations respectively. On Craig Leek and Meall Gorm the dark schists are interspersed with outcrops of diorite and limestone, and soils of the Tarves Association have been distinguished. Tarves soils have also been mapped on parent materials formed from acid rocks, but irrigated by drainage water from limestone. Such areas have a number of base-rich plant indicators, including the sedges *Carex flacca* and *C. capillaris*, and the broadleaved cotton grass *Eriophorum latifolium;* one area has an abundance of the rare alpine milk-vetch, *Astragalus alpinus.*

The soils include brown forest soils, humus-iron podzols, gleys and peaty gleys, peaty podzols, subalpine podzols, alpine soils and peat. Peaty podzols are less frequent, and rocky complexes more frequent, as compared with land having a similar range of elevation on the adjacent Sheet 75.

Most of the land is above 500 m (1600 feet) and has been rated as Class 6 and Class 7, but some of the humus-iron podzols are improvable and the land has thus been assigned to Class 5. The brown forest soils mainly occur as a component of a rocky complex of the Deecastle Association, and rock outcrops are too frequent for improvement to be feasible. Most of the land is managed for grouse shooting and deer stalking. The better grouse moor

is in the eastern half of the area surveyed, where the soils (mainly of the Tarves Association) have a higher base status. 801

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

Revision of Sheet 52 (Tobermory) and those areas of Sheets 51 (Coll) and 44 (Mull) which will be incorporated with it for publication has been completed. No new survey has been carried out. Attention has been focussed on the definition and mapping of soil complexes on steep land and the interpretation of plant communities in terms of relative grazing values for land use capability classification. Correlation between complexes in the orohemiarctic and oroarctic zones of the west and complexes in similar climate zones in the east has been carried out.

The programme of investigation into the proportions of soils in different complexes was continued with morphological description of 140 sites in two complexes of Darleith Association. This phase of the work is now complete and analysis is being undertaken to assist the production of the memoir. 801

Sheet 47 (Crieff)

Approximately 160 km^2 (60 square miles) of new mapping has been completed during the current field season. This has included the important and complex Highland Border Zone north-east of Crieff comprising Abercairney and Scone Estates, and the truly Highland area centred on Upper Glen Almond on Glenalmond and Achnafree Estates.

The soil pattern is extremely complex and many of the soils are prone to trace element deficiencies, especially cobalt. Those encountered have all been previously described and have been included in the Balrownie, Corby, Darleith, Doune, Forfar, Foudland, Gourdie, Stonehaven and Strichen Associations. 801

Sheet 45 (Oban)

Survey on Sheet 45 was confined to agricultural land adjacent to the settlements of Taynuilt, Kilmore and Balvicar and to Craig Farm, Dalmally, the former in response to requests for information of value in a planning study by Argyll District Council. A set of complexes similar to those observed in other areas of the west was identified on the andesitic rocks of the Lorne volcanic plateau, the main features of which are reported in Ann. Rept., No. 39, 1968-69. The soils of Craig Farm are derived from slates, quartzites and quartz-schists of the Dalradian series. Soil textures are fine sandy and sandy loams with the quartzose rocks giving stonier soils than the slates. A more extensive moraine cover is present than on the andesites, or indeed on quartz-schists of Sheet 52. Podzolic soils are present at low altitudes and on steeper mid-slopes, but the upper hill is dominated by peaty gleys and peats. A small area of soils developed under orohemiarctic climate is found on the summit ridge of Beinn Donachain (above 490 m).

Approximately 30 km^2 (11.5 square miles) of new survey has been completed. Four tensiometer and dip well sites have been established. 801

Sheets 34/44 (Isle of Mull)

Assessments of land use capability for agriculture and preparation of the draft map are now complete. Only 1.5 per cent of the island is considered to have potential for arable agriculture, 21 per cent is suitable for reclamation for grassland and 71 per cent is suitable only for rough grazing. Of the reclaimable ground (Class 5) approximately 65 per cent would be reclaimed with little risk of failure under good management. Only 20 per cent of the rough grazings can be considered of good quality and 65 per cent is very poor.

In a continuing attempt to develop improved methods of describing and defining soil complexes, statistical examination of Scarisdale, Cruachan and Mishnish complexes was undertaken. Three hundred randomly selected sites were visited and described. Analysis of the results is currently being undertaken with a view to determining the constitution of the complexes and investigating whether differences in methods of collecting data (grid or stratified random sample) produce significant differences in results. 801

Sheet 37 (Inverary)

Analysis of data generated by the grid survey of Lephinmore Farm has been used to aid selection of sites for sampling. Samples from 14 profiles have been taken for further investigation at the Institute. 801

Sheet 28 (Jura) and 29 (Rothesay)

As part of a reconnaissance to widen knowledge of the soils of North Kintyre and at the request of Department of Agriculture and Fisheries (Oban) to provide soils and land capability information on potential for agriculture and forestry, a survey of 28 km² (11 square miles) at Kennacraig and Achnancarranan was conducted. The hill land of the estate is dominated by Dalradian quartzose mica-schist (Ben Bheula schists). Till deposits of Kintyre Asociation occupy the lower ground and these are extensively modified by water action. Sands and gravels occur on the raised beaches. The textures are predominantly fine sandy loams and loamy sands, sands and gravels, and gley morphology is prevalent. Peaty gleys, peat and shallow organic deposits over rock are extensive above 150 m (500 feet). Combinations of rock outcrops with both tills and organic soils form the basis of complex mapping units. Six profiles were sampled for analysis. 801

Sheet 23 (Hamilton)

Progress during the current season has been curtailed due to a combination of bad weather, unreliable transport and shortage of staff. Some 100 km² (38.6 square miles) have been surveyed in the environs of Carstairs on grid square NS94.

The central part of the area is occupied by a complex distribution of Darvel series and various alluvial soils on and around the Carstairs kame-moraine. Basin peat is also extensive to the north of the moraine forming the Cranley, Blackgate and Carnwath Mosses. Soils of the Eckford, Lanfine and Sorn Associations have been identified in the eastern parts of the

grid square while Caprington (Rowanhill Association) and Glenpark (Sorn Association) series predominate in the north-west. Linhope and Kedslie series (Ettrick Association) have been identified on the Tinto inlier of Silurian rocks and Bemersyde and Dirrington series (Bemersyde Association) have been found on the micro-granite of Cairngryffe Hill.

Field records for the area described above have been kept on tick-in-a-box forms listing fourteen environmental attributes for each point of inspection and twelve properties for each horizon described. The forms are suitable for key-punching for computer use, but may also be " read " by the surveyor without the difficulty of decoding. A short program has been written in IMP in order to compress and encode the raw data. 801

Sheet 5 (Kirkcudbright) and 9 (Maxwelltown)

Approximately 225 km² (90 square miles) have been surveyed and 40 profiles described and sampled.

Mapping has been concentrated in two areas. The larger, extending westwards from Dumfries as far as the Water of Urr, comprises part of Kirkgunzeon, Lochrutton, Kirkpatrick Irongray, Kirkpatrick Durham and Terregles Parishes. The smaller, a coastal strip between Kirkcudbright and Dundrennan, includes parts of Kirkcudbright and Rerrick Parishes.

Around Terregles the underlying strata are red sandstones and conglomerates of Permian age which, with their derived drifts, form the parent material of the Holywood Association. The drifts and tills have been strongly modified by water action and are generally loamy sands or sandy loams on which the freely drained brown forest soil, Craigdhu series, is widely developed.

Westward from Terregles to the Water of Urr the underlying rocks are Silurian greywackes and shales. The clay loam to loam tills have generally been deposited as drumlins interspersed amongst eroded areas forming a pattern similar to that encountered farther west around Castle Douglas and Borgue. Along the east bank of the Urr Water the till is generally reddish brown and the soils, mainly brown forest soils with gleyed B and C horizons, have been placed in the provisionally established Castle Douglas Association. Between Lochrutton and Crocketford and northwards to Lochenkit and Glenkiln, the tills are grey or greyish brown and soils with imperfect natural drainage, the Altimeg and Kedslie series, are predominant. Throughout the area the Achie complex, characterized by outcropping rock, is widespread and areas of peat, Dochroyle and Dod series, make up the moorlands around Lochenkit.

Along the coast between Kirkcudbright and Dundrennan the tills are also mainly greywacke-derived and range from reddish brown to greyish brown in colour, but unlike similar tills occurring to the north, are not in the form of drumlins. The soils are mainly imperfectly drained brown forest soils with gleyed B and C horizons and range from those placed in the Castle Douglas Association to those in the Ettrick Association. The Achie complex occurring on glacially eroded areas is also extensive in this locality.

801

Special Surveys

Ugadale Farm, Argyll. A soil survey of Ugadale Farm was carried out to provide information on the distribution of soils suitable for reclamation and sites for pig-slurry disposal. The soils were derived principally from quartz-mica-schists and red sandstones, were imperfectly to poorly drained and of very fine sandy loam texture.

During survey of the Campbeltown area (Ann. Rept., No. 45, 1974-75) such soils were correlated provisionally with the Balrownie Association. It is now appreciated that there is a considerably higher content of Highland schists and gneisses in the till and soils on this parent material are now considered to form a separate soil association, the Kintyre Association which is expected to be confined to Arran, Bute, Kintyre and parts of Islay and Jura.

Greenwelltree Farm, Craibstone. A detailed survey was carried out to assist the Grassland Husbandry Division of the North of Scotland College of Agriculture in cattle response to shelter experiments.

Tarland Basin. The land use capability assessment of the Tarland Basin and surrounding countryside was completed prior to a meeting of the DAFS Lands officers when the Soil Survey system of land classification was demonstrated and discussed.

Loch Garten Reserve. A soil map covering about 1.5 km² at a scale of 1 : 10 000 was provided for the Royal Society for the Protection of Birds.

Easter Gallovie. A detailed survey was carried out in collaboration with the North of Scotland College of Agriculture to aid a proposed reclamation project. 801

Vegetation Surveys

During November 1977 a visit was paid to Rinteln, West Germany, to discuss with Professor R. Tüxen the plant communities of Scotland and also the feasibility of producing a joint publication with him, his son, Dr J. Tüxen, and Professor J.-M. Géhu of Lille on the vegetation of Scotland. A provisionai set of chapter headings was drawn up and the several chapters allocated to individual authors.

Since 1968 a considerable number of new plant community records has been collected and the winter of 1976-77 was spent in revising the communities set up in " Plant Communities of the Lowland and Southern Upland Regions of Scotland." New communities have also been set up from the greater wealth of material at hand.

During the summer months the mapping of the Cairnsmore of Fleet vegetation was initiated and the greater part of the area completed. The primary units of vegetation are based on samples collected during the previous two field seasons, but most of the mapping units are complexes of these. This is due to the uneven rock platform underlying the often shallow drift which produces an intricate pattern of soil drainage and depth of soil.

In July, four shallow soil pits were dug and sampled in the bracken and heather replacement plots at Glen Saugh, Kincardineshire. Routine chemical and physical analyses will be carried out on the samples, but, in addition, special analyses will be carried out by the Department of Soil Organic Chemistry to ascertain what changes, if any, have been wrought on the soil organic matter by the replacement of bracken *(Pteridium aquilinum)* with heather *(Calluna vulgaris)* and *vice versa.*

The plant communities of Sheets 103 (Golspie) and 109 (Achentoul) were recorded by standard phytosociological methods with emphasis on the relationships between vegetation and soils within each soil complex. The paper on Anthyllido-Rhacomitrietum canescentis, previously reported, has been published[59].

Further systematic sampling of the vegetation to ascertain the frequency of occurrence of the individual plant communities has been undertaken in the area comprised of parts of Sheet 51 (Coll) and 52 (Tobermory). In this area, the soil surveyors have already carried out statistical sampling of the units making up certain soil complexes and each sample point has been given a general vegetation description. The plant communities within these complexes were analyzed to relate these broad types to the classification of vegetation evolved by the Vegetation Survey. From this information it is possible to calculate the approximate percentage occurrence of each of the more widespread plant communities within the area.

An assessment of the relative grazing values of the plant communities recorded in the above area has also been carried out in response to a request from a technical group of the Working Party on Land Classification for the Hill Areas of Scotland. The species within a community were rated on a simple 10-point scale related to dry matter production and a total numerical value calculated for each community. The plant communities were then classed in terms of good, moderate or poor grazing value.

The vegetation of the island of Eday (part of Sheets 120 and 122) was mapped at a scale of 1 : 10 000 using aerial photographs to test the practicability of mapping vegetation rapidly at association and sub-association level. The final map will be produced at a scale of 1 : 25 000. 802

Soil Micromorphology

At the beginning of the current year delivery was taken of a new Zeiss polarising microscope. A Jones & Shipman 540VS surface grinding machine is now being installed to augment the existing thin section cutting equipment. Some 320 soil thin sections have been prepared and a number of additional soil monoliths have been preserved for inclusion in the Soil Monolith Library.

Investigations are continuing to clarify the conditions under which clay has been mobilised, translocated and deposited within the soil profile. This has involved a general view of all available contemporary seminatural and cultivated profiles and their comparison with selected soil profiles buried in an archaeological context at different times during the last 5 000 years. Some experimental work is being carried out to check the provisional con-

clusions reached. Some preliminary work has been done in connection with soil problems arising from the intense application of cattle court slurry on strip grazed grassland.

A short paper on the stratigraphy of the buried soil at Teindland Forest[51] has been published and a joint paper entitled "Some characteristics of the brown forest soils of Scotland"[63] has been submitted for publication. An appendix has been written to a paper on Mounds at Corrylach Plots, Kintyre, Argyll[104]. 804

Other Work

Collaboration has continued with the Department of Agriculture and Fisheries for Scotland and the three Scottish Colleges of Agriculture, particularly on land classification and drainage projects. Talks and field demonstrations have been given to staff of these organisations, notably during a visit to the Institute by DAFS Lands staff attending their annual conference, to students of various departments of Aberdeen, Glasgow and Heriot-Watt Universities, to the Society of University Cartographers and to local scientific societies.

Assistance has been given to the Environmental and Medical Division, A.E.R.E. Harwell, in the selection of sites for a U.K. Survey of radioactive fall-out accumulation; to the Highland Regional Council with drainage problems on the new A9 road route; to the Northern Constabulary, Inverness, in an investigation involving extensive liaison on the interpretation of aerial photographs and the supply of soils and terrain information; and to the Soil Survey of England and Wales in establishing limits of the thermal sub-zones on mountains for the production of a climate map. Many requests for detailed soils and LUC information on specific sites have been dealt with.

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

Papers on computer areal mapping[52] and the identification of podzolic soils[53] have been published; a paper on the use of air photo interpretation for land evaluation[105] has been submitted for publication; and a chapter on soils has been written for inclusion in a County Flora[106]. 801, 802, 804

Maps, Memoirs and Cartography

The 1 inch Soil Survey map covering combined Sheet 84/94 (Nairn/Cromarty) has been published together with 1 inch Land Use Capability maps for combined Sheets 33/34 (Haddington/Eyemouth), 40/41 (Kinross/Elie) and 66/67 (Banchory/Stonehaven). Colour proofs of the Soil Survey map for Sheet 31 (Airdrie) have been corrected and returned to Ordnance Survey for final printing. Colour positives of Land Use Capability Sheet 31 (Airdrie) have been sent to Ordnance Survey for printing; all the cartographic work for this sheet, including strip masking and colour proofing on plastic, has been completed within the department.

Scribed negatives and colour models for Land Use Capability Sheet 57 (Forfar) and combined Sheet 84/94 (Nairn/Cromarty) have been sent to Ordnance Survey for colour proofing.

The scribed negative and colour model for Soil Survey combined Sheet 85/95 (Rothes/Elgin) are being held in abeyance whilst some additional field work is undertaken. Work has started on the scribed negatives and colour models for the Land Use Capability combined Sheet 35/36/43/44/51 and 52 (Island of Mull) and combined Sheet 85/95 (Rothes/Elgin).

The following limited circulation maps have been prepared: Provisional Soils, Land Use Capability for Agriculture and Land Use Capability for Forestry of the Mull/Ardnamurchan area on 1:250 000 scale; Assessment of Climatic Factors in LUC classification and Climate Guidelines for Division of Class 3, both on 1:625 000 scale; Areas suitable for Direct Drilling on 1:2 000 000 scale; Provisional Soil Maps of the Oban area on 1:25 000 scale; The Soils of Oatridge Farm, Lothian Region, on 1.5000 scale.

Two sheets have been added to the uncoloured 1:25 000 Soil Survey field sheets for restricted circulation; they are both from the Moray Firth area around Forres.

Twelve members of the Society of University Cartographers visited the department in connection with the SUC Summer School held in Aberdeen; a paper based on a talk on the Maps of the Soil Survey of Scotland, has been submitted for inclusion in their proceedings[107].

A paper on the production of coloured Land Use Capability maps has been submitted for publication[108].

The memoir to accompany combined Sheet 110/116 (Latheron/Wick) has been published[54]. 801

SOILS OF THE COUNTRY ROUND TOMINTOUL

Sheet 75 (Tomintoul) covers about 1120 km² (432 square miles) within the former counties of Aberdeenshire, Banffshire and Moray. The area is now almost entirely within the Grampian Region, although the north-west corner near Grantown-on-Spey is within the Highland Region.

The country is sparsely populated; there are no towns and only one village, Tomintoul. Agriculture, forestry, and the use of moorland for grouse shooting and deer stalking provide most of the employment, but tourism and whisky distilling are important around Tomintoul.

Landform Regions

The area can be subdivided into six landform regions which, with the exception of the Ladder Hills, extend beyond the boundaries of Sheet 75:

1. The Eastern Hills
2. The Speyside Hills
3. The Ladder Hills
4. The Cairngorm Mountains
5. The Don and Dee Valleys
6. The Spey Valley

The Eastern Hills lie within the catchment areas of the Rivers Don, Dee and Deveron. Igneous intrusions, many composed of basic rocks, form

over half the region and include the highest hill, Morven (871 m; 2858 feet). Morven dominates the scenery of the southern sector of the region, as does The Buck (721 m; 2365 feet) in the Cabrach area. Hillside slopes are usually strongly sloping (7-11°) or moderately steep (11-15°) to steep (15-27°), the main exceptions being the gentle (1-3°)to moderate (3-7°) slopes in the Old Red Sandstone basin around the hamlet of Cabrach. Summits often have gentle or moderate slopes, the most extensive being the 1.5 km-long top of Brown Cow Hill (829 m; 2721 feet) on the Don-Dee watershed. Most hills have smooth outlines, occasionally broken by rock outcrops, an example being the tors on the summit of The Buck.

The Speyside Hills are drained by the River Spey and its tributaries. The most elevated country is formed of erosion-resistant siliceous schists and quartzites as evidenced by Geal Chàrn (821 m; 2694 feet), the highest summit in the region. Slopes tend to rise moderately steeply to steeply from the valleys to the gently- or moderately-sloping rounded summits. Notable exceptions are the Braes of Glenlivet and the peat-covered country drained by the Water of Caiplich where slopes tend to be only gentle to moderate. Rock outcrops are infrequent.

The Ladder Hills lie between the Eastern and the Speyside Hills on the Don, Spey and Deveron watersheds. Their summits, in the narrow range of about 730-800 m (2400-2600 feet) form the most extensive continuous area of high ground other than the Cairngorm Mountains. Slopes on the hillsides are steep, but become gentle to moderate on the summits. Rock outcrops are rare on these predominantly slatey hills.

The granite plateau of the Cairngorm Mountains forms the highest ground; the most elevated summits encircle the south-western margin of Sheet 75 and include Bynack More (1090 m; 3574 feet) and Ben Avon (1171 m; 3843 feet). The mountain sides are usually steep or very steep, becoming precipitous on corrie walls. The rounded summits are gently to moderately sloping. Rock outcrops more frequently than in the other landform regions, sometimes (as on Bynack More and Ben Avon) as prominent tors. Moundy and terraced relief is a feature of the valley floors of the River Avon and its tributaries.

The Don and Dee Valleys comprise the smallest region, situated in the south-eastern quarter of the area. The Don and its tributaries have narrow valleys, often floored by prominent mounds and terraces of fluvioglacial material. The Dee Valley includes the Logie Coldstone basin where slopes are usually moderate to gentle and where the relief is moundy and terraced in the southern sector.

The valley of the River Spey is about 5 km wide. The river alluvium is bordered by fluvioglacial deposits with a terraced and moundy relief, behind which are the moderate to moderately steep slopes of the valley sides. The region includes the lower valleys of the River Nethy and the Dorback Burn, and Strath Avon and Glenlivet.

Climate

Precipitation and temperature are the components of climate which chiefly affect the soils. Rainfall increases with elevation from about 900

mm in the lower valleys of the Spey, Don and Dee, to about 1150 mm on the Ladder Hills and to over 1500 mm on the highest ground. There is recent evidence that the precipitation on the summits of the Cairngorms may be as much as 2250 mm. On the lowest ground, monthly mean air temperatures rise from about 2°C in January to 14°C in July, and the growing season is 200-210 days. By applying the vertical lapse rate of 0.65°C per 100 m (330 feet) rise in altitude to data from the nearest recording station (Braemar), estimates of monthly mean temperatures are −4°C in January and 8°C in July on the highest ground, where there is a growing season of about 90 days.

The river valleys below an elevation of about 305 m (1000 feet) have been classified as having a cool and rather wet climate, with accumulated temperatures (above 5·6°C) of 825-1100 day degrees C and a moisture deficit in the range 0-25 mm. The deficit occurs during the summer months when evapotranspiration exceeds rainfall. The valleys are moderately exposed, with wind speeds averaging 2·6-4·4 m/s, and have rather severe winters, with accumulated frost of 110-230 day degrees C. The highest ground has an extremely cold, wet climate, with accumulated temperatures of <275 day degrees C and a summer (April to September) rainfall exceeding summer evapotranspiration by at least 500 mm. The high summits are extremely exposed, with wind speeds >8·0 m/s, and have extremely severe winters with accumulated frost of >470 day degrees C.

Geology

The geological succession is:

Quaternary	Recent	Peat, alluvium and blown sand
	Pleistocene	Fluvioglacial sand and gravel
		Solifluction deposits, moraine deposits and till
Palaeozoic	Middle Old Red Sandstone	Conglomerate and sandstone
		Newer Igneous Intrusions
		Granite and diorite
		Norite and gabbro
		Serpentine
		Older Igneous Intrusions
Precambrian	Dalradian Series	Hornblende-schist and epidiorite
		Mica-schist, biotite gneiss and andalusite-schist
		Slate and phyllite
		Black schist and limestone
		Quartzite
	Moine Series	Siliceous granulitic schist and mica-schist

The solid rocks are largely masked by the Pleistocene and Recent deposits but are, in general, the major contributors to the material which overlies them. The geological map is thus a good guide to the distribution of soil parent materials.

Soils

Fifteen soil associations have been distinguished and are listed in the accompanying table.

Association	*Parent Material*
Aberlour	Mixed drifts derived from acid schists and granite
Boyndie	Fluvioglacial sands derived from acid rocks
Corby	Fluvioglacial gravels derived from acid rocks
Corriebreck	Mixed drifts derived from ultrabasic, basic and acid rocks
Countesswells	Granites and their derived drifts
Deecastle	Limestone and calc-silicate rocks and their derived drifts
Dulsie	Stratified and partially-sorted gravelly fine sands derived from acid schists and granite
Durnhill	Quartzites and their derived drifts
Foudland	Slates and fine-grained schists and their derived drifts
Insch	Basic rocks and their derived drifts
Leslie	Ultrabasic rocks and their derived drifts
Nochty	Fluvioglacial gravels, sands and silts derived from basic rocks
Strichen	Siliceous schists and mica-schists and their derived drifts
Tarves	Biotite-gneisses and diorites and their derived drifts, and mixed drifts derived from acid and basic rocks
Tomintoul	Middle Old Red Sandstone conglomerates and sandstones and their derived drifts

The Aberlour Association has been mapped mainly in the catchment area of the River Gairn near the southern margin of the sheet. The soils are formed on a brown to yellowish brown (10YR 5/3 to 5/4) drift which has a sandy loam texture. The parent material is unexpectedly common in Glen Gairn within the granite area shown on the geological map, probably because the bedrock is actually a complex of granite and acid schists. Boyndie is an inextensive association which occurs mainly in the Dorback area near the western margin of the sheet; the soils are formed on fluvioglacial sand, the colour of which is usually light yellowish brown (10YR 6/4). The Corby Association is widely, but locally, distributed in river and tributary valleys especially those of the Rivers Spey and Avon; the gravel parent material of fluvioglacial origin has a colour similar to that of the Boyndie Association. Corriebreck is an inextensive association, restricted almost entirely to the Strathdon and Glenkindie areas of Donside. The parent material is a yellowish brown (10YR 5/4) sandy loam to loam drift. The Countesswells Association is extensive in the Cairngorm Mountains with smaller areas in the Eastern Hills, Glenlivet and the Dorback area. The usual parent material is a drift which is generally a pale brown (10YR 6/3) to brown (7·5YR 5/4) gritty sandy loam to loamy sand. Small areas of the Deecastle Association have been mapped, mainly in the valley of the River Avon around Inchrory. Most soils are formed on a yellowish brown to light olive-brown (10YR 5/4 to 2·5Y 5/4) sandy loam to loamy sand

drift. The Dulsie Association covers a small area near the western margin of Sheet 75. The loamy sand drift which forms the parent material of the soils is usually pale brown (10YR 6/3). The main area of the Durnhill Association is near the northern margin of the sheet around Corryhabbie Hill; other areas are found in the Tomintoul area, on Donside, and elsewhere. The usual parent material is a drift which has a sandy loam to loamy sand texture and a characteristic light yellowish brown colour (10YR 6/4).

The Foudland Association is extensive on the Ladder Hills and is also frequent in Glenlivet and on the Eastern Hills. The parent material is a drift of fine sandy loam texture. The colour is often light olive-brown (2·5Y 5/4) but olive-brown (2·5Y 4/4) or even olive (5Y 5/4) where the drift is formed from black schists. The Insch Association occurs on the Eastern Hills where it is extensive around Morven and in the Cabrach and Strathdon areas. Most soils are formed on drift, which is often a yellowish brown (10YR 5/4) sandy loam to loamy sand. The Leslie Association is not extensive. As would be expected, it occurs in areas adjoining the Corriebreck Association and is found on the Green Hill near Strathdon and in Glenkindie. The parent material is often a dark greyish brown (10YR 4/2) sandy loam. The Nochty Association occurs mainly in the valley of the Water of Nochty near Strathdon, with a smaller area in the Cabrach basin. The parent materials are of gravel, sand and silt texture, the usual colour being yellowish brown (10YR 5/4) to olive-brown (2·5Y 4/4). These are approximate colours, the black and light-coloured grains of the material having a speckled appearance.

The Strichen Association occurs mainly in the Speyside Hills, where it is extensive. Most parent materials are light yellowish-brown (10YR 6/4) drifts of sandy loam to loamy sand texture. The Tarves Association is found in the Eastern Hills, mainly in the catchment area of the River Don. Nearly all parent materials are drifts, the colour of which is usually yellowish brown (10YR 5/4). The texture is usually a sandy loam, but is sometimes a loam or a loamy sand. In the catchment areas of the Ernan Water and the Water of Nochty, Tarves soils are more extensive than inspection of the geological map would suggest because numerous narrow basic igneous dykes outcrop along the bands of slate and quartzite. The main area of the Tomintoul Association is around Tomintoul. The usual material is a reddish brown (5YR 5/4) drift of sandy loam texture.

A number of major soil groups have been distinguished for these associations. They are described separately below.

Brown forest soils, freely drained. The Tarves series (Tarves Association) is representative of this major soil subgroup. A brief, generalized description is:

A	0-20 cm	Brown to dark brown (10YR 4/3) loam
B_2	20-50 cm	Strong brown (7·5YR 5/6) loam
B_3	50-70 cm	Yellowish brown (10YR 5/5) sandy loam; weakly indurated
C	70 cm +	Yellowish brown (10YR 5/4) sandy loam

Nine profiles were described and sampled for analysis. The A horizon has a pH of 5·5-6 in cultivated, and 4·5-5 in uncultivated soils; the base saturations are 30-60 per cent and 5-30 per cent respectively. In cultivated soils pH and percentage base saturation change little with depth, but in uncultivated soils the pH rises to about 5·5 in the C horizon where the base saturation is in the range of 5-40 per cent. The carbon : nitrogen ratio of the A horizon is in the range of 12-14 for cultivated soils. In uncultivated soils breakdown of organic matter is slower and the ratio is 17-24.

The freely drained brown forest soils of other associations are fairly similar to Tarves series, except for the Deecastle series (Deecastle Association) which is formed on limestone and on drifts derived from limestone. The pH of the A horizon is in the range of 5-7, and is usually above 7 in the C horizon which thus often has a base saturation of 100 per cent. The B horizon is less brightly coloured than the B horizons of other associations the chroma usually being 4 or less.

Freely drained brown forest soils occur below about 400 m (1300 feet) elevation, mainly in the Eastern Hills, but also in Strath Avon and elsewhere.

A variant within this group, marked by a highly organic surface horizon, is represented by the Leslie series (Leslie Association). A generalized description is:

H	18- 0 cm	Black (5YR 2/1) peat
B_2	0-45 cm	Brown (7·5YR 5/4) loam
B/C	45-75 cm	Yellowish brown (10YR 5/4) loam
C	75 cm+	Brown (10YR 5/3) sandy loam; merging into serpentine bedrock

This soil differs from humus-iron podzols and peaty podzols (described below principally in the chroma of the B_2 horizon, which is consistently 4 or less. Two profiles of the Leslie series were described and sampled. The pH of the peaty H horizon is about 5, rising to 6·5-7 in the C horizon; the corresponding base saturations are 20-30 per cent rising to over 90 per cent. The carbon: nitrogen ratio of the H horizon is 15-20. A feature of the series, and indeed of all the serpentine soils of the Leslie and Corriebreck Associations, is that amounts of exchangeable magnesium usually exceed exchangeable calcium even in the surface horizon.

The main areas of these soils are on Green Hill near Strathdon and in Glenkindie.

Brown forest soils, imperfectly drained. Most soils of this subgroup are cultivated. A generalized description of the Invernettie series (Insch Association) is:

A	0-45 cm	Very dark greyish brown (10YR 3/2) loam
$B_{(g)}$	45-65 cm	Yellowish brown (10YR 5/4) sandy loam; frequent dark yellowish brown (10YR 4/4) mottles
B_3	65-80 cm	Brown (10YR 5/3) sandy loam; indurated
$C_{(g)}$	80 cm+	Light olive-brown (2·5Y 5/4) sandy loam; frequent strong brown (7·5YR 5/6) mottles

Two profiles were described and sampled. The pH is between 5 and 6 and either rises or changes little with the depth. The base saturation is 40-70 per cent. The carbon : nitrogen ratio is about 12. Another series which has been mapped in the subgroup is the Thistlyhill series (Tarves Association), which tends to have a lower base saturation in the C horizon.

Imperfectly drained brown forest soils occur below about 400 m (1300 feet) in the Eastern Hills, mainly in the Strathdon area.

The imperfectly drained equivalent of the Leslie series above is represented by the Greenhill series of the Leslie Association.

A description is:

L and F	15- 5 cm	Very dark brown (10YR 2/2) fibrous organic matter
H	5- 0 cm	Black (2·5Y 2/0) peat
$A/B_{(g)}$	0-18 cm	Brown (10YR 5/3) loam; many strong brown (7·5YR 5/6) and light brownish grey (2·5Y 6/2) mottles
$B_{(g)}$	18-83 cm	Greyish brown (2·5Y 5/2) loam; mottles as for $A/B_{(g)}$ horizon
$C/D_{(g)}$	83 cm+	Partially-weathered serpentine

Samples from one profile have been analyzed. The pH rises from about 6 in the organic horizons to 6·4 in lower horizons. The base saturation rises from about 80 per cent in the L and F horizons to over 95 per cent in the lowest horizon. The carbon : nitrogen ratio of the L and F horizon is 22, and that of the H horizon is 11.

The series occurs mainly on Green Hill and in Glenkindie.

Humus-iron podzols, freely drained. The Strichen series (Strichen Association) is representative of this subgroup; a generalized description is:

L, F and H	5- 0 cm	Black (5YR 2/1) fibrous organic matter
A_2	0- 7 cm	Dark grey (10YR 4/1) sandy loam
B_{21}	7-10 cm	Dark reddish brown (5YR 3/2) humose sandy loam
B_{22}	10-35 cm	Strong brown (7·5YR 5/6) sandy loam
B_3	35-55 cm	Pale brown (10YR 6/3) sandy loam; weakly indurated
C	55 cm+	Light yellowish brown (10YR 6/4) sandy loam

Cultivated humus-iron podzols have been separated as phases of the series for a number of associations including Strichen; these have a brown mineral surface A horizon, incorporating the former organic and bleached A horizons. Five profiles of Strichen series were described and sampled. The pH of the uppermost horizon is around 4·5 (about 6 in cultivated soils) and is between 5 and 6 in the C horizon. The base saturation of the surface horizon is about 20-40 per cent (but over 70 per cent in cultivated soils) and that of the parent material 15 per cent or less. The carbon : nitrogen ratio of the surface horizon averages 28 in uncultivated soils, but is only 15 in those that are cultivated.

Freely drained humus-iron podzols are widely distributed over the area, although they are more common in the Eastern Hills than elsewhere. They occur at elevations below about 550 m (1800 feet). Cultivated soils are found below 400 m (1300 feet).

Humus-iron podzols, imperfectly drained. A description of the Obney series (Strichen Association) is representative of this subgroup:

H	13- 0 cm	Dark reddish brown (5YR 2/2) fibrous organic matter
$A_{2(g)}$	0- 9 cm	Very dark grey (10YR 3/1) sandy loam
$B_{2(g)}$	9-38 cm	Brown to dark brown (7·5YR 4/4) sandy loam; many greyish brown (10YR 5/2) mottles
$B_{3(g)}$	38-72 cm	Light yellowish brown (10YR 6/4) sandy loam; frequent strong brown (7·5YR 5/6) mottles; indurated
$C_{(g)}$	72 cm+	Yellowish brown (10YR 5/4) sandy loam

Most soils of the subgroup are cultivated, as were two of the three profiles which were described and sampled for analysis. The cultivated soils have dark greyish brown loamy A horizons which incorporate the former H and $A_{2(g)}$ horizons. The pH of the surface horizons is about 6-6·5, even in the uncultivated soil, which carried pasture recently improved from moorland. The pH in the C horizon is usually only slightly less, about 6. The base saturation in the C horizon is 100 per cent in the two cultivated soils but only 6 per cent in the uncultivated one. The carbon: nitrogen ratio of the A horizon is about 11, but is 24 in the H horizon of the uncultivated soil.

The subgroup is found mostly at elevations below 400 m (1300 feet).

Peaty podzols, freely drained below iron pan. The Charr series (Countesswells Association) is representative of this subgroup. A generalized description is:

H	20- 0 cm	Black (5YR 2/1) peat
A_{2g}	0-20 cm	Dark grey (10YR 4/1) gritty sandy loam
B_1	20 cm	Thin iron pan
B_2	20-45 cm	Strong brown (7·5YR 5/6) gritty sandy loam
B_3	45-75 cm	Brownish yellow (10YR 6/6) gritty sandy loam; indurated
C	75 cm+	Pale brown (10YR 6/3) gritty sandy loam

Four profiles were described and sampled for analysis. The pH of the H horizon is very acid, about 4; the value increases with depth and is about 5 in the C horizon. The base saturation is about 20 per cent or less in the H horizon, and is usually below 10 per cent in the C horizon. The carbon: nitrogen ratio of the H horizon averages 27.

Included in the subgroup are soils with a black peaty H layer about 10 cm thick or more overlying A_2 and lower horizons similar to those of

freely drained humus-iron podzols. In such soils an iron pan may not be present, and the A_2 horizon is often not gleyed.

Peaty podzols occur mainly in the elevation range of 400-550 m (1300-1800 feet).

Non-calcareous gleys, poorly drained. Representative of this subgroup is the Fisherford series (Foudland Association); a generalized description is:

A_1	0-20 cm	Dark grey (10YR 4/1) loam
A_{2g}	20-45 cm	Grey (5Y 5/1) loam; frequent strong brown (7·5YR 5/6) mottles
B_g	45-80 cm	Dark greenish grey (5BG 4/1) loam; mottles as for A_{2g} horizon
C_g	80 cm +	Dark greenish grey (5BG 4/1) sandy loam; frequent yellowish red (5YR 4/6) mottles

Three profiles were described and sampled for analysis. The pH of the A_1 horizon is 5-6, rising to pH 6-6·5 in the C_g horizon. The base saturation tends to increase from an average of about 35 per cent in the uppermost horizon to 40-70 per cent in the parent material. The carbon:nitrogen ratio is low, between 9 and 15.

In this subgroup many soils show a gleying maximum in the A_{2g} horizon, downward movement of water being restricted by compact or indurated lower layers.

Non-calcareous gleys are found mainly below an elevation of 450 m (1500 feet).

Peaty gleys, very poorly drained. The Pettymuck soils (Tarves Association) is representative of this subgroup. A generalized description is:

H	25- 0 cm	Very dark brown (10YR 2/2) peat
A_g	0-15 cm	Grey (5Y 5/1) loam
B_g	15-70 cm	Greenish grey (5GY 5/1) sandy loam
C_g	70 cm +	Greenish grey (5G 5/1) sandy loam

Three profiles were described and samples were taken for analysis. The pH tends to rise with depth from pH 4-5 in the H horizon to pH 5-6 in the C_g horizon. The base saturation shows no clear trend with depth, and lies within the range of 10-70 per cent. The carbon:nitrogen ratio of the H horizon is about 20.

Soils containing ultrabasic material (Charleston and Lochain series) have large amounts of exchangeable magnesium relative to exchangeable calcium and usually have base saturations of over 70 per cent.

Peaty gleys have a wide, but local, distribution in the area. They tend to be less common below about 400 m (1300 feet).

Subalpine podzols, freely drained. These soils can be regarded as inter-grades between humus-iron and peaty podzols, and alpine soils. The

Kichanroy series (Strichen Association) is representative of the subgroup; a generalized description is:

L, F and H	3- 0 cm	Black (5YR 2/1) humus
A_2	0-10 cm	Dark grey (5YR 4/1) sandy loam
B_{21}	10-20 cm	Black (5YR 2/1) to dark reddish brown (5YR 3/2) humose sandy loam
B_{22}	20-35 cm	Brown to dark brown (10YR 4/3) sandy loam
B/C	35-70 cm	Yellowish brown (10YR 5/4) fine sandy loam; well-developed silt caps on stones
C	70 cm+	Yellowish brown (10YR 5/4) sandy loam

Three profiles were described and sampled for analysis. The pH of the organic surface horizon is about 4, rising to about 5 in the C horizon. The base saturation is in the range of 11-17 per cent in the surface horizon; it falls with depth to below 5 per cent, but rises again in the C horizon to an average of 10 per cent. The carbon:nitrogen ratio of the organic surface horizon averages about 25.

Subalpine podzols occur in the elevation range of about 550-700 m (1800-2300 feet) although locally, for instance on the relatively sheltered eastern slopes of Ben Avon, they are found as high as 850 m (2800 feet).

Alpine soils, freely drained. The Rinnes series (Countesswells Association) is representative of the subgroup; a generalized description is:

L, F and H	2- 0 cm	Black (5YR 2/1) humus
A_2	0-10 cm	Very dark grey (5YR 3/1) humose gritty loamy sand; abundant bleached sand grains
B_{21}	10-40 cm	Black (5YR 2/1) humose gritty loamy sand; mineral grains coated with organic matter
B_{22}	40-50 cm	Dark brown (7·5YR 3/2) gritty loamy sand
B/C	50-80 cm	Yellowish brown (9YR 5/4) gritty sandy loam; well-developed silt caps on stones
C	80 cm+	Yellowish brown (9YR 5/4) gritty loamy sand

Five profiles were described and sampled for analysis. The pH of the organic surface horizon is about 4, rising to about 5 in the C horizon. The base saturation is 5-20 per cent in the surface horizon, falling with depth and is usually below 5 per cent in the parent material. The carbon:nitrogen ratio of the organic surface horizon averages about 25.

Alpine soils are found at elevations above about 600 m (2000 feet).

Soil complexes. A number of complexes have been distinguished, most comprising one or more of the major soil groups already described, together with other components:

(a) Complexes of alpine soils and peat

(b) Complexes of alpine soils, rock and boulder lobes

(c) Complex (distinguished for the Countesswells Association only) of gleyed soils, peat and alpine soils

(d) Complexes of rock crags and scree on very steep (usually >35°) slopes
(e) Complexes of peaty podzols, subalpine podzols and peat
(f) Complexes of humus-iron podzols, peaty podzols and other soils on steep scree-covered slopes
(g) Complexes of humus-iron podzols, peaty podzols and other soils on frequent rock outcrops.

Other Soils

Peat. Two mapping units have been used for peat: basin, valley and terrace peat, and blanket peat. Basin, valley and terrace peat occurs at lower elevations, usually below 450 m (1500 feet). This peat is most extensive in the Dorback area and in the Cabrach basin, with smaller areas in the valley floors of the rivers and their tributaries. Nearly all the peat is over 1 m deep. Blanket peat is extensive in the elevation range of 450-700 m (1500-2300 feet) where the slope is less than 8°. There is very little peat above 850 m (2800 feet).

Four profiles were described and sampled for analysis. Throughout the peat, the pH is about 4 and the base saturation is about 10-20 per cent. In common with the organic surface horizons of the podzols and the peaty gleys already described, the peat usually has a higher content of exchangeable bases (measured per unit weight of soil) relative to mineral horizons. Because of their much lower density, however, peat and organic surface horizons are usually poor suppliers of nutrients for plant growth. The carbon : nitrogen ratio of the peat is usually between 30 and 40.

Alluvium. Five named series have been distinguished, differentiated by the texture of the topsoil and the drainage class. The most extensive series is Culnacoyle, developed on a freely drained sandy alluvium. The other series are formed on freely drained gravelly alluvium, on imperfectly and poorly drained sandy alluvium, and on imperfectly drained loamy alluvium. Three other mapping units have been distinguished: undifferentiated alluvium, undifferentiated alluvial fans, and peat-alluvium complex. The main areas of alluvium are in the valley floors of the Rivers Spey, Don and Avon.

Fourteen profiles were described and sampled for analysis. Thirteen of the profiles are on cultivated land, and thus have surface horizons which are only moderately acid, pH 5-6·5. In general, the pH level is maintained with depth. One profile is an uncultivated peaty alluvium, which has a pH of 4 in the organic surface horizon, rising to 5 in the C horizon. The base saturation of the cultivated soils is usually 50-80 per cent in the surface horizon, declining generally to below 50 per cent in the C horizon. The uncultivated soil has a base saturation of 16 per cent in the organic surface layer; the base saturation falls to 5 per cent with depth, but rises again to 12 per cent in the C horizon. The carbon : nitrogen ratio is 10-15 in the A horizon of the cultivated soils, and is about 20 in the surface horizon of the uncultivated peaty alluvium.

Other mapping units. Mixed bottom land, mainly comprising narrow stream channels, and quarries and disturbed ground have been mapped. In the Dorback area, some stabilized windblown sand has been mapped.

One profile, on windblown sand, was described and sampled for analysis. The pH is 5-5·5 in the surface horizon, rising to 5·5-6 at depth. The base saturation is about 40 per cent in the surface layer, falling to below 20 per cent in lower horizons. The carbon : nitrogen ratio of the surface horizon is 11.

Vegetation

Rotational and grass pastures that are periodically renewed by ploughing down and reseeding usually carry the typical subassociation of the Lolio-Cynosuretum association, rye-grass—crested dog's tail pasture. The soils include humus-iron podzols, freely and imperfectly drained brown forest soils and non-calcareous gleys. A wet variant of the community, usually on non-calcareous gleys, has a proportion of soft rush, *Juncus effusus*.

The most extensive of the natural and seminatural plant communities in the area is the Empetro-Ericetum cinereae association, boreal heather moor, found on brown forest soils, humus-iron podzols, peaty podzols and subalpine podzols. On blanket peat the most frequent community is the subassociation with *Vaccinium vitis-idaea* of the Vaccinio-Ericetum tetralicis association, upland blanket bog. Above about 700 m (2300 feet) blanket peat carries the *Rhytidiadelphus loreus—Sphagnum fuscum* community, mountain blanket bog. The cloudberry, *Rubus chamaemorus*, is present in both communities but not on basin, valley and terrace peat where the usual association is Erico-Sphagnetum magellanici, blanket and raised bog. On alpine soils the *Empetrum hermaphroditum—Rhacomitrium lanuginosum* community, crowberry—woolly fringe-moss heath, is common.

The best sheep and cattle grazing of the area, apart from the ley pastures, is provided by the pasture on the brown forest soils of the Deecastle series, around Inchrory in Glen Avon. The limestone soil carries a species-rich community, as yet un-named but which has affinities with the English limestone grassland communities. The plants include the fescues *Festuca ovina* and *F. rubra*, meadow oat *Helictotrichon pratense*, common rock rose *Helianthemum chamaecistus*, and spring sedge *Carex caryophyllea*.

The woodland communities distinguished include *Erica cinerea—Pinus sylvestris* (bell-heather—Scots pine plantation), the *Betula pubescens* community (heathy birchwood), and the Galio saxatilis—Quercetum association (oakwood). The soils are usually humus-iron podzols in the plantation and heathy birchwood communities, and brown forest soils in the oakwood.

Land Use Capability

The capability of the land for agricultural use has been provisionally assessed. The highest class distinguished is Class 3, which has been mapped below about 305 m (1000 feet) on suitable soils and relief. The most extensive area is in the Spey Valley with smaller areas in the Don and Dee Valleys and in Strath Avon. The land is cropped regularly, but is only marginally suitable for Class 3, indeed some may be finally assessed as Class 4, because of the short growing season and consequent late harvest. The soils are mainly brown forest soils, cultivated humus-iron podzols, non-

calcareous gleys and alluvium. Some areas of humus-iron podzols in the Spey Valley, at present used for forestry and rough grazing, have also been assessed as Class 3 land.

Class 4 land, suitable for permanent pasture and for occasional arable cropping, has been mapped below about 400 m (1300 feet). The main areas are on Donside, Glenlivet, Strath Avon and the Cabrach area. Frequently, climate is the main limitation rather than the soil, and the land has then been rated as Class 4c. The soils are mainly brown forest soils, humus-iron podzols and non-calcareous gleys.

Class 5 land, suitable for use as improved grazing, has been mapped below about 500 m (1600 feet) chiefly in the Strathdon and Tomintoul areas. The soils are humus-iron podzols, brown forest soils, non-calcareous gleys and, on lower ground, peaty podzols. Peaty podzols on higher ground have been provisionally excluded from this class, because it is difficult to maintain good improved pasture on the wet peaty surface horizon.

Class 6 land, suitable for use only as rough grazing, has been mapped below about 700 m (2300 feet). Such land is widespread, and the class is the most extensive one. The soils are mainly peats and peaty podzols, but also include peaty gleys, subalpine podzols and, on steep or stony land, humus-iron podzols and brown forest soils.

Class 7 land, with no or very little grazing value, has been mapped above about 700 m (2300 feet). The most extensive area is in the Cairngorm Mountains. The soils are mainly alpine soils, but also include the subalpine soils of the Durnhill and Countesswells Associations and the complexes that have rock or scree.

9. LIBRARY

MRS J. M. D. ALCOCK

The reorganisation of the Annex, to make room for older stock from the Main Library, was completed in July. This work was carried out with the help of students on practical placement from the School of Librarianship, Robert Gordon's Institute of Technology.

Extensive use was made of the library by staff, visiting research workers and students and staff from nearby establishments. The level of borrowing from external sources increased by 30% over the previous year. 1186 items were borrowed of which 600 were from the British Library Lending Division. 128 items were lent out to other libraries in response to 229 requests. 286 books were added to stock. The Library Committee decided to discard runs of several little-used non-current journals to provide more space. They also agreed to cancel Biological Abstracts and substitute several primary journals.

The two current awareness Bulletins produced by the library became well established during the period. The Periodicals Bulletin was distributed regularly each week while the Book Bulletin appeared every two months. Although they are regarded primarily as internal publications, copies are also distributed to the other Scottish Institutes and to local research establishments.

Ninety copies of the Collected Papers of the Macaulay Institute for Soil Research volume XI, 1973-1975 were published in May. Thirty-two were distributed on exchange to other libraries and 18 were sold for £6.00 each. A few copies are still available for sale; as are several of the previous volumes. A List of Available Publications was mailed in August and there has been a high response. Anyone wishing to receive a copy of this list should apply to the Librarian.

In March a Weber Minigraph Duplicator was purchased. This has greatly improved the standard and efficiency of catalogue card reproduction. During the period the School of Librarianship, Robert Gordon's Institute of Technology offered on-line facilities for information searching *via* DIALOG. Three queries have been searched to date; all fairly successful and relatively inexpensive.

10. TECHNICAL SERVICES

MR A. W. STUART

At present Technical Services is divided into three sub-sections, namely Instrumentation, Electronics and Photography. During the past three months the work output of all three sections has been reduced due to construction of a new extension to the existing workshop complex. This extension is now in its final stage of completion and the three sub-sections are endeavouring to become fully efficient as soon as possible.

The main function of Technical Services as a whole is to assist the various departments throughout the Institute to operate smoothly and efficiently, by designing and modifying instruments and equipment, both mechanical and electronic, and providing photographic records of specimens and field experiments, illustrations for scientific publication and visual aids for lectures. Minor building maintenance and laboratory refurbishing is also undertaken by Technical Services.

INSTRUMENTATION

This section has a well equipped machine shop, a sheet metal shop, plastics shop and paint spray shop and during the past year the section has handled 500 jobs of varying nature, from building and plant maintenance to scientific aids and instruments. Some examples of work carried out for various departments are as follows:

Spectrochemistry. A stainless steel burner unit for atomic absorption using concentration by atom trapping on a water-cooled silica tube fitted with X-Y movements; development of a special tool for producing by injection moulding a satisfactory polythene mould for the manufacture of pressed sample electrodes for the Spark-Source Mass Spectrometer; the manufacture of natural gas Meker burner units; fluorescence heat pipes, pin hole mount with X-Y movements, camera and laser trigger mount, adjustable Pellicle mount and an adjustable Prism table for the dye laser project;

Pedology. A controlled atmosphere cleaning chamber for the pre-treatment of Pyrolysis wires by heating to high temperature in hydrogen;

Soil Survey. The construction of a gamma meter probe locating platform for the Survey's Edinburgh Office; bending jigs for producing aluminium sample cases, an attachment for the diamond saw to produce thin sections, also a vacuum chuck designed to receive the mounted thin sections for finish grinding. The chuck was experimental and proved very successful and the intention is to produce one large enough to take four large sections or 16 slide type sections.

Under construction there is a triple monochromator mount, to determine the major elements using high temperature techniques, a water-cooled " 100 transistor " bank for current regulation of the DC Arc (Spectrochemistry) and a multiple magnetic stirrer (Soil Organic Chemistry).

In the near future it is hoped to begin construction of a rotating swivel

mount for a two metre long reflecting telescope (Spectrochemistry Laser project) and also a pneumatic sampling instrument (Soil Fertility).

ELECTRONICS

This section is a relatively new one and over the past year there has been a steady increase in the demand for repair and maintenance work which is due, only in part, to the withdrawal of manufacturer's service contracts. Modifications have also been carried out on new pieces of equipment in order to make them compatible with existing systems. In this connection, development work has been carried out in the production of printed circuit boards, which have proved invaluable in constructing new or ancillary circuits. Development work is being continued since it is foreseen that an economical, simple method for producing complex double-sided printed circuit boards for data handling systems will inevitably be essential.

Circuits produced have included a range of both analogue and digital timers, impedance converters and digital interfaces.

It is proposed that the Intel 8080A Microprocessor Unit, acquired during this past year, will be set up and evaluated during 1978. This, it is hoped, will result in an economic alternative to commercially built data handling and control units, being made available for use in the Institute.

PHOTOGRAPHY

The section is responsible for providing the eight departments of the Institute with the photographic recording of routine specimens and field work, illustrations for scientific publications and visual effects for lectures.

During the past year the Cibachrome process of producing colour prints direct from colour transparencies was evaluated and should prove a useful method of providing illustrative information.

Examples of the type of work carried out by this section may be detailed as follows: 16 mm Ciné films were made for Forest Soils Section (Pedology) to show some aspects of the study of the nutrient cycle in forests, and for Microbiology to record disease patches in the pea field due to the pathogen *Sclerotinia Sclerotiorum* and macrophotography of the damage to the individual plants.

Low level oblique aerial photography and false colour photography from multi-band spectral satellite imagery was undertaken to assist in the research of survey evaluation and classification by remote sensing and aerial photographic methods, for Peat and Forest Soils Section (Pedology).

The Information Officer was provided with photographic prints depicting the diverse nature of the work of the various departments for exhibition and display boards.

In 1978 the section will be involved in the re-organisation of the lecture and audio-visual facilities in the Auditorium in Craigiebuckler House.

APPENDIX

SECOND

T. B. MACAULAY LECTURE

24th NOVEMBER, 1977

AMATOLA HOTEL, ABERDEEN

by

PROFESSOR E. W. RUSSELL, CMG, DSc, FInstP, FIBiol, FIAgrE

Chairman:

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

SECOND T. B. MACAULAY LECTURE

Aberdeen, 24th November, 1977

SOIL SURVEY METHODOLOGY AND AGRICULTURE

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Professor Emeritus, University of Reading

I have chosen this topic as the subject of my address both because soil survey has been a major concern of your Institute since its foundation and because many new ideas are being discussed at the present time on how to carry out soil surveys to make this work meet, as effectively as possible, the needs of the users of the soil and in particular the needs of agriculture and forestry. It is also a particularly fitting topic for another reason, because your founder Director, Sir William Gammie Ogg, broke completely new ground when he decided that soil survey was a proper study for an agricultural research institute. I feel certain that it was the success of this department, under the late Dr Alex Muir, that helped Sir William to play such a leading role in getting soil survey accepted by the Agricultural Research Council and your Department of Agriculture and Fisheries as an essential activity in any agricultural development or land use policy programme. The older members of this audience will remember that when Sir William moved to Rothamsted in 1942 he took Dr Muir with him to organise and head the Soil Survey of England and Wales. At the same time the Agricultural Research Council set up the Soil Survey Research Board, with Sir William as Chairman, whose function was to keep under review both the policy of the two Soil Surveys and the methodology of the practice of soil survey. This Board remained in existence until the Rothschild reorganisation of agricultural research, when the appropriate interests of the Board were taken over by the Soil Science Committee of the Arable Crops and Forage Board of the JCO; and I can assure you that this committee is continuing to take very seriously its responsibilities in this field.

The primary function of our two Soil Surveys is to make an inventory of the soil resources of Great Britain with particular reference to their value for crop production. I have inserted this apparent restriction because the Surveys are paid for out of agricultural funds, but if you look at the reports issued by the Surveys you will see that the interests of forestry are not neglected.

There are three major groups of problems involved in carrying out these surveys. The first includes the way the soil profile is to be described, which involves the selection of those particular properties of the soil profile, from out of the almost indefinite number of properties that could be observed and measured, that are of most relevance to the survey. The second involves the way soils with these various properties are to be grouped into classes or types, and the third is that of mapping the areal distribution of these types.

These three groups of problems are not independent, for the soil characteristics used to describe the soil profile, and the system of classifying

soils are obviously inter-related, as are the problems of classification and mapping. In particular the scale the map is to be produced at determines, to a considerable extent, the system of classification to be adopted. Thus a system appropriate to the mapping of soils in a given district is unlikely to be appropriate for mapping the distribution of the soils over the world.

The Problems of Soil Classification

I want to begin by discussing the second group of problems, those dealing with soil classification, as these are central to all problems of soil survey, and they also illustrate very well the central problems facing soil surveyors in the field. The primary philosophy of soil classification is still subject to debate, for it poses the question of whether a soil survey is an end in itself, or whether it is carried out for a given purpose. There is no conflict between these two objectives if the soil characters chosen for the profile description include those relevant for all possible uses of the soil; but this is clearly an unattainable ideal unless we know what are all the uses that will be made of the soil and the soil properties relevant to each of these uses. Classification must, therefore, be based on a selection of soil characters, and the selection made on the basis of characters that are readily observable or measurable, or on characters known to be important if the survey is made for a particular purpose. The major use of soils in this country is for the growth of plants, whether they are agricultural or horticultural crops, forests, or the vegetation of our rough grazings; and it is for this reason that the British Soil Surveys have been financed by the Government out of the national agricultural or agricultural research budgets. But land can also be used as a source of water for rivers and underground aquifers, as a foundation for buildings and roads, for leisure and for pipelines.

A major problem in soil classification can be stated immediately. No two soil profiles are exactly alike, it is only necessary to look at the side of a trench dug for laying a pipeline to see the considerable and continuous variation in the profile from metre to metre along the trench, and to note that very rarely is there any sharp break in the visual appearance on the trench side. Soil classification thus differs fundamentally from the classification of most living organisms, for the unit of classification must include a group of defining profiles with the range of variability in profile properties that can still be associated with these profiles. Variability is thus inherent in soil classification and the amount to be allowed in any soil class depends on the minimum area of land that must be mapped as a single unit, that is on the scale of the soil map that is to be produced. For many agricultural purposes, the unit of area of importance is the typical smaller field, which is usually of the order of 2-5 hectares; and the unit of classification on this scale is the soil series. The series is typically defined in terms of profile characters that can be readily observed in the field or rapidly measured in the laboratory using relatively simple equipment; and many of these characters have obvious agricultural significance, such as the texture, drainage status and structure of the soil.

This brings me to the fundamental problems of classifying soils into series, which is that of deciding how to choose the profile characters which

should be used, and their range of variability that should be accepted, when defining the range of soils to be included in a given series; for it is not obvious that there are any fundamental criteria available on which to base these decisions. There was, in the past, the feeling that the division of soils into series reflected an inherent property of soils, largely irrespective of what particular characters one chose for defining the series. It was agreed that some properties were more useful as discriminants than others, but I think there was little doubt in the minds of many surveyors that soils belonging to different series were inherently different, though with additional knowledge it might be necessary to subdivide a series. But there is no *a priori* reason for believing that separating out soils on the basis of what the surveyor can fairly readily see in the profile face will necessarily be appropriate for all the uses that will be made of the soil, and if this view is taken it means that it is not possible to separate out the problems of classification from those of land management. It is for this reason that there has been a tendency in the Soil Surveys to accept that the problem of deciding on the full definition of the range of soils to be included in a given series is not one solely for the Survey to decide, but that the views of some of the users of the soil should be considered. I believe this consultation has been best developed with land drainage engineers and consultants and with members of the agricultural advisory services concerned with drainage[1].

There is a second major factor that complicates soil classification, for our knowledge of the soil is not static, but is continuously increasing. Soil survey has been active in this country for over 40 years, and during this time great advances have been made by the large number of research workers in the fields of soil genesis, soil fertility and crop production; so we now know a great deal more about the ways soils are formed and the soil conditions conducive to high crop yields than we did when soil survey was first seriously started. This has resulted in the soil surveyor being able to give a much more detailed description of what he can see in the profile, for the more that is known about the genesis and behaviour of the soil, the more the eye of a trained surveyor can see in the profile. It has also resulted in a laboratory worker being able to measure more and more soil properties known to be of agricultural significance. This poses a very important problem in soil classification policy, for it is arguable that the basis of classification should be continuously modified to incorporate this new knowledge. It is interesting to note that the validity of the separation of soils into definite soil series is continuously being tested using characters that can be observed with new methods for visually observing the soil structure and for determining the constitution of the clay fraction in the soil, but much less attention has been paid to the significance which advances in the understanding of the factors affecting soil fertility can have on classification.

Very difficult problems must face the soil surveyors if they try to incorporate relevant current advances in soil science, crop production and land management into their system of classification; for a considerable measure of conservatism in the definition of a soil series is essential if the system of classification used by the Surveys is to be accepted by the farmer, his adviser and the land use planner. Nothing would be more fatal to the

acceptance of the work of the Soil Surveys than the regular re-classification of soils into new groups of series based on defining properties not previously measured, so preventing the re-allocation of soils already classified on the basis of the old series definition to the newly defined series.

There are two separate and important problems that will need continuous attention in the future, namely how far will it be worth while maintaining classification into previously defined series when new knowledge shows that the series contains disparate groups of soils for some land management purposes, and how far will it be possible to devise flexible systems of classification that can be continuously modified to incorporate all relevant advances in our understanding of the inter-relations between classifiable soil properties and the practical problems of land use. The answer to the first problem will be found through the day-to-day contacts between the Surveys and the user of their work. Answers to the second problem are being developed as the Soil Surveys are looking into the role that computers can play in helping them carry out their tasks more efficaceously. One role being developed actively is the use of computers for testing the value of various statistical techniques, such as multiple discriminant analysis, to the problems of soil classification.

The Application of Multiple Discriminant Analysis in Soil Classification

During the last 10 years there has been considerable interest in the application of the modern statistical techniques of multi-variate and multi-discriminant analysis to the problems of soil classification. For these purposes, the soil profile is characterised by the measured value of a set of soil properties that should be of relevance to the purpose of the survey. For agricultural purposes these could be texture of the horizons, depth of horizons, organic matter content, and structure. The statistical techniques can be used to show how far the soil profiles in a given area can be considered to belong to a single group with a fairly wide scatter of properties, or how far they cluster naturally into several distinct groups with possibly only a few soils intermediate between these groups, based on an analysis of the degree of similiarity or dissimilarity of the profiles from each other when all the measured properties are considered, and not only on those used to define the series.

Mr Muir of your Institute and his colleagues were among the first to look at the value of these methods of analysis for the separation of soils into classes using a large number of profile sites and a large number of soil properties for each profile[2]. Since then, the Survey of England and Wales have extended this work, using sampling areas of under 100 square kilometres. Let me give three examples of this examination. The first is from an area on the Berkshire Downs near Lambourn, where the soils are developed on the Chalk. The majority of the profiles were classified into one of three Series, the Coombe, the Icknield, and the Charity. The soil profiles were characterized by 17 properties, 10 in the surface horizon, of which 8 were determined in the laboratory, and 7 in the subsurface, of which only 2 were determined in the laboratory. Six profiles in each series were designated by the Survey as typical of the series. The analysis

showed that nearly all the other profiles fell within the range expected from the designated profiles, but there were a few well separated from the three main groupings, so definitely intermediate between the series, and a very few classified as belonging to one series that fell into a group characteristic of another. The analysis also showed that if an improvement in classification was needed, the soils should be grouped into seven classes instead of three, any smaller number not giving an appreciably better separation[3]. My second example comes from Oxfordshire for an area on limestone gravels. Most of the profiles were again classified as belonging to one of three series—the Carswell, the Kelmscott and the Bardsey. An analysis using a similar though not identical set of soil properties was made, which showed that almost all the profiles classified as Bardsey fell within one distinct group, almost all those as Carswell into another, but whilst the majority of those classified as Kelmscott fell into a third distinct group, an appreciable proportion fell into the Carswell group. The Carswell were described as gleyed brown calcareous soils and the Kelmscott as calcareous gleys, so here the use of a wider range of soil properties definitely alters the groupings into which these gleyed soils fall[4].

My third example also comes from southern England and illustrates the problem of whether too wide a range of properties are included in a given series. The Denchworth Series is recognised on Oxford, Kimmeridge and Gault clays, and the question investigated is whether it is justifiable to ignore changes in parent material. Three separate groups of statistical analyses were made; the first was based on 16 typical properties described by the surveyor in his examination of the soil profile, the second on 16 typical laboratory measurements on profile samples, such as percent silt and clay, loss on ignition, pH, cation exchange capacity, bulk density, stoniness and soluble and total P; and the third used the elemental constitution of the soil as measured by 8 major and 13 trace elements as well as 7 properties from the previous group. These were all determined for the top three horizons, and 10 profiles were chosen on each parent material. Of these 30 profiles, the field surveyors considered 8 fell outside the limits used for defining the Denchworth Series in the field[5].

The results of this examination showed that, based on field descriptions of the profiles, there was no justification for splitting the series on the basis of parent material. But on the basis of the laboratory properties, most of which are of agricultural significance, the profiles on the Gault and the Oxford Clays were well separated, but those on the Kimmeridge were almost evenly divided between these two groups[6]. However on the basis of chemical constitution, the profiles fell into three distinct groups, based on parent material[7]. It is interesting to note that in none of these examinations did the eight aberrant profiles stand out as intermediate between the main groups. This analysis shows that there is no unique system of soil classification: there are a number dependent on what particular soil properties one is interested in. In the case of the Denchworth Series, visible profile characteristics allow all the profiles to belong to one group, in so far as the laboratory properties are of agricultural significance the profiles belong to

two groups, whilst changes in parent material are reflected in the overall chemical constitution of the soil.

These statistical techniques of comparing similarities between soil profiles are likely to be valuable for a related purpose, namely to give a quantitative measure of the amount of variation that must be included in any definition of a soil mapping unit or series. Soils are continuously changing in the field from site to site. One can arbitrarily agree that in general the amount of variation found between soil profiles in a circle of say 10 metres diameter will measure the minimum inherent variability in profile properties within the Series the soil belongs to. This statistical technique thus allows a quantitative measure of the minimum amount of variability or "noise" that must be accepted in any definition of a soil classification unit, and it is interesting to note that in the Oxfordshire area, the variability between profiles over a fairly wide area belonging to the same series, if the series is properly defined, may not greatly exceed that within the area of about 100 square metres around a typical profile[8].

The use of these statistical techniques to help assess how wide a range of soil properties should be accepted in the definition of a soil series does not preclude the series being sub-divided into phases based on making an arbitrary division in a property of agricultural importance within the range of its variation. Subdivision on the amount of stones, or on minor changes of soil texture are examples of phases that are commonly used.

Soil Mapping

So far I have dealt with the problem of soil classification, and I now want to look at some of the problems of soil mapping. Typically the problem facing the soil surveyor, when making a soil map, is that of delimiting on the ground the boundary between two series, whose definitions have already been agreed, for it is the boundaries that are shown on the map; and I want to begin by emphasising the difference between classification and mapping. We have seen that the definition of a soil series must include a statement on the range of variation in the soil profiles that can be included in the series. But it often happens that the range of variation in the profiles in a restricted area, say a single field, is greater than is allowed for in the series. If most of the profiles in that area conform to the series description, the area will be mapped as belonging to this series. In this sense the Series name is a mapping unit, for it may contain soils that do not belong, in which case the mapping unit will contain a certain proportion of aberrant profiles as an impurity. The inclusion of impurity in a mapping unit has always been accepted as inevitable, but there is a policy decision to be made by the surveyor on the amount of impurity that can be accepted in a mapping unit. If the observed variations in soil properties are randomly distributed among the characters defining the series, these variations really constitute noise, and show that, for this particular area, the series definition is too narrow. If the variations are systematic, the aberrant soils may fall within one or more other series and the mapping unit can be described as possessing a given proportion of soils belonging to these series, though the actual areas occupied by them are too small to be shown on the map. If the proportion

of aberrant profiles is high, or if they occur systematically over the area, the area will be mapped as an association of different soil series not individually separated on the map.

Decisions on the proportions of aberrant profiles that may be included in a mapping unit, and the accuracy with which this proportion is to be estimated, should be agreed when the survey is being planned; for the more accurately the proportion of aberrant profiles is to be assessed, the more sampling sites must be examined, and the slower and the more expensive the survey. Decision must obviously depend on the scale of mapping to be used: a map on the scale of 1 : 10 000 is likely to have mapping units with less impurity than if the scale is 1 : 50 000.

The role of the computer in soil mapping is still very much a matter for research. Experience to date has shown that it has no appreciable advantages over existing practice for the production of the master copy of the soil maps as at present published by the Surveys. One role for which the computer is well adapted is to locate on the map the point corresponding to the position of the sampling site in the field and print a symbol on this point representing the particular soil property being mapped. A trivial example is when this property is simply the soil series name fed into the computer as an input. But a more important use is where the soils are to be re-classified on a basis different from that of the series, whether this includes additional properties to those used in the series description, or only a few simple properties, such as texture and drainage class, for example. It can be programmed to check if the system of classification adopted is the most suitable for the region, based on an examination of the similiarities between profiles when judged on whatever set of profile properties is fed into the computer, as already noted. It can be programmed to draw boundaries between soil mapping units, provided sampling sites are sufficiently close together to justify this, and it can be programmed to select mapping units that contain any pre-selected degree of impurity[9]. Thus the computer allows the Survey to produce rapidly maps showing the distribution of soils having any set of properties desired by the user, together with an estimate of impurity, based on the sampling sites in the region. But the value of the computer here depends entirely on the density of the sampling sites and the amount of soil data available for each site.

The Choice of Sampling Sites

The introduction of the computer into soil survey procedures raises the whole question of the most efficient way of choosing the sites of the profiles to be described. The computer can only be used to give unbiased estimates of such properties as the range of variability of the soils of an area, or the areal distribution of soils with any given set of soil properties, if the sampling sites cover the area in a fairly uniform manner. The principal methods that have been used involve either sampling at the points of intersection of a square grid, or at uniform distances along traverses chosen to reflect the principal features of the lanscape. Such methods have been in regular use in developing countries for surveys carried out in flat alluvial areas and in bush country where tracks have to be cut to allow access to the

area. They have only been used in a few selected areas in Great Britain, and for large scale mapping have about the same predictive value as normal sampling for the properties of the profile at sites that had not been visited, for equal number of sampling points per square kilometre, except when there were visual external features controlling the soil boundaries[10].

The Purpose of a Soil Data Bank

An important byproduct of a soil survey is that the observations made on a soil in the field and in the laboratory are tabulated in a systematic manner and can be fed into a data bank. A data bank is simply a file that holds all the available data relevant to the soil at particular sampling sites. When consulted, it will give information on the measured properties of the soils at these sites, or will give the location of sampling sites whose soils possess any given set of properties. It does not need to be associated with a computer, for if it is not too complex it can simply be a collection of suitably punched cards.

A soil data bank can have an additional value if the location of sampling sites is sufficiently close to justify the assumption that the samples fairly reflect the distribution of soils in the region, for it is then possible to link the bank up to a computer so that an estimate can be made of the area occupied by soils with any selected properties, and the computer can also be programmed to draw isorithm maps, that is maps on which lines are drawn on which the selected soil property, or group of properties, has a constant value. But the validity and the accuracy of such maps depends on the samples giving an unbiased representation of the soils of the region and on the density of sampling sites, that is the number of sites per square kilometre, which in turn depends on considerations of the acceptable cost to the community of setting up these banks.

Soil data banks are only just beginning to be set up in Great Britain, and they are still being thought of in terms of retrieval of data from a file or as a source of data for studying the inter-relations between soil properties. We have had no experience yet of the demands agricultural advisers and other users of the soil will make on them or of the kinds of soil data they should contain if they are to be of maximum value to the potential users. Again, the more data they are to contain, the more expensive it will be to obtain the necessary data to feed into the bank, and the larger and more expensive must be the computer and its peripherals for the extraction of any particular piece of information. But the Agricultural Research Council is funding a research project under Dr Beckett of Oxford University to look into the problem of using data banks to give information on the distribution of soil properties over a region, and the conditions under which they can be used for predicting soil conditions between sampling points. The project covers an area in Oxfordshire and adjacent counties that has been very intensively surveyed over a number of years, and for which there is a great deal of analytical data available for most of the samples; but during the course of these surveys, the surveyors have been using somewhat different methods of description and analysis, so that input data to the bank is far from homogenous. Thus the definitions of silt and

fine sand have altered over the period covered, as has the method for estimating organic carbon. Thus the project is concerned with handling not strictly comparable data, with the intensity of sampling sites necessary for a given accuracy in determining soil distribution patterns, with interpolations between sites, and with the kind of information users are likely to ask for from the bank.

Soil Survey and the Quantitative Determination of Soil Properties

The Soil Survey is the only organisation that is systematically examining all the soils of this country, so the soil profiles they sample for laboratory analysis constitute the principal source of quantitative information on their properties. The analyses should, therefore, include as many properties of the profile known to be important for crop production and for the health of the stock feeding on them. These are problems that also involve the advisory chemists, but whereas the chemists are concerned with variations in those properties which can be modified by day-to-day management practices, the Survey must be concerned with properties largely independent of these practices, for they can only repeat the survey of a region after a great many years. Thus the profile properties they measure should be inherent in the soil itself and not be too strongly dependent on the current system of land management; so it is probable that more subsoil than surface soil properties should be assessed by these analyses.

Soil properties relevant to crop growth and to land management fall into three broad categories: those dependent on pore space distribution and consistency, those dependent on nutrient supply and the presence of toxins, and those dependent on the activity of the soil population. This last group are probably so dependent on the detailed system of land management adopted, that they are unlikely to contribute any properties worth measuring quantitatively. The second group—the factors controlling nutrient supply to the crop, are largely the advisory chemists' concern under conditions of high fertilizer use, though inherent soil properties may affect both the most economical ways to use them, and their residual value for subsequent crops. I believe enough is now known about the phenomena of potassium fixation and release to decide what soil properties affecting these should be measured, as soon as it is agreed that they are sufficiently important to be worth measuring, but I doubt if enough is yet known about the corresponding phenomena for phosphates. The first group of problems, on pore space distribution and plasticity are of obvious importance, and I want to discuss them in some detail as the Survey has only recently been interested in trying to assess these properties quantitatively.

The pore space distribution is of fundamental importance for a number of reasons. First of all the soil is the home of the plant roots, and the feeding roots can only proliferate rapidly throughout the soil if the soil contains an adequate system of pores wide enough for the young rootlets to grow into without hindrance. Since the diameter of the rootlets typically lies in the range 0·05 to 0·2 mm, this corresponds to pores emptied of water by suctions between 15 and 60 mbar. The roots can only function efficiently in an aerobic environment, so the better distributed the air space is within

the root zone, the more suited the soil is for root growth. The air space in wet soils is controlled by the distribution of pores larger than about 0·06 mm in diameter, that is pores emptied by suctions of up to 50 mbar, reaching from the soil surface down to the groundwater; and the better distributed these pores, the greater is the rate of acceptance of rain by the wet soil. Maps of the rate of rainfall acceptance for catchments have in fact been produced by the Surveys for water supply authorities in parts of Great Britain.

The soil is also the water reservoir for the crop during dry spells. The size of this reservoir has no definite value, for as the suction of the soil water increases above some ill-defined value, crop growth is increasingly restricted. The growth of most of our agricultural crops, though not of all our horticultural ones, is probably not appreciably affected by water stress until the suction exceeds 2 bar, but in the range 2 to 15 bar the reduction in growth rate is dependant on climatic conditions. In consequence the Soil Survey of England and Wales have agreed that the pore space distribution in selected profiles, representing the principal series, should be measured and should include the air content of the soil at 50 mbar suction, and the moisture content at 50 mbar, 2 bar and 15 bar suction[11].

Three other important physical properties of the soil which are not very dependent on management practices, but are of obvious agricultural significance, are firstly the moisture content at the lower plastic limit, for below this the soil is friable and suitable for cultivation or subsoiling and above is plastic; secondly the amount of shrinkage as a wet soil dries for this determines the amount of cracking during this process; and thirdly the stability of the coarse pores, channels and cracks when the dry soil is wetted. The variations of these properties within any given series, and as between series, has not been looked at in detail, but the little work that has been done on the plastic limit indicates that it is not well correlated with the series the soil belongs to[12].

The Composition of the Mineral and Organic Material of the Soil

I do not need to stress the importance of work in these fields here at the Macaulay, because your Institute, and particularly your Pedology Department, is generally recognised as a major centre for research in these topics. As exact a description as possible is needed of the constitution of the soil particles, and particularly of the surface films on the clay particles, if we are to understand many of the chemical and physico-chemical properties of the soil. Work both here at the Macaulay, and elsewhere, is now showing the importance of colloidal organic material in modifying the surface chemistry of the inorganic particles; but work in this field has been seriously limited by lack of methods for studying the constitution of these organic materials and their mode of interaction with the inorganic surfaces. I consider this is a field of study worth intensive development because of their agricultural importance.

Another group of problems I want to comment on concerns the cation exchange capacity and the aluminium status of soils. When ideas concerning cation exchange capacity and exchange saturation were being discussed

Land use capability classification divides the land up into seven classes, class 1 being land that is suited to a wide range of crops that will give high yields over a run of years without too many expensive inputs and class VII being land that has such severe limitations as to be of no use for forestry and of little value even for rough grazings. The limitations recognised by the British Soil Surveys are undesirable soil properties such as stoniness, shallowness, extremes of texture, inadequacies in the drainage and the liability of the soil to erosion, and the unfavourable environmental conditions of liability to flooding, the slope of the land and its altitude[13].

The major problem in this system of classification is that of defining how severe these limitations must be to allow the allocation of the soil to a given class. There are not yet any inherent criteria for defining these classes, but guidelines have been agreed as a result of discussions with agricultural advisers and when relevant with drainage engineers. I have been very gratified to note that this close collaboration has yielded a classification that has the confidence of progressive farmers in areas where they have had an opportunity to compare it with their own experience.

The primary objective of this classification must be borne in mind when discussing the class any particular soil should be allocated to. It is not a classification of soils according to the yield of a particular crop. Thus clays soils are downgraded relative to loams because they are only suited to a more restricted range of crops, and they are likely to be more difficult or more expensive to manage in unfavourable seasons, yet they may give higher yields of, say, winter wheat than the loams in the more favourable seasons. Even if new techniques, such as direct drilling, increase the probability of good yields in unfavourable years, the clay soils could still be downgraded, although not so severely, because of the restriction on the crops they are well suited to.

The classification also depends on the importance given to extraneous inputs, such as the introduction of a drainage or irrigation scheme. Sandy soils will give poorer yields than loams in dry summers, so will be downgraded, but this difference will become less noticeable the smaller the summer soil moisture deficit, so they may have a better relative grading in the west of the country where the summers are wetter, than in the east. But if irrigation is introduced in areas of dry sunny summers, the sandy soils may be as productive as irrigated loamy and more productive than unirrigated loams. So soils may be given two classes—one in its present condition and another if a major limitation is removed.

The land use capability classification pays little attention to the soil profile except in so far as it displays readily observable limitations for crop production; so it appears to be independent of the classification of soils into series, for the surveyor defines his series using many characteristics of the profile that are ignored in the capability classification. As would be expected, capability class and sub-class boundaries often coincide with series boundaries, but the same sub-class can include several series, and the same series can include two capability classes, though the phase of the series can commonly be made to change with the class. Thus the stony

50-60 years ago the general view held was that an acid soil held both exchangeable bases and also hydrogen ions which were neutralised as the pH was raised. Aluminium was not considered to be an exchangeable base and its role in cation exchange phenomena was ignored. The ideal agricultural soil was considered to be a neutral soil, that is a soil of pH 7, so the custom developed of measuring the exchange capacity of a soil at pH 7, often with the feeling that at this pH all acidity was neutralised. If in fact it was agricultural policy to bring all soils up to pH 7, and this was accepted by the farming community, one could justify this definition of cation exchange capacity; but such a policy has no justification for many systems of agriculture being practiced in this country. We now know that the cation exchange capacity at this pH has no fundamental interpretation, however the titration curve of the soil is carried out. Agriculturally what is important is the number of exchangeable cations the soil can hold at its field pH, and this is not measured in the normal routine analyses of the soil surveys. Further aluminium is known to affect the titration curves of a soil at pHs well above that at which $Al(OH)_3$ is precipitated in solution, though neither the forms it is present in at these pHs, nor how far these forms are an inherent characteristic of the soil, nor their agricultural significance are well understood, and their study forms an important part of Dr Bache's work here in the Macaulay.

The role of the Soil Survey analytical services in characterising the organic matter in the soil has still to be clarified, because it must be concerned with inherent and not ephemeral soil properties. Thus the total organic matter content of a cultivated soil at the time of sampling, which is usually the only properties of the organic matter at present determined, is a property that may concern the advisory chemist but not the Soil Survey, as it is so dependent on the system of land management being adopted. The Survey should be concerned with those soil properties which determine the amount and strength of absorption of the organic matter, and the properties of the clay humic surfaces, for these are much more conservative properties, but unfortunately not enough is known to justify the adoption of analytical procedures for these purposes.

Land Capability Surveys and Mapping

The soil surveyors in Great Britain not only produce soil maps, in which the soils are classified into soil series or associations of series, but also land use capability maps in which the land is classified into units that affect its value for agriculture. This classification differs from that for soil survey in that it is being made for a specific purpose, namely an evaluation of the inherent features of the land that affects its economic value for agricultural production. It is based on the philosophy of recognising, evaluating and mapping those characteristics of the land that limit its agricultural value, so should, in the future, link up with the work of agronomists interested in determining the maximum yield potential of a given crop in a given field, for this also is based on discovering and ameliorating all the factors preventing the crop giving its maximum potential yield.

phase and non-stony phase, the deep and the shallow phase, or the steeper slope and gentler slope phase of the same series may fall into contiguous capability classes.

The relative independence of these two systems of classification raises the very important problem of how much value does the land use capability classification lose for agricultural purposes by ignoring changes in the soil series within a given class. This is a topic that has received little critical attention. A preliminary investigation on this has been made using the results of about 400 sugar beet experiments made in England between 1957 and 1970. There was no close relation between yield and the series or the group and subgroup the soils belonged to, and the only profile character having any appreciable correlation with yield was the drainage status of the soil: soils having a certain proportion of gley in the subsoil tending to give the higher yields[14]. This conclusion could justify the assumption that the major effect of the soil on crop yields is through a few measurable properties, and if valid this would increase the value of soil data banks containing the data likely to be relevant to crop yields; and the soil series would then only be relevant in so far as these properties were amongst those used in defining the series.

The relevance of these findings to the basic policy of the Soil Surveys is clear. The value of a soil for agriculture can be increasingly accurately assessed, the more that its properties, known to be of importance, can be recognised and measured. The recognition of these properties, and the development of the most appropriate methods for measuring them, are the responsibility of the soil and crop scientists; but once this has been done, the Soil Surveys can reasonably be asked to take responsibility for measuring those properties that are little dependent on farm management practices. This would result in the properties the Surveys determine, and the analytical methods used, changing over the course of years. This raises the fundamental question of how far soil survey necessarily involves dividing soils up into named classes, such as the soil series; for this policy must involve maintaining the definition of the series for an appreciable number of years; and this can only be done if the profile properties defining the series do not change in response to advances in our knowledge of soil fertility, soil genesis or land use. I believe a major policy decision the Surveys must take in the not so distant future is how far it is worth retaining series names, or how far the Survey will wish to modify the naming of soils, after they have been given the opportunity of measuring and observing new groups of properties of agricultural significance, whose distribution through the soils of the region is appreciably different from that of the series to which the soils have been allocated.

REFERENCES

1. A. J. Thomasson, (Ed) Soils and Field Drainage. Soil Survey of England and Wales. *Tech. Monog.*, **7,** 1975.
2. J. W. Muir, H. G. M. Hardie, R. H. E. Inkson and A. J. B. Anderson. The classification of soil profiles by traditional and numerical methods. *Geoderma,* **4,** 81-90, 1970.
3. R. Webster and P. A. Burrough. Computer-based soil mapping of small areas from sample data. I. Multivariate analysis and ordination. *J. Soil Sci.,* **23,** 210-221, 1972.
4. R. Webster and P. A. Burrough. Multiple discriminant analysis in soil survey. *J. Soil Sci.,* **25,** 120-134, 1974.
5. C. L. Bascomb and M. G. Jarvis. Variability in three areas of the Denchworth soil map unit. I. Parity of the map unit and property variability within it. *J. Soil Sci.,* **27,** 420-37, 1976.
6. C. F. Banfield and C. L. Bascomb. Variability in three areas of the Denchworth soil map unit. II. Relationships between soil properties and similarities between profiles using laboratory measurements and field observations. *J. Soil Sci.,* **27,** 438-50, 1976.
7. C. Williams and J. H. Rayner. Variability in three areas of the Denchworth soil map unit III. Soil grouping based on chemical composition. *J. Soil Sci.,* **28,** 180-195, 1977.
8. R. Webster and C. H. E. de la Cuando. Soil Transect correlograms of N. Oxfordshire and their interpretation. *J. Soil Sci.,* **26,** 176-194, 1975.
9. R. Webster and P. A. Burrough. Computer-based soil mapping of small areas from sample data. II. Classification smoothing. *J. Soil Sci.,* **23,** 222-234, 1972.
10. P. H. T. Beckett and P. A. Burrough. The relation between cost and utility in soil survey. IV. Comparison of the Utilities of soil maps produced by different survey procedures, and to different scales. *J. Soil Sci.,* **22,** 466-80, 1971.
11. D. G. M. Hall, M. J. Reeve, A. J. Thomasson and V. F. Wright. Water Retention, Porosity and Density of Field Soils. Soil Survey of England and Wales. *Tech. Monog.,* **9,** 1977.
12. M. J. Reeve. The use of water retention studies in agriculture and hydrology. *Welsh Soil Disc. Gp.,* Rept., **17,** 1976.
13. J. S. Bibby and D. Mackney. Land use capability classification. Soil Survey *Tech. Monog.,* **1,** 1969.
14. R. Webster, C. A. H. Hodge, A. P. Draycott and M. J. Durrant. The effect of soil type and related factors on sugar beet yield. *J. Agric. Sci. Camb.,* **88,** 455-469, 1977.

PUBLICATIONS

(A) *Published*

1. Prelude to thermal analysis. By R. C. Mackenzie, pp. 405-407 of *Proc. 5th Int. Conf. Therm. Analysis, Kyoto, Japan.* Edited by H. Chihara. London: Heyden & Son, 1977.

   A very brief historical review of the uses of heat in testing methods from prehistoric times up to 1887, when Henry Louis Le Chatelier first automatically recorded heating curves, thus laying the foundation of modern thermal analysis. Attention is focused on development of methods for producing heat, for controlling heat, for measuring degree of heat (thermometry and pyrometry) and for measuring amount of heat (calorimetry).

2. Electron probe microanalysis of cell walls of *Cunninghamella echinulata.* By D. Jones, W. J. McHardy and V. C. Farmer, and Yvonne Jones (Dept. Biol. Sci., Univ. Dundee), *Trans. Br. Mycol. Soc.*, **69**, 71-75, 1977.

   The feasibility of using the electron probe microanalyser attachment of the scanning electron microscope to obtain qualitative data on inorganic elements in individual fungal cell walls has been explored. The results obtained were supported by chemical analysis of bulk samples.

3. Crystal structure of aluminium iodate hydrogen iodate hexahydrate and preparation of anhydrous aluminium iodate. By P. D. Cradwick and (the late) A. S. de Endredy, *J. Chem. Soc., Dalton Trans.* (2), 146-149, 1977.

   The compounds formed when aluminium is in solutions containing more than one anion are of interest in relation to the formation of aluminosilicates under natural conditions in soils. In this study the structure of $Al(IO_3)_3.2HIO_3.6H_2O$, which crystallizes from the same solution as $Al(IO_3)_2NO_3.6H_2O$ has been determined. As in the latter compound, the structure of which has already been described, the Al^{3+} is associated with six water molecules.

4. The weathering of chloritic minerals in some Scottish soils. By D. C. Bain, *J. Soil Sci.*, **28**, 144-164, 1977.

   The clay mineralogy of 15 soils of various drainage classes developed on different parent materials rich in chlorite reveals that the soils are immature and that weathering is at an early stage. The chlorite, which is iron-rich, generally persists throughout the profiles varying little in amount or chemical composition between horizons. Oxidation of iron modifies the thermal characteristics of the chlorite in all the freely-drained soils, but usually only in the surface horizons of gleys. In most soils, chlorite weathers only slightly, by transformation to vermiculite around the edges of flakes.

5. The weathering of ferruginous chlorite in a podzol from Argyllshire, Scotland. By D. C. Bain, *Geoderma*, **17**, 193-208, 1977.

   In all but one of a number of soils rich in chlorite from the Loch Awe area, Argyllshire, clay-size chlorite persists throughout the profile. The exception is a podzol with a humus iron pan, the A_2 horizon of which contains no chlorite, the clay fraction being dominated by an interstratified mica-vermiculite mineral which has formed from mica. It is probable that organic solutions percolating downwards from the surface have been responsible for the dissolution of the chlorite (an iron-rich species), the only detectable product being goethite.

6. Halloysite in some soils from north-east Scotland. By M. J. Wilson and J. M. Tait, *Clay Minerals*, **12**, 59-66, 1977.

   Halloysite is a common constituent of the clay fractions of soils derived from granite, gabbro, schist and slate in north-east Scotland, and occurs in lath-like and tubular particles. Since it is found in soils under widely varying drainage regimes, it probably does not result from contemporary soil-forming processes.

7. The pedogenesis of some gibbsitic soils from the Southern Uplands of Scotland. By M. J. Wilson and C. J. Bown, *J. Soil Sci.*, **27**, 513-522, 1976.

   The soils developed on the summit areas of the Merrick and Kells Hills in the Southern Uplands contain gibbsite, a mineral relatively uncommon in Scottish

soils. The distribution and form of the gibbsite suggest that the soils are polygenetic and have been strongly influenced by preglacial or interglacial weathering as well as by recent pedogenic processes.

8. Mineralogy and origin of dust fall on Skye. By D. C. Bain and J. M. Tait, *Clay Minerals*, **12**, 353-355, 1977.

   Optical microscopy reveals that iron-stained aggregates of quartz are the main constituent of the coarse fraction, accompanied by calcite, halite, sylvite, plagioclase felspar, chlorite and opaque black iron ixides. An origin in volcanic eruptions is eliminated. The fine material is composed of quartz, calcite, illite, chlorite, felspar and also palygorskite which not only excludes local contamination, but is consistent with an origin in North Africa as suggested by meteorological studies.

9. Synthesis of imogolite: a tubular aluminium silicate polymer. By V. C. Farmer, A. R. Fraser and J. M. Tait, *J. Chem. Soc., Chem. Commun.*, 462-463, 1977.

   Soluble hydroxyaluminium silicate complexes form when dilute solutions containing aluminium salts and monomeric silicic acid are partially neutralised. On heating such solutions, a dispersion of a fibrous polymer is obtained, each fibre consisting of tubes about 22 Å external diameter and 10 Å internal diameter. The product is essentially identical with the natural mineral, imogolite, and its mode of formation strongly suggests that imogolite in the B horizon of Scottish soils forms from silica and alumina leached from the A horizon. Even under conditions unfavourable for imogolite formation, soluble hydroxyaluminium silicate complexes must play an important role in the transport of aluminium and silicon in acid soils and natural waters.

10. Specific surface area and pore structure of allophanic soil clays. By E. Paterson, *Clay Minerals*, **12**, 1-9, 1977.

    Relatively small amounts of poorly ordered inorganic materials can have a disproportionately large effect on the physical and chemical properties of soil, presumably as a result of their high specific surface area and the chemical nature of the surfaces. The specific surface areas and pore size distribution characteristics of the clay fractions of a number of allophanic soils reveals the presence of a large number of very small pores, which contribute markedly to the high specific surface area values.

11. Nitrogen adsorption on synthetic akaganéite and its structural implications. By E. Paterson and J. M. Tait, *Clay Minerals*, **12**, 345-352, 1977.

    The structural implications of specific surface area determinations and pore size distributions obtained by low-temperature nitrogen adsorption techniques on synthetic akaganéite have been considered. These results and also electron micrographs are not consistent with a tubular structure, but support a structural scheme involving solid rods.

12. Pyrolysis studies on humus in freely drained Scottish soils. By J. M. Bracewell and G. W. Robertson, pp. 167-178 of *Proc. 3rd Int. Symp. Analytical Pyrolysis, Amsterdam, 1976.*

    Of the organic products obtained during the pyrolysis of total soils and separated by gas chromatography, certain relatively simple compounds show characteristic variations in their abundances (a) within the soil profile according to the genetic horizon and (b) between different soils according to the humus type. A numerical index based on these variations distinguishes between well decomposed mull humus and rawer mor humus better than do most other soil properties. In soils containing mull humus it correlates highly with properties reflecting base status and the presence of mineral organic complexes, whereas the more commonly used ratio of carbon to nitrogen shows almost no correlations of this type.

13. Structure of the crown ether complex: Ca(benzo-15-crown-5)$_2$(3,5-dinitrobenzoate)$_2$, $3H_2O$. By P. D. Cradwick and N. S. Poonia (Vikram University, India), *Acta Crystallogr.*, **B33**, 197-199, 1977.

Complexes involving metal salts and macrocyclic polyethers are of interest because they may act as model components for the study of ionic transport through cell membranes. The crystal structure of Ca(benzo-15-crown-5)$_2$(3, 5-dinitrobenzoate)$_2$.3H$_2$O is elucidated.

14. Peat. By P. D. Hulme, A. T. Nicol and R. A. Robertson, in Memoirs of the Soil Survey of Great Britain: *Soils of the country round Wick*. By D. W. Futty and F. T. Dry. pp. 83-110. Macaulay Institute for Soil Research, 1977.

Survey results for selected peatland areas are presented outlining the relationships between mire morphology, basal topography and stratigraphy, nature and distribution of plant communities and the effect of different land-use practices. Results of physical and chemical analyses of peat samples are also presented and discussed.

15. Growth of *Pinus contorta* at different water-table levels in deep blanket peat. By R. Boggie and H. G. Miller, *Forestry*, **49**, 123-131, 1976.

Drainage is a prerequisite for successful establishment of trees in peat. In a field experiment lowering of the water-table resulted in a linear increase in tree height and exponential increases in stem volume, tree weight and photosynthetic area. Nutrient status of the trees was broadly related to drainage treatment, but showed no improvement as a result of the increased drying of the peat that followed canopy closure.

16. A simple device for recording maximum and minimum water-table levels in soils. By R. Boggie, *J. Appl. Ecol.*, **14**, 283-285, 1977.

A cheap and simple device is described which indicates the water-table level in a bore hole and records the maximum and minimum levels since the previous inspection.

17. Apparatus for collecting rainwater and litter fall beneath forest vegetation. By J. D. Miller and H. G. Miller, *Lab. Practice*, **25**, 850-851, 1976.

Studies of the input and movement of major elements within a forest stand require measurements of rainwater and litter reaching the forest floor. However, the considerable spatial variation in both litter fall and throughfall means that many collectors have to be used, and the large volumes of stemflow per tree can present collection problems. Details are given of a cheap and easily constructed throughfall gauge, a simple stem-flow recorder that utilizes a self-priming siphon, and a means of collecting litter fall, that were developed for use in a spruce forest.

18. Effect of nitrogen supply on nutrient uptake in Corsican pine. By H. G. Miller, J. D. Miller and O. J. L. Pauline, *J. Appl. Ecol.*, **13**, 955-966, 1976.

Growth and nutrient uptake and accumulation were assessed in a nitrogen fertilizer experiment in pole-stage Corsican pine. The total retention of fertilizer nitrogen in the trees, soil and ground vegetation was complete at the lowest rate of application, but decreased thereafter, the larger part of that retained being in the trees. Models of growth and of the accumulation and release of nutrients were used to calculate the annual nutrient uptake required to sustain the growth rates temporarily achieved by the fertilized trees. Fertilizer nitrogen retained within the trees is alone sufficient to explain the 8-13 year-long response period.

19. The characterization by Mössbauer spectroscopy of the secondary iron in pans formed in Scottish podzolic soils. By B. A. Goodman and M. L. Berrow, *J. Phys., Paris*, **37**, Colloque C-6, 819-823, 1976.

Twelve well-developed iron pans have been studied by Mössbauer spectroscopy. The spectra of the samples from podzol profiles suggest that a large proportion of the iron exists either as a mixture of iron oxyhydroxides or as extremely small particles of α-FeOOH. A spectrum consistent with the presence of well-defined α-FeOOH was obtained from one sample from a ground water gley.

Accumulation of organic matter rich in carboxylate groups is observed in the iron pans and a structure is proposed in which it is envisaged that organic molecules form surface coatings on FeOOH particles and effectively act as cementing agents by binding together a number of inorganic particles. The hard relatively impervious structure of iron pans can thus be accounted for.

20. Metal distribution and nature of some Cu, Mn and V complexes in humic and fulvic acid fractions of soil organic matter. By M. V. Cheshire, M. L. Berrow, B. A. Goodman and C. M. Mundie, *Geochim. Cosmochim. Acta*, **41**, 1131-1138, 1977.

The organic matter of an arable soil derived from base-rich parent material has been fractionated into humic and fulvic acids. The humic acid has been further subdivided by hydrolysis with water and 6M HCl and the fulvic acid by adsorption chromatography on a charcoal: Celite column. The distribution of copper, iron, manganese, vanadium and other metals between the various fractions has been measured and an attempt has been made to characterize the type of organic matter-metal bonding by means of electron paramagnetic resonance spectroscopy.

21. The carbon-rod atomizer for the determination of cadmium and lead in plant materials and soil extracts. Part II. Improved rod geometry for atomic fluorescence spectrometry. By A. M. Ure and M. P. Hernandez-Artiga, *Anal. Chim. Acta*, **94**, 195-197, 1977.

A description is given of a carbon-rod atomizer, whose rod-geometry has been redesigned to offer improved precision for atomic fluorescence spectrometry.

22. Some investigations into the electroanalytical chemistry of selenium. By S. Forbes and G. P. Bound, *Proc. Analyt. Div. Chem. Soc.*, **14**, 253-256, 1977.

23. Quantitative determination of minor and trace elements in rocks and soils by spark source mass spectrometry. By A. M. Ure and J. R. Bacon, *Advances in Mass Spectrometry*, Vol. **7**, 549-552, 1977.

The method used for determination of trace elements in rocks and soils by spark source mass spectrometry is outlined with particular reference to the correction of interference effects.

24. Spark source mass spectrometry applied to the determination of the total and extractable trace element content of soils. By A. M. Ure and J. R. Bacon, *Paper 291 of Proc. XX Colloq. Spectroscopicum Int., Prague*, 1977.

25. Recognition of imogolite structures in allophanic clays by infrared spectroscopy. By V. C. Farmer, A. R. Fraser, J. D. Russell and N. Yoshinaga (Ehime University, Japan), *Clay Minerals*, **12**, 55-57, 1977.

The tubular aluminium silicate hydrate, imogolite, is commonly associated with reactive amorphous clays in soils, but there has been no simple method for recognizing its presence or estimating its amount. Far infrared spectroscopy has now revealed a band at 348 cm^{-1} which appears to be characteristic of the imogolite structure. This infrared procedure can be applied to size fractions unsuitable for electron microscopy, and should facilitate investigations on the distribution of imogolite structures in soils.

26. Adsorption on hydrous oxides: I. Oxalate and benzoate on goethite. By R. L. Parfitt, V. C. Farmer and J. D. Russell, J. Soil Sci., **28**, 29-39, 1977.

Oxalic acid is a common plant acid which persists in soil, possibly adsorbed on iron and aluminium oxide surfaces. In this paper its mode and strength of adsorption on goethite is compared with those of phosphoric and benzoic acids. On a goethite sample which strongly adsorbs 200 μmole g^{-1} of phosphate, only some 100 μmole g^{-1} of oxalic acid is strongly adsorbed in a bidentate form, but a further 200 μmole g^{-1} is more weakly adsorbed as a monodentate acid oxalate. Unlike phosphate, the amount of oxalate strongly adsorbed falls off rapidly with increasing pH to near zero at pH8. Benzoic acid is only weakly adsorbed.

27. Adsorption on hydrous oxides: II. Oxalate, benzoate and phosphate on gibbsite. By R. L. Parfitt, A. R. Fraser, J. D. Russell and V. C. Farmer, *J. Soil Sci.*, **28**, 40-47, 1977.

Aluminium hydroxide surfaces are thought to play an important role in anion adsorption in soils. Such surfaces occur not only on pure oxide minerals, but also on many aluminosilicates. The present study shows, however, that only edge faces on gibbsite are active in adsorbing phosphate and the two organic acids. The predominant faces, which are inactive, have a structure like that of predominant faces of many soil clays.

28. Adsorption on hydrous oxides: III. Fulvic acid and humic acid on goethite, gibbsite and imogolite. By R. L. Parfitt, A. R. Fraser and V. C. Farmer, *J. Soil Sci.*, **28**, 289-296, 1977.

The mode of adsorption of humic and fulvic acid on gibbsite (an aluminium hydroxide), goethite (an iron hydroxide), and imogolite (a hydrated aluminium silicate) has been studied because much of the organic matter in mineral soils is probably bound to hydrous oxides of aluminium and iron. Humic and fulvic acids displace surface hydroxyl groups from goethite and so form strong ionic linkages with cations in the sub-surface layer. Only edge faces of gibbsite crystals participate in this reaction, but the principal faces do adsorb unionized fulvic acid more weakly by hydrogen bonding. Fulvic acid is strongly adsorbed into the pores of imogolite, but forms fewer ionic linkages than with gibbsite or goethite.

29. Adsorption on hydrous oxides: IV. Mechanisms of adsorption of various ions on goethite. By R. L. Parfitt and J. D. Russell, *J. Soil Sci.*, **28**, 297-305, 1977.

The surfaces of iron oxides in soil play an important role in retention of agriculturally important ions. Infrared spectroscopy has been used to identify the mechanisms by which a wide range of ions, including phosphate, sulphate, nitrate, fluoride, copper and zinc, are adsorbed on the surface of goethite. One particular surface hydroxyl group the singly co-ordinated A-type, has been identified as the site at which adsorption occurs.

30. Comment on "Contamination of humic acid by silica gel and sodium bicarbonate" by K. H. Tan. By J. D. Russell and H. A. Anderson, *Pl. Soil*, **47**, 263-264, 1977.

It is pointed out that the failure to recognize spurious absorption bands of inorganic contaminants in the infrared spectra of humic and fulvic acid fractions, has led to uncontested, erroneous conclusions which may impede progress in the already difficult field of structural investigations of soil organic matter.

31. The effect of lattice substitutions on the derivation of quantitative site populations from the Mössbauer spectra of 2:1 layer lattice silicates. By B. A. Goodman, *J. Phys., Paris*, **37**, Colloque C-6, 849-855, 1976.

Calculations using a point charge model of the lattice contributions to the electric field gradients at the octahedral sites in layer lattice silicates have indicated that Mössbauer spectra are more realistically fitted to two doublets per site than to the usual single doublet. The effect of the choice of model for fitting spectra to the derived site populations is emphasised.

32. Origins and stability of soil polysaccharide. By M. V. Cheshire *J. Soil Sci.*, **28**, 1-10, 1977.

The main importance of polysaccharide in soil is thought to be its function of binding soil particles into aggregates. This review describes recent work on the origin of soil polysaccharide, its stability in soil and its chemical fractionation.

33. A disposable Petri dish modified for plant growth. By D. C. Gordon and I. R. MacDonald, *Ann. Appl. Biol.*, **85**, 317-318, 1977.

A modification to a disposable plastic Petri dish is described making it a simple and convenient growth chamber for cereal seedlings.

34. A comparison of the polycarboxylic acids extracted by water from an agricultural top soil with those extracted by alkali By D. J. Linehan, *J. Soil Sci.*, **28**, 369-378, 1977.

    A procedure is described for the isolation and purification of a polycarboxylic acid from a water extract of an agricultural soil. The isolated material was compared with humic and fulvic acids isolated by conventional procedures and it was concluded that the purified water extract is indistinguishable from fulvic acid both with regard to its chemical character and its ability to promote the growth of isolated tomato roots. The growth promoting properties of the water extract encourage the belief that the soluble humic substances present in soil solutions might directly influence plants growing in soils and it is concluded that the close resemblence of the polycarboxylic acid of the water extract to that of fulvic acid justifies the use of the latter in investigating this possibility.

35. Growth promoting properties of soil fulvic acid and a synthetic polycarboxylic acid. By D. J. Linehan, *Soil Biol. Biochem.*, **9**, 427-428, 1977.

    The growth rate of cultured tomato roots is promoted by fulvic acid, a major component of the alkali extracts of all agricultural soils, and by the structurally similar polycarboxylic acid, polymaleic acid. These acidic polymers are chemically similar to the humus material of soil solutions which might have important effects on plant growth and nutrition under field conditions. The finding that a polymer synthesised under controlled conditions has growth promoting properties similar to those of the natural material may enable us to distinguish the chemical structures required for growth promotion.

36. Metabolic changes associated with calcium deficiency. By P. C. DeKock, *J. Sci. Fd Agric.*, **28**, 872, 1977. Abstract from *Agriculture Group Symposium: Progress in Plant Nutrition.*

    Blossom-end-rot (BER) of tomatoes has been shown to be aggravated by ammonium-nitrogen and alleviated by nitrate-nitrogen. Analyses of affected and healthy tissues showed that the syndrome was consistent with an induced calcium deficiency.

37. Infection of plant tissue by *Sclerotinia sclerotiorum:* a scanning electron microscope study. By D. Jones, *Micron*, **7**, 275-279, 1976.

    A scanning electron microscope has been used to explore the fine detail of stem lesions in vining peas caused by the fungus *Sclerotinia sclerotiorum*, and to determine the manner in which this fungus enters potato leaves.

38. *Paratetramitus jugosus*, an amoebo-flagellate of soils and freshwater, type-species of *Paratetramitus* nov. gen. By J. F. Darbyshire, F. C. Page (N.E.R.C. Culture Centre for Protozoa and Algae, Cambridge) and L. P. Goodfellow (N.E.R.C. Culture Centre for Protozoa and Algae, Cambridge), *Protistologica*, **12**, 375-387, 1976.

    The protozoan, *Paratetramitus jugosus*, has been isolated from 19 soils in the north of Scotland on the mainland and the Orkney Islands. This unusual soil amoeba, which has a mobile flagellate phase in its life history, has also been found in freshwater near Cambridge, England, and from Idaho, U.S.A. The flagellate phase is described for the first time with the aid of light and electron microscopy.

39. The morphology of a common soil flagellate, *Heteromita globosa* Stein (Mastigophorea : Protozoa). By C. M. Macdonald, J. F. Darbyshire and C. G. Ogden (British Museum (Natural History), London), *Bull. Br. Mus. (Nat. Hist.): Zoology*, **31**, 255-264, 1977.

    The soil protozoan, *Heteromita globosa*, is frequently confused in the light microscope with flagellates of the genus *Bodo*. *H. globosa* has been examined in the scanning and transmission electron microscopes for the first time, and many diagnostic features of *Bodo* spp. were absent. Two organelles, which are new to soil flagellates, were discovered in *H. globosa*. Although the taxonomic position of *Heteromita* within the colourless zooflagellates is still uncertain, the new ultrastructural evidence from *H. globosa* clearly shows that *Heteromita* is a valid genus, quite distinct from *Bodo*.

40. The nitrogen requirement of barley. By P. W. Dyson, *J. Sci. Fd Agric.*, **28,** 873, 1977.

41. Effects of fertilizer and date of sowing on the rates of growth and nutrient uptake in swedes. By P. W. Dyson, pp. 35-40 (Paper 8) of *Proc. U.K. Conf. Brassica Fodder Crops, February, 1977.* Edited by J. F. D. Greenhalgh and others for The Scottish Agricultural Development Council.

    The major nutrients increased yields by different effects on root growth. N increased root growth rate in the middle and late stages of the growth period, P increased the rate of early growth and K increased the growth rate in both the early and late periods. Late sowing delayed the start of root growth, but there was little evidence of any compensatory increase in growth later, consequently yield was reduced. Crops in lowland Kincardine grew more rapidly until mid-September and then more slowly than crops grown further north at greater altitude. Yield differences between the two locations appeared to be mainly the result of differences in planting date. The patterns of growth and nutrient uptake were generally similar as there was relatively little change with time in nutrient concentrations in the roots.

42. Effects of fertilizers on the yield and mineral composition of swedes. By J. W. S. Reith, pp. 41-45 (Paper 9) of *Proc. U.K. Conf. Brassica Fodder Crops, February, 1977.* Edited by J. F. D. Greenhalgh and others for The Scottish Agricultural Development Council.

    Results from field experiments are used to check the suitability of fertilizer recommendations to produce satisfactory crops of swedes. The response to N is now larger and that to P slightly smaller than they were over fifteen years ago, but there is no indication that there should be any major change in the N, P and K dressings normally recommended. Variations in the mineral contents of crops from different sites may be of some significance in animal nutrition. Applying about twice the standard rate of boron may be advantageous on boron-deficient soils. Preliminary results are given for the effects of cobalt applications on the content of swede and turnip roots grown on cobalt-deficient soils.

43. Practical implications of quantity-intensity relationships. By B. W. Bache, pp. 777-787 of *Proc. Sem. Soil Environ. Fertil. Manag. Intensive Agric., Tokyo, October, 1977.* Japan Soc. Sci. Soil Manure, 1977.

    The behaviour of nutrients in soils is described in terms of quantity, intensity and buffer capacity. These terms are defined, and their importance for the following topics is discussed: nutrient supply to crops, evaluation of nutrient status in soils, and fertilizer application.

44. An investigation into the relations between some growth parameters and yield of barley. By P. W. Dyson, *Ann. Appl. Biol.*, **87,** 471-483, 1977.

    Grain yield in barley is the product of grain number and average grain size. It is generally accepted that grain number is determined before ear emergence and that grain size is usually dependent on photosynthesis after ear emergence. The main conclusion drawn from twenty-five field experiments is that both grain number and size, and therefore yield, are closely related to growth before ear emergence. Photosynthesis after ear emergence does not appear to be a major limiting factor.

45. Relationships between grain yield and the nitrogen and excess base contents of young barley plants. By W. M. Crooke, *J. Sci. Fd Agric.*, **28,** 589-597, 1977.

    The usefulness of analyses of young plants for assessing nitrogen requirements of barley in north-east Scotland has been examined. Significant relationships have been found connecting the amounts of both nitrogen and excess base (reflecting the content of organic acids) in young plants with final grain yield. The practical usefulness of the relationships, however, is limited because the levels of both factors can vary markedly depending not only on the age of the plant at sampling, but also on the site, season and variety.

46. The influence of the level of nitrate nutrition on ion uptake and assimilation, organic acid accumulation, and cation-anion balance in whole tomato plants. By E. A. Kirkby (University of Leeds) and A. H. Knight, *Plant Physiol.*, **60**, 349-353, 1977.

    Tomato plants were grown in solution culture with a wide range of nitrate nutrition. The balance was determined of cations and anions (both inorganic and organic) by analyses of plants. The effect of increasing nitrate nutrition was a stimulation of organic acid accumulation. The excess uptake of anions over cations by the plant was balanced by efflux of hydroxyl ions from the roots. This effect amounts to only 20% of the anion charge shift. It is concluded that only a small fraction of the potassium absorbed is recycled in this plant.

47. The development of a solid state reference electrode for use in soil measurements. By G. P. Bound and B. Fleet (Imp. Coll. Sci. Tech., London), *J. Sci. Fd Agric.*, **28**, 431-435, 1977.

    A pressed pellet liquid junction membrane and a solid state reference electrode have been developed which, being non-porous, are not liable to blockage by soil particles. The electrodes provide a reasonably constant "reference" voltage over the range of pH and concentration conditions usually encountered in soils and soil extracts.

48. Determination of nitrate in soil pastes by ion selective electrodes. By G. P. Bound, *J. Sci. Fd Agric.*, **28**, 501-505, 1977.

    An ion selective electrode was used to measure the nitrate ion concentration in pastes of soil and saturated calcium sulphate solution. A good correlation, for both air-dried and field-moist soil samples, was obtained between nitrate values found by colorimetric analysis subsequent to KCl extraction, and those found by a nitrate electrode, non-porous reference electrode couple. A ceramic frit reference electrode, although effective in pastes of air-dried soils, gave rise to erroneous results in pastes of field-moist soils.

49. Tracing magnesium. By A. H. Knight and H. Shepherd, *Newsl. Applic. Nucl. Meth. Biol. Agric.*, (7), 13-14, 1976.

    Although magnesium is an important element in plant and animal nutrition there are relatively few references to use of radioactive isotopes as tracers. Short half-lives of the isotopes of magnesium and difficult methods for their production are the reasons. The use of ^{28}Mg is reported in plant physiological experiments.

50. Anthyllido-Rhacomitrietum canescentis ass. nov. prov. dans la région Grampian de l'Écosse. By E. L. Birse, *Doc. Phytosociol.* n.s. **1**, 19-22, 1977.

    A new community, Anthyllido-Rhacomitrietum canescentis, has been recorded on the gravels of the flood-plain of the River Avon in the Grampian Region, Scotland. It occurs on the stony phase of a eutric fluvisol. It belongs to the class Sedo-Scleranthetea, but the order and alliance are not yet clear. More relevés from similar habitats are needed to clarify this.

51. The stratigraphy of the buried soil at Teindland Forest, Scotland. By J. C. C. Romans, *Nature*, **268**, 622-623, 1977.

    The stratigraphy and provenance of materials deposited above the buried soil horizon at Teindland Forest (NJ 297/570) are described and discussed in relation to information collected during the soil survey of Sheet 85 (Rothes). It is concluded that the buried soil, dated at *ca* 28,000 b.p. by E. A. Fitzpatrick has been subsequently covered by solifluction deposits derived from glacial deposits on the east facing slopes of Teindland Forest.

52. The recording and organisation of soil survey field data for computer areal mapping. By J. M. Ragg, *Geoderma*, **19**, 81-89, 1977.

    A brief review of contemporary soil information systems is followed by a description of the methods used in a pilot study of the collection and storage of soil survey field data in computer campatible form. The organization of this data for the generation of thematic soil maps by the program CAMAP is described.

53. Identification of podzolic soils (Spodosols) in upland Britain. By B. W. Avery (Rothamsted Experimental Station), B. Clayden (Rothamsted Experimental Station) and J. M. Ragg, *Soil Sci.*, **123**, 306-318, 1977.

Criteria for identifying Spodosols are compared with those used to identify podzolic soils in England and Wales, with particular reference to upland soils classed as brown podzolic soils and stagnopodzols. Applied to British soils, the chemical criteria for the spodic horizon seem unduly restrictive, whereas those for the podzolic B entail identification as brown podzolic of soils with non-illuvial B horizons which may resemble those of Andepts. Some stagnopodzols also fail to qualify as Spodosols, but grouping them in different classes at the highest categorical level is considered inadvisable on both genetic and practical grounds.

54. The soils of the country round Wick (Sheets 110, 116 and part 117). By D. W. Futty and F. T. Dry, with an account of the vegetation by E. L. Birse and J. S. Robertson. pp. iix + 287 *Memoirs of the Soil Survey of Great Britain,* Macaulay Institute for Soil Research, 1977.

The soils of an area of 1146 sq km of Caithness, extending from Thurso and John o' Groats in the north to the Ord of Caithness in the south, are described. The soils are brown calcareous soils, brown forest soils, podzols, peaty podzols, calcareous gleys, noncalcareous gleys and peaty gleys, included in eleven soil associations comprising twenty-eight soil series and five soil complexes. Organic soils and alluvial soils are also described.

Introductory chapters deal with physical features, climate and parent materials; later chapters cover the peat deposits, analytical data, land use capability, vegetation, agriculture and forestry, and appendices contain sections on the system of classification, definitions of terms and tables of analytical data and plant communities.

The memoir includes coloured soil and land use capability maps on the scale of 1 inch to 1 mile.

(B) *Awaiting publication at 30th September, 1977*

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

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

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

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

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

60. Release of potassium by acid extraction in relation to the mineralogy of selected soils from Southern Turkey. By N.Güzel (Cukurova Univ., Turkey) and M. J. Wilson. Submitted to *Agrochimica.*

61. X-ray identification of clay minerals in thin sections. By M. J. Wilson and D. R. Clark. Submitted to *J. Sediment. Petrol.*

62. The effect of Fe-for-Si substitution on the *b*-dimension of nontronite. By J. D. Russell and D. R. Clark. Submitted to *Clay Minerals.*

63. The occurrence of imogolite in some Scottish soils. By J. M. Tait, N. Yoshinaga (Ehime Univ., Japan) and B. D. Mitchell. Submitted to *Soil Sci. Pl. Nutr.*

64. Alteration of allophane and imogolite by alkaline digestion. By V. C. Farmer, B. F. L. Smith and J. M. Tait. Submitted to *Clay Minerals.*

65. Some characteristics of the brown forest soils of Scotland. By J. M. Ragg, J. M. Bracewell, J. Logan and L. Robertson. Submitted to *J. Soil Sci.*

66. An investigation of peat at the Slochd Pass Inverness-shire. By S. E. Durno and A. T. Nicol. Submitted to *Scottish Geog. Map.*

67. Water-table depth and oxygen content of deep peat in relation to root growth of *Pinus contorta.* By R. Boggie. Submitted to *Pl. Soil.*

68. Ground vegetation and humus nitrogen levels as indicators of nitrogen status in an established sand-dune forest. By H. G. Miller, B. L. Williams, C. S. Millar (Univ. Aberdeen) and T. R. Warin (Univ. Aberdeen). Submitted to *Forestry.*

69. Growth of Scots pine under nutritional and climatic stress. By H. G. Miller, J. D. Miller and W. O. Binns (Forestry Commission). Submitted to *Pl. Soil.*

70. Effect of afforestation with *Pinus contorta* on nutrient content, acidity and exchangeable cations in peat. By B. L. Williams, J. M. Cooper and D. G. Pyatt (Forestry Commission). Submitted to *Forestry.*

71. Trace element levels in soils: effects of sewage sludge. By M. L. Berrow and J. C. Burridge. To appear in *Proc. Conf. Inorganic Pollut. Agric.*

72. Metal contaminants in sewage sludges and some effects on soil and plant contents. By M. L. Berrow and J. C. Burridge. To appear in *Research Seminars on Effects of Metal Contaminants in Sewage Sludge.* Tech. Note, D.O.E. Standing Comm. Disposal of Sewage Sludge.

73. Some early British contributions to atomic spectroscopy (1672-1835). By T. S. West. Submitted to *Analyst.*

74. A carbon-rod atomizer for the determination of cadmium and lead in plant materials and soil extracts. Part III. Simultaneous determination of cadmium by atomic fluorescence and lead by atomic absorption spectrometry. By A. M. Ure, M. P. Hernandez-Artiga and M. C. Mitchell. Submitted to Analytica Chimica Acta.

75. Some recent developments in atomic fluorescence spectroscopy. By T. S. West. To appear in *Proc. IUPAC Congr. Toyko Sept. 1977.*

76. Differential pulse polarography of selenium IV in the presence of metal ions. By G. P. Bound and S. Forbes. Submitted to *Analyst.*

77. Scandium, yttrium and the rare earth contents of water lily (*Nuphar lutea*). By A. M. Ure and J. R. Bacon. Submitted to *Geochim. Cosmochim. Acta.*

78. Glauconite and celadonite: two separate species. By H. A. Buckley (Dept. Mineral. Br. Mus. Nat. Hist.), L. R. Johnson (Dept. Mineral. Br. Mus. Nat. Hist.), J. C. Bevan (Dept. Mineral. Br. Mus. Nat. Hist.), K. M. Brown (Dept. Mineral. Br. Mus. Nat. Hist.) and V. C. Farmer. Submitted to *Mineralog. Mag.*

79. Ammonia-treated vermiculite—a possible controlled-release N-fertiliser. By J. D. Russell and A. R. Fraser. Submitted to *J. Sci. Fd Agric.*

80. Water on particle surfaces. By V. C. Farmer. To appear in *The Chemistry of Soil Constituents.* Edited by D. J. Greenland and M. H. B. Hayes. London: Wiley.

81. Chemical and infrared spectroscopic studies of fulvic acid fractions from a podzol. By H. A. Anderson, A. R. Fraser, A. Hepburn and J. D. Russell. Submitted to *J. Soil Sci.*

82. Comment on "Spectroscopie infra-rouge de quelques fractions d'acides humiques obtenues sur Sephadex." By J. D. Russell and H. A. Anderson. Submitted to *Pl. Soil.*

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

84. Fractionation of humic acid by gel permeation chromatography. By H. A. Anderson and A. Hepburn. Submitted to *J. Soil Sci.*

85. Phenolic hydrolysis products from gel chromatographic fractions of soil humic acids. By K. R. Tate (Soil Bureau, DSIR, Lower Hutt, New Zealand) and H. A. Anderson. Submitted to *J. Soil Sci.*

86. Ether-soluble hydrolysis products in humic and fulvic acids. By H. A. Anderson, A. Hepburn and A. Sim. Submitted to *J. Soil Sci.*

87. Polycarboxylic acids extracted by water and by alkali from agricultural top soils of different drainage status. By D. J. Linehan. Submitted to *J. Soil Sci.*

88. The uptake by plants of polymaleic acid: a polycarboxylic acid structurally related to those of soils. By D. J. Linehan. Submitted to *Pl. Soil.*

89. Geo-stimulation of root growth and pigment synthesis in mustard seedlings. By I. R. MacDonald and D. C. Gordon. Submitted to *Nature.*

90. Nitrate reduction in plant leaves in relation to calcium. By P. C. DeKock, A. Hall, A. Naylor and R. H. E. Inkson. To appear in *Proc. 6th Long Ashton Symp. Nitrogen Assimilation of Plants.*

91. Aluminium toxicity and accumulation in lucerne and bromegrass. By P. C. DeKock, A. Hall and G. R. Webster (Univ. Alberta, Canada). Submited to *Can. J. Pl. Sci.*

92. Some microbial and chemical changes in soil near the roots of spring barley, *Hordeum vulgare* L., infected with take-all disease. By J. F. Darbyshire, M. S. Davidson, N. M. Scott and P. J. Shipton (North of Scotland College of Agriculture). To appear in *Proc. 6th Int. Colloq. Soil Zoology,* Uppsala, Sweden, 1976.

93. Effect of different preparative techniques on epi-cuticular wax of narcissus flowering stems as revealed by scanning electron microscopy. By D. Jones. Submitted to *Micron.*

94. Scanning electron microscopy of cystosori of *Spongospora subterranea.* By D. Jones. Submitted to *Trans. Br. Mycol. Soc.*

95. The morphology of a soil flagellate, *Spiromonas angusta* (Duj.) Alexieff (Mastigophorea: Protozoa). By C. M. Macdonald and J. F. Darbyshire. Submitted to *Protistologica.*

96. Soil fungi as food for giant amoebae. By K. M. Old (Dundee Univ.) and J. F. Darbyshire. Submitted to *Soil Biol. Biochem.*

97. Soil reaction. By B. W. Bache. To appear in *Encyclopedia of Earth Science—Volume VI B: Soil Science.*

98. Base saturation. By B. W. Bache. To appear in *Encyclopedia of Earth Science—Volume VI B: Soil Science.*

99. Activity ratio. By B. W. Bache. To appear in *Encyclopedia of Earth Science—Volume VI B: Soil Science.*

100. Chemical composition of soils. By B. W. Bache. To appear in *Encyclopedia of Earth Science—Volume VI B: Soil Science.*

101. Soil solution. By B. W. Bache. To appear in *Encyclopedia of Earth Science—Volume VI B: Soil Science.*

102. Long term culture methods for the production of isotopically labelled plant material. By A. H. Knight. Submitted to *New Phytol.*

103. Tracing water movement, using tritium, in a peaty gley soil under Sitka Spruce. By R. Boggie and A. H. Knight. Submitted to *Forestry.*

104. Appendix, on the micromorphology of an artificial mound, attached to "Mounds at Corrylach Plots, Kintyre, Argyll, by P. J. Ashmore and others." By J. C. C. Romans and L. Robertson. Submitted to *Proc. Soc. Antiquar. Scotl.*

105. Use of air photo interpretation for land evaluation in the Western Highlands of Scotland. By P. H. T. Beckett (Oxford Univ.), R. Webster (Oxford Univ.), G. Lawrence (Oxford Univ.), J. S. Bibby and G. Hudson. Submitted to *Catena.*

106. Soils. By J. H. Gauld. To appear in *County Flora: Moray, Nairn and Easterness.*

107. The maps of the Soil Survey of Scotland. By W. S. Shirreffs. To appear in *Proc. 1977 Ann. Summer School Soc. Univ.. Cartographers, Aberdeen.*

108. Design and production of 1:25 000 multicolour land use capability maps. By W. S. Shirreffs. Submitted to *Cartographic J.*

AGRICULTURAL RESEARCH INSTITUTES IN GREAT BRITAIN

The research programmes of the following agricultural research institutes supported by public funds are co-ordinated by the Agricultural Research Council. These institutes generally publish annual reports or periodical reports summarizing the research work that is in progress. Full details can be obtained from the secretaries of the institutes concerned.

ARC Institutes

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

State-aided Institutes (Scotland)

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

State-aided Institutes (England and Wales)

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