M. S. Davidson

ISSN 0369-0385

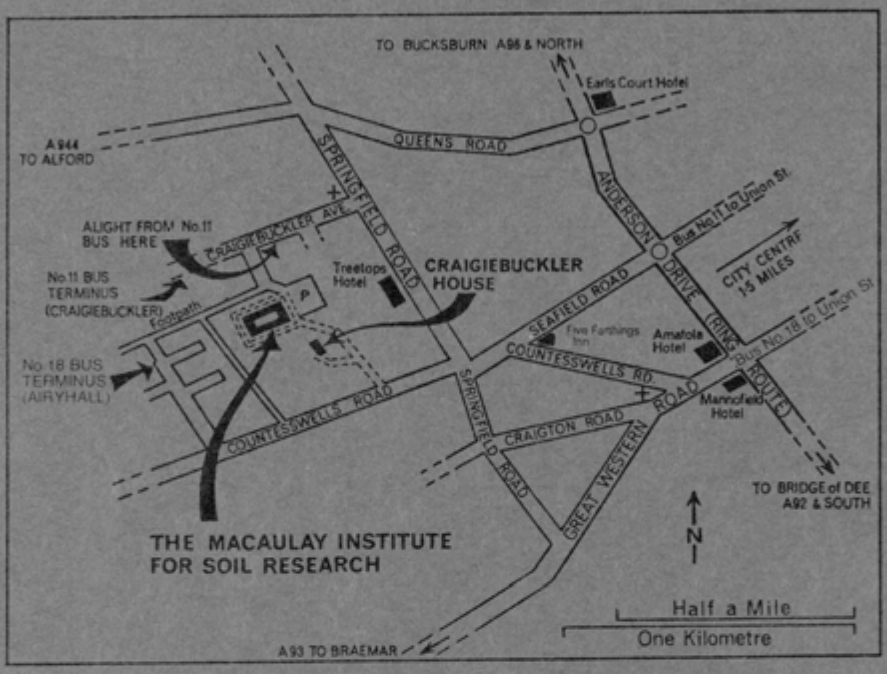
THE MACAULAY INSTITUTE FOR SOIL RESEARCH

FOUNDED 1930

1983 ANNUAL REPORT

No. 53

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



The Macaulay Institute is situated on the western outskirts of Aberdeen, about three miles from the centre of the city. The main entrance is on Countesswells Road, but visitors using public transport should take either the corporation Bus Route 11 to the point indicated, from which the Institute is reached in a few minutes by Craigiebuckler Drive, or Bus Route 18 (less convenient) to the Airyhall terminous.

Telephone–ABERDEEN (0224) 38611

The main part of this report covers the period from 1st October, 1982, to 30th September, 1983. The staff list is that current in November / December, 1983, and the Introduction is similarly updated. The report was published in May, 1984.

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

N.B.–Previous Reports have been issued under the dates 1981-82, etc. This has caused some confusion and accordingly the present Report is listed as 1983 rather than 1982-83.

THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

(Founded 1930)

COUNCIL OF MANAGEMENT

Professor H. M. Keir.

Miss E. A. Piggott.

Chairman—
PROFESSOR H. M. KEIR—appointed 30/5/83

Appointed by the Secretary of State for Scotland—
G. I. Lumsden, Esq., B.Sc., F.R.S.E.
Professor G. A. Sim, B.Sc., Ph.D.
Professor Lord Tedder, M.A., Sc.D., D.Sc., F.R.S.C., F.R.S.E.

Appointed by the University of Aberdeen—
Professor C. H. Gimingham, B.A., Sc.D., Ph.D., F.I.Biol., F.R.S.E.—appointed 1/10/83.
Professor H. M. Keir, B.Sc., Ph.D., D.Sc., F.I.Biol., F.R.S.C., F.R.S.E.
Professor J. W. Parsons, B.Sc., Ph.D.

Appointed by the North of Scotland College of Agriculture—
D. Morrison, Esq., B.Sc(Agric.), Dip.Agric.(Cantab.), M.S.—resigned 12/5/83.
W. J. Ferguson, Esq.
G. J. F. Copeman, Esq., B.Sc.—appointed 13/5/83.
J. H. Topps, Esq., B.Sc., Ph.D., F.R.S.C.

Appointed by the West of Scotland Agricultural College—
Professor J. E. Smith, B.Sc., M.Sc., Ph.D., D.Sc., F.I.Biol., F.R.S.E.

Appointed by the East of Scotland College of Agriculture—
Professor N. F. Robertson, C.B.E., B.Sc., M.A., Ph.D., Dip.Agric.Sc., F.R.S.E.

Co-opted—
A. J. Grayson, Esq., M.A., M.Litt.
M. Mackie, Jnr., Esq., B.Sc., M.A.
Professor J. D. Matthews, B.Sc.(For.), F.R.S.E., F.S.F.

Secretary: Miss E. A. Piggott, M.B.I.M.

Members of the House of Lords Select Committee on Science and Technology together with the Director and members of staff during their visit to the Institute in July, 1983. Seated (left to right): Lord Sherfield, Lord Shackleton (Chairman), Mr R. D. G. Hayter (Clerk to the Sub-Committee). Standing (left to right): Mr R. A. Robertson, Professor T. S. West, Dr G. C. Stove, Mr R. Grant.

STAFF

1983

Director—
PROFESSOR T. S. WEST, B.Sc., Ph.D., D.Sc., C.Chem., F.R.S.C., F.R.S.E.

Deputy Director—
G. ANDERSON, B.Sc., Ph.D.

DIVISION OF PEDOLOGY

MINERAL SOILS

Head of Department: R. C. Mackenzie, D.Sc., Ph.D., F.G.S., F.R.S.E.—retired 30/9/83.
M. J. Wilson, B.Sc., Ph.D.—appointed Head of Department 1/11/83.
B. D. Mitchell, B.Sc., C.Chem., F.R.S.C.—Acting Head 1/10/83-1/11/83.
W. J. McHardy, B.Sc., Ph.D.
J. M. Bracewell, B.Sc., C.Chem., F.R.S.C.
D. C. Bain, B.Sc., Ph.D.
E. Paterson, B.Sc.
A. C. Birnie, L.R.S.C.
B. F. L. Smith, B.Sc., M.Sc.
J. M. Tait, B.Sc., Ph.D.
D. M. L. Duthie, B.Sc.
R. Swaffield, L.R.S.C.
G. W. Robertson, B.Sc.
Miss C. J. Bruce.
D. R. Clark.
Mrs S. Ritchie.
Miss J. L. Bunch.
Miss Y. Bisset.
Miss L. J. P. Potter.
Miss L. A. Mielewczyk.
Miss M. I. Thom.
Mrs L. Forsyth.
Miss S. Buchan.
Miss M. R. Grant—appointed 7/2/83.
D. Johnston.

and

PEAT AND FOREST SOILS

Head of Department: R A. Robertson, B.Sc.
H. G. Miller, B.Sc.(For.), Ph.D., D.Sc., F.I.For.
G. C. Stove, B.Sc., Ph.D.—resigned 30/9/83.
B. L. Williams, B.Sc., Ph.D.
J. D. Miller, L.R.S.C.
P. D. Hulme, B.Sc., Ph.D., M.I.Biol.
A. W. Blyth, B.Sc., L.I.Biol.
P. F. S. Ritchie, B.Sc., B.A.
R. V. Birnie, B.Sc., Ph.D.
J. S Anderson.

Mrs J. Shirriffs, L.I.Biol.—resigned 31/7/83.
G. G. Wright, B.Sc.—transferred from Soil Survey 1/11/83.
J. R. Christie, B.Sc., L.R.S.C., A.M.B.C.S.
Mrs J. G. Cairns, M.A.
J. W. Mitchell.
Miss C. A. Flower (C.E.G.B. Term Contract) until 31/1/83.
Miss M. E. Young.
Miss A. M. Largue.
Miss K. Downie.
Miss J. Sutherland.

SPECTROCHEMISTRY

Head of Department: A. M. Ure, B.Sc., Ph.D., C.Chem., F.R.S.C.
V. C. Farmer, B.Sc., Ph.D., C.Chem., F.R.S.C., F.R.S.E.
J. D. Russell, B.Sc., D.Sc., C.Chem., F.R.S.C.
I. C. Burridge, M.A., B.Sc.
M. L. Berrow, B.Sc., Ph.D., C.Chem., F.R.S.C.
B. A. Goodman, B.Sc., Ph.D.
B. L. Sharp, B.Sc., Ph.D., D.I.C., C.Chem., F.R.S.C.
J. M. Ogilvie.
A. R. Fraser, L.R.S.C.
J. R. Bacon, B.Sc., Ph.D.
M. J. Adams, G.R.S.C., Ph.D., D.I.C., C.Chem., M.R.S.C.
W. Matheson, B.Sc.
Miss I. J. Hewitt.
Mrs M. C. Mitchell.
G. A. Reaves, B.Sc.—transferred to Statistics 12/9/83.
G. J. Ewen.
Miss S. M. Fraser, B.Sc.—appointed 1/10/83.
Miss W. M. Stein.
D. B. McPhail, B.Sc.
Miss K. M. Duff—resigned 30/11/83.
I. Black.
Mrs G. Hudson—resigned 9/9/83
Miss L. M. Melvin.
Mrs S. E. Sim—resigned 15/4/83.
Miss J. A. Lynch.
D. Cumming—resigned 28/2/83.
R. Johnston.
I. G. Finlayson.
Miss P. M. Reid.
Miss P. J. Smith.
A. J. McAllister.
Miss S. M. Allardice—resigned 20/5/83.
Miss G. B. Adam—resigned 24/6/83.
Miss F. M. J. Berry—appointed 14/3/83.
Miss A. M. Little—appointed 9/5/83.
Miss J. R. Strachan—appointed 27/6/83.
Miss L. A. Clark—appointed 29/8/83.
Miss J. J. Harthill—appointed 12/9/83.
I. M. Still.
E. Lawson.

SOIL ORGANIC CHEMISTRY

Head of Department: G. Anderson, B.Sc., Ph.D.
I. R. MacDonald, B.Sc., Ph.D.
M. V. Cheshire, B.Sc., Ph.D.
D. Vaughan, B.Sc., Ph.D.
H. A. Anderson, B.Sc., Ph.D.
D. J. Linehan, B.Sc., Ph.D.
C. M. Mundie, C.Chem., F.R.S.C.
R. E. Malcolm.
A. Hepburn, L.R.S.C.
D. C. Gordon.
B. G. Ord.
Mrs M. Stewart.
Mrs S. McGuigan—resigned 14/10/83.
Miss R. M. Paterson.
Mrs S. E. Black—resigned 15/4/83.
Miss S. M. Crooke.
R. G. Main—appointed 6/12/82.
Miss A. M. Hall—appointed 10/1/83.
Miss S. A. Cope—appointed 13/6/83.

PLANT PHYSIOLOGY

Acting Head of Department: A. E. S. Macklon, B.Sc., Ph.D.
A. Sim, L.R.S.C.
Mrs M. R. Tyler.
I. D. McFarlane.
Mrs J. E. Fairlie—resigned 3/3/83.

MICROBIOLOGY

Head of Department: J. F. Darbyshire, M.Sc., Ph.D., Dip.Agric.Sc
D. Jones, M.Sc., Ph.D., M.I.Biol., F.R.M.S.
G. P. Sparling, B.Sc., Ph.D.—resigned 5/7/83.
M. S. Davidson.
R. E. Wheatley, B.Sc.
B. S. Griffiths, B.Sc., Ph.D.—appointed 7/2/83.
S. Wood, B.Sc., Ph.D.—appointed 17/10/83.
Mrs C. E. Alexander, B.Sc., Ph.D. (EEC Term Contract) —appointed 1/11/83.
Mrs J. A. Leighton.
Mrs H. A. Kidd.
Mrs B. Doyle (née Ross).
Miss J. M. A. Melvin.
Mrs M. M. Justice.

SOIL FERTILITY

Head of Department: B. W. Bache, M.A., Ph.D., C.Chem., F.R.S.C.

J. W. S. Reith, B.Sc.(Agric.), Ph.D., C.Chem., F.R.S.C.
A. H. Knight, B.Sc.
P. W. Dyson, B.Sc., Ph.D.
N. M. Scott, Ph.D., C.Chem., F.R.S.C.
W. E. Simpson, B.Sc.
K. S. Caldwell, S.D.A., S.D.D.H.
H. Shepherd, L.R.S.C.
T. E. Edmonds, B.Sc., M.Sc., Ph.D., C.Chem., M.R.S.C.—resigned 5/1/83.
A. H. Sinclair, B.Sc., Ph.D.
J. A. M. Ross, N.D.A.
G. S. Sharp, L.R.S.C.
Miss S. M. Law—retired 31/10/83.
S. Cooke, B.Sc., Ph.D.
P. Wilson, B.Sc.
Mrs G. Coutts.
P. Millard, B.Sc., Ph.D.
Mrs C. Duncan (née Ireland).
Mrs D. R. Donald (née Melville).
S. D. Porter.
Miss E. J. Donald.
Miss M. E. Watson.
Mrs E. B. Still.
Mrs K. L. Stevenson (née Stark).
Miss L. Balloch.
C. J. Wilkinson.
Miss J. P. Downie—resigned 30/11/83.
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.
K. W. M. Brown, B.Sc., M.Sc.
G. A. Reaves—transferred from Spectrochemistry 12/9/83.
Miss E. I. Duff, B.Sc.
Miss M. Macdonald—resigned 28/2/83.
I. Earley—resigned 13/4/83.
Miss K. A. Robertson, B.Sc.
T. Gilmour, B.Sc.—appointed 11/7/83.
Miss A. West.
Mrs M. E. Wilson (née Lamont).

SOIL SURVEY

Head of Department: R. Grant, M.A., B.Sc.—retired 31/10/83.
J. S. Bibby, B.Sc.—appointed 1/11/83.
C. J. Bown, B.Sc.
B. M. Shipley, B.Sc.
A. D. Walker, B.Sc.
D. W. Futty, 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.
G. Hudson, B.Sc.
C. G. B. Campbell, B.Sc.
D. J. Henderson, B.Sc.
G. G. Wright, B.Sc.—transferred to Peat and Forest Soils 1/11/83.
W. Towers, B.Sc.
J. S. Bell, B.Sc
J. A. Hipkin, B.Sc.
A. J. Nolan, B.Sc.
A. Lilly, B.Sc.
W. S. Shirreffs.
A. D. Moir.
Miss P. R. Carnegie.
Miss L. A. Murray—resigned 18/1/83.
Miss D. A. Hughson—appointed 11/4/83.
C. Halliday.

LIBRARY AND INFORMATION SERVICES

Librarian Mrs A. H. W. Dickie, A.L.A.
Mrs L. Lawson—resigned 13/5/83.
Miss M. S. Thomson—appointed 17/10/83.

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

TECHNICAL SERVICES

Head of Section A. W. Stuart.
J. H. Normington.
G. J. Gaskin.
A. I. A. Wilson.
N. P. Hird.
R. D. Malcolm.
G. Sim.
D. W. Clark.
A. J. Slater.
P. Docherty—appointed 9/5/83.

STAFF—*continued*

Photographer	J. Mitchell, A.B.I.P.P., A.I.M.B.I. D. J. Riley.
Clerk of Works	G. Forbes.

ADMINISTRATION

Secretary and Treasurer	Miss E. A. Piggott, M.B.I.M.
Personal Secretary	Miss E. J. Cockburn.
Deputy Secretary	Mrs M. Milne. Miss K. E. Weir, M.A.
Personal Secretary to Director	Miss M. H. F. B. Nicol.
Office Staff	Miss L. S. Thomson—resigned 11/3/83. Mrs C. M. R. Burness. Mrs E. Gillanders. Miss J. Taylor—appointed 14/3/83. Miss J. M. Laing. Mrs I. M. Shand. Mrs C. T. Garden. Miss S. M. Cruickshank—resigned 8/4/83. Mrs C. Smollet. Miss J. Buchan. Miss E. A. Munro—19/4/83-24/10/83.
Telephonist	Mrs P. M. McSporran—retired 29/7/83 Mrs R. M. Simpson—appointed 1/8/83.
Storekeeper	A. S. Riddoch. Miss E. M. Middleton.
Driver Handyman	I. Findlay.
Attendant	J. D. C. Nicol—retired 15/7/83. J. Robertson—appointed 18/7/83.
Outdoor Staff	A. Mutch—retired 31/8/83. W. L. W. Ross. R. A. R. Clarke. J. S. West. C. S. Robertson.

HONORARY FELLOWS

E. G. Williams, B.Sc., Ph.D.
Mrs A. F. Stewart, M.A.
Miss E. J. Dey, M.B.E.

HONORARY ASSOCIATES

D. M. Webley, M.Sc., Ph.D., F.I.Biol., F.R.S.E.
R. Glentworth, B.S.A.(Manitoba), Ph.D.
R. O. Scott, B.Sc., Ph.D., A.R.C.S.T., C.Chem., F.R.S.C.
P. C. DeKock, M.Sc., D.Phil.
R. C. Mackenzie, D.Sc., Ph.D., F.G.S., F.R.S.E.
R. Grant, M.A., B.Sc

VISITING RESEARCH WORKERS

Dr F. Bartoli, Department of Mineral Soils (Centre de Pedologie Biologique, France).

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

Dr L. J. Evans, Department of Mineral Soils (University of Guelph, Canada).

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

*Miss S. Fraser, Department of Soil Fertility, M.O.D. Research Student.

Fu Bin, Department of Spectrochemistry (Beijing Mining and Metallurgical Research Institute, Beijing, China).

Ms Y. Geelen, Soil Survey (Agricultural University, Wageningen, Netherlands).

*M. J. Hepher, Department of Soil Fertility, A.R.C. Research Student.

Professor F. E. Koehler, Department of Soil Fertility (Washington State University, Pullman, Washington, U.S.A.).

*Lau Chau-Ming, Department of Spectrochemistry, Research Student.

Dr R. Lee, Department of Soil Fertility (D.S.I.R. Soil Bureau, Lower Hutt, New Zealand).

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

Professor Dr F. Palmieri, Department of Spectrochemistry (Istituto di Chimica Agraria, Universita degli Studi di Napoli, Italy).

S. U. Patwary, Department of Soil Fertility (Institute of Nuclear Agriculture, Mymensingh, Bangladesh).

C. Pijs, Soil Survey (Agricultural University, Wageningen, Netherlands).

*Miss F. Proctor, Department of Plant Physiology, D.A.F.S. Research Student.

*M. F. Proe, Department of Peat and Forest Soils, N.E.R.C./C.A.S.E. Research Student.

Ms L. Schoot, Soil Survey (Agricultural University, Wageningen, Netherlands).

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

Professor J. M. Stewart, Department of Peat and Forest Soils (University of Manitoba, Winnipeg, Canada).

T. B. R. Yormah, Department of Soil Fertility/Soil Organic Chemistry (University of Sierra Leone, Sierra Leone).

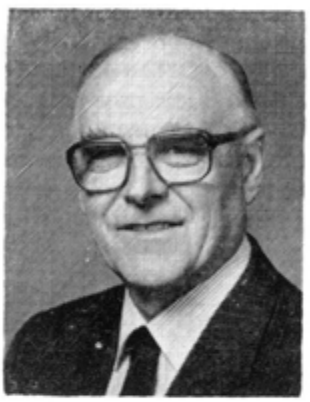
Dr J. Young, Department of Peat and Forest Soils (Edinburgh University).

*Ph.D. Student.

CONTENTS

INTRODUCTION

T. S. WEST



The uncertainty regarding the future of research in the ARS stations referred to in the introduction to the previous Annual Report has continued and intensified in 1983. Redundancies have now been declared at Rothamsted Experimental Station in addition to those at Long Ashton Research Station and at the Animal Breeding Research Organisation. In addition, further measures of economy were announced later in the year and this, combined with the need for ARC to broaden its terms of reference to include food research, has not only led to a change of name to the Agricultural and Food Research Council (AFRC), but to further retrenchment in less-favoured areas of research so that work on food can begin within AFRC stations with no additional funds. By the end of the year, following the publication of AFRC's Corporate Plan[1] it became clear that *ca.* 500 posts would have to be vacated shortly. Subsequent decommissioning by the Ministry of Agriculture, Fisheries and Food (MAFF) with the AFRC suggested that another 100 posts were at risk in England and Wales. The Scottish Agricultural Research Institutes (SARI), funded by the Department of Agriculture and Fisheries for Scotland have not been involved in this sudden excision but, as in the past few years, there has been a progressive trimming of SARI staff budgets during the year. Nevertheless, staff made redundant in AFRC stations can displace less long serving staff in similar disciplines within service-wide declared areas of redundancy in the Scottish Agricultural Research Institutes. This is a continuing cause for concern.

In 1983, however, this Institute has been able to begin replacing some of the vacancies created by retirement of senior staff in 1981-82 and which were held over pending the outcome of the 1982 MISR Programme Review. This has been a protracted affair due to the need to ensure that AFRC staff who might be losing their posts in England and Wales should have the opportunity to be considered for these vacancies. As a result of acceptance of most of the recommendations of the MISR Programme Review by DAFS the Institute will now be able to expand its effort and capacity in some topics such as Microbiology, Remote Sensing, Soil Physics and Trace Element work, whilst largely maintaining its 1981-82 level of activity in most other areas. Nevertheless, the retirement of several long-serving and experienced members of staff in key positions, most of them at the relatively early retiring age of 60 years, during 1983 will cause additional serious hold-up in several parts of the Institute's work in 1984. In addition, the loss of two of the Institute's most active team leaders to high posts in the academic

world in 1984 will cause further problems, although it is a tribute to the quality of their work as well as to the Institute that both won their new positions against stiff competition from academics within and outwith the U.K.

Despite these uncertainties and staff losses and during the lull in replacement, it is heartening to report that 93 publications appeared in 1983 as opposed to 104 in 1982, 80 in 1981 and 92 in 1980. The Institute's policy of devoting more of its energy and time to study problems of immediate concern to the community that supports it has been continued to good effect as will be seen from the paragraphs that follow and in the individual departmental reports. Several new initiatives have also been taken in strategic research, *i.e.* fairly fundamental research undertaken with the specific aim of solving a particular problem.

Blockage of Field Drains by Iron Ochre

In the previous Report[2] mention was made of a rather elegant solution to the prevention of blockage of field drains by iron ochre based on some observations and work on basic research in organic chemistry. Work on ochre has continued this year, as will be seen from Sections 1, Mineral Soils; 4, Organic Chemistry; and 6, Microbiology. Blockage could be prevented in those sites where the drainage system incorporated inspection pits where porous plastic sacks of weathered coniferous bark could be deposited to remove iron, mobilized into the soil solution as Fe(II), before it could be reoxidised to Fe(III) and deposited as voluminous iron ochre. During the past year, a more thorough understanding of ochre formation and structure has been obtained and an extension of this elegant, environmentally acceptable and inexpensive ameliorative measure is now being sought for other forms of drainage system.

Soil Fertility Information System for Scotland

The advisory services for farmers are operated in Scotland by the three Colleges of Agriculture. This Institute has always had very close ties with the North of Scotland College of Agriculture and has been involved in the provision of advice through the College advisory staff and indeed in carrying out all the soil and plant analyses for the North College area. More recently, the Institute's links with the East and West Colleges, which cover the remainder of Scotland, have been strengthened and improved greatly through the regular meetings of the MISR/COSAC Liaison Committee and its Working Parties on specific topics. This has led to standardisation of analytical procedures between the three centres and the introduction of common reporting and recording procedures throughout Scotland. Within the past few months agreement to set up a Scottish Soil Fertility (Data Base) Information System has also been achieved. Information will be recorded on microcomputers on floppy disks at all three centres in a common format and will be subsequently incorporated in the Institute's mainframe computer to provide a fertility data base for Scotland. This will enable information to be obtained for Scotland as a whole on many topics, *e.g.* trends in soil acidity (lime status) nutrient status, practical differences between soil series,

fertilizer practice, etc. Thus, much more information of permanent value will be derived from advisory analyses in addition to the immediate lime and fertilizer recommendations given to farmers. See Section 7, p. 105.

It is perhaps relevant here to refer also to the Institute's Soil Data Bank which stores soils information from the Soil Survey and the mineralogy and trace element analyses of systematic soil survey information from all over Scotland. A combination of the information from both data banks will provide a powerful tool for future research and development work for Scottish agriculture.

Trace Element Contents of Herbage Crops

Many years' work on the contents of the trace elements, cobalt, copper and molybdenum in clover and grass in herbage, particularly in relation to the level of nitrogen fertilization and to soil drainage conditions, has been summarized. The pattern of results is complex, as described in Section 7 of this Report, p. 107-108, but it confirms the generalisations that have been proposed in the past, namely that imperfect and poor pedoligical drainage conditions increase trace element availability, and that high levels of added nitrogenous fertilizers reduce trace element contents of herbage, mainly by eliminating clovers from the sward. The reduction is due also to some extent to dilution of the level of trace elements within the plant by increased carbohydrate and other organic matter content of the enhanced plant growth.

Variations in Manganese Availability. Mobilization in Soil around the Root

The chemical and biological reactions which occur in the soil in the rhizosphere, *i.e.* in close proximity to the root, can have a key influence on the availability of nutrients to crops, Section 4, p. 83, Section 7, p. 105 In two soils where advisory soil tests had indicated that manganese deficiency was likely to occur, the manganese concentration in the soil solution near the root was monitored. In both soils the concentration increased for a time in the summer, but the pattern of mobilization, and the levels reached were different at the two sites. At one site, spring barley showed considerable symptoms of manganese deficiency, but none was apparent at the other. It is suggested that the mobilization is probably caused by microbial action, although reducing conditions during the very wet spring may also have played a prominent role. The greater acidity of the rhizosphere soil in relation to the bulk soil is a noticeable feature of these experiments, but cannot alone account for the increased manganese mobility. The reasons for the differences between the two soils will be further investigated.

In the Department of Microbiology, Section 6, p. 98, studies on the transfer of nutrients from the microbial community to plant roots have continued and are being extended to include trace elements. Micro-organisms appear to be important to the availability of cobalt as well as manganese. These investigations are continuing and will soon be extended to include sulphur.

Soil Organic Nitrogen: Role of Soil Invertebrates

Detailed investigations have now begun into the nitrogen transformations which occur in soil/plant systems, particularly the conversion of applied fertilizer nitrogen into organic forms and the rate of subsequent mineralization of these forms. Materials labelled with ^{15}N are being used and analysis will be carried out using both optical emission spectroscopy and mass spectrometry. A considerable amount of the nitrogen in soils has not yet been characterized and improved methods for the extraction and identification of these compounds are being studied. Particular attention is also being paid to microbial components, such as nucleic acid derivatives, whose turnover rate is likely to be rapid, Section 4, p. 83, Section 6, p. 98. In connection with the recycling and plant availability of nitrogen from invertebrate activity in the soil the use of pyrolysis-mass spectrometry for detecting changes in food during the digestion of soil animals is a new departure. It is, of course, dependent on the expertise previously acquired with GC-mass spectrometry with other samples of soil organic matter. The study of the effects that soil invertebrates have on the decomposition of plant material has been hampered in the past by the small size of the gut contents of individual animals. This has necessitated bulking the samples from different parts of the alimentary canal together or in some cases even bulking samples from different animals together, see Section 6, p. 101.

Investigation of Soil Antibiotics: Soil Pores and Protozoa

Also in the field of soil microbiology the isolation of the antibiotic vermiculine, from *Penicillium wortmannii* is an interesting observation, Section 6, p. 99, because it suggests that this antibiotic is more widespread amongst microorganisms than previously thought. It has been shown that it affects some plant pathogenic and saprophytic fungi in the soil and not other species. Such antibiotics may play important roles in the microbial competition in the soil.

A system of estimating the range and number of soil pores available for colonization by soil protozoa has been developed and compared with three other methods of estimating soil porosity. This new method, Section 6, p. 99, may be successfully applied in other research projects concerned with soil structure.

Complete Mapping and Land Use Assessment of the Soils of Scotland

The highlight of the Soil Survey's year was the publication of the 1:250 000 soil and land capability for agriculture maps covering the whole of Scotland, Section 9, p. 126. This successful completion of the project was marked by an official " launch " of the maps by the Scottish Secretary of State for Agriculture, the Earl of Mansfield. The maps have been well received and there has been an encouraging demand from a wide range of interests, both academic and practical.

SOIL SURVEY: The way ahead

With the ending of the 1:250 000 mapping project the Soil Survey has returned its attention to completing the mapping of those areas of arable

soil that as yet remain unmapped at the 1 : 50 000 or 1 : 63 360 scales. Whilst this constitutes its first priority, the Survey is increasingly turning its attention to producing " user-friendly " information such as simplified literature for soil users based on individual soil series, the inclusion of more information on the physical properties of soils, production of special feature maps (*e.g.* trace element distribution) and so on. In addition, the Survey is looking increasingly to progressive introduction of automation and computer techniques in areas such as cartography. The pressure now being brought to bear upon the Soil Survey Department to produce such " user-friendly " information by its own volition, by the reconstituted Soil Survey Research Advisory Committee of AFRC and the MISR/COSAC Liaison Committee makes the restoration of vacancies in Survey held over from the Programme Review exercise a matter of considerable urgency, particularly since the vacancies are likely to be deployed in areas that will be largely of a non-traditional survey nature.

Trace Element Initiatives

Another department of the Institute that is altering the focus of its attention considerably is Plant Physiology. In the past, under the leadership of Dr P. C. DeKock, it has made major contributions to the effects of some major nutrients, particularly nitrogen and, the forms in which it is applied, on the physiology of vegetable crops. Whilst the scientific community was slow to recognise the validity of the conclusions drawn about the effects of recognition is now forthcoming and this work, having been taken to a satis- *e.g.* ammonium nitrogen causing incidence of calcium deficiency problems, factory conclusion, has been phased out during 1983. Major emphasis is now being given to the study of trace element uptake and transport in plants, as part of a multidisciplinary study of trace element deficiencies in soil/plant/animal systems, Section 5, p. 94. Work on cobalt, deficiency of which in animal diets is widespread in Scotland, has started with an examination of location and exchange in plant roots. This work on trace elements in plants will be linked with new work on trace element cycling in the Department of Microbiology and new analytical capability for trace element work in the Department of Spectrochemistry. The programme will contribute to an envisaged thrust in trace element work in the Aberdeen area involving trace element animal nutrition studies at the Rowett Research Institute, the work of the veterinary services of the North of Scotland College of Agriculture and work on trace elements in human nutrition at the Medical School of the University of Aberdeen, which is at present supported by this Institute.

New Spectroscopic Technique comes on line

An important new development in optical emission spectroscopy — the inductively coupled plasma (ICP) source — has been introduced for the routine analysis of major cations, Section 3, p. 66. Initially, it is being applied to the determination of calcium and magnesium in crop samples, but it is intended that the technique will be extended to other sample types such as soil extracts and to other elements. For major cations it is

anticipated that this technique will progressively replace existing flame atomic absorption spectrometric methods and will complement them for some trace element anlyses.

Microcomputers in Spectrochemical Technology

This year the microcomputer revolution has had a major impact on spectrochemical techniques and here, as in other fields, the microcomputer can no longer be regarded simply as a helpful accessory, but has an integral role in instrumentation itself, in data processing and presentation and in the interactive interpretation of experimental results. Many instances of such applications are detailed in Section 3 of this Report and the fruitful example of interfacing an infrared absorption spectrometer to a microcomputer is illustrated in Fig. 3·1, p. 73. In this case the microcomputer not only permits complex spectral manipulations to be carried out, but also provides access to the Institute's mainframe computer in which a library of, currently, some 800 spectra are stored-a library expected to increase by the 1000 spectra generated by the spectrometer each year. Experience gained in the past year with a prototype microcomputer-controlled microdensitometer, now in operation for evaluating spark source mass spectrographic plates, has encouraged embarkation on the construction of an automatic microcomputer-controlled microdensitometer for the rapid (1 spectra on a 10-inch plate per minute) evaluation of both spark source mass- and dc arc emission spectrographic plates. This development is regarded as offering a fundamental transformation of the capability and potential of optical emission spectrography in two respects, firstly in speeding up and improving the precision of the trace element analysis of soil profiles from the Department of Soil Survey and, secondly, in extending sensitivity and element coverage by making routine use of the high-current argon arc as a spectrographic source. This application of the microcomputer does, therefore, promise to revitalise the use of analytical optical emission spectrography and may well fill the role hitherto played by direct-reading polychromator instruments and fill it more flexibly.

New Spectroscopies

With the return of Dr B. A. Goodman from his sabbatical year in the U.S.A., the growing importance of magnetic spectroscopies, such as nuclear magnetic resonance (NMR) spectroscopy, in structural and speciation studies of elements in agricultural systems has been emphasised. This also serves as a reminder of the extent to which the magnetic properties of matter are involved in the techniques used in the Department of Spectrochemistry. These include electron paramagnetic resonance (EPR) spectroscopy, spark source mass spectrometry (SSMS) and the use of magnetic separation methods for magnetic mineral species such as the Macaulayite exemplified in Fig. 3.1, p. 73.

Progress in Computing

The Institute's central computing system, the Data General Eclipse C/150 has had an increase to 29 in the number of lines to terminals, peri-

pheral devices, mini- and micro-computers, and instruments in various department. The memory size has also been increased. One of the additional devices is a graphics terminal with local printing facilities.

A recent survey of computing equipment in the Institute showed that there are 39 micro- and mini-computers, Apples being the most numerous.

The demand for knowledge of computer programming and experience in computer use has not abated and three courses of instruction were provided with 14 members of staff on each.

Tree-Soil Interactions and Nutrient Cycling

Increasing attention is being given to the modifications vegetation may impose on soil and the consequent effects on nutrient availability and cycling on marginal land. A detailed examination of the literature on nutrient accumulation and release in birch crops, and the construction of models of nutrient cycling in this species, failed to reveal any reason why birch should be regarded as a soil improver, Section 2, p. 52. Accordingly, a field study has been intiated in collaboration with the Institute of Terrestrial Ecology to monitor nutrient cycles in birch stands of various ages on two contrasting soil types, one of which is showing changes following invasion of heath by trees. A somewhat related project that also started during the year under review, has the object of elucidating the processes that enable nitrogen and other nutrients to cycle more rapidly in mixed spruce-larch and spruce-pine stands in pure spruce stands. This study arises from observations that, whereas Sitka spruce planted on poor peats and upland heaths invariably becomes nitrogen-deficient by age 12, no such deficiency appears in trees planted in intimate mixture with larch or pine. With the encouragement of the Forestry Commission a joint proposal was drawn up with the Irish Forest and Wildlife Service and submitted to the Commission of European Communities for support under their Research and Development Programme on Wood as a Renewable Raw Material. This proposal was successful and has attracted sufficient funding to enable a microbiologist to be attached to the project.

Acid Rain

Following suggestions in Germany that rainwater-introduced acidity may be mobilizing sufficient aluminium in soils to damage tree roots, experiments have been carried out to establish the tolerance of trees to soluble aluminium. To date, in a number of hydroponic experiments, no damage has been caused to the roots of either Sitka spruce or sycamore at soil aluminium levels at least as high as 20 ppm, and perhaps higher. It seems very unlikely, therefore, that acid rain effects on soil aluminium could lead to growth disturbances.

In studies of the effect of vegetation on rainwater acidity, an increase in pH values was generally recorded. However, in eastern sites receiving fairly acid rain, a regular annual oscillation was found in the pH of water collected beneath trees, the reduction in acidity being least pronounced in late winter and most pronounced in late summer.

Barley Agronomy

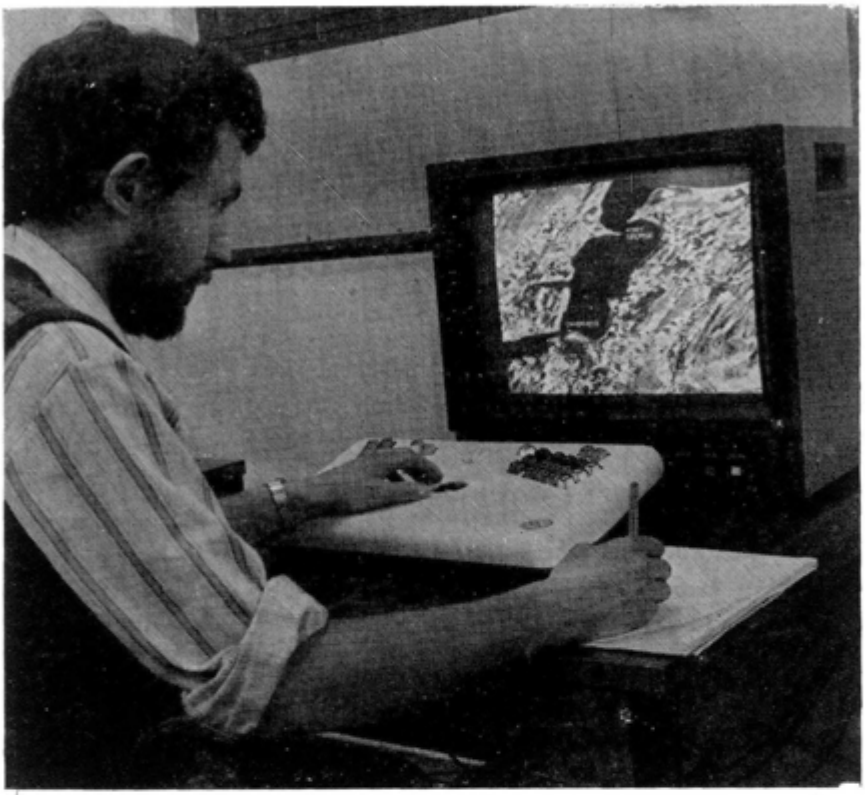
Experimental winter barley yields in 1983 were somewhat lower than in the previous year, due mainly to climatic effects, either directly or by interaction with weed and disease infestation. The achievement of high yield is still not fully understood, but the need for high nitrogen fertilization, averaging 180 kg/ha N applied in the spring, has been emphasised. Experiments with growth regulators, such as Cycocel, hold out the promise of altering the growth pattern of the winter barley crop to produce somewhat higher yields. The pattern of decreasing use of lime that has become evident in recent years may have potentially serious consequences for barley production. This has led to a re-examination of the critical soil pH for the growth of barley. Yields of both spring barley (Golden Promise) and winter barley (Igri) in carefully-controlled field plots are not reduced until soil pH falls below about 5.7-5.8. This is lower than older estimates, possibly because of the widespread use of phosphates, for high phosphate levels have been shown to give a lower critical pH. However, the target pH for liming soils must still be 6.2 to take account of the variability in pH normally found in field soils.

New Image Processing System

Work in the Department of Peat and Forest Soils, Section 2, p. 45, underlines the growing importance and practical application of remote sensing techniques for terrain resource survey and environmental monitoring operations. The recent acquisition of a GEMS image processing system will greatly enhance the capability of the department's Remote Sensing Unit to establish its role as a centre for the development and promotion of remote sensing activities within the Agricultural Research Service. The new highly versatile electronic memory system is hosted by a PRIME 250 minicomputer and is capable of holding and manipulating up to 16 separate 512×512 8-bit digital images. Primarily, the system will be used for the display, analysis and interpretation of image data derived from the present LANDSAT series of high resolution earth observation satellites and from future satellites including the French SPOT and the European ERS 1 which will carry a microwave (radar) imaging system. The main objective of this research will be to develop and apply techniques, in collaboration with other departments and institutes, for mapping and monitoring agricultural crops, vegetation types, soil characteristics, land cover and other terrain features using multi-temporal space imagery.

New Techniques for Surface Analysis and Isotopic Work

During the year a VG Escalab-2 electron spectrometer was obtained by the Department of Mineral Soils and successfully commissioned. In order to assess the potential of the instrument an assortment of samples has been rapidly surveyed including amongst others, plant material and clay minerals. It is already apparent that the wide range of elements detected by the technique make it a most valuable acquisition, especially because of its sensitivity for low atomic numbers elements such as N, O and C. Currently, a great deal of attention is being given to methods of sample preparation.



The GEMS console and colour monitor displaying a LANDSAT scene of the Inverness area for Dr R. V. Birnie, Remote Sensing Unit, Department of Peat and Forest Soils.

A triple collector isotope mass spectrometer, SIRA 9 was delivered to the same department in December, 1983, to service the growing Institute requirement for N isotope analysis in field and laboratory nitrogen tracer experiments. This instrument has a measured precision of 0·02 per mil enrichment which is about 0·000008 atoms % at near natural abundance. Samples containing 0·05 to 0·5 μg N can be processed in about 10 minutes. The instrument can be potentially modified for analysis of other stable isotopes C, O and S.

EVENTS AND PEOPLE

Eighth T. B. Macaulay Lecture

The Eighth T. B. Macaulay Lecture, entitled "Scottish Agricultural Improvements in the Post War Years," was delivered by Mr J. I. Smith, C.B., Secretary of the Department of Agriculture and Fisheries for Scotland, in the Marine Suite of the Amatola Hotel on 25th November, 1983. The lecture, which was attended by an audience of *ca.* 200 from the Institute, University and other local research stations, is presented as

Appendix I of this Report. Mr Smith's account of developments during the past 38 years shows how the efficiency of agricultural practice has increased quite substantially, much of it due to the introduction of new ideas arising from research work at Institutes such as this. The lecture also shows how scientists' freedom to conduct research according to their own ideas was circumscribed sharply in the early 70s by the introduction of Lord Rothschild's paper[3] "A Framework for Government Research and Development." This control tightened very greatly 10 years subsequently, due to additional economic considerations culminating in the publication of the Corporate Plan of AFRC in December, 1983[1], and events referred to in the opening paragraph of this Report. The chairman of the Council of Management, Professor H. M. Keir, took the chair and the director gave the vote of thanks and presented the Macaulay Scroll to Mr Smith.

During the year there have been a number of retirements throughout the Institute. Amongst non-scientific staff, Mrs Gladys Adams retired on 16th May having been employed as a cleaner since 1976, latterly in the Department of Soil Survey. Mr E. P. Drysder, Patrolman, retired on 3rd July, after four years' service, and Mr J. D. C. Nicol, Messenger, on 15th July having been employed since 1978. Mrs Pat McSporran, Telephonist, a well-known voice to all who spoke to Institute staff on the telephone, retired on 29th July, having served the Institute well and faithfully in this capacity for 21 years. An even longer serving non-scientific member of staff and "well kent" figure, who left the service of the Institute on 31st August, was Mr Andrew Mutch, Head Gardener. He joined the grounds staff in 1947 and occupied the position of Head Gardener since 1974. We wish all of these, our friends and colleagues, a long and happy retirement.

Amongst scientific staff there were also several retirements.

Dr R. C. Mackenzie, Senior Principal Scientific Officer, Head of the Department of Mineral Soils and Division of Pedology, retired on 30th September. Dr Mackenzie was a first-class honours graduate in chemistry of the University of Edinburgh and joined the staff of the Institute in 1944 after gaining his Ph.D. degree at Edinburgh for work on gas phase kinetics of the decomposition of hydrogen peroxide. His first experience was in Soil Survey, but, under the influence of Dr "Sandy" Muir, he became progressively engaged in X-ray crystallography and, using his basic training and knowledge of physical and analytical chemistry, he notably developed thermoanalytical techniques for the examination of clays and minerals. His skills brought him to the fore as a world leader in this technique and he won international recognition and many awards including: The Centenary Medal of Charles University (Czechoslovakia), 1961; The Mettler Award (U.S.A.), 1968; The Society of Analytical Chemistry Gold Medal (U.K.), 1980; The Netzsch GEFTA Award (F.R.G.), 1982; and The Emanuel Boricky Medal (Czechoslovakia), 1983. In 1948 he set up the new section of Physical Chemistry and when this was amalgamated with several others to become the Department of Pedology Dr Mackenzie became its Head in 1959. His tenure of this position was distinguished for its many contributions, not only to techniques, but to research in Pedology, and brought much renown

to this Institute as well as a continuous stream of distinguished scientists from overseas. A more detailed summary of Dr Mackenzie's career and achievements is recorded in the Institute's news magazine " Profile[4]." A special meeting of the Clay Minerals Group of the Mineraliogical Society and the Thermal Methods Group of the Royal Society of Chemistry was organized in London in November, 1983, in his honour as an appreciation of his many contributions to British science.

Miss Sheila Law, Higher Scientific Officer in the Department of Soil Fertility, retired on 31st October. A pupil of Aberdeen High School for Girls, she joined the 40-strong staff as a Scientific Assistant in 1942 and went to work in the part of Craigiebuckler House that constituted the laboratories of the Institute at that time. Under the supervision of Miss A. J. Preddy she joined the group responsible for analysing soil samples from field experiments and farmers' samples and, as time went on, became responsible for the team of five assistants who did this vitally important task. Although her 41 years' work did not produce scientific publications, their value to the Institute, the North of Scotland College of Agriculture's Advisory Services and to the farming community in the North of Scotland was outstanding. In addition to her scientific skills, Sheila Law also enriched the social life of the Institute and the community in Aberdeen by her contributions to dramatic productions with the Gavin Players and as producer of various plays, including some for the BBC. A fuller account of her career at the Institute is recorded elsewhere[5].

Mr R. Grant, Senior Principal Scientific Officer, Head of the Department of Soil Survey, also retired on 31st October. A pupil of Lossiemouth School and Elgin Academy, his career at Aberdeen University was interrupted by the Second World War, during which he flew with the R.A.F. as a Flight-Lieutenant. After the end of the war he completed his M.A., B.Sc. degrees in 1946 and 1949 respectively, and joined the Soil Survey in 1950. His contributions to the systematic soil survey of Scotland have been as profound and valuable as they have been quiet and unobtrusive. As a surveyor under the leadership of Dr R. Glentworth, he passed from field surveyor to correlator and in 1976 he himself became Head of Survey and almost immediately was given the onerous task of carrying out a complete survey and mapping of the soils of Scotland at the 1:250 000 scale. His achievement in discharging this task and harnessing the energy and drive of the staff of his department to completing it in 1983 not only for soils, but for Land Capability Assessment for Agriculture in a series of seven soil and seven LCA maps, together with a handbook for each, is a monumental achievement of which the Institute is justly proud. It is a matter of considerable disappointment and chagrin that the Land Use for Forestry

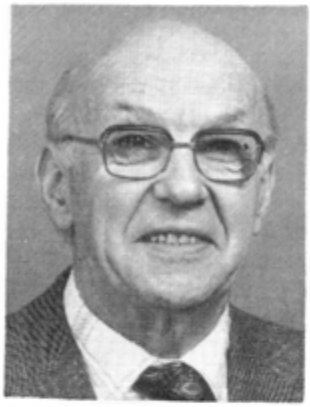
Assessment system, which was also devised under his leadership, could not be published for administrative reasons. Not only did the LCA coverage constitute one of the first complete coverages of a country, the LCF would have been the first ever to be devised and published. An account of Mr Grant's career has been written elsewhere[6]. Mr Grant's contributions to science and the community may not have brought spectacular tokens of recognition, but their importance and endurance are remarkable and will be for many years to come. Mr Grant was succeeded as Head of Soil Survey by Professor J. S. Bibby, formerly PSO in charge of the Oban office of the Survey.

Dr V. C. Farmer, Senior Principal Scientific Officer and Leader of the Infra-Red Team of the Department of Spectrochemistry, retired on 31st December. Dr Farmer graduated with first-class honours in chemistry at the University of Glasgow in 1943 and joined the Institute staff in the same year as an ARC student, gaining the Ph.D. degree from Aberdeen University in 1947 for his work on the d.c. spectrography of minor elements in plants and soils. He was appointed SO in 1946. His first two papers on background emission corrections in spectrography, published in 1944 and 1946, reveal his mastery of physical chemistry and mathematics, which was to shape much of his subsequent distinguished career at the Institute including the award of the Fellowship of the Royal Society of Edinburgh (1979), Fellowship of the Japan Society for the Promotion of Science (1982) and the ARC Individual Merit Award of SPSO grade in 1968 from the Agricultural Research Council. His interests and capabilities spread rapidly into other branches of spectroscopy and he took charge of the Institute's first Infra-Red absorption spectrometer in 1954. From then on his work on the structure of soil constituents, both organic and inorganic, on biological organic matter, *e.g.* fungal cell walls, plant residues, etc., by Infra-Red spectroscopy received prominent recognition the world over and his 125-+ research papers reveal a depth of scholarship and grasp of fundamental principles with which few academics would care to contend. These contributions have won renown for Dr Farmer, his team and the Institute over the years and resulted in many distinguished chemists and soil scientists beating a pathway to his door to learn from him. Most scientists " peak " in their mid-career in terms of scientific publications and innovation, but Dr Farmer's pattern is completely different. It shows a continuously rising curve — a crescendo might be more appropriate — culminating in his evolution of a significant and revolutionary theory of the mechanism of transport of aluminium and iron in soil profiles and the formation of podzols. This theory, based on his studies of the curiously structured alumino-silicate mineral Imogolite[7] and its precursor Protoimogolite, has

already won acceptance in several countries and will undoubtedly have a very considerable impact on future thinking in soil science. A tribute to his career has been published in the Institute news magazine, "Profile[8]." Responsibility for the Infra-Red research team now rests with Dr J. D. Russell (PSO), who has been Dr Farmer's principal colleague on the team since 1957.

Mr A. H. Knight, Principal Scientific Officer, Department of Soil Fertility, and Leader of the Radiochemical Services to the rest of the Institute, also retired on 31st December. A first-class honours graduate in chemistry at St Andrews University in 1945, Mr Knight first continued his studies at University College, Dundee, 1945-47, and then at King's College, Newcastle, 1947-49 before he joined the staff of the Institute in 1950 as a member of the Department of Plant Physiology under Dr J. G. Hunter's leadership to engage in research on the application of radioactive techniques to soil science and plant nutrition. He sacrificed his opportunity to finish his Ph.D. work at Newcastle in order to discharge his new duties at the Institute. Quickly he established the provision of a suite of central facilities for radioactive tracer work for the Institute and became involved in the research activities of virtually every department. In addition to his dedicated service to the research of others, he also found time to pioneer several new techniques including two which are now in widespread use in soil science throughout the world, namely the neutron probe method for measuring soil moisture and radioisotope tracing of root systems in the soil. These latter achievements received more recognition elsewhere characteristically, than in the U.K. and led to his being awarded two overseas fellowships from the University of California, Berkeley (1957) and the University of Beirut (1963). He also played a leading role in the affairs of the European Society of Nuclear Methods in Agriculture (ESNA) where his contributions were widely recognised in both East and West Europe and very much appreciated. In 1973, following the recommendations of the 1972 ARC Visiting Group, Mr Knight was transferred from the Department of Plant Physiology to the Department of Soil Fertility and in 1974 he assumed the onerous role of Institute Safety Officer, thus to permit the Institute to meet the requirements of the Health and Safety Executive. He maintained his lifelong dedicated service to the Institute and its staff in this role, as Radiation Protection Officer and as Head of Radioactive Services, until his retirement. His knowledge of plant science and the influence and translocation of major and minor nutrients in plants is quite unique and the staff of the Institute well recognise that he subjugated these interests and enthusiasms to their needs and service in taking on these other roles. His career in this Institute was completely selfless and thoughtful for others[9]. We shall miss him

keenly. Significantly, it has taken three people to pick up some of Alistair Knight's responsibilities: Harry Shepherd (SSO) for the Radioactive Facilities; Lindsay Robertson (SSO) for Radiation Protection Officer; and James Ogilvie (SSO) for Institute Safety Officer.



Lastly, Dr J. W. S. Reith, Senior Principal Scientific Officer, Department of Soil Fertility, also retired on 31st December. A first-class honours graduate in agriculture of the University of Aberdeen, Dr Reith joined the Department of Soil Fertility to assist with advisory work and general soil fertility investigations in 1943 and quickly assumed responsibility for running the department's field experiment programme under the overall guidance of Dr A. B. Stewart, who subsequently became Director of the Institute, and later Dr E. G. Williams, who ultimately became Deputy Director. Dr Reith gained his Ph.D. from Aberdeen University in 1950 for a thesis on comparative studies of placement of fertilizers. Much of this work related in the earlier days to fertilizer placement and subsequently phosphate fertilization. His later work centred on soil acidity and lime recommendations and his skills in interpreting experimental data and linking these to soil conditions and fertility became very well known indeed throughout Scotland. In more recent years he has turned his attention increasingly with good effect to trace element deficiency problems in crops and grazing animals and again has established an enviable reputation for his skills and knowledge on this subject, which is particularly appropriate to Northern Scotland where the soils, derived chiefly from acid igneous rocks and sandstones, are responsible for widespread deficiencies in bioessential trace elements such as Co, Cu, Mo and Se in grazing swards. His philosophy that the quality of a crop is at least as important as its yield is one that is increasingly receiving recognition in relation to emerging problems in animal and human nutrition.

Because of his knowledge and skills Dr Reith's advice was very widely sought and by virtue of this and his equitable, open and friendly character he acted as an ambassador-par-excellence for the Institute. He served on numerous DAFS advisory committees, played a prominent role in the MISR/COSAC Soils Liaison Committee and gave innumerable talks to Farmers' Clubs, which were greatly appreciated by all concerned.

Dr Reith's work and responsibilities were recognised in 1977 by promotion to Senior Principal Scientific Officer and in 1982 he was the recipient of the Royal Northern Agricultural Society's Award and the Aberdeen Press & Journal Shield for his services to agriculture in North-east Scotland. A tribute to Dr Reith is recorded in the Institute's news magazine " Profile " by Dr B. W. Bache[10]. Dr Reith's responsibilities have been taken over by his colleague Dr A. H. Sinclair (SSO).

Visitors to the Institute

The Earl of Selborne, who succeeded Lord Porchester as Chairman of AFRC early in 1983, visited the Institute on 6th April, accompanied by Mr J. S. Gibson, Department of Agriculture and Fisheries for Scotland.

On 6th July, Lord Shackleton and Lord Sherfield, accompanied by Mr P. D. G. Hayter (Clerk to the Committee), House of Lords Select Com-

Dr A. M. Ure (standing) discusses trace elements with Lord Selborne, Chairman of AFRC (centre right), and Mr J. S. Gibson, Assistant Secretary, DAFS (right), on occasion of Lord Selborne's visit to the Institute.

mittee on Science and Technology, Sub-committee on Remote Sensing and Digital Mapping, visited the Institute to talk to staff and see the work in the Remote Sensing Unit.

Monsieur R. DeCraene, Agricultural Section of the Belgian Embassy, London, visited the Institute on 9th June, and Dr S. Pandey, Head of the Division of Cartography, All India Soil and Land Use Survey, New Delhi, visited on 5th August. Dr Vilip Biswas, Director of the Ministry of the Environment, India, visited on 22nd June. Visits were also made by various members of the staff of AFRC and DAFS.

Other visitors who came to the Institute and delivered lectures were: Dr P. Nadeau, Department of Earth Sciences, Dartmouth College, Hanover, U.S.A., on "Clay mineral and resource exploration applications of remote sensing"; Dr L. J. Evans, Department of Land Resources, University of Guelph, Canada, on "The soils of Canada"; Professor J. M. Oades, Department of Soil Science, Waite Agricultural Research Institute, University of Adelaide, Australia, on "Soil structure"; Dr V. Vancura, Head of Department of Microbial Ecology, Institute of Microbiology, Czechoslovak Academy of Science, on "Metabolic interactions between plants and

microbes in the rhizosphere "; Dr D. J. Swaine, CSIRO Division of Fossil Fuels, New South Wales, Australia, on " Trace elements in Australian bituminous coals " and also " The fate of trace elements during the combustion of coal "; Professor T. Fujinaga, Chemistry Department, Kyoto University, Japan, and now Vice-Chancellor of Nara University, on " Spectrophotometric analysis of traces of phosphate in natural water using ternary solvent extraction "; Dr H. G. MacFie, Head of Statistics Section, Meat Research Institute, Bristol, on " Multivariate statistical methods of analysis "; Dr J. A. McKeague, Head of Soil Classification Section, Land Resource Research Unit, Ottawa, Canada, on " Podzols in Canada "; Mr F. Filippello, Remote Sensing Centre, Rome, on " Remote sensing at FAO "; Dr L. J. Ottendorfer, Bundesanstalt für Wassergüte, Vienna, on " Special requirements for analytical work connected with aquatic samples "; Mr C. H. Thompson, CSIRO Division of Soils, Brisbane, Australia, on " Development of giant podzols on dune systems in Queensland "; Dr D. D. Eberl, U.S. Geological Survey, Denver, Colorado, U.S.A., on " Dissolution of sparingly soluble compounds by ion exchange and its potential application to agriculture "; and Dr D. P. Bickmore, Cartographic Consultant, Oxford, on " Digital cartography and soil information systems."

Short-term visitors came to the Institute from 19 countries during the year and group visits included delegates from various conferences held in Aberdeen, *e.g.* International Peat Society, who also held their Council meeting at the Macaulay, Varian Techtron Users Group, S.A.I. Trainees Group, 1983 World Petroleum Congress, South Grampian Geographers, Grampian Schools Science Convention, Westhill Gardening Club. Students came from the Biochemistry, Chemistry and Soil Science Departments of the University of Aberdeen, the Geography Department of Edinburgh University, North of Scotland College of Agriculture and Aberdeen College of Education, as well as pupils from several local schools.

Long-term visitors were received from Canada, China, France, Italy, The Netherlands, Sierra Leone and U.S.A.

Honours and Appointments

Dr R. C. Mackenzie, of the Department of Mineral Soils, delivered the plenary lecture entitled " Soil Clays: Subjects for Chemistry, Mineralogy or Physics? " at Euroclay 1983 in Prague in September and received the Emanuel Boricky Medal from the Faculty of Science of Charles University, Prague. The medal is the highest honour awarded by the Science Faculty of the University. He was appointed the first Distinguished Member of the Clay Minerals Groups of the Mineraliogical Society at a meeting held in his honour in London in November. Dr Mackenzie has also been appointed to the International Scientific Committee of the Eighth International Conference on Thermal Analysis, 19th-23rd August, 1985, at Bratislavia, Czechoslovakia.

Dr M. J. Wilson, the newly-appointed Head of the Department of Mineral Soils, has been elected to the International Group Committee of the British Crystallographic Association and has been appointed Honorary Research Associate of the University of Aberdeen.

Mr R. A. Robertson, Head of the Department of Peat and Forest Soils, gave two interviews on radio on the development and application of remote sensing techniques for peat resource and land use surveys.

Dr R. V. Birnie, of the same department, was also interviewed on BBC radio with respect to his work on the use of aerial photography and space imagery for snow monitoring operations and for mapping the distribution of bracken in Scotland on a temporal basis. Dr Birnie was appointed PSO Head of the Remote Sensing Unit in the Department of Peat and Forest Soils in succession to Dr G. C. Stove.

Dr G. C. Stove, Head of the Remote Sensing Unit, resigned from the Institute on 30th September to become Scientific Director of the Earth Research Satellite Application Centre Ltd. (ERSAC) in Livingstone. Dr Stove joined the Institute in 1975 and was responsible for the development of the unit in subsequent years.

Dr H. G. Miller, PSO in the Department of Peat and Forest Soils, has been appointed to represent the Institute of Chartered Foresters on the Acid Rain Working Group of the Watt Committee on Energy. He was also invited by the Swedish University of Agricultural Sciences to participate in an evaluation of its current environmental research and will succeed Professor J. D. Matthews, Member of the Council of Management, as Professor of Forestry at the University of Aberdeen in April, 1984.

Dr B. W. Bache, Head of the Department of Soil Fertility, has been appointed to the Editorial Board of the Journal of Agricultural Science (Cambridge) and also a U.K. Government representative on the Convention for Long-range Transboundary Air-pollution of the United Nations Economic Commission for Europe. Dr Bache has also been appointed to the post of Senior Lecturer in the Department of Applied Biology at the University of Cambridge, with effect from April, 1984.

Dr A. H. Sinclair has been appointed Editor of " Norgrass " the journal of the North of Scotland Grassland Society.

Professor J. S. Bibby, the newly-appointed Head of the Department of Soil Survey, has been appointed Honorary Research Associate of the University of Aberdeen.

Professor T. S. West was appointed Honorary Research Professor by the University of Aberdeen and delivered his inaugural lecture on 1st December. He was elected Secretary General of the International Union of Pure and Applied Chemistry at the IUPAC General Assembly in Copenhagen for the period 1983-87 and became a member of its Executive Committee and Bureau as well as Chairman of the Editorial Board of the Union's news magazine " Chemistry International."

Professor West also became, *ex officio*, a member of the British National Committee for Chemistry, 1983-87. He accepted an invitation from the Royal Society to be one of its representatives on the Joint Management Committee of The Royal Society, The Swedish Academy of Sciences and The Norwegian Academy of Sciences and Letters to investigate the acidification of surface waters in southern Scandinavia. He also served on the

Joint Consultative Organization of AFRC, DAFS and MAFF Soil Science Committee and, at the request of the University of London, chaired an Advisory Group of the University's Joint Planning Committee to give guidance on the future position of Analytical Chemistry in the Federal University of London. He was also re-appointed to serve on the Advisory Committee on Forest Research of the Forestry Commission, 1984-87.

Visits Overseas by Staff, etc.

Details of visits overseas by staff and of U.K. meetings where lectures were given are presented in Appendices II and III.

Post-graduate Students

Mr C. D. Campbell, a B.Sc. graduate from Strathclyde University, has been awarded an ARC post-graduate studentship, commencing in October, 1983, to work in the Department of Microbiology towards a Ph.D. degree of Strathclyde University.

Miss Sheila Fraser has now finished her experimental work for the degree of Ph.D. and is currently writing up her thesis for submission to the University of Aberdeen.

Dr Lau Chau Ming, who worked in the Department of Spectrochemistry, and Dr Sarah G. Williams, who worked in the Department of Plant Physiology, have both been awarded the degree of Ph.D. for work undertaken at the Institute.

Institute Events

Professor C. H. Gimingham

The Council of Management met twice on 30th May and 25th November. At the meeting in May, Professor H. M. Keir was appointed Chairman and will also continue as Convener of the Staff Committee. Professor J. D. Matthews retired from the University of Aberdeen, but has been co-opted to the Council. Professor C. H. Gimingham, Botany Department, succeeds Professor Matthews as the university representative. Professor J. W. Parsons was appointed Convener of the Finance Committee. Mr D. Morrison, representative of the North of Scotland College of Agriculture, has also retired from the Council and the college has nominated Mr G. J. F. Copeman as his replacement.

Launch of 1:250 000 Survey Maps

On 28th March, Lord Mansfield, Minister of State, came to the Institute for the official launch of the Quarter Million survey literature and maps of the Soil Survey of Scotland. Based on this survey of Scotland's soils and land classification for agriculture, seven new soil maps plus seven

LCA maps with explanatory booklets have been published. Lord Mansfield spoke to invited respresentatives of potential users of the new maps and books, members of Council, DAFS, AFRC, SARI and the press, see p. 127.

Subject Day

On 8th September the Institute held a Subject Day to which SARI, college and university staff, farmers and others representing agriculture, had been invited, along with family and friends of the Macaulay staff. Some 500 visitors came along to inspect the laboratories and learn something of the on-going programme.

Institute Caravan

Early in the year the Institute purchased a caravan for use at the various agricultural shows where some aspects of the Institute work could be exhibited in the form of diagrams, photographs and surveys maps. As in previous years, the Institute exhibited some of the Soil Survey work in the DAFS Pavilion at the Royal Highland Show at Ingliston in June. Exhibits were also set up on three occasions during the " Money from Grass " meetings organised by the Scottish Colleges of Agriculture — at the " Silage 83 " demonstration at Craibstone on 26th May, at " Scotsheep " at Morebattle on 2nd June, and again in the McRobert Pavilion at Ingliston on 25th October. The caravan was located on site for the first two of these meetings. Other shows at which the caravan was used were at Turriff, 1st-2nd August, Black Isle, 4th August, and Keith, 7th-9th August. The Institute also provided an exhibit for the Royal Agricultural Show at Stoneleigh on 4th-7th July.

MISR Contracts

Dr B. W. Bache and Dr H. G. Millar have been awarded a DOE contract for £244,200 over a five-year period for work on acid rain.

Dr H. G. Miller and Dr J. F. Darbyshire have won an EEC contract for £176,267 over a three-year period on wood as a renewable raw material.

Associateship of the Institute

At its meeting on 25th November the Council of Management conferred the title of Honorary Associate on Dr V. C. Farmer, Mr R. Grant, Dr R. C. Mackenzie and Dr J. W. S. Reith.

Programme Units and Research Objectives

During 1983 the Programme of Work of the Institute, which had been organized in nine Research Packages and *ca.* 60 research projects since the Rothschild reorganization of research in Government-funded laboratories, was reclassified according to the new AFRC information system, ARCIS, in which work is organized in Programme Units — which correspond in dimension to the former Research Packages and within these in Research Objectives, which correspond closely to the former Research Projects.

This opportunity has been taken to effect several changes in the organization of the Institute's research programme, partly as a result of the 1982 ARC Programme Review, partly as a result of changes in staffing and partly as a reflection of new initiatives.

The Programme Unit (PU) numbers given in the following section correspond to those listed in the AFRC ARCIS (1983-84) list. The Research Objective (RO) numbers given correspond to the DAFS Research Objective Costing System rather than the AFRC RO letters, but a correspondence table is given for those who wish to consult or use the ARCIS listings. Readers who wish to make the conversion should bear in mind that the ARCIS listing re-uses discarded code letters so that listings invariably begin with the letter " a " within each Programme Unit. The DAFS numeration does not re-use numbers and is, therefore, unequivocal in identifying and following ROs from one year to another. In this Annual Report, the first two digits of the DAFS six-digit RO numeration, being 00, are omitted.

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

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

Interdepartmental projects are listed as 0800. Thus PU 1801 represents interdepartmental project 01 in Mineral Soils; the numbers 4801 and 6801 listed alongside show that the RO is also part of the programme of Soil Organic Chemistry and Microbiology. Service Objectives will be listed as 0900. RO numbers are allocated serially across the Institute. Interdepartmental and Service Objectives will also be listed serially within the 0800 and 0900 series, *i.e.* 0801, 0802, etc.; 0901, 0902, etc. Objective numbers will be discarded once the Objective has been discontinued.

References

1. Corporate Plan of the Agricultural and Food Research Council, 1984-88, AFRC London, 1983, pp. 1-45.
2. Annual Report, 1981-82, **52**, 1-12.
3. A Framework for Government Research and Development. Cmnd. 5046, July, 1972.
4. B. D. Mitchell, Profile, 1983, **77**, 5-6.
5. J. W. S. Reith, Profile, 1983, **79**, 9-10.
6. J. S. Bibby, Profile, 1983, **78**, 7-8.
7. Annual Report, 1981-82, **52**, 66-67.
8. A. M. Ure, Profile, 1983, **80**, 15-17.
9. I. R. MacDonald, Profile, 1983, **80**, 19-21.
10. B. W. Bache, Profile, 1983, **80**, 17-18.

PROGRAMME OF WORK

(1983)

PROGRAMME UNITS AND RESEARCH OBJECTIVES

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

RO

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

1002 Determine the nature, origin and susceptibility to weathering of minerals in Scottish soils.

1003 Determine the surface properties and colloidal characteristics of solid particules that contribute to soil properties and plant nutrition and estimate their relative importance.

1004 Develop, where necessary, methods suitable for the above objectives.

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

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

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

RO

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

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

3009 Investigate the forms of occurrence of trace elements in soils and the mechanisms of their transport to the plant root.

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

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

PU 3: SOIL SURVEY OF SCOTLAND.

RO

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

9013 Produce maps of land capability for agriculture.

9014 Elucidate soil structure and soil forming processes.

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

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

PU 4: NATURE AND PROPERTIES OF SOIL ORGANIC MATTER.

RO

3017 Characterise soil organic matter by infrared and ultraviolet spectroscopy.

1018 Characterise organic materials in soils by examination of their thermal decomposition products by mass spectrometry.

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

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

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

4022 Characterise soil humic substances by paramagnetic resonance and other forms of electron spectroscopy.

4023 Examine the effects of organic constituents of soil on the growth and nutrition of plants, with particular reference to processes involving the root.

4024 Examine the effects of organic constituents of soil on biochemical processes in plants.

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

RO

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

6026 Investigate the interrelationships of fungi with plant roots.

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

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

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

6030 Characterise the microorganisms involved in the decomposition of peat deposits or horticultural composts and increase crop production on these media.

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

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

RO

2032 Develop remote sensing methods for agricultural application and for peat and natural resource surveys.

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

2034 Undertake contractual applications of remote sensing for natural resource surveys and environmental monitoring for other Institutes in the ARS, etc.

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

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

PU 7: SOIL FACTORS AFFECTING CROP PRODUCTION.

RO

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

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

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

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

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

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

7043 Assess the lime and major nutrient status of soils.

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

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

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

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

PU 8: FACTORS AFFECTING CROP AND PLANT COMPOSITION.

RO

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

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

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

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

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

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

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

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

RO

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

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

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

PU 10: STATISTICAL METHODS FOR SOIL-CROP RESEARCH AND DEVELOPMENT AND MANAGEMENT OF COMPUTER TECHNIQUES AND EQUIPMENT.

RO

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

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

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

1802/ 8802/ 9802 Establish an information system for Scottish soils by means of database and statistical techniques.

MISR Research Objectives 1983 —

The correspondence between the numeration of the DAFS RO costing system used throughout this Report and the AFRC (ARCIS) code is shown in this table. The first two digits, being 00, are omitted in the body of the Report.

ARCIS code		DAFS code
RO 1	a	001001
	b	001002
	c	001003
	d	001004
	e	003005
	f	001006
RO 2	a	003007
	b	003008
	c	003009
	d	003010
	e	003011
RO 3	a	009012
	b	009013
	c	009014
	d	009015
	e	009016
RO 4	a	003017
	b	001018
	c	004019
	d	004020
	e	004021
	f	004022
	g	004023
	h	004024
RO 5	a	006025
	b	006026
	c	006027
	d	006028
	e	004029
	f	006030
	g	006031
RO 6	a	002032
	b	002033
	c	002034
	d	002035
	e	002036
RO 7	a	007037
	b	007038
	c	007039
	d	007040
	e	007041
	f	007042
	g	007043
	h	007044
	i	007045
	j	007046
	k	001801/ 004801/ 006801/ 009801
RO 8	a	007047
	b	007048
	c	007049
	d	005050
	e	005051
	f	005052
	g	004053
RO 9	a	002054
	b	002055
	c	002056
RO 10	a	008057
	b	008058
	c	008059
	d	001802/ 008802/ 009802

1. MINERAL SOILS

R. C. MACKENZIE and B. D. MITCHELL

R. C. Mackenzie.

B. D. Mitchell.

The function of the work of the department is to obtain information on the factors controlling the formation, composition, constitution and properties of mineral soils in Scotland. A mineral soil has been defined as a soil consisting predominantly of, and having its properties principally determined by, mineral matter; although it usually contains <20 per cent organic matter, it may have an organic surface layer, which can be up to 30 cm thick. The studies currently in progress, therefore, involve physical and chemical characterization of both the inorganic and organic fractions.

As in previous years the specialized facilities and expertise available within the department have been made use of, usually in collaborative studies, by a number of outside bodies, including DAFS, the National Coal Board, the Forestry Commission, the Rowett Research Institute, the Scottish Crop Research Institute, the University of Aberdeen, the University College of North Wales, and companies associated with the oil industry in Aberdeen.

Soil Analysis

Chemical Studies. Systematic chemical and physical tests on all profile samples collected by the Soil Survey of Scotland in the 1982 field season have been completed. Profile samples have also been examined for other departments of the Institute and for a number of outside bodies. Work has progressed on the input of data into the Institute's Soil Data Bank. Data for approximately 50 per cent of the National Soil Inventory profiles and approximately 70 per cent of the systematic soil survey profiles collected between 1979 and 1982 have now been entered. 1001, 9012, 1802/8802

The demand for total sulphur determination by X-ray fluorescence spectrometry has grown considerably in the past year with 890 analyses carried out for the Department of Soil Fertility on a wide variety of herbage samples, barley grain and oil seed rape. Herbage samples have also been

analysed at the request of the Rowett Research Institute. A comparison of the major and minor element contents of soil profiles of the Thurso and Canisbay Association in the Orkney Islands and of their parent rocks of the Middle Old Red Sandstone series has revealed distinct chemical differences between the two asscciations. The effect of the higher Si content of the Canisbay Association parent material can be traced throughout all profiles of the association. Although soils of the Thurso Association are more susceptible to weathering than those of the Canisbay, soil processes have a similar effect on both. The initial effects of chemical weathering can be detected in the C horizons with the accumulation of Al, Fe and Ti and the loss of Na, Ca and Si relative to the rocks. Total major and minor elements have also been determined by X-ray fluorescence spectroscopy on a range of geological materials including a group of illites, smectites and interstratified illite-smectites. The interfacing of a microcomputer to the X-ray fluorescence spectrometer for instrument control and data handling purposes is now complete. 1001, 1002, 9012, 7038

In collaboration with the Department of Spectrochemistry investigations have continued on the extraction using selective chemical techniques — principally ammonium oxalate and pyrophosphate — of inorganic forms of translocated Al, Fe and Si from the illuvial horizon of podzolic soils[1]. A spectrophotometric method for the determination of Si in ammonium oxalate extracts of soils has been devised and shown to be accurate, reproducible and more sensitive than the conventional flame atomic absorption technique[2]. 1002, 3005

In collaboration with the Department of Soil Survey the study on the major element composition of stream waters has been extended to catchment areas with semi-natural vegetation in the North of Scotland, the West Highlands, Central Valley and Southern Uplands. Initial results indicate that in the North-West Highlands the Si content of stream water is 5 to 10 times lower than that of streams in the other areas suggesting that in the Highland regions weathering is restricted. The pH of stream water in areas of acid soil parent materials is seldom $<6{\cdot}5$ and is invariably >7 in areas where the parent material is more basic, values which reflect the quite considerable buffering action of the soil. However, in a catchment area within the Durnhill Association developed on massive quartzite in Caithness the pH of the stream water ranged from 4·9 to 5·3, which is by far the lowest so far recorded in this present study. 1006, 9012

An account of the relationship between the degree of polymerization of silica, as revealed by the formation of organosilicon derivatives, and the degree of weathering of certain freely drained residual soils of north-east Scotland has now been published[3]. 1002, 9012

Thermoanalytical Studies. Thermal analysis arose from the curiosity of early man about the effect of heat on materials[4, 5]. Although the number of thermoanalytical techniques available over the years has gradually increased[6, 7, 8] the most common for soil studies are currently differential thermal analysis (DTA), differential scanning calorimetry (DSC) and thermogravimetry (TG)[9]. Development work on the data system based on

the Apple II microcomputer has continued and a series of programs for the acquisition and treatment of data from the thermobalance prepared. The system is now being extended to include the differential thermal analysis apparatus. 1004

Soil Mineralogy

The minerals in the soil, derived either directly from or through weathering of parent rock, control to a considerable extent the soil fabric and contain the nutrient capital of the soil, thus determining its inherent fertility. Moreover, because of the associations between minerals and, no less important, between mineral and biological materials, a large range of investigational methods has to be used for their examination. One of the earliest stages of rock weathering is that attributable to lichens, and lichen encrusted rock presents a relatively simple soil microprofile for the study of biotic/mineral relationships. In collaboration with the Department of Microbiology a study of some lichen encrusted rocks containing potentially toxic elements suggests that these may be mineralized from the growing lichen by being precipitated in an unavailable form. It was found, for example, that *Stereocaulon vesuvianum* growing on siliceous limestones contaminated with lead dust from the ruins of a lead smelting flue, contained a crystalline basic lead carbonate — hydrocerussite — on or within the hyphae of the mycobiont[10]. Similarly, extracellular crystalline deposits of manganese oxalate dihydrate are associated with *Pertusaria corallina* growing on manganese ore[11]. This is the first report of manganese oxalate as a natural mineral and it suggests that a variety of hitherto unreported oxalate minerals may exist where oxalic acid-secreting lichens have colonized substrates of unusual composition. A general paper on the effects of lichen weathering on rock forming minerals and the implications for pedogenesis has been published[12]. 1002, 6028

Volkonskoite, a chromium bearing mineral, usually contains significant amounts of Fe. However, the sample examined in detail from the Daba marble of Jordan, admixed with calcite and a silica phase, contains 16 per cent Cr and no Fe. Chemical and instrumental methods have shown it to be uniform in composition and although essentially dioctahedral it does have certain trioctahedral features[13]. A paper dealing with the early history of the mineral has been prepared[14]. Infrared absorption and X-ray diffraction data on a chemically analysed specimen of leadhillite, a lead carbonate sulphate hydroxide have been shown to be different from those in the literature. It is thought that mutual replacement of SO_4, CO_3 and OH may occur in this mineral and account for variation in X-ray spacings[15]. 1002, 3005

The forms and distribution of Fe and Mn in surface-water pseudo-gley and gley soils of the Strichen Association are being characterized by optical, scanning electron microscope and microanalytical methods. The ochreous mottles of the Bg horizon of the pseudo-gley consist of the crystalline iron oxide lepidocrocite. Iron and manganese oxides accumulated in the lower part of the alluvial horizon which is strongly indurated. The iron phase is

ferroxyhyte and the manganese phase is vernadite. Recently the same techniques were employed successfully to elucidate the problem of cementation within the illuvial horizons of some Scottish podzolic soils developed on coarse textured parent materials[16]. 1001, 1002, 9012

The scanning electron microscope facility has been improved by the addition of a cryosystem which enables direct examination of frozen hydrated material in the microscope thus avoiding shrinkage, distortion and other artefact-producing phenomena induced by conventional specimen drying methods. The low-temperature technique has already proved to be of great value in the examination of biological material[17]. Preliminary results of the application of the technique in an investigation of fluid bearing sandstone were communicated at a joint meeting of the Clay Minerals Group and the Petroleum Exploration Society. 1002, 1004, 9016, 6028

Clay Fraction. Because of the nature of the minerals it contains and its large area of reactive surface, the clay fraction has a disproportionate effect on soil properties. The application of sophisticated instrumentation to clay investigations has enabled much greater attention to be paid to the surface characteristics and properties of both the crystalline and highly disordered components. This approach, however, demands that the utmost care be taken in the separation and pretreatment of clay samples because time honoured procedures can bring about changes in the sample, which make it impossible to extrapolate from the laboratory to the field[18]. 1002

An investigation of interstratified clay minerals in collaboration with Dr P. H. Nadeau using X-ray diffraction (XRD) and transmission electron microscopy (TEM) has led to a new concept of interstratified clay minerals, which occur widely in soils and sediments. Current understanding of these clays requires that they occur as relatively large crystallites made up of a regular and random repetition of different types of silicate sheets. In this study TEM observations show that such crystallites do not exist in selected $<0{\cdot}1$ μm fractions which nevertheless yield XRD patterns typical of interstratified clay minerals. TEM shows that those fine fractions consist of particles only one or two unit cells thick and it is suggested that the interstratified XRD patterns result from the sedimentation on to glass slides of such a population of exceedingly thin particles. For example, regularly interstratified illite-smectite was shown to consist of a homogeneous population of 20Å thick particles whose interfaces are expandible with ethylene glycol. The XRD pattern is an inter-particle diffraction effect, a concept confirmed by the diffraction patterns obtained after physically mixing highly dispersed suspensions of regularly interstratified illite-smectite and smectite. These preparations yield XRD patterns identical to those of randomly interstratified illite-smectite with relative proportions of the two components — as judged by XRD — being related to the proportions of the two components in the mixed suspensions. XRD patterns typical of mixtures resulted where suspensions containing substantially thicker particles were mixed[19]. Similar experiments have been carried out on other clay minerals and there are strong indications that the work will have general

applicability to interstratified minerals as a whole. Should this be the case, much of the previous work in this field will require to be reviewed. 1002

A study of the relationship between swelling and structure of a fibrous and non-fibrous saponite shows that both aspects are affected by physical and chemical pretreatments[20]. A new mineral, Macaulayite, has been described[21]. It is blood red in colour, very fine grained, has a calculated density of 4·41 g / cm^3 and an ideal formula of $Fe_{24}^{3+}Si_4O_{43}(OH)_2$. Macaulayite has a layer structure and is thought to consist of a double hematite unit terminated on both sides by silicate sheets and with water between the sheets. The IR spectrum includes bands arising from the hydroxysilicate and hematite components. On the basis of the chemical composition, Macaulayite appears to be close to the so-called melanosiderate but the latter was proved to be mainly siliceous ferrihydrite[22]. 1002, 3005

Application of a quantitative X-ray diffraction method to determine the amount of chlorite in soils with highly chloritic clay fractions has revealed that the amount of chlorite in any one horizon increases with decreasing particle size. Also, the amount of chlorite in the total soil as well as in the fine and coarse silt fractions decreases towards the surface, particularly in podzolic soils. This suggests, contrary to previous work, that chlorite is being weathered out of the clay fractions of these soils, but the effect is being masked by the replacement of chlorite from the fine silt fraction. 1002

Collaborative studies with overseas organizations on the characterization of soils, clays and accessory minerals have continued. In conjunction with the Istituto de Chimica Agraria, University of Naples, Italian andosols which are derived from volcanic material, have been examined and shown to contain large amounts of imogolite and proto-imogolite allophane as well as halloysite and other clay minerals[23]. These minerals result principally from the weathering of volcanic glass and of primary minerals such as feldspars and leucite. A study involving the Faculty of Agriculture, Cukurova University, Turkey, on the physical, chemical and mineralogical characteristics of some Turkish soils, also formed on volcanic material, has continued. These soils are very different from the Italian andosols and show high pH values (7·5-8·0), low amounts of organic matter, low available water capacities and low-to-medium phosphate sorption. The dominant clay mineral is a poorly ordered smectite which yields anomalously high X-ray spacings[24]. Examination of some Turkish alluvial soils from a high mountain plain which is surrounded by carbonate and ultrabasic rocks shows that they contain an unusual assemblage of high magnesium clays including sepiolite and palygorskite[25]. In a collaborative study with the Faculty of Agriculture, University of Riyadh, Saudi Arabia, palygorskite was found to be widespread in wadi soils[26]. Nordstrandite, an aluminium hydroxide polymorph, has been the subject of a joint study with the Istituto de Chimica Agraria, University of Naples, and it has been shown that its crystal shape depends on the conditions under which it is formed[27] and furthermore that synthetic preparations can contain small amounts of bayerite and gibbsite sometimes co-crystallizing with the nordstrandite[28]. During the year other samples submitted for study included soils from

Belize, Nigeria, Brazil, Australia and India. Clay mineral analyses have also been made on rock samples submitted by the oil industry and the Building Research Station. 1002

Surface Characteristics of Soils and Soil Components

Aggregate stability studies on soil profiles of the Stirling Association developed on estuarine silt and clay have been completed and the effect of " air-explosion " during the rapid wetting of aggregates elucidated. Because of this effect the " stability " measured using air-dry aggregates is of value when dealing with problems involving surface crusting but less reliable in the evaluation of the stability of mole drains since it is most unlikely that these would ever dry out. Predictive tests of mole drain stability in these soils indicated that they were highly unstable, but field observations indicate a lifetime of two years. These observations are now being considered in terms of the physical and morphological characteristics of soil aggregates. 1003

Until this year work on manganese oxides has been mainly concerned with a synthetic model compound, buserite. Attention is now being given to naturally occurring oxides and two manganese pans have been examined using transmission electron microscopy and electron microprobe analysis. It has been demonstrated that their particle morphologies are similar to those of synthetic buserite, and Ni, Cu and Zn accumulations are evident in the Mn nodules. In addition relatively large amounts of Ba are present and this is consistent with the high selectivity for this element exhibited by buserite. The ability of a high surface area gibbsite to absorb Cu^{2+} has been studied and chemisorption sites are thought to be at the gibbsite crystal " steps " observed under the electron microscope[29]. 1002, 1003, 3005

During the year the department obtained and commissioned a VG " Escalab-2 " electron spectrometer. In order to make a preliminary assessment of the capability of the instrument and equally important to acquire the necessary skills in operational techniques a wide range of samples including plant material, soil organic matter fractions and clay minerals has been examined. The instrument's sensitivity for low atomic number elements was demonstrated in an examination of ammonium-micas with an N content of 0·2-1·5 per cent, the N ls peak was quite evident. Currently effort is concentrated on devising methods of sample preparation which will minimize frequency of sample changing and on developing quantitative determination for a number of elements. 1003, 1004

Organic and Biological Materials

Natural variations of soil organic matter play a significant part in the character and properties of soil humus, and previous work has demonstrated the potential of analytical pyrolysis in determining the relevant characteristics of this composition. A more comprehensive examination of these variations has been made possible by the method of direct dynamic pyrolysis-mass spectrometry (PY/MS). This was developed in conjunction with computerised multivariate data analysis which aids the objective

selection of relevant diagnostic criteria in the mass spectra, allowing a wider range of products to be examined. These advances have been brought about during the year by (a) technical developments in the operation and scanning of the mass spectrometer at low ionizing voltage, (b) full utilization of the dedicated data system and software, (c) development of our own multivariate software such as principal components, factor and discriminant analyses, and (d) the development, construction and installation of a direct data link to the Institute mainframe computer. 1004, 1018

These improvements have already placed much of the earlier work on a firmer and more comprehensive basis. Examination of a wide range of Scottish soil A horizons by PY/MS has partitioned them in terms of two main factors. By examination of the relevant covariant groups of pyrolysis product ions, the first was found to reflect the polysaccharide/polypeptide balance and to correspond to the extent of mull-like humification most characteristic of the brown forest soil (ultimately expressed in the mollic or umbric horizon). This factor was approximated by the simple " pyrolysis ratio " of previous pyrolysis-gas chromatography (PY/GC) work. The second factor was characterized by a preponderance of aromatic hydrocarbon products ions and corresponded in the soil sequence to increasingly poor drainage characteristics. It could represent " skeletal " organic matter similar to kerogens, stripped of O and N, and/or anaerobic metabolites, and accompanies loss of product ions associated with aerobic biota. Whole soil samples can readily be characterized and classified in terms of these two factors which represent aspects of soil organic composition fundamental to its properties[39]. This work marks the beginning of a more systematic survey aimed at providing standards for the assessment of soil organic matter in a pedological context, mainly in relation to the effects upon it of parent vegetation, humification, translocation, drainage and agricultural practise, and as it in turn affects other relevant soil properties and general criteria of fertility. 1018

An examination by PY/MS of a small group of weakly podzolised woodland soils was carried out in conjunction with the Department of Soil Survey; the extent of the podzolisation process corresponded with the soils' placing in terms of the PY/MS humification factor. A similar result was obtained with French ochreous brown and eutrophic brown soils. Another PY/MS investigation, in collaboration with the Department of Microbiology, showed the selective removal of specific nitrogen-containing materials by larvae of *Tipula paludosa* (leather jackets), namely proteins, peptidoglycans and chlorophyll porphyrins. This was achieved by comparative examination of food and faeces which showed differences significant at $P < 0{\cdot}01$, whereas no significant changes in polysaccharide or lignin products were found. By request, samples of fresh water organic matter were examined from lakes in the area of Mount St Helens, U.S.A., for effects of volcanic products on the organic matter. The samples available were too small to elicit major differences from the controls, apart from the loss of some polysaccharide and increase of methanethiol and small amounts of unidentified compounds. 1018, 4021, 6027

Quantitative pyrolysis-gas chromatography studies of the origin of soil nitrogen pyrolysis products have been concluded, showing the origin of pyrrole and acetonitrile in specific amino acids[31]. Gas chromatography-mass spectrometry service work during the past year has included the identification of TMS derivatives of humic and fulvic acid hydrolysates and standard aliphatic and phenolic carboxylic acids for the Department of Soil Organic Chemistry, and fungal metabolic products for the Department of Microbiology. A paper dealing with extraction and characterisation of soil polysaccharide by whole soil methylation has now appeared[32].

1018, 4020, 4021, 6027

References

1. Extraction of inorganic forms of translocated aluminium, iron and silicon from a podzol Bs horizon. By V. C. Farmer, J. D. Russell and B. F. L. Smith, *J. Soil Sci.*, **34**, 571-576, 1983.
2. The determination of silicon in ammonium oxalate extracts of soils. By B. F. L. Smith. Submitted to *Common. Soil Sci. Pl. Anal.*
3. Susceptibility to weathering of some Scottish rocks and their derived soils. By B. F. L. Smith, B. D. Mitchell and R. C. Mackenzie. *Trans. R. Soc. Edinb. Earth Sci.*, **73**, 191-203, 1983.
4. Origin of thermal analysis. By R. C. Mackenzie, *Isr. J. Chem.*, **22**, 203-205, 1982.
5. *De calore*: Prelude to thermal analysis. By R. C. Mackenzie. To appear in *Thermochim. Acta.*
6. Complementary techniques. By R. C. Mackenzie. To appear in *Thermogravimetry*. Edited by J. P. Redfern and C. J. Keattch. Chichester: Wiley.
7. Origin and development of differential thermal analysis. By R. C. Mackenzie. To appear in *Thermochim. Acta.*
8. Nomenclature in thermal analysis. By R. C. Mackenzie, in *Treatise on Analytical Chemistry*, 2nd edition, Part I, Vol. 12. Edited by I. M. Kolthoff, P. J. Elving and C. B. Murphy. New York: Wiley Interscience, 1983, pp. 1-16.
9. 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. Chichester.
10. Observations on the location and form of lead in *Stereocaulon vesuvianium*. By D. Jones, M. J. Wilson and J. R. Laundon, *Lichenologist*, **14**, 279-286, 1982.
11. The occurrence and significance of manganese oxalate in *Pertusaria corallina*. By M. J. Wilson and D. Jones. Submitted to *Pedobiologia.*
12. Lichen weathering of minerals: implications for pedogenesis. By M. J. Wilson and D. Jones, *J. Geol. Soc. Special Publication, Residual Deposits*, 5-12, 1983.
13. An iron-free volkonskoite. By H. N. Khoury (University of Jordan, Jordan), R. C. Mackenzie, J. D. Russell and J. M. Tait. Submitted to *Clay Minerals.*
14. Discovery of volkonskoite. By R. C. Mackenzie. Submitted to *Mineralog. Mag.*
15. New authentic IR and XRD data for leadhillite of ideal composition. By J. D. Russell, A. Milodowski (IGS, London), A. R. Fraser and D. R. Clark, *Mineralog. Mag.*, **47**, 371-375, 1983.
16. An optical, scanning electron microscopic and microanalytical study of cementation in some podzols. By W. J. McHardy and L. Robertson, *Geoderma*, **30**, 161-170, 1983.
17. Low temperature scanning electron microscopy of biological specimens. By D. Jones, W. J. McHardy and J. M. Tait. Submitted to *Trans. Brit. Mycol. Soc.*

18. Soil clays: subjects for chemistry, mineralogy or physics? Invited plenary lecture to Euroclay 1983, Prague. By R. C. Mackenzie. To appear in *Proceedings of Fifth Meeting of the European Clay Groups.*

19. Interstratified XRD characteristics of physical mixtures of elementary clay particles. By P. H. Nadeau (Dartmouth College, Hanover, New Hampshire, USA), J. M. Tait, W. J. McHardy and M. J. Wilson. Submitted to *Clay Minerals.*

20. Structure and swelling of fibrous and granular saponitic clay from Orrock Quarry, Fife, Scotland. By A. Cowking (RGIT, Aberdeen), M. J. Wilson, J. M. Tait and R. H. S. Robertson (Pitlochry), *Clay Minerals,* **18**, 49-64, 1983.

21. Macaulayite, a new mineral from north-east Scotland. By M. J. Wilson, J. D. Russell, J. M. Tait, D. R. Clark and A. R. Fraser. To appear in *Mineralog. Mag.*

22. Melanosiderite is siliceous ferrihydrite. By M. J. Wilson and J. D. Russell, *Mineralog. Mag.*, **47**, 85-87, 1983.

23. Mineralogy of some Italian andosols with special reference to the origin of the clay fraction. By P. Violante (University of Naples, Italy) and M. J. Wilson, *Geoderma,* **29**, 157-174, 1983.

24. Chemical, physical and mineralogical characteristics of some Turkish volcanic soils. By N. Güzel (Cukurova University, Turkey) and M. J. Wilson. Submitted to *Trans. R. Soc. Edinb. Earth Sci.*

25. High-magnesium clays from alluvial soils of the Acipayam Plain, Southern Turkey. By N. Güzel (Cukurova University, Turkey) and M. J. Wilson. To appear in *Proceedings of the Fifth Meeting of the European Clay Groups.*

26. Origin of palygorskite in some soils of the Arabian peninsula. By R. C. Mackenzie, M. J. Wilson and A. S. Mashhady (University of Riyadh, Saudi Arabia). To appear in *Occurrence and Genesis of Sepiolite and Palygorskite.* Edited by A. Singer and E. Galan. Amsterdam: Elsevier.

27. Morphology of nordstrandite. By P. Violante and A. Violante (University of Naples, Italy) and J. M. Tait, *Clays and Clay Miner.*, **30**, 431-437, 1982.

28. Co-crystallization of gibbsite and bayerite in nordstrandite. By J. M. Tait, A. Violante and P. Violante (University of Naples, Italy), *Clay Minerals,* **18**, 95-99, 1983.

29. Cu(II) interaction with microcrystalline gibbsite. By M. B. McBride (Cornell University, USA), A. R. Fraser and W. J. McHardy. Submitted to *Clays and Clay Miner.*

30. Characteristics of soil organic matter in temperate soils by Curie point pyrolysis-mass spectrometry. I-organic matter variations with drainage and mull humification in A horizons. By J. M. Bracewell and G. W. Robertson. Submitted to *J. Soil Sci.*

31. Quantitive comparison of the nitrogen-containing pyrolysis products and amino acid composition of soil humic acids. By J. M. Bracewell and G. W. Robertson. To appear in *J. Anal, Appl. Pyrol.*

32. The extraction and characterisation of soil polysaccharide by whole soil methylation. By M. V. Cheshire, C. M. Mundie, J. M. Bracewell, G. W. Robertson, J. D. Russell and A. R. Fraser, *J. Soil Sci.*, **34**, 539-554, 1983.

2. PEAT AND FOREST SOILS

R. A. ROBERTSON

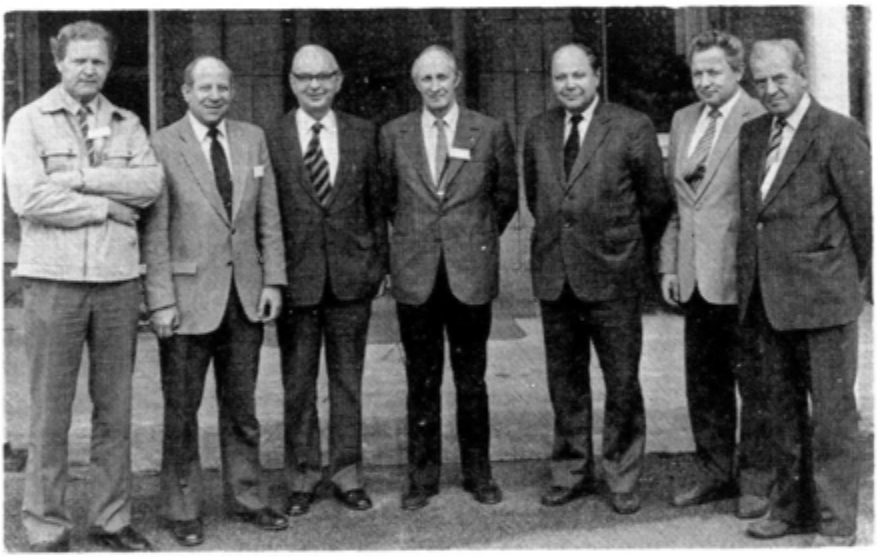
The work of the Department has concentrated primarily on the survey and evaluation of peat, vegetation and other terrain resources, the development and deployment of remote sensing and photogrammetric techniques for resource mapping and crop monitoring operations, using information derived from ground survey, airborne sensors and space platforms, and the establishment of new field and laboratory experiments designed to further elucidate the biogeochemistry of nutrient cycles on impoverished upland soils[1, 2, 3, 4, 5].

As mentioned in the Introduction, the recent acquisition of a fast, interactive image processing and display system now provides the Department's Remote Sensing Unit with an in-house facility for the enhancement, analysis, interpretation and classification of multi-temporal LANDSAT data and the capability to take full advantage of the wealth and quality of information to be derived from the next generation of space missions. Some preliminary research has also been done on the use of GEMS for manipulating and displaying digitised map information and in the development of an experimental geographic information system. Many of these investigations and related applications have involved close collaboration with the National Remote Sensing Centre, Royal Aircraft Establishment, Farnborough, the European Space Agency, the Department of Industry (Space Division), Robert Gordon's Institute of Technology and the Universities of Aberdeen and Edinburgh. In association with the Forestry Commission (Research and Development Division) and private forest agencies, further progress has been made with studies designed to investigate the factors and mechanisms which influence the size and rate of nutrient fluxes, including atmospheric inputs, in different plant/soil systems and the environmental consequences of any change in management practice. A new project to investigate the effect of afforestation on stream water quality has been initiated in collaboration with the Forestry Commission and the Institute of Hydrology and more recently, in co-operation with the Irish Forest and Wildlife Service, means of maximising the nitrogen nutrition of trees without resort to fertilizer application are being investigated with support from EEC.

Implementation and application of these and related developments have resulted in close and fruitful co-operation with other Departments within the Institute and with external organizations including the Department of Agriculture and Fisheries for Scotland, the Scottish Development Department, the Highlands and Islands Development Board, the North of Scotland Hydro-Electric Board, the U.K. Peat Producers' Association, the Scottish

Agricultural Colleges, Grampian, Highland and Strathclyde Regional Councils, Orkney and Shetland Islands' Councils, the Natural Environment Research Council, the Ordnance Survey, the Scottish Crop Research Institute and the Water Research Centre.

Members of staff have continued to serve on a number of national and international committees and working groups. These include the Council of the International Peat Society and the Executive of the Scottish Peat and Land Development Association (R. A. Robertson); the Watt Committee for Energy, the Aberdeen Institute of Ecology and the NERC, Terrestrial Life Sciences Grants Committee (H. G. Miller); the NRSC Land Applications Working Group (G. C. Stove and R. V. Birnie); and the Mires Research Group (P. D. Hulme).



Members of the Council of the International Peat Society during a break from their annual meeting, which was held at the Institute in September, 1983. (Left to right): E. Wold (Norway), D. N. Grubich (USA), R. A. Robertson (Vice-President, UK), Professor L. Heikurainen (President, Finland), Deputy Minister B. N. Sokolov (USSR), Dr I. Davydik (Secretary General), A. K. Dergunov (USSR).

In September, 1983, the Department was pleased to welcome members of Council of the International Peat Society, who held their annual meeting at the Institute, and also participated in an International Symposium on Remote Sensing and other Methodologies in Peat and Terrain Resource Surveys, which was attended by some 80 delegates from 12 countries.

It is also a pleasure to welcome a new member of staff, Mr G. G. Wright, formerly of the Department of Soil Survey, whose main responsibilities will be concerned with the application of remote sensing techniques for crop survey and monitoring operations and soil drainage investigations. In February, Miss C. A. Flower took up her appointment under an ARC Research Studentship following completion of her one year CEGB contract.

Terrain Resource Survey and Monitoring Operations

Peat Survey and Eva'uation. Growing interest in peatland reclamation and in the production, processing and utilization of peat and peat products for horticulture, fuel and other purposes has underlined the value of the Department's role in acquiring and maintaining scientific and technical information on the nature, distribution and development potential of Scottish peat resources. Results from recent surveys, now frequently commissioned, are finding increasing application in the production of detailed maps and reports for development agencies within both the public and private sectors and in the provision of information for statutory strategic plan reviews conducted by local authorities. 2032, 2034, 2035, 2036

In terms of unit energy costs, peat is now a highly competitive fuel and many countries, including the UK, are currently re-assessing its potential as an alternative energy source both for domestic appliances and space-heating systems and, in special circumstances, for the generation of electricity[6]. New techniques for the production, drying, harvesting and combustion of peat fuel coupled with advances in fuel conversion processes now provide a unique opportunity to develop and diversify the peat industry in Scotland. A report[7] on the nature and extent of peat resources on the Island of Yell, Shetland, has now been submitted to the North of Scotland Hydro-Electric Board as a basis for assessing the feasibility of establishing a peat-fired generating station on the island. This report illustrates how remotely sensed data and photogrammetric techniques can be effectively employed for reconnaissance survey and thematic mapping operations. Preliminary assessments to locate and rank deposits with development potential were based on the acquisition from aerial photography and space imagery of information on the extent, topography, vegetation, erosion characteristics, hydrology and accessibility of all peatland areas. The results of these investigations together with those from selected ground survey and sampling operations were subsequently used to identify eight major deposits covering approximately 1000 ha and containing a total of 3·7 million tonnes of peat on an air dry (40%) moisture basis. Although, on average, the peat seldom exceeded 2·0 m in depth, its degree of decomposition, ash content and calorific value are all conducive to the production of high quality sod peat fuel. The report also contains an analysis of climatic statistics, based on the computation of monthly potential water deficits, which indicates the possible number of peat harvests that might be obtained, on average, per annum. A more comprehensive survey and classification of the peatlands of Shetland based primarily on land-use and vegetation characteristics has continued using information derived from ground, air and space. To date, distribution of the peatland categories over 80% of the land area has been mapped at 1:50 000 scale.

2033, 2034, 2035, 2036

In collaboration with the Highlands and Islands Development Board, a study has been initiated to investigate the effects of peat type, drainage intensity, field moisture conditions and sod size on the production, rate of drying, yield and quality of peat fuel at Dale Moss, Caithness. 2035, 2036

A peatland vegetation classification study of the Isle of Lewis and Harris[8, 9] and a similar, though provisional, classification of the Shetland Islands has been completed. The resulting classifications reflect and are expressed in terms of the land-use, hydrology, chemistry and developmental stage of the mires. In addition, the traditional European phytosociological classification system has been applied to the results so that the peatland vegetation of the remoter Scottish Islands can be placed and reviewed in a European context. 2033, 2035

Collaborative work with the Central Excavation Unit of the Scottish Development Department has continued at Strathallan, Perthshire[10]. Stratigraphic and palaeobotanical studies of a peat deposit and of mineral soils have provided information on past environmental change and on the effect of man on soil and vegetational development. Results of an investigation into the seasonal growth of *Sphagnum* species have been published[11]. 2035

Bracken Survey. A report on a pilot study to assess the value of remote sensing techniques for mapping and monitoring the distribution of bracken on a national scale has been submitted to the Department of Agriculture and Fisheries for Scotland[12]. Maps of selected areas produced by satellite image analysis have been shown to be about 80% accurate when checked by conventional ground survey and air-photo interpretation techniques. This figure is considered adequate for reconnaissance mapping purposes. Other maps derived from large scale aerial photography for 1946 and 1980 have revealed an 112% increase in bracken cover of a sample area near Cairn o' Mount in Grampian Region. Work is now in progress at other sites to determine how far this figure is representative of Scotland as a whole. 2032, 2033, 2034

Snow Surveys. Following on from the aerial surveys conducted in 1981 and 1982, a further seven flights were flown in 1983 to provide records of snow cover and quality at sites identified as potential skiing areas by the Highlands and Islands Development Board. Three winter/spring periods have now been successfully documented. Further work using LANDSAT multi-spectral imagery for snow cover mapping was also commissioned by HIDB. Two scenes (20/4/76 and 3/4/81), first geometrically rectified to the national grid, were subsequently used to prepare spring snow-cover maps at 1:50 000 as overlays to six Ordnance Survey sheets covering the Cairngorms and the Western Highlands. This information fills a major gap in our knowledge of snow distribution in the Scottish mountains. 2034

Aerial Surveys. In addition to aerial surveys specifically related to the snow monitoring project and the AGRISPINE experiment, to be discussed later, a number of other sorties to acquire 1:10 000 scale panchromatic, colour and infra-red false colour photographs have been flown during the year. Increasingly, such missions are being requested and deployed for the assessment of field moisture and sub-surface characteristics prior to the installation or renovation of land drainage systems and for recording and comparing site conditions before mineral extraction and after rehabilitation.

As part of a wider study being planned in collaboration with the Scottish Crop Research Institute, air photo cover at 1 : 10 000 scale has also been obtained for selected areas of the current year's potato crop in the Tayside Region. 2032, 2034

At the request of the Department of Agriculture and Fisheries for Scotland, video cover of the Clyde-Calders area, east of Glasgow, has been obtained to assist the District and Regional authorities, the Countryside Commission, the SDA and DAFS in implementing a joint pilot study on Urban Fringe Management. In collaboration with Robert Gordon's Institute of Technology, work is now in hand to develop an aircraft facility for acquiring vertical video photography. Further results from the thermal infra-red aerial survey of Aberdeen city are awaiting publication[13, 14]. 2032, 2034

AGRISPINE Experiment

The Space Informatics Network Experiment (SPINE) was designed to test a system for the rapid relay of satellite data for time-dependent studies. The UK component of the project, AGRISPINE, was primarily directed towards the monitoring of crop development and forest mapping using LANDSAT multi-spectral data[15]; other applications included monitoring sea ice in the Gulf of Finland and the calving behaviour of the Jakobshavns Glacier in West Greenland[16].

During the period March to October, 1982, records of soil and crop characteristics on two farms in the Laurencekirk area were made at 18-day intervals to coincide with times of LANDSAT overpass. On the same dates, oblique and vertical aerial photography of the test fields was obtained to provide supplementary information. The main objectives of this investigation were to characterise the spectral response patterns of the crops at different imaging dates and relate these to known ground conditions, to compare the spectral responses of the same crop type at different locations in order to assess the importance of geographic variation in growth patterns, and to examine within-field variation of reflectance values with respect to known crop stress conditions.

Within the experimental period, eight partially cloud-free scenes of the East Grampian area were received, a success rate of 70%. Four of these scenes, which provided cloud-free views of the sample farms, were analysed at RAE, Farnborough, using a GEMS image processing system. By correlating reflectance values with information from fields previously ground-truthed, visible/near infra-red spectra were obtained for the major crop types. It was then possible to demonstrate that by overlaying spectra from different dates these crops could be differentiated and identified on a more general basis. This multi-temporal classification technique is much more successful than attempting to classify crops on single images where overlap in spectral responses greatly reduces the accuracy of identification. Examples of crop reflectance spectra for three imaging dates (Fig. 2·1) illustrate how differences in phenology and management allow separation by multi-temporal analysis. The changing slope of the spring barley

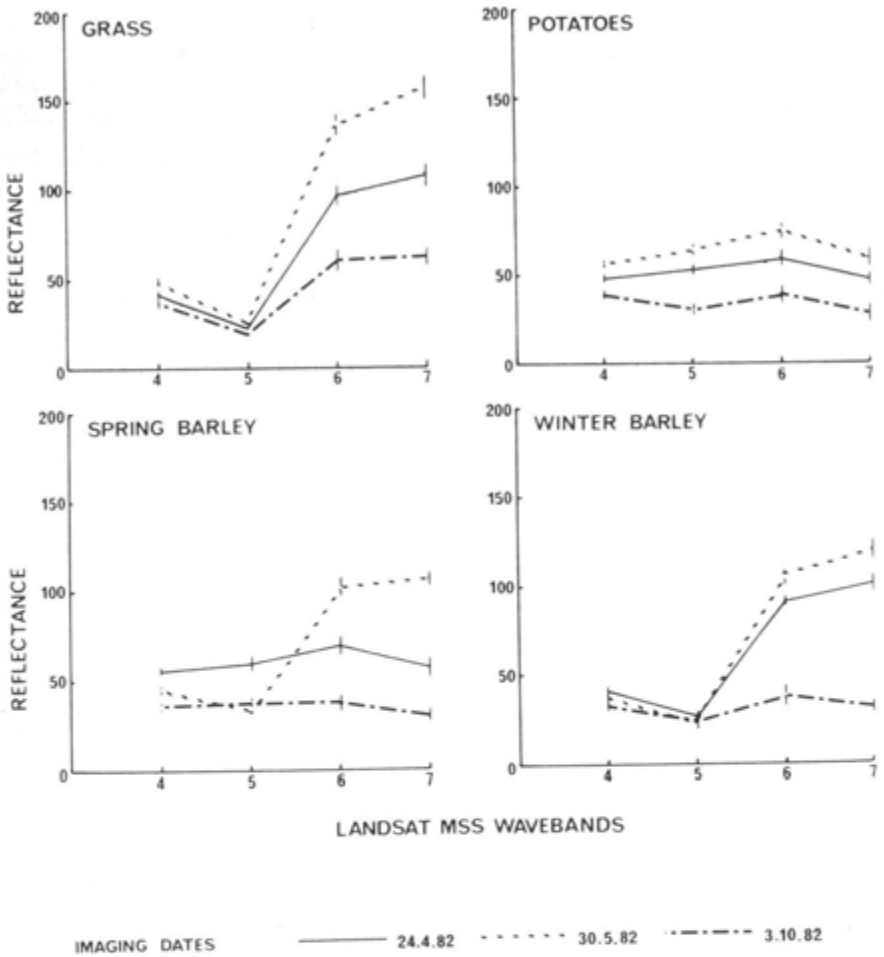


Fig. 2.1.

Visible/near-infrared reflectances for selected crop types as recorded by LANDSAT on three different imaging dates. (Bands 4, 5, 6 and 7 refer to the spectral ranges 0.5-0.6, 0.6-0.7, 0.7-0.8 and 0.8-1.1 microns, respectively).

response between 24th April and 30th May as ground cover becomes established is very apparent.

Geographic variations in reflectances due to differences in mesoclimate and soil type appeared to have less influence on classification than crop management, although these relationships have yet to be fully tested. Likewise, analysis of the data set showed that, whereas within-field reflectance anomalies could consistently be identified from one imaging date to the next, further work is required on the detection and diagnosis of crop stress. Research on these problems will be continued using the higher 30 m spatial and 7 band spectral resolution of LANDSAT TM (Thematic Mapper).

Crop Reflectance Studies

In collaboration with the Department of Spectrochemistry, work on the development of a field radiometer for crop and vegetation studies has continued along the lines previously reported. The system has now been field tested[17], but further modifications are required to improve its portability. Meanwhile, in co-operation with the Department of Soil Fertility, weekly photographic monitoring of potato canopy development at seven levels of nitrogen application has been undertaken coupled with the simultaneous acquisition of high resolution (2 nm) single-leaf reflectance spectra using a Shimadzu spectro-photometer. Preliminary results indicate a relationship between chlorophyll A and B content and the position of maximum slope on the derivative reflectance spectrum of the potato leaves. This opens up the possibility of determining chlorophyll contents remotely.

3005, 2032

Automated Photogrammetry

Further progress has been made with the development and application of the hybrid automated photogrammetric and image processing system for the display, classification and output of data in vector or raster form[18, 19]. Particular attention has been given to the development of software suites to provide communication between the Wild B8S stereoplotter, a PET microcomputer and the Aviotab flatbed plotter and the improvement of graphics facilities for the display of digitised features derived from existing maps. A large scale map of the field experimental plots at the Plant Breeding Institute, Cambridge, has been prepared using photogrammetric and digital processing techniques.

2032, 2033, 2034

Nutrient Cycling in Forests

A major development during the year was the award by the Commission of the European Communities of a contract, under their research and development programme on wood as a renewable raw material, to investigate, in conjunction with the Irish Forest and Wildlife Service, methods of enhancing productivity through manipulation of the nitrogen cycle. This study arises out of recent observations in both the United Kingdom and the Republic of Ireland that, whereas Sitka spruce (*Picea sitchensis* (Bong.) Carr.) planted on poor peats and upland heaths invariably becomes nitrogen deficient by age 12, no such deficiency appears in trees planted in intimate mixture with larch or pine. The various mixture experiments in Britain and Ireland, therefore, provide properly replicated plots in which nitrogen is clearly cycling at very different rates. The Macaulay Institute, with the encouragement of the Forestry Commission, has drawn up proposals in conjunction with the Research Branch of the Irish Forest and Wildlife Service to investigate two experiments in Scotland (at Inchnacardoch and Culloden forests) and one in Ireland (at Ballyhooley forest). The prime objective is to elucidate the processes that enable nitrogen and other nutrients to cycle more rapidly in mixed stands than in pure spruce stands, and the support of the Commission of the European Communities will enable a microbiologist to be assigned full-time to the

project. Work so far has focussed on establishing the pattern of rooting in one of the experiments. Here no suggestion was found of a close association of the roots of the spruce with those of the intermixed pine, indeed the roots of the two species concentrate at different depths. 2054, 2055, 2056

Analysis of the samples collected from the ten-year study on nutrient cycling in Sitka spruce is now almost complete. This investigation centred on six experiments designed to elucidate the relationship between element cycling and tree growth. Vegetation and soil organic layers were sampled at the initiation of each experiment and again after five years, when samples were taken separately from replicated NPK-fertilized and unfertilized plots. During the intervening years samples were taken fortnightly of incident rainfall and, from all plots, of throughfall, stemflow and litterfall. Throughout the study close collaboration has been maintained with the Department of Statistics to ensure rapid preliminary processing, checking and storage of the large amount of data collected. To date, further processing and publication has centred on aspects of rainwater chemistry both above and below the tree canopy, particularly in relation to the current debate on the effects of acid rain on forests and streams[20, 21].

2054

The earlier study on Corsican pine (*Pinus nigra* var. *maritima* (Ait.) Melv.) remains a useful data source for testing different concepts relating nutrient cycling and tree growth[22]. As mentioned in last year's report, an NERC/CASE student has been developing a simulation model of the nitrogen control of growth in pine. This is now producing seemingly sensible predictions over periods of several centuries and is about to be tested against data collected by other organizations. Similarly, the University of British Columbia has sought collaboration in testing their simulation models prepared under contract to the Canadian Forest Service.

2054, 2056

Nutrient cycling in broadleaved deciduous forests has not been widely studied in recent years, although collation of the data presently available suggests that the concepts developed in coniferous forests do not have to be much modified to apply to broadleaved species[22]. Thus, models of nutrient cycling developed for short-rotation, high-yielding alder crops showed that, as with pine, nutrient demands on the soil fall dramatically following canopy closure[23]. A similar conclusion was reached in a paper-study of nutrient cycling in birchwoods, and no indication was found as to why birch should have a reputation as a " soil improver "[24]. However, studies carried out by the Institute of Terrestrial Ecology suggest that there are soils on which birch can induce a significant change in profile features and soil acidity. Accordingly, a collaborative study has been initiated with Dr J. Miles, of that organization, jointly to monitor the accumulation and cycling of nutrients in birch stands of a range of ages both at Silpho, in North Yorkshire, and at Craggans, on Speyside. At the latter site, birch invasion of heathland is observed to be associated with a change in soil acidity, whereas no such effect has been detected at the Yorkshire site. Sample trees of all ages were taken from both localities in mid-summer, when foliage biomass

was at its greatest, and litterfall has been collected monthly beneath replicated plots. Detailed dimensional analysis of the sample trees revealed surprisingly little difference between the two localities in the relationships of weights of different components to stem sectional area at 0·5 m, a particular exception being foliage for which there was a significant difference between the two site-based regressions. 2054

A new investigation has also been initiated at Balquhidder (Strathyre forest) with the objective of determining the input, accumulation and loss of nutrients in a forested catchment. The hydrologic balance at this site is being measured by the Institute of Hydrology, in conjunction with various interested parties including the Forestry Commission, the Water Research Centre and the Forth River Purification Board. Access to properly recorded streamflow data from a well-defined and sealed catchment presents an ideal opportunity to assess the magnitude of nutrient loss in drainage water. During the year, therefore, a proportional sampling device was installed, with the assistance of Technical Services, in the outflow stream. In addition, three sites within the catchment were equipped with gauges to sample rain and aerosol inputs, and at each site replicated plots were installed for measuring throughfall and stemflow beneath two or three species of trees. Tree growth in these plots is to be monitored by the Forestry Commission Research Branch. The Forestry Commission proposes to fell the catchment progressively, starting in about a year's time, and the intention is to continue monitoring streamwater chemistry throughout this period. 2054

Nutrition of Coniferous Trees

Nutrient cycling studies have done much to indicate the period in the life of a tree when nutritional problems might be expected[25]. Even with this information, however, diagnosis of deficiencies and prescription of fertilizer treatment can be difficult. Various approaches are possible based upon site classification, soil analysis, visual foliar symptoms or tissue analysis, each having particular advantages, although tissue analysis appears to be the most precise technique[26]. Work is continuing to characterize the value of bark, root and litter analysis, as well as the more conventional foliar analysis, for this purpose. 2056

The sewage sludge application to the experiment in Angus forest, referred to in last year's report, stimulated significant increases in foliage nitrogen levels in the Scots pine (*Pinus sylvestris* L.) at the end of the first season after application. The Forestry Commission, in collaboration with the Water Research Centre, the Highland Regional Council and the Macaulay Institute, have now laid-out a second experiment in which sewage sludge has been applied to heather heathland at Ardross forest prior to ploughing and planting. In conjunction with the Departments of Soil Surveys and Spectrochemistry, an intensive sampling of the soil and surface organic layers was carried out prior to treatment and these samples, together with those of the sludge applied, are presently being analysed. Samples of foliage and soil will continue to be taken at regular intervals throughout the duration of both experiments. 2056

Forest Nursery Nutrition

As in previous years, the Department continues to provide a nutrition advisory service to forest tree nurseries based on soil analysis carried out by the Department of Soil Fertility. The year under review was characterized by a cold, wet spring followed by a prolonged drought. Many of the problems for which managers sought advice appear to be associated with this drought, although, in addition, copper deficiency has been noted more frequently than usual. 2056

Studies on Acid Rain

Information pertinent to the acid rain debate has been obtained both from the intensely studied spruce experiments and, more recently, from the CEGB financed investigation at Glen Tanar. In the latter, rainwater chemistry, including acidity, was monitored beneath a range of tree species growing within close proximity. A striking feature was that all species reduced acidity of throughfall excepting 110-year-old Scots pine, despite the reduction recorded beneath a 45-year-old stand of the same species[20]. A careful analysis of the data available in the literature has since revealed that age appears to be a more important factor than species in controlling pH change in water passing through a forest canopy[20]. Beneath all species,

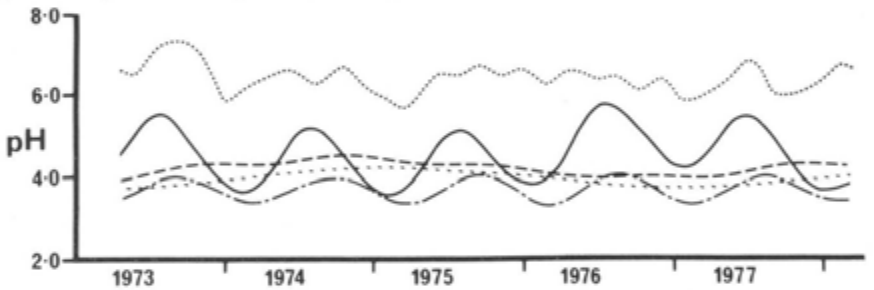


Fig. 2.2.

Time series analyses for acidity in water collected at Fetteresso, near Aberdeen. Samples were unaltered rainwater (— — — — — —), water collected beneath an interception gauge (- - - - -), throughfall water (————) and stemflow water (— - — - —) collected beneath Sitka spruce and drainage water (· · · · · ·) leaving the forest.

including evergreen species, effects on throughfall pH were more pronounced in summer than in winter, although for Sitka spruce, at least, removal of hydrogen ions from rainwater continues throughout the winter. However, data from the six experiments in this species, referred to earlier, suggest that where the average pH of the incident rainwater is low, the throughfall acidity develops an annual oscillation, neutralization being least pronounced in the early months of the year and most pronounced in mid- to late-summer[21]. A time series analyses of the pH data from the most easterly experiment is shown in Fig. 2.2. Despite the absence of any annual pattern in acidity of either bulk precipitation or in water collected beneath an interception gauge (gauge surmounted by a vertical cylinder formed from polyethylene coated wire mesh designed to enhance the input of intercepted

aerosols, dust and mist), regular oscillations are pronounced in both throughfall and stemflow, though apparently not reflected in the acidity of the drainage water. At western sites, rainwater acidity beneath trees showed no significant annual oscillation. 2054

Investigations continue to determine the effect of soluble soil aluminium on the health of tree roots. Results from four experiments, three on Sitka spruce and one on sycamore (*Acer pseudoplatanus* L.), show that no adverse effects can be expected at least until the aluminium concentration in the nutrient solution exceeds 20 ppm. This is in full agreement with results from parallel experiments carried out in Norway and Canada and would seem to discount recent theories that pollution-derived acidity may mobilize sufficient soil aluminium to destroy or impair tree roots. Any effects are more likely to be *via* direct effects of gaseous pollutants, and then probably only at levels greater than are likely in rural areas of Scotland[20]. However, the fact that rain introduced acidity may reach streams, and the possibility that this may be exacerbated by forests[27], continues to cause concern and is to be the subject of a major new series of investigations sponsored by the Department of the Environment. 2054

Nutrient availability in highly Organic Soils

Nitrogen and phosphorus in peats and mor humus occur almost entirely in organic compounds that must first be degraded to inorganic forms for uptake by plant roots. These transformations, which depend to a large extent on the growth and activity of microorganisms, may be regarded as transfers between nutrient pools having different rates of turnover. Identification of these pools and measurement of the fluxes of nutrients between them may form a basis for predicting the effects of cultivation and management practices on nutrient availability in these soils. 2055

The studies on the nitrogen concentration and decomposition of particle size fractions separated from peats by wet sieving, described in last year's report, have been published[28]. The distribution of microbial material and metabolites between these fractions has been studied jointly with the Departments of Microbiology and Soil Organic Chemistry. Peat, from a raised bog, was amended with ^{14}C labelled glycine and then incubated. After incubation for 1, 6 and 12 months, samples were separated by sieving and the distribution of the ^{14}C label, incorporated in sugars and polysaccharide materials, determined in the fractions. This study was extended to include additions to a blanket bog peat of ^{15}N labelled plant material and ^{15}N in urea and ammonium sulphate. The particle size fractions have been separated in preparation for the analysis and identification of the chemical forms of labelled nitrogen. 2055, 9014, 4020

The soil microbial biomass is regarded as a relatively labile pool of nutrients with higher rates of turnover than native soil organic matter. The applicability of methods of estimating biomass C, N and P, developed mainly on near-neutral mineral soils, has been tested on acid organic soils in a joint study with the Department of Microbiology[29]. Fumigating

samples with chloroform to kill the biomass resulted in the immediate release of phosphate extracted with 0·01 M Ca Cl_2 and of nitrogen soluble in 1M KCl. An incubation period following fumigation to measure CO_2 release is not recommended for these soils because of the behaviour of unfumigated controls that produced anomalously low values for biomass carbon. More consistent estimates of biomass carbon were obtained using the Anderson and Domsch method based on respiration of samples amended with glucose. Estimates of biomass-P in a range of peats and mor humus suggested that a relatively high proportion of the total phosphorus, 7-22%, resides in the microbial biomass 2055, 9014

Amounts of readily mineralized nitrogen, measured by incubating samples under aerobic and anaerobic conditions, have been compared in samples taken from a wide range of peatland types of contrasting vegetation and topography and related to the chemical characteristics of the peat[30]. Readily mineralized-N, estimated under anaerobic (waterlogged) conditions, correlated significantly with pH and total nitrogen. Nitrification, detected under aerobic conditions, was observed only in samples with an appreciable proportion, >30%, of mineral matter and with pH >4·3. The results of a field incubation study of mineral nitrogen accumulation in the litter and humus beneath Sitka spruce, described in last year's report, has been published[31]. 2055

A comparative study of the physical and chemical changes in peat on Lewis resulting from reseeding indicated that some effects were evident more than 20 years after treatment[32]. At the five reseeded sites examined, the composition of the sward consisted mainly of native grass species together with clover, and gains in nitrogen of approximately 80 kg N ha^{-1} yr^{-1} were compatible with biological nitrogen fixation. Interestingly, no gain in nitrogen was found in samples from a peat low in potassium which had been taken from a site cutover for fuel and sheltered from atmospheric inputs derived from the sea. 2055, 8057, 8059

The results of a joint study with the Department of Microbiology into the effects of lowering the water-table on bacterial numbers and available nitrogen in deep peat are being prepared for publication. Visual examination of peat cores from unplanted sub-plots at the controlled water-table experiment, Lon Mor, Inchnacardoch forest (Highland Region) revealed an increase in rooting depth, from 10 to 40 cm, accompanying a fall in water-table height from 0 to 33 cm. At the same time, the mean mineral nitrogen concentration in the upper 60 cm of the peat increased by a factor of 1·7, but this was small compared with the five-fold increase in available mineral nitrogen resulting from the increase in rooting depth.

2055, 6027, 8057, 8059

References

1. Peat. By P. D. Hulme and R. A. Robertson. To appear in *Memoirs of the Soil Survey of Great Britain: Soils of Fife and Kinross.* By D. Laing and J. S. Robertson. Aberdeen, Macaulay Institute for Soil Research.

2. A mechanical aid for use with peat samplers. By A. W. Blyth. To appear in *Proc. Seventh Int. Peat Congr., Dublin,* 1984.

3. Current use of remote sensing data in Scotland. By G. C. Stove, *Phil. Trans. R. Soc. Lond.*, A309, 1983, 271-281.

4. Aspects of coastal terrain and estuarine hydrography in north-east Scotland interpreted from sequential Landsat data. By A. W. Odell (RAE, Farnborough), G. C. Stove and R. Wright (University of Aberdeen). In *N.E. Scotland Coastal Field Guide and Geographical Essays for the IGU Coastal Commission Symposium.* Edited by W. Ritchie. Aberdeen, Department of Geography, University of Aberdeen, 1983, 126-140.

5. Studies of proton flux in forests and heaths in Scotland. By H. G. Miller. In *Effects of Accumulation of Air Pollutants in Forest Ecosystems.* Edited by B. Ulrich and J. Pankrath, Dordrecht, D. Reidel, 1983, 183-193.

6. Peat as an energy source in Scotland. By R. A. Robertson and N. M. Godsman (Northern Peat and Moss Company). To appear in *Proceedings of a Conference on Energy for Rural and Island Communities,* Inverness, September, 1983.

7. The Peat Resources of the Island of Yell, Shetland. By R. V. Birnie, P. D. Hulme and R. A. Robertson. Report of survey and evaluation for the North of Scotland Hydro-Electric Board. Aberdeen, Macaulay Institute for Soil Research, 1983.

8. A classification of the peatland vegetation of the Isle of Lewis and Harris, Scotland. By P. D. Hulme and A. W. Blyth. To appear in *Proc. Seventh Int. Peat Congr., Dublin,* 1984.

9. The peatland vegetation of the Isle of Lewis and Harris and the Shetland Islands, Scotland. By P. D. Hulme. To appear in *Aquilo Ser. Botanica.*

10. Notes on the pollen content of soil samples from the mound and henge at North Mains Farm, Strathallan. By P. D. Hulme and J. Shirriffs. To appear in *Proceedings of the Society of Antiquaries of Scotland.*

11. The annual growth period of some *Sphagnum* species on the Silver Flowe National Nature Reserve, South-West Scotland. By P. D. Hulme and A. W. Blyth, *Journal of Bryology,* **12**, 287-291.

12. Mapping the distribution of bracken in Scotland by remote sensing techniques: Interim Report for the Department of Agriculture and Fisheries for Scotland. By R. V. Birnie, G. C. Stove and P. S. F. Ritchie. Aberdeen, Macaulay Institute for Soil Research, 1983.

13. Thermal infrared survey of Aberdeen city: data processing analysis and interpretation. By R. V. Birnie, M. J Adams, P. F. S. Ritchie and G. C. Stove. To appear in *International Journal of Remote Sensing.*

14. Aerial thermography: principles and applications. By M. J. Adams and R. V. Birnie. To appear in *Geographical Magazine.*

15. Monitoring crop development in N.E. Scotland from Landsat MSS data: results of the AGRISPINE experiment. By R. V. Birnie, *Proc. Int. Conf. "Remote Sensing for Rangeland Monitoring and Management,"* Silsoe, Bedford, September, 1983, 178-190.

16. The use of Landsat data to monitor iceberg production: Results from the AGRISPINE experiment for the Jakobshavns Isbrae. By R. V. Birnie and G. C. Stove. Macaulay Institute for Soil Research/National Remote Sensing Centre, Farnborough, 1983.

17. Development of a spectrometer for monitoring crop reflectance. By R. V. Birnie and M. J. Adams. To appear in *Anal. Proc. R. Soc. Chem.*, London, 1983.

18. Interpretation and automated mapping of airborne and satellite imagery using the Macaulay MAPIPS system. By P. F. S. Ritchie and G. C. Stove. In *Ecological Mapping from Ground, Air and Space.* Edited by R. M. Fuller. Monkswood, ITE Symposium No. 10, 1981, 113-124.

19. Interaction of remotely sensed data on an automated photogrammetric image processing system. By G. C. Stove. To appear in *Proc. Remote Sensing Soc. Conference on Geographical Information Systems, Swindon, NERC,* 1981.

20. Deposition-plant-soil interactions. By H. G. Miller. To appear in *Proc. Royal Society Meeting on Ecological Effects of Deposited Sulphur and Nitrogen Compounds*, September, 1983.

21. The interaction of acid precipitation and forest vegetation in northern Britain. By H. G. Miller and J. D. Miller. *Water Quality Bulletin*, **8**, 1983, 121-126.

22. Dynamics of nutrient cycling in plantation ecosystems. By H. G. Miller. To appear in *Nutrition of Forest Trees in Plantations*. Edited by G. D. Bowen and E. K. S. Nambier, London, Academic Press.

23. Nutrient cycling in alder. By H. G. Miller. Report No. 2 of *Programme Group "B," International Energy Agency — Forestry Energy Agreement*. Stockholm, National Swedish Board for Energy Source Development, 1983.

24. Nutrient cycles in birchwoods. By H. G. Miller. To appear in *Proc. Botanical Society of Edinburgh Symposium on Birch*. Edited by D. G. Mann.

25. Maintenance and improvement of forest productivity — a general overview. By H. Miller. To appear in *Proc. IUFRO Symposium on Forest Site and Continuous Productivity*, Seattle, 1982.

26. Wood energy plantations — Diagnosis of nutrient deficiencies and the prescription of fertilizer applications in biomass production. By H. G. Miller. Report No. 3 of *"Programme Group B," International Energy Agency — Forestry Energy Agreement*. Maple, Ontario Tree Improvement and Forest Biomass Institute, 1983.

27. Water in forests. By H. G. Miller. To appear in *Scott. For.*

28. The nitrogen content of particle size fractions separated from peat and its rate of mineralization during incubation. By B. L. Williams, *J. Soil Science*, **34**, 113-125.

29. Extractable nitrogen and phosphorus in relation to microbial biomass in UK acid organic soils. By B. L. Williams and G. P. Sparling. To appear in *Plant and Soil*.

30. Influence of peatland type and the chemical characteristics of peat on the content of readily mineralized nitrogen. By B. L. Williams. To appear in *Proc. Seventh Int. Peat Congr., Dublin*, 1984.

31. Nitrogen transformations and organic matter decomposition in litter and humus beneath closed-canopy Sitka spruce. By B. L. Williams, *Forestry*, **56**, 1983, 17-32.

32. Changes in physical and chemical characteristics of peat following reseeding. By B. L. Williams, R. Boggie and J. W. Mitchell. To appear in *J. Agricultural Science*.

3. SPECTROCHEMISTRY

A. M. URE

The activities of the Department of Spectrochemistry continue to embrace the main themes of recent years. These are devoted to (1) studies of the distribution of trace elements in soils, soil profiles and plant and biological materials, (2) the elucidation of the structure, composition, and forms of soil components, (3) the provision of an analytical service for major and trace elements to the Institute and to the North of Scotland College of Agriculture for their advisory service to farmers and (4) the development of spectrochemical methods of analysis appropriate to these programmes.

In addition to attendance and the presentation of papers at various national and international conferences detailed elsewhere in this report, the Department has been represented by members of staff on several national and international committees and working parties. These include DAFS Consultative Committee on Spectrochemical Work (T. S. West, chairman; A. M. Ure, Technical Secretary), IUPAC Commission V-4 on Spectrochemical methods (A. M. Ure), Department of the Environment/National Water Council Standing Committee of Analysts (Main Committee, A. M. Ure; Working Group 4, M. L. Berrow), Department of the Environment, Sludge to Land Committee, Working Group 3 (M. L. Berrow), Analyst Editorial Board (A. M. Ure), Annual Reports on Analytical Atomic Spectroscopy (Chairman, B. L. Sharp; J. C. Burridge), Association of Scottish Industrial Analysts (J. C. Burridge). Departmental staff in addition are members of various committees of the Analytical Division of the Chemical Society (M. J. Adams, B. L. Sharp, A. M. Ure) and A. M. Ure was this year responsible for co-ordinating the Scientific Programme for the International SAC '83 Conference of the Analytical Division of the Chemical Society held in Edinburgh. Dr Goodman completed his sabbatical year's studies in the Departments of Agronomy and Chemistry at the University of Illinois, Urbana, U.S.A. and, as is detailed later in this report fruitfully extended his E.P.R. and Mössbauer researches. He was, in addition, able to have first-hand experience of other magnetic spectroscopies — including Nuclear Magnetic Resonance — and his new experience in these latter fields will be of crucial importance in assessing the need and the instrumentation requirements for the envisaged Nuclear Magnetic Resonance spectrometer.

Trace Elements in Soil Plants and Biological Materials

Collaborative work this year with the Department of Soil Fertility has, in addition to extensive analysis of soils and plants from field experiments,

included the preparation of a candidate Ryegrass Reference Material, together with the soil on which it was grown, for the Community Bureau of Reference of the Commission of the European Communities. This reflects the current interest of the Bureau in providing Certified Reference Materials containing elemental contents at natural levels as well as materials from polluted areas. This work made use of the expertise of the Institute in providing material free of soil- and other contamination. A candidate Sewage Sludge Reference Material, prepared by the good offices of Grampian Regional Council at their treatment plant in Persley, Aberdeen, has also been supplied to the Bureau. Assistance in temporarily storing these bulky (150 kg each) materials *en route* to the Bureau has kindly been given by the Grassland Research Institute.

The Department has collaborated in a comparison and assessment of the methods used at the three Scottish Colleges of Agriculture for the analysis of soils and crops, under the auspices of the MISR/COSAC Liaison Group.

The views of the Department and the Department of Soil Fertility on the proposed Directive of the Commission of the European Communities on the use of sewage sludge in agriculture have been represented to the European Communities Committee of the House of Lords. Particular attention was drawn to the impact on soils of metals in sewage sludge. 3007, 3008

Soil and Soil Parent Materials

The determination of trace elements in selected profiles sampled by the Department of Soil Survey has continued. Extractable trace elements in profiles from the Ardnamurchan and Morvern area (Sheets 52 and part of sheets 44 and 51) have been determined. Analysis of extractable molybdenum in topsoils of profiles from the Tomintoul area (Sheet 75) have also been completed.

Following the study of total lead levels in nearly 4000 soil samples from about 900 soil profiles taken throughout Scotland, reported last year, an investigation of the acetic acid-extractable lead in the same soils has been carried out. The results of both studies have been accepted for publication[1, 2]. Acetic acid-extractable lead in 3764 samples from 751 profiles ranged from $<0{\cdot}001$ to 160 mg/kg and the distribution was approximately log-normal in form. After log-transformation to provide a more satisfactory means of describing the distribution, the derived mean for the full set of data was $0{\cdot}24$ mg/kg and the normal range $0{\cdot}016$ to $3{\cdot}4$ mg/kg.

Total lead concentration was found to be the dominant factor determining the level of extractable lead in soils. The extractability (i.e. the *percentage* of the total lead extractable by acetic acid) rather than the amount of extractable lead was, therefore, used to relate lead to other soil variables. Extractability of lead was enhanced under conditions of impeded drainage, but there was no evidence that it was related to clay or ash content.

Extractable lead was found to be generally higher in surface horizons than at depth, thus reflecting the pattern of variation shown by the total

lead concentration. Moreover, the extractability of lead showed little evidence of variation with depth.

A report of the distribution of the total copper contents of Scottish soils has also been submitted for publication[3]. The contents in 4179 samples from 946 soil profiles ranged from <1 to 2500 mg/kg with a mean of 18 and a median of 15 mg/kg. The frequency distribution of concentration levels was found to be approximately log-normal and after log-transformation the derived mean for the full set of data was 10 mg/kg and the normal range 0·93 to 110 mg/kg.

The copper contents of soils derived from basic and intermediate igneous rocks exceeded those derived from acidic rocks by a factor of about five. Among soils derived from sedimentary rocks, copper contents were higher in argillaceous than in arenaceous types. The copper content of organic soil samples was generally lower than that of mineral samples. The general trends found were for soil copper contents to increase with increase in depth and ash content and to decrease with increasing sand content.

A paper reporting the distribution of EDTA-extractable copper contents in Scottish soils is in preparation. A feature of the use of EDTA as a soil extractant for copper is the remarkable stability of copper extractability so obtained over long periods of soil storage. This feature has been noted earlier (Ure and Berrow, 1972) and has been confirmed by more recent analyses. For eight typical Scottish topsoils analysed about 10 times by different analysts over a period of seven years the relative standard deviations averaged 7%. For two of these soils, examined in further detail, the within-batch relative standard deviations for 9 simultaneous extractions were 1·3 and 4·3 per cent and the between-batch relative standard deviations for 13 analyses carried out over 7 years were 7·7 and 6·7 per cent respectively. This aspect is of particular importance when soil samples from long-term field experiments or from soil surveys, for example, are analysed for extractable trace elements after considerable periods of storage. 1001, 3007

The future analysis of top-soils from the Scottish Soil Inventory, collected on a 10 km grid basis, offers a new approach for assessing soil trace element status. This scheme is also planned for England and Wales and is based on acid digestion of the soils and analysis by inductively coupled plasma optical emission spectrometry (ICP-OES). The harmonization of procedures north and south of the border is under active discussion with Rothamsted Experimental Station, who are responsible for this work in England and Wales. It is currently envisaged that analysis of Soil Inventory samples will be carried out in the Department both by existing d.c. arc emission spectrographic methods to provide true total contents and by ICP-OES analysis of acid digests of the soils. This dual procedure will allow an assessment to be made of the extent to which the extraction technique effectively provides total soil contents for different elements and will cover a wider range of element contents than either technique alone. 1001

The information in the Spectrochemistry Trace Element data file is in process of being transferred to the Institute Soil Data Bank. The file con-

tains the total contents of 12 elements, acetic acid-extractable contents of 8 elements and the EDTA-extractable contents of 3 elements in all the soil profiles examined by Spectrochemistry. Data will thus be made available for some 5000 soils from 1000 profiles.

It was also agreed that all the information for a selected sheet area should be put into the soil data bank as an example to be used for evaluation of the system and as a demonstration of its possibilities. Complete information has been produced, therefore, from the recent sheet for the Fife and Kinross area (Sheet 40 and parts of 41 and 32). The trace element data for this sheet area has been verified and made available to the soil data bank.

Soil Status and Plant Uptake

The Department has again collaborated with the Department of Soil Fertility in the analysis of soils and plants from long-term field experiments involving the elements cobalt, copper, manganese, molybdenum and zinc. The main analytical effort has been to complete the analysis from a field experiment laid down to investigate the effects of nitrogen and added cobalt, copper, molybdenum and zinc on pasture herbage composition. An important finding is that the soil (Newton Series) at this experimental site rapidly converts applied cobalt to a form relatively unavailable to plants. Herbage contents on cobalt-treated plots fell from about 0·4 mg Co/kg DM in the first year (1978) after application to about 0·06 in the fourth year. Further studies are in progress. Discussions of the results from four long-term experiments to investigate the effects of major element fertilizers, and nitrogen in particular, on the uptake of cobalt, copper and molybdenum have been accepted for publication[4, 5]. The results and conclusions from several field experiments carried out by the Department of Soil Fertility concerning the effects of soil drainage status, liming, fertilizers and trace element soil treatments on crop composition and yields awaits publication[6]. A summary of the results from field-plot experiments on the effects of pedological drainage conditions on extractable soil trace-element levels and plant trace element uptake have been published[7]. Proceeding from the findings that the relationship between plant and soil cobalt contents, but not copper contents, are strongly influenced by soil drainage status (Annual Report No. 52, Fig. 3·1) a further study of the use of neutral molar ammonium acetate extraction for cobalt diagnostic purposes has been started. While preliminary results are encouraging there are considerable analytical difficulties because of the low concentration of cobalt extracted and further development of analytical procedures is required.

3007, 3008, 7042

The pot experiments being carried out in collaboration with the Department of Soil Organic Chemistry on the effects of adding peat of low copper content to two soils heavily contaminated with copper from distillery wastes have been extended to take account of pronounced pH effects on the growth of the lucerne used. A chapter in "Metalle in der Umwelt"[8] still awaits publication. 3007, 3008, 4022

Analysis of soils sampled in 1981 from the two long-term sewage sludge experiments at ADAS Experimental Stations are being made to assess the retention of metals in the topsoils thirteen years after the application of sludge. A report of the work on the persistence of metals in available form in soils treated with sludges was presented this year at the Third International Symposium on Processing and Use of Sewage Sludge held in Brighton and will be published in the Symposium proceedings[9]. A study of the extraction of metals from soils and sewage sludges by *aqua regia* digestion has been published[10].

Several hundred soil samples have been analysed this year using *aqua regia* digestion and atomic absorption spectrometry to determine their heavy metal contents, particularly cadmium and zinc, which are difficult to determine using direct current arc spectrometry. The zinc contents of 164 topsoil samples range from 9·7 to 185, mean 43 mg/kg. Zinc in 497 samples from 78 soil profiles developed on a wide range of geological parent materials range from 1·7 to 350, mean 60 mg/kg.

Studies are being carried out in collaboration with the Department of Peat and Forest Soils, the Forestry Commission, the Water Research Centre and Grampian and Tayside Regional Councils on the use of sewage sludge as a fertilizer for forest trees at two sites. At the first, a natural forest at Montreathmont, near Brechin, sewage sludge, surface soils, soil profile samples and foliage, sampled last year have been analysed for heavy metals. Samples of fungi, which are known to accumulate certain heavy metals, have also been taken from this experimental site for analysis. A second experiment has begun at Ardross Forest, near Tain, to investigate the effects of applying sludge prior to tree planting and samples have been taken from this experiment for analysis. 3007, 3008, 6027

Studies on the mobilization of trace and major elements by soil microbes have continued. This investigation, carried out in collaboration with the Department of Microbiology, has involved the killing of the soil biomass by fumigation and/or irradiation and measuring the release of extractable metals. Irradiation or fumigation generally caused relatively small increases in the extractable levels of most trace elements. The levels of manganese and cobalt were markedly increased, however, particularly by the irradiation treatment. Amendment with glucose or cellulose caused considerable changes in carbon, respired as CO_2, and in extractable nitrogen and phosphorus. The amendments caused comparatively small effects on ammonium acetate exchangeable levels of the majority of trace elements, notable exceptions being manganese and cobalt. Fumigation caused large increases in the extractability of these two elements from the glucose-amended soil, probably related in part to the reducing conditions caused by the enhanced microbial activity. A paper reporting this work has been submitted for publication[11].

Recent work using water extraction showed that the air-drying of soils caused considerable increases in extractable Mn, Co, Cu and V, but reductions in extractable Ca, Mg, K and Zn. The effect of fumigation of the

moist soil was to increase water-extractable Mn, Co, Cu, K and V, while Ca and Mg showed small decreases. Extractable Na was unaffected by both the treatments. 3007, 3008, 6027

Miscellaneous materials analysed during the year include samples of sewage sludge from Grampian Regional Council, oil-drilling cores from Britoil, lead smelter dusts supplied by the Rowett Institute, soil from Pentlands Scotch Whisky Research Ltd., laboratory dust and floor polish used in the Institute, potatoes and raspberries from the Scottish Crop Research Institute and cabbage, in relation to " pepper spot " disease, from the National Vegetable Research Station.

Spectrochemical Methods of Analysis

Arc Emission

Arc methods have continued unchanged. The grade of carbon used for many years (Morganite SG305) is no longer manufactured. Alternative materials found to be suitable for cathode-layer arc procedures are available from (a) Le Carbone (Gt. Britain) Ltd., grade 208, rods 4·6 mm dia. × 300 mm long, and (b) MCP Electronic Materials Ltd., Ringsdorff, grades RW-II and RW-V, size 4·58 mm dia. × 30 mm long. The first type (a) is rather more graphitic than the SG305 and is not very suitable for anodes. The second type (b) has the advantage of being available in short lengths suitable for making cathodes without the need to saw rods.

Zirconium crucibles, now obtainable in high purity, were evaluated for sodium carbonate fusion. They were found to be unsuitable replacements for platinum crucibles. Apart from problems of spectral line interference, high zirconium levels in the arced materials led to a marked reduction of molybdenum emission[12].

Thionalide, used for many years in the Department in conjunction with 8-hydroxyquinoline and tannic acid as a reagent to precipitate and pre-concentrate trace elements selectively from solution, is no longer obtainable commercially. As this procedure is still essential for the determination of several elements in soil extracts and plants by arc emission methods a replacement for thionalide is urgently being sought. Preliminary work suggests that the formation of H_2S in solution, following the addition of Na_2S, would be effective in precipitating those elements (e.g. lead) for which thionalide is at present used. Any practical procedure, however, has to overcome the well-known disadvantages of H_2S in the laboratory, and this aspect is being examined. 3007

Flame Emission and Atomic Absorption Spectrometry

Following the report last year (Annual Report No. 52, p. 60) on the use of *aqua regia* digestion for the determination of elements in polluted soils and in sewage sludges, further work on uncontaminated soils has been carried out using this procedure to assess the extent to which *aqua regia* extracts the total soil content of several metals. For this purpose four Canadian reference soils with certified contents for several elements and

25 uncontaminated Scottish topsoils derived from a wide range of parent materials have been analysed by *aqua regia* digestion and atomic absorption spectrometry. Total contents for the Scottish soils were determined by d.c. arc emission spectrometry or by atomic absorption spectrometry following a lithium metaborate fusion/nitric acid digestion procedure. The results show that *aqua regia* extracted some 70 to 90% of the total soil contents of Cd, Cr, Cu, Fe, Mn, Pb and Zn, some 70% of the magnesium, 50% of the calcium, 40% of the aluminium, 20% of the potassium and 4% of the sodium.

It appears that the more easily disrupted ferromagnesian minerals are broken down by this procedure, while the more stable alumino-silicates such as feldspars are not. Much of the total contents of some of the biologically important trace elements including Cr, Cu, Cd, Mn and Zn are contained in the ferromagnesian minerals and are therefore released. Where it is necessary to determine the total contents of some of the major elements such as Al, Ca, Na and K, *aqua regia* digestion is not sufficiently vigorous and alkali fusion or HF digestion is necessary.

The siliceous residues remaining after extraction of the four Canadian soils and four sludge treated soils have been analysed by direct current arc spectrography. The results indicate that about 75% of the total cobalt contents had been extracted. In seven other soils examined, mostly contaminated, some 70% of the nickel, 80% of the lead and 90% of the Cr, Cu and Mn were extracted.

Tests have been carried out to compare the results obtained from digestions of soils with *aqua regia* prepared from redistilled 6M HCl and from AnalaR HCl (d_{20} 1·42) which is approximately 11M. With four contaminated soils there was little or no difference in the amounts of Cd, Cr, Cu, Mn, Ni or Pb extracted, but the amounts of Zn extracted were 5 to 10% greater with the stronger acid at soil Zn levels of 300 to 700 mg/kg. With six uncontaminated topsoils the amounts of trace and major elements extracted were little affected except for Cr and Mn which were increased by 2 to 12%, mean 8%, in the stronger acid. 3007, 3011

The development and application of atom-trapping atomic absorption spectrometry has continued and descriptions of the technique[13] and its application to the determination of lead and cadmium in soils[14] have now been published. The technique was also displayed at a Royal Society soiree in London. A discussion of the application of the method to a range of sample types detailing the sensitivity, detection limits and operational conditions for the 12 elements so far investigated has been submitted to *Analytical Chemistry*. The technique has proved particularly useful for the determination of lead and cadmium in extracts of soils and provides a method, hitherto lacking, for determining arsenic, in *aqua regia* digests of soils.

Increasing use has been made of graphite furnace atomic absorption using the IL751 with the 555 constant temperature furnace in the determination, for example, of copper, cobalt and manganese in biological tissues

prepared for analysis by oxygen combustion and nitric acid digestion in a Trace-O-Mat VAE (Paar Scientific Ltd.) automated combustion apparatus. In collaboration with the Department of Soil Organic Chemistry techniques have been developed for the determination, by graphite furnace atomic absorption spectrometry, of manganese, copper, zinc and, with some reservations as to sensitivity, for cobalt in the soil solution obtained by centrifuging field-moist soils. These techniques are being applied to field/plot studies on manganese uptake and on the effects of agricultural treatments on manganese at the soil-root interface. These studies have served to confirm the viability of graphite furnace atomic absorption as an analytical technique for trace element speciation studies envisaged for the soil solution.

The number of routine determinations of the major cations Ca, K and Mg carried out this year increased by some 10%. The number of determinations were also considerably increased for Co (3x), Cu (2x), Mn (2x) and Zn (3x) while the numbers for Al, Cd, Ni and Pb increased by 50%. In all about 110,000 elemental analyses were made in the past year by these techniques. 1001, 3007, 3011, 7038, 7041, 7043, 7047, 7048, 5050, 2056

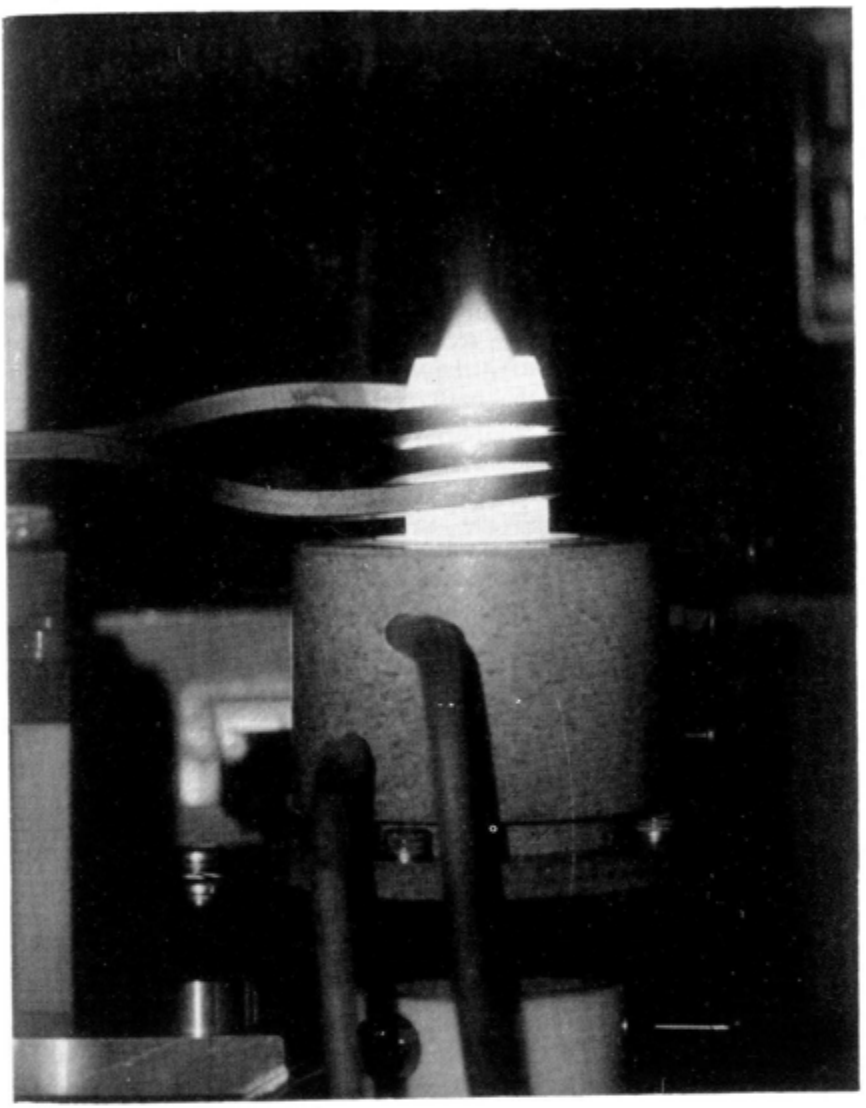
The critical survey of flame emission and atomic absorption spectrometry in the analysis of soils mentioned last year (Annual Report No. 52) has now been published[15]. A description of the interfacing of an Apple II microcomputer to the three-channel atomic absorption spectrometer noted last year has now been published[16]. The early contributions of the Rumanian chemist Nicolae Teclu have been briefly reviewed[17]. 3011

Radiofrequency Plasma Emission

The inductively-coupled plasma (ICP) emission spectrometer is now operational and is being applied, initially, to the determination of major elements in Kjeldahl digests of crop samples. Optimization studies taking account of the parameters power, height of measurement, outer gas flow and injector gas flow, using the SIMPLEX algorithm, have shown that under appropriate conditions, plant digests can be analysed for individual elements using, for calibration, simple aqueous standards unmatched for major matrix components.

The optimized operating conditions appear to be quite robust, and have been shown to work equally well with hydrochloric acid solutions of ashed samples or Kjeldahl plant digests in sulphuric acid. The precision of determination under routine operation is *ca* 2% (RSD). The use of ICP emission spectrometry is currently being extended to provide an analytical service to the Institute for other elements and other sample types, particularly soil extracts and natural waters.

The high temperature, *ca* 6000°C, of the flame-like plasma emission source, illustrated in Fig. 3.1, offers the advantage over the chemical flame sources used in atomic absorption spectrometry of relative freedom from chemical interference effects. It is particularly suitable for the determination of elements such as calcium or molybdenum which form refractory oxides or compounds in chemical flames. Because ICP optical emission



The flame-like, inductively-coupled, argon plasma (ICP) source for multi-element analysis by optical emission spectrometry, showing the silica torch and the coil for coupling the radiofrequency generator to the plasma.

spectrometry can also provide simultaneous multi-element analysis with a linear response over some four or five decades in concentration and a sensitivity, in general, similar to that of flame atomic absorption, the technique will increasingly be used to replace flame atomic absorption spectrometry for the determination of major cations and some trace elements in soil extracts and plant digests especially in those cases where use can be made of its simultaneous multi-element capability.

The research programme on nebulizers and spray chambers has continued and this year collaborative studies on the droplet size distributions produced by nebulizers and spray chambers have been undertaken in association with the National Institute for Agricultural Engineering and Long Ashton Research Station. Two new designs of nebulizer have been developed during this programme, and a major review of the subject is in preparation for *The Analyst*. A review of the agricultural applications of ICP emission spectrometry awaits publication[18].

Microwave Plasma Emission

The optical emission method for determining $^{14}N:^{15}N$ isotope ratios has been regularly used, and has recently been transferred back to the Department of Spectrochemistry. Papers concerning N_2 bandhead shifts[19] and the analytical use of the (3,0) and (4,1) bandheads[20] have been accepted for publication.

Reflectance Spectroscopy

Collaborative work with the Remote Sensing Unit has continued with the development of a portable spectrometer for monitoring soil and crop reflectance spectra[21]. Preliminary studies indicate several useful applications for such an instrument, including ground-truth measurements in the analysis of airborne and satellite recorded imagery.

With the Remote Sensing Unit and the Department of Soil Fertility a study has been initiated to examine the use of derivative reflectance spectroscopy for monitoring *in-vivo* chlorophyll and plant nutrient status. The results to date, on potato leaflet samples, indicate a high correlation between the wavelength of the near-infrared reflectance edge and the chlorophyll and nitrogen status of the plant material. A more detailed investigation is being planned to include other crop varieties. 2032

Laser Spectroscopy

The laser, remote-sensing system, constructed from equipment supplied by the Royal Society, the Science Research Council and the Agricultural Research Council, has been used for the determination of sulphur dioxide in the environs of the Institute, at ranges up to 1·2 Km. The results have been correlated with those from a chemical SO_2 analyser. Arising from this project, an application has been made jointly with the National Physical Laboratory, for funding from the EEC to study agricultural field emission of N_2O using infrared-laser long-path absorption spectrometry.

Spark Source Mass Spectrometry

Relative Sensitivity Coefficients (RSCs) have been established for 54 elements in a biological matrix (a synthetic base designed to simulate a liver ash). The majority of elements have RSCs below, but close to, 1·0 and 46 have RSCs in the range 0·5 to 1·2, thus highlighting the uniform sensitivity of the technique. The analysis of a similar series of soil standards has been completed and the data are being evaluated. So far RSCs have been established for 34 elements in the soil matrix and compari-

son with those for the biological matrix shows that, in general, the former are higher. Although in most cases the differences are relatively small, they can be significant as, for example, in the case of the lanthanides for which RSCs in a soil matrix can be twice those in a biological matrix. Work has also started on the analysis of a similar series of synthetic plant standards. This will expand the range of sample types for which quantitative analysis can be attempted.

Developments in instrumentation have continued. The second mass spectrometer has been fitted with two turbomolecular pumps in place of three oil diffusion pumps and their liquid nitrogen traps. At present one diffusion pump has been retained to achieve a good vacuum in the source and it may also be necessary to fit a further pump and liquid-nitrogen trap to improve the vacuum in the analyser section. The instrument is now in operational condition and ready for fitting a thermal ionisation source presently awaited. This will be used to evaluate the instrument for possible use in stable isotope tracer studies.

The microprocessor-controlled microdensitometer (Annual Report No. 52) is now in daily routine use and operating procedures have been devised. An AIM computer is used to establish the mass distance relationship for each photoplate and can also be used to calculate the concentrations for a limited number of elements. The limited memory size, however, restricts applications to cases where fewer than about 30 element lines needs to be measured and no correction procedures are required. This is the case in the analysis of the synthetic standard samples, but for other samples programs have been written for off-line Apple and PET computers to do the complete calculations and it is intended that these programs will form the basis for a new micro-densitometer system with an on-line microcomputer for all calculations. This microdensitometer, at present under construction, will also be used for the rapid evaluation of d.c. arc spectrographic plates at present evaluated on slow, manual instruments.

In the analysis of soils and geological materials by spark source mass spectrometry, quantitative determination of elements has been successfully based on the use of indium as an internal standard element. For the analysis of biological materials, however, the presence, in such sample matrices, of major amounts of alkali and alkaline earth metals, and of chloride in addition, results in significant superpositional spectral interference on indium lines by molecular ions such as $^{39}K_2{}^{35}Cl$ (on ^{113}In) derived from these major matrix components. While mathematical corrections are routinely made for these interferants such corrections are often insufficient at the high levels of interference encountered in some biological materials. For this reason an additional internal standard element, ytterbium, is being used together with an increased amount of indium. Sample electrodes are prepared from a mixture (1+1) of sample powder and aluminium conducting powder containing 1250 ppm indium and 300 ppm ytterbium as oxides. In this way interferences on indium from molecular species which were generally significant only at long exposures (50-1000 nC) are eliminated by using one of the seven ytterbium

isotopes. Standardisation of shorter exposures is achieved by using the isotope lines from indium now present at ten times the concentration used for soil analysis. With these modifications internal standardisation is achieved over a dynamic exposure range of 0·01 to 1000 nC, i.e. over a five-decade concentration range. Trace and rare earth element analysis by SSMS have contributed to the elucidation of the composition and origin of a group of Norwegian eudialyte-eucolite minerals[22]. 3007, 3010

Samples analysed include fungi, both with and without preconcentration by cementation, various reagent blanks, oil-well core samples, and samples of thallium- and sodium heparinate which did not require ashing before analysis.

Multi-element Analysis of Biological Materials

Much of the work on the development of sample preparative methods and analytical methodology for the determination of a wide range of elements in biological materials of animal and human origin has been carried out in the Department of Spectrochemistry by Dr C. A. Shand, Research Fellow supported by the Scottish Hospitals Endowment Research Trust, in collaboration with Dr P. J. Aggett, of the Centre for the Study of the Metabolism of Trace Elements, Department of Physiology, Aberdeen University. The analytical techniques have principally been spark source mass spectrometry and flame and graphite furnace atomic absorption spectrometry available in the Department, but considerable use has been made of instrumental neutron activation analysis, especially for standardisation and validation of these other methods. The neutron activation analyses were carried out at the Scottish Universities Research and Reactor Centre, East Kilbride, in collaboration with Dr J. E. Whitley, of that establishment.

Using these techniques, eight different human foetal samples from a single foetus have been analysed for some 30 trace elements; these included the biologically important transition elements and Ag, Ba, Bi, Ce, Ga, Ge, La, Mo, Pb, Sb, Sn and Tl. Upper limits of concentration have been obtained for a further 20 elements present at levels (10 μg/kg) below the detection limits. Similarly, 10 different foetal livers, the NBS Bovine Liver Certified Reference Material (SRM 1577) and a bulk sample of bovine blood (supplied by the Rowett Research Institute) have been analysed. All these samples were prepared for SSMS analysis by dry-ashing, at 450°C without ashing aids, the freeze dried homogenate. Satisfactory, low-carbon ashes have been obtained in this way for all samples with the exception of some livers. The reasons for this are being investigated. Where homogenization of dried material was necessary use was made of the Waring Blendor, modified to minimize chromium and other transition metal contamination, reported last year[23], or a commercial homogenizer (Virtis 60K supplied by Techmatiron Ltd.) similarly modified by replacing stainless steel components by titanium ones fabricated by the Institute's Technical Services Unit.

The collaborative study, discussed previously (Annual Report No. 52), with Dr A. Gelman, of the North of Scotland College of Agriculture, on the

determination of ruthenium used as an inert marker element in investigations of sheep digestive processes has continued. Analyses have now been carried out by SSMS on ashed and unashed samples, by graphite furnace atomic absorption spectrometry and by neutron activation analysis. This work has shown that, contrary to expectations, only small losses (*ca* 10%) of ruthenium occur when digesta samples are ashed by combustion in oxygen at high temperatures, and that a simple dry-ashing technique (at 450°C) might be used for sample preparation without the large losses of ruthenium (as the volatile oxide) which readily occur during wet oxidation procedures. The retention of ruthenium in the ash is presumably due to the formation of involatile ruthenates as a result of reaction with the high concentrations of alkali and alkaline earths present in such duodenal digesta.

The preconcentration technique described previously (Annual Report No. 52) which uses column cementation on aluminium powder has been further developed by Mr Fu Bin, visiting research worker from Beijing (Pekin) China, who discussed the method at the Colloqium Spectroscopicum International in Amsterdam. A description of the technique and its application in SSMS analysis for the determination of copper, lead, ruthenium and the noble metals has been published[24]. The analysis of plant material by SSMS with and without preconcentration by cementation has also been discussed[25]. This technique has also been used for determination of arsenic and selenium in human and animal tissues by SSMS. For these and other elements the cementation procedure not only provides a modest preconcentration, but eliminates interference in the SSMS determination from molecular ions derived from these biological matrices. The procedure adopted for arsenic and selenium in these materials involved mixing with an equal weight of pure cellulose powder, pelletting for combustion in oxygen using the Trace-O-Mat VAE apparatus discussed above and digesting the resulting ash under reflux with 6M hydrochloric acid which retains the arsenic and selenium in solution. This solution with washings, amounting to 25-50 ml, is used for the column cementation process and the aluminium from the column with its collected trace elements is used to fabricate the SSMS electrode for analysis.

The Trace-O-Mat VAE automated combustion system installed last year (Annual Report No. 52) has been modified by fitting a tap, close to the combustion chamber, in the oxygen inlet tube to prevent trapping and loss of condensate in the tube during the acid refluxing cycle following the combustion stage. Quantitative recovery of selenium in biological tissues has been obtained with this combustion apparatus using 6M hydrochloric acid as the refluxing and selenium-collecting acid. 3010, 3011

Molecular Spectrometry of Soil Components

The proposal[26] that aluminium migrates in podzols as a hydroxy-aluminium silicate (proto-imogolite) sol, and that the organic matter in Bh horizons migrates independently, has stimulated much new research, both in the field and in the laboratory, and has initiated a careful re-appraisal of

published information on the diverse types of podzol. Two powerful tools for the recognition of proto-imogolite allophane in B horizons have been developed, one based on chemical extraction, and the other on infrared spectroscopy. The most widely applicable procedure is to measure the amount of oxalate-soluble Si present in the soil, and to assign this to allophane[27]. This provides a semi-quantitative estimate of the amount of allophane present, on the basis that an oven-dry proto-imogolite allophane contains 13% Si, but the method gives no direct information on the source of the silicon. However, proto-imogolite allophane can be recognized by its infrared spectrum, and an examination of the difference spectrum between clays isolated from podzol Bs horizons and the residues after

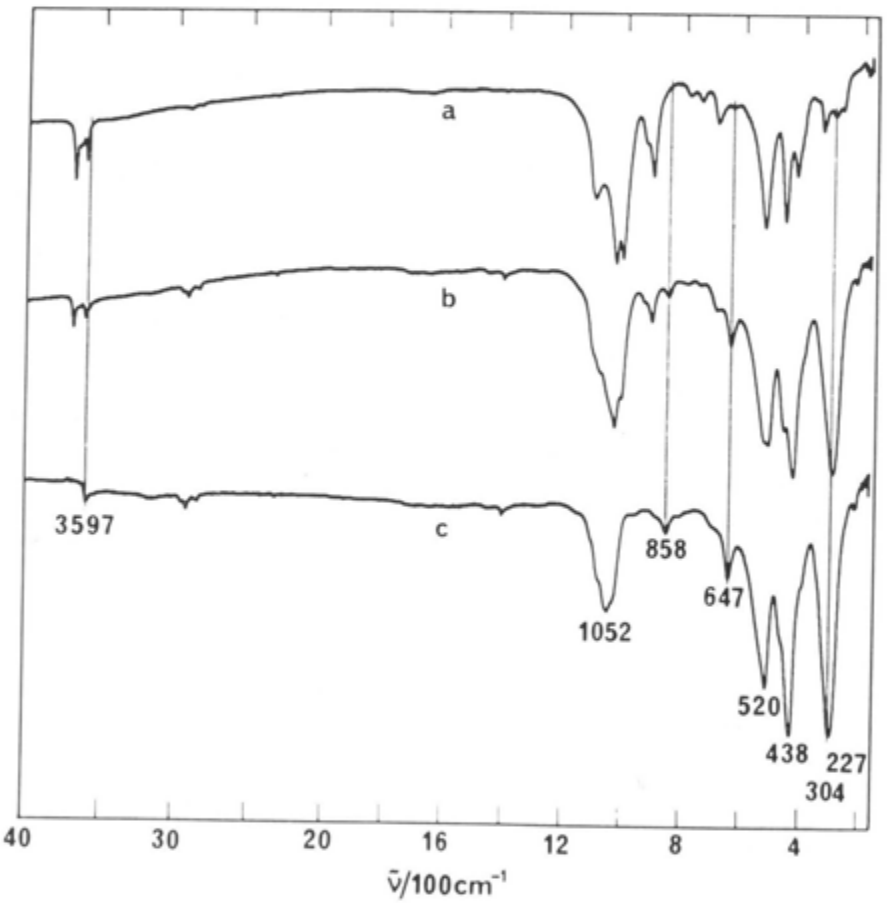


Fig. 3.1.

Infrared absorption spectra of Macaulayite: (a) in untreated <2μm clay (predominantly kaolinite); (b) in electro-magnetically concentrated <2μm clay (predominantly Macaulayite); (c) as computer-generated difference spectrum b-a (such that the absorption bands of kaolinite have been completely cancelled out). The positions of four characteristic absorption bands of Macaulayite are indicated.

oxalate treatment indicates that the oxalate does indeed extract only the silicon associated with allophane and amorphous iron oxides. The presence of proto-imogolite allophane can also be recognized in difference spectra between a clay heated to 150°C and the same clay heated to 350°C in a KBr disk. These spectral subtraction procedures have only become possible by virtue of the facilities recently developed for the computer manipulation of infrared spectra, exemplified in Fig. 3.1. 1001, 1002, 3005

The application of these techniques to concretions from the Bs horizons of Australian sandy podzols has shown that allophane is the cementing agent[28]. Microscopic examination of thin sections of these concretions has provided the first direct evidence that the allophane is deposited from solution, as it appears as a layered coating on the sand grains. This work has also led to the recognition that proto-imogolite sols can also provide an explanation for the migration of aluminium in certain types of laterite. 3005, 4019

In these well-drained podzols, Bh horizons, if present, form a porous upper sub-horizon of the B, where colloidal humus has precipitated on allophane-coated sands. In contrast, in coastal sands with high water tables, the Bh horizon forms a cemented, non-porous, hard pan at the level of the ground-water, and no allophanic Bs horizon is present. It has been proposed[29] that this type of Bh horizon is formed by precipitation of the humus-bearing surface water by Al-bearing ground-water, so that the humic precipitates completely fill the inter-granular spaces in the sands. 3005

Two different mechanisms have been proposed for the migration of iron in podzols: one involves reduction of iron, and its migration in ferrous form until precipitated by re-oxidation, and the other involves migration of iron in a mixed Al-Fe-Si hydroxide sol. The first process begins to operate in podzols once drainage becomes impeded in the B horizon by allophanic precipitates, and leads to the formation of an iron pan in the upper B horizon, with reducing conditions above the pan, and oxidizing conditions below[26]. Such a feature is common in Scottish podzols. An extreme example of this process has been identified under the very high rainfall conditions (2 to 3 metres of rain per annum) of the west coast of South Island, New Zealand, where the iron pan has migrated to depths of several metres below the surface[30]. As a result, gravels that were once freely drained are now water-logged to the surface, but the evidence of podzolic leaching is preserved in deep A2 horizons overlying allophane-rich B horizons, from which iron has been leached under the reducing conditions that now prevail.

The second process, migration of iron in mixed oxide sols, was proposed to account for the parallel distribution of iron in the Bs horizon of freely drained podzols, and has been justified by laboratory studies which show that such sols can have a high colloidal stability, comparable to that of proto-imogolite sols[31]. Examination of the dispersed phase in the mixed sols by ESR and IR spectroscopy, and by electron microscopy, has shown that the iron is associated in clumps, rather than substituted into the

imogolite-like hydroxyaluminium silicate structure[32]. Apparently, the proto-imogolite phase acts as a protective colloid for the iron oxide.
3005, 3007, 3009

Self-association of iron into discrete clumps is also a feature of iron-humate complexes. Using a combination of many of the physical techniques available at the Institute, including Mössbauer, EPR and IR, it has been shown that in the pH 9 EDTA extracts of Bh horizons of podzols, iron occurs principally as discrete 50 Å hydroxy-iron cores associated with humic acid-like organic matter (O.M.). Lesser amounts of other forms are also present, for example a monomeric iron-O.M. complex. Because of the failure of significant amounts of dimeric iron-EDTA complexes to appear in the extract at a pH which is optimal for the formation of this complex, it was concluded that the 50 Å cores and their associated O.M. are stable to EDTA at pH 9 and that they probably exist as such in the Bh horizons. A paper reporting these findings has been accepted for publication[33]. 3005, 3007, 3009, 3017

On a similar theme, continuing earlier work on the form of iron in weathering products, one paper reporting the further purification of Macaulayite (Annual Report No. 51) by magnetic separation, and giving more precise IR and XRD data (Annual Report No. 52) has been accepted for publication[34], and another on melanosiderite, previously thought to be related to Macaulayite, but here shown to be siliceous ferrihydrite, has been published[35]. 1002, 3005

Collaborative work with the Departments of Mineral Soils and Soil Organic Chemistry has continued to prove fruitful. In an investigation of a volkonskoite, a chromium-rich swelling clay from Jordan, IR has combined with XRD and TEM to provide vital information on the structure of this mineral. It is an iron-free end-member containing excess Mg in the structure, and IR has suggested that a high-frequency OH stretching band at 3678 cm^{-1} arises from regions of trioctahedral filling in the otherwise dioctahedral structure. A paper describing this unusual mineral, and comparing it with a conventional volkonskoite, has been accepted for publication[36]. 1002, 3005

In investigations of soil organic matter, IR spectroscopy is a powerful tool for identifying the functional groups present: A paper on the structure, composition and possible role in soil of the insoluble humin fraction has been published[37], and another on the characterization of soil polysaccharide using a whole-soil methylation technique, has been accepted for publication[38]. 9014, 3017, 1018, 6028, 4029

The paper on leadhillite, a lead sulphate carbonate hydroxide mineral, reported in Annual Report No. 52, has now been published[39], and this investigation has resulted in a follow-up study, in collaboration with the Royal Scottish Museum, of Macphersonite, a new, third member of the leadhillite family. IR has proved a particularly valuable adjunct to XRD in distinguishing all three polymorphs and showing the high degree of crystalline ordering in Macphersonite. A paper reporting these findings

has been accepted for publication[40]. The paper describing the results of collaborative work with the Department of Soil Fertility on the pot-trials using ammonia-treated vermiculite (ATV) as a nitrogeneous fertilizer (Annual Report No. 52) has now been published[41]. As a result of the conclusion that ATV might have potential in the management of ryegrass, a limited field-trial has been set up to compare ATV with conventional ammonium salt fertilizer particularly with respect to the rate of release of N and losses due to leaching. 3005, 7048

The ability of IR spectrometry to provide essential information on the structure of inorganic compounds in general and clay minerals in particular, and the value of many of the techniques used for this purpose, has been recognized by the inclusion of a new chapter in a standard text on laboratory methods in IR spectroscopy[42]. A review of the properties, synthesis and possible uses of synthetic imogolite has been submitted for publication[43]. 3005

Mössbauer Spectrometry

Most of the work in Mössbauer spectrometry during the past year has concentrated on the characterization of iron in layer silicates and, to a lesser extent, in the oxide components of soil. The paper on the characterization of Fe(II)- and Fe(III)-exchanged hectorites and montmorillonites (Annual Reports No. 50-52) has now been published[44] and a paper on the transformation of biotite to vermiculite as a function of the degree of oxidation of the structural iron has been submitted for publication[45]. In this latter work it was shown that, if extensive oxidation occurs some iron may be released from the structure and be present in the form of hydroxy species. Other materials investigated at ambient or liquid nitrogen temperatures include samples of saponite, montmorillonite, smectite and illite-smectite with the objective of determining ferrous/ferric ratios. 1002, 3009

In work at the University of Illinois, two samples of iron-rich trioctahedral micas (a biotite and a lepidomelane) have been studied at temperatures down to <5K. At low temperatures, spontaneous magnetic ordering occurs and the resulting complex envelope of peaks is currently being analyzed. A preliminary interpretation suggests that two different types of ferric iron are present at low abundance, but only one type of ferrous iron can be distinguished. If one of the ferric components arises from iron on the surfaces of the minerals, then these results could provide support for the calculations of Goodman (Annual Report No. 47), which suggested that the spectra from ions in the two different crystallographic sites with octahedral coordination would be virtually indistinguishable.

Samples of the lepidomelane used above have also been studied after oxidation by bromine water for up to 150 weeks. This work was carried out in collaboration with the University of Illinois and Iowa State University and the results show that there is a fraction of unaltered material present in all but the most highly-oxidized specimens. Taking these results in conjunction with those obtained from bulk magnetic susceptibility measurements *vide infra*, then it appears that the oxidation proceeds inwards from the edges of the mica crystals.

A paper on the forms of iron in alkaline EDTA and NH_4OH extracts of podzol Bh horizons (Annual Report No. 51) has been accepted for publication[33] and Mössbauer measurements have shown that the largest fraction of the iron extracted at pH 9 is in the form of hydroxy iron polymers. A small decrease in pH, even temporary, resulted in the conversion of this component to a Fe(III)-EDTA complex when the former extraction reagent was used. Some work has also been performed in collaboration with Rothamsted Experimental Station on the characterization of pyrophosphate extracts of podzol Bh horizons.

In a study of the attempts to incorporate Fe(III) into imogolite, Mössbauer spectrometry was able to confirm that much of the iron was present in a separate iron-rich phase, as suggested by EPR measurements, and that little or any of the iron was in the imogolite structure. A paper on this work has been submitted for publication[32]. 3005, 3009

No experiments on the characterization of iron in plants have been performed during the past year, but a paper reviewing this area of application has been published[46].

Magnetic Susceptibility

The bulk magnetic properties of the two iron-rich micas, which were the subject of the Mössbauer investigations, have been measured on a Squid susceptometer (in the Department of Physics, University of Illinois) at temperatures down to 1·8K and in magnetic fields from 20 mT to 4·5 T. The principal coupling between the ferrous ions was found to be ferromagnetic and measurements using single crystals showed that this interaction is within the plane of the silicate sheets. No evidence was found for any antiferromagnetic coupling between adjacent silicate sheets as had been found by other works for 1:1 layer silicates and had been suggested to occur in the 2:1 layer minerals. The paramagnetic Curie temperature was found to be field-dependent and there was also some anisotropy in the susceptibility within the plane of the mica sheets. Further work is continuing at the University of Illinois with the aim of gaining a better understanding of the complex magnetic properties of these minerals.

In the oxidized lepidomelane samples (see section on Mössbauer spectrometry) the magnitude of the ferromagnetic interaction was found to be related directly to the ferrous content, thus supporting the Mössbauer evidence that oxidation proceeds along a boundary in the crystals. In the (almost) fully-oxidized specimens, the net interactions between the ions became antiferromagnetic, thus illustrating that antiferromagnetic coupling occurs between neighbouring ferric ions. In contrast to these results, specimens that were oxidized by heating in air did not have the same relationship between their magnetic properties and ferrous contents as the bromine-oxidized samples, suggesting that in this case oxidation occurred at random in the structure.

In the study of magnetic interactions in the oxidation of trioctahedral micas, there is always the problem that some iron might be ejected from the structure but remain in contact with the mineral, either in the interlayer

spaces or on the surface (see for example reference[11]). This problem is avoided if reduction of iron in a dioctahedral mineral is investigated. Nontronite, an iron-rich smectite, has been studied with the iron reduced to various levels by a sodium dithionite solution buffered to pH 7. The results are similar to those obtained from the bromine-oxidized mica, thereby confirming the ferrous-ferrous and ferric-ferric magnetic interactions. These results indicate that in this nontronite the reduction also proceeds along a boundary. However, it must be pointed out that the nontronite used in this work had little or no tetrahedral iron and that a different reduction mechanism might be operative when significant amounts of tetrahedral iron are present. At low temperatures, the reduced nontronite was found to undergo a phase transition and to become ferromagnetic.

Nuclear Magnetic Resonance (NMR) Spectrometry

Several different NMR experiments were performed at the University of Illionois during the past year, with the objective of assessing at first hand some of the potential applications of the technique to problems of soil research. Emphasis was placed on the study of mineralogical problems, primarily because this area of research has been developed to a much smaller extent than that dealing with organic materials.

Experiments using the aluminium and sodium nuclei were carried out in order to define the conditions necessary for quantification of quadrupolar nuclei in solids spinning rapidly at the " magic angle " (54·7°) relative to the applied magnetic field. A number of difficulties were encountered which arise from (a) the different number of transitions responsible for spectra from nuclei with large and small electric field gradients, (b) the different size of the $\mu/2$ pulse for nuclei with different environments, and (c) the complex variation of signal intensity with pulse length for nuclei with large electric field gradients. This work is currently being finalized in the Chemistry Department at the University of Illinois.

In structural studies of aluminosilicates, the determination of the amounts of aluminium in tetrahedral sites is a long-standing problem, because of difficulties in distinguishing silicon and aluminium by x-ray diffraction. With clay minerals it is common to rely on chemical analyses of the bulk material for such assignments, but problems can arise if additional phases are present or if some elements are not determined. The procedure is also very time-consuming. The NMR method is non-destructive and comparatively quick. Results from three well-characterized montmorillonites show good agreement with tetrahedral/octahedral ratios obtained chemically.

NMR has also been used to characterize the aluminium in some allophanes and imogolites of both natural and synthetic origin. In allophanes the aluminium present in the imogolite-like structures can readily be distinguished from that in any gel-like phase.

In natural minerals, iron is often found both as a substituent and as an oxide or oxyhydroxide coating. Since the presence of paramagnetic ions can have a marked effect on the NMR spectrum, experiments have been

performed on zeolites doped with Fe^{2+} and Fe^{3+} ions in order to assess the relative effects of isolated paramagnetic ions and surface coatings on the width and intensity of the NMR spectrum from aluminium in the zeolite structure. It was found that sensitivity decreased with increasing iron contents of the samples as a result of large dipolar interactions that cannot be removed by " magic angle " spinning. Some difficulties in observation and interpretation of spectra might be expected for paramagnetic ion contents greater than about 3%. Problems arising from iron in an external phase were less severe, providing it was not ferromagnetic in character.

The characterization of the structure of gels is of importance in understanding the physical properties of clay minerals. Experiments using ^{13}C NMR on gels of a natural hectorite in *p*-xylene have shown that the xylene in the liquid phase can be distinguished from that in the gel. This is possible because of shifts in the latter case which are probably caused by interactions of the carbon with small amounts of Fe^{3+} in the clay structure. If preliminary interpretations are correct, it appears that, although molecular motion within the gel phase is fast, exchange between the gel and liquid phases is slow on the NMR time-scale.

The large dipolar shifts arising from the interaction of a paramagnetic ion with a magnetic nucleus have been used to determine the distribution of Fe^{2+} and Fe^{3+} ions around the hydroxyl groups in a mica. This promises to be a useful method for measuring the randomness of the distribution of paramagnetic ions in layer silicate structures. However, because of the possible existence of polytypic defects, it is not possible to use the technique to distinguish occupancies of the different types of octahedral structural site as has been suggested by other workers.

Electron Paramagnetic Resonance (EPR) Spectrometry

A review of the use of EPR spectrometry as a tool for the investigating the uptake of trace metals by plants (Annual Report No. 52) has now been published[47]. Studies have continued on the nature of low molecular weight complexes that are of relevance to the rhizosphere and a paper on the copper(II)-diglycine system, in which 11 different species have been identified by EPR, has been submitted for publication[48]. By undertaking parallel experiments using both 63- and 65-copper isotopes in copper-amino acid and copper-peptide systems, it has been possible to obtain further spectroscopic parameters, which were not available from single or natural abundance isotopic studies. Work on the ability of TRIS buffer to complex copper has shown that, in a biochemically-relevant system, superoxide dismutase enzyme, TRIS can remove a substantial proportion of the enzyme's copper. These results have now been submitted for publication[49], but further investigations are being undertaken in order to establish why some, but not all, of the copper can be removed from the enzyme. 3009

In collaboration with the Institute of Marine Biochemistry, work on the forms and distribution of copper in oysters is continuing with particular emphasis this year being given to the low molecular weight complexes in

the blood. The paper on the nature of the copper(II) components of caeruloplasmin (Annual Reports Nos. 51 and 52) has now been published[50].

In an attempt to see whether EPR spectrometry can differentiate seed groups with low and high germination rates, work has been commenced in collaboration with the Department of Agriculture, Aberdeen University. Preliminary results appear not to support the theory that free radical contents change significantly with age.

The paper on the characterization of iron in alkaline EDTA and NH_4OH extracts of podzols[33] contains a significant contribution from EPR spectroscopy in identifying Fe(III)-EDTA monomers and monomeric complexes of Fe(III) with soil organic matter. EPR has also been used in the investigation of the possible substitution of Fe in synthetic imogolite and protoimogolite. It was shown that a comparatively small fraction of the iron was present in a magnetically dilute environment and that this fraction was less in the imogolite than in the protoimogolite phase. A paper on this work has now been submitted for publication[32]. 3005, 3007

In work at the University of Illinois, EPR spectrometry has been used in the characterization of bimetallic complexes of either platinum or iridium with copper acetylacetonate derivatives. In the platinum complex the copper was found to be in the usual square planar environment, but the iridium complex was highly distorted as a result of additional bonding between the iridium and the organic ligand. This bond could be displaced by the formation of an adduct with SO_2 or dissolution in a coordinating solvent, such as 2-methyl tetrahydrofuran, when the copper was able to adopt a square planar configuration.

Computerisation and Automation

Further studies have been conducted on the use of microcomputers for instrument control and data processing (Annual Report No. 51). Since the installation in the Institute of the DEC Eclipse mainframe computer in 1980, difficulty has frequently been experienced in reading the perforated paper-tape output from the 49-channel Polychromator. The d.c.-arc emission polychromator has now been interfaced to an Apple II microcomputer which records the data on magnetic disk instead of recording it on punched paper-tape. This magnetically stored data may now be transmitted directly to the Institute mainframe computer for further processing and analysis. This microcomputer-mainframe link is also used by the infrared laboratory and enables an extensive library of infrared spectra of clays and minerals to be stored in readily accessible form. This has, in addition, greatly facilitated the manipulation of infrared spectra and enables operations such as computer-subtraction of spectra to eliminate interfering spectral components to be carried out as illustrated in Fig. 3·2. A description of this system and its use has been published[51]. Work is in progress to interface the EPR spectrometer to a similar computer network to facilitate spectral manipulation and to improve signal-to-noise ratios by computer signal averaging. A microcomputer will also be an integral part

of the automatic microdensitometer, at present being constructed, for the rapid evaluation of spark source mass- and d.c. arc emission spectrographic plates. 3005, 3009, 3010, 3011

A semi-automatic method for the fluorimetric determination of selenium in soil and plant extract solutions is being developed. The technique employs an autoanalyser system to perform the reaction of the selenium analyte with 2,3-diaminonaphthalene (DAN) reagent and the subsequent extraction of this complex into a non-aqueous solvent (cyclohexane). The complexed selenium is determined by its fluorescence emission. The system uses a phase-separator and fluorimeter flow-cell designed in the Department. 3011

References

1. Total lead concentration in Scottish soils. By G. A. Reaves and M. L. Berrow. To appear in *Geoderma.*
2. Extractable lead concentration in Scottish soils. By G. A. Reaves and M. L. Berrow. To appear in *Geoderma.*
3. Total copper concentrations in Scottish soils. By G. A. Reaves and M. L. Berrow. Submitted to *J. Soil Sci.*
4. Effects of fertilizers on the cobalt content of herbage cut for conservation. By J. W. S. Reith, J. C. Burridge, M. L. Berrow and K. S. Caldwell. To appear in *J. Sci. Fd Agric.*
5. Effects of fertilizers on the contents of copper and molybdenum in herbage cut for conservation. By J. W. S. Reith, J. C. Burridge, M. L. Berrow and K. S. Caldwell. To appear in *J. Sci. Fd Agric.*
6. Soil factors and treatments affecting trace elements in crops and herbage. By J. C. Burridge, J. W. S. Reith and M. L. Berrow. In *Trace Elements in Animal Production and Veterinary Practice.* Occasional Publication No. 7, Brit. Soc. Animal Production, 77-85, 1983.
7. Soil drainage conditions and related plant trace element contents. By M. L. Berrow, J. C. Burridge and J. W. S. Reith. *J. Sci. Fd Agric.*, **34**, 53-54, 1983.
8. Uptake, distribution and effects on plants. By M. L. Berrow and J. C. Burridge. To appear in *Metalle in der Umwelt.* Ed. E. Merian, Verlag Chemie, Weinheim, FRG.
9. Persistence of metals in sewage sludge treated soils. By M. L. Berrow and J. C. Burridge. Submitted to *Proceedings of the Third International Symposium. "Processing and use of sewage sludge,"* Brighton, September, 1983.
10. Extraction of metals from soils and sewage sludges by refluxing with *aqua regia.* By M. L. Berrow and W. M. Stein. *Analyst*, **108**, 277-285, 1983.
11. Trace element mobilization by soil microbes. By G. P. Sparling and M. L. Berrow. Submitted to *J. Agric. Sci.*
12. Decreased molybdenum emission in a carbon arc caused by zirconium carbide formation on the sample electrode. By J. C. Burridge and I. J. Hewitt. To appear in *Anal. Chim. Acta.*
13. Atom trapping atomic absorption spectrometry. By C. M. Lau, A. M. Ure and T. S. West. *Anal. Proc.*, **20**, 114-117, 1983.
14. The determination of lead and cadmium in soils by atom-trapping atomic absorption spectrometry. By C. M. Lau, A. M. Ure and T. S. West. *Anal. Chim. Acta.*, **146**, 171-179, 1983.
15. Atomic absorption and flame emission spectrometry. By A. M. Ure. In *Soil Analysis: Modern Instrumental Techniques.* Ed. K. A. Smith, Marcel Dekker, New York, 1-53, 1983.

16. A microcomputer system for processing data from a three-channel atomic absorption spectrometer. By M. J. Adams, M. C. Mitchell and G. J. Ewen. *Anal. Chim. Acta.*, **149**, 101-106, 1983.

17. Nicolae Teclu (1839-1916): A pioneer of flame spectroscopy. By G. E. Baiulescu, S. Moldoveanu and T. S. West. *Talanta*, **30**, 135-137, 1983.

18. Agricultural applications. By B. L. Sharp. To appear in *Analysis by Radio Frequency Inductively Coupled Plasma Emission Spectrometry*. Ed. P. W. J. M. Boumans, Wiley.

19. Isotope shifts in the $N_2(C^3\pi - B^3\pi_g)$ Second Positive system. By J. C. Burridge and I. J. Hewitt. To appear in *Spectrochim. Acta B.*

20. The determination of $^{14}N:^{15}N$ isotope ratios by using the (3,0) and (4,1) bandheads of the N_2 Second Positive system. By J. C. Burridge and I. J. Hewitt. *Anal. Chim. Acta.*, **153**, 347-350, 1983.

21. Development of a spectrometer for monitoring crop reflectance. By R. V. Birnie and M. J. Adams. To appear in *Anal. Proc.*

22. Geochemistry of some Eudialyte-Eucolyte specimens and a co-existing catapleiite from Langesund, Norway. By H. J. Bollingberg, A. M. Ure, I. Sorensen and E. Leonardsen. To appear in *Tschermak's mineralogische u. Petrographische Mitteilungen.*

23. Preparation of biological samples for multi-element analysis by spark source mass spectrometry in "*Trace Element Analytical Chemistry in Medicine and Biology*" Vol. 2. Eds P. Bratter and P. Schramel, Walter de Gruyter, Berlin, 1983, 1025-1037. By C. A. Shand, P. J. Aggett and A. M. Ure.

24. Column cementation on aluminium powder as a preconcentration technique for trace element determination by spark source mass spectrometry. Part I. Copper, Lead, Ruthenium and the Noble metals. By B. Fu, A. M. Ure and T. S. West. *Anal. Chim. Acta*, **152**, 95-104, 1983.

25. Analysis of plant materials by spark source mass spectrometry directly and following preconcentration by cementation. By J. R. Bacon, K. H. Welch and A. M. Ure. *Int. J. Mass Spectrometry and Ion Physics*, **47**, 1983, 307-310.

26. Significance of the presence of allophane and imogolite in podzol Bs horizons for podzolization mechanisms: A review. By V. C. Farmer. *Soil Sci. Plant Nutr.*, **28**, 571-578, 1982.

27. Extraction of inorganic forms of translocated Al, Fe and Si from a podzol Bs horizon. By V. C. Farmer, J. D. Russell and B. F. L. Smith. *J. Soil Sci.*, **34**, 571-576, 1983.

28. Proto-imogolite allophane in podzol concretions in Australia: Possible relationship to aluminous ferrallitic (lateritic) cementation. By V. C. Farmer, A. R. Fraser, L. Robertson and J. R. Sleeman. Submitted to *J. Soil Sci.*

29. Genesis of humus B horizons in hydromorphic humus podzols. By V. C. Farmer, J. O. Skjemstad and C. H. Thompson. *Nature*, **304**, 342-344, 1983.

30. A novel proposal for the pedogenesis of the "gley podzols" of the West Coast of South Island, New Zealand. By V. C. Farmer, G. Mew, B. Clayden and R. Lee. Submitted to *J. Soil Sci.*

31. Chemical and colloidal stability of sols in the Al_2O_3–Fe_2O_3–SiO_2–H_2O system: Their role in podzolization. By V. C. Farmer and A. R. Fraser. *J. Soil Sci.*, **33**, 737-742, 1982.

32. Iron substitution in aluminosilicate sols synthesized at low pH. By M. B. McBride, V. C. Farmer, J. D. Russell, J. M. Tait and B. A. Goodman. To appear in *Clay Minerals.*

33. Characterization of iron in alkaline EDTA and NH_4OH extracts of podzols. By M. B. McBride, B. A. Goodman, J. D. Russell, A. R. Fraser, V. C. Farmer and D. P. E. Dickson. To appear in *J. Soil Sci.*

34. Macaulayite, a new mineral from North-East Scotland. By M. J. Wilson, J. D. Russell, J. M. Tait, D. R. Clark and A. R. Fraser. To appear in *Mineral. Mag.*

35. Melanosiderite is siliceous ferrihydrite. By M. J. Wilson and J. D. Russell. *Mineral. Mag.*, **47**, 85-87, 1983.

36. An iron-free volkonskoite. By H. N. Khoury, R. C. Mackenzie, J. D. Russell and J. M. Tait. To appear in *Clay Minerals.*

37. An IR spectroscopic study of soil humin and its relationship to other soil humic substances and fungal pigments. By J. D. Russell, D. Vaughan, D. Jones and A. R. Fraser. *Geoderma*, **29**, 1-12, 1983.

38. The extraction and characterization of soil polysaccharide by whole soil methylation. By M. V. Cheshire, C. M. Mundie, J. M. Bracewell, G. W. Robertson, J. D. Russell and A. R. Fraser. *J. Soil Sci.*, **34**, 539-554, 1983.

39. New authentic IR and XRD data for leadhillite of ideal composition. By J. D. Russell, A. E. Milodowski, A. R. Fraser and D. R. Clark. *Mineral. Mag.*, **47**, 371-375, 1983.

40. Infrared absorption spectra of the three polymorphs of $Pb_4SO_4(CO_3)_2(OH)_2$ (leadhillite, susannite and macphersonite). By J. D. Russell, A. Livingstone and A. R. Fraser. To appear in *Mineral. Mag.*

41. Ammonia-treated vermiculite — an efficient controlled release nitrogenous fertilizer for a variety of crops. By N. M. Scott, A. R. Fraser and J. D. Russell. *J. Sci. Fd. Agric.*, **34**, 233-238, 1983.

42. Infrared spectroscopy of inorganic compounds. By J. D. Russell. To appear in "*Laboratory Methods in Infrared Spectroscopy.*" Ed. H. Willis, Wiley.

43. Synthetic imogolite: Properties, synthesis and possible applications. By V. C. Farmer, M. J. Adams, A. R. Fraser and F. Palmieri. To appear in *Clay Minerals.*

44. Characterization of iron(II) and iron(III)-exchanged montmorillonite and hectorite using the Mössbauer effect. By J. A. Helsen and B. A. Goodman. *Clay Minerals*, **18**, 117-125, 1983.

45. Evolution des biotites en fonction des conditions d'oxydo-reduction du milieu. By J. Vincente-Hernandez, M. A. Vicente, M. Robert and B. A. Goodman. Submitted to *Clay Minerals.*

46. Applications of Mössbauer spectroscopy in the study of iron in plants. By B. A. Goodman and P. C. DeKock. *European Society for Nuclear Methods in Agriculture, Physical Methods Newsletter*, 16-27, 1981. (Published 1982.)

47. The use of EPR spectroscopy as a tool in the investigation of the uptake of trace metals by plants. By D. B. McPhail, D. J. Linehan and B. A. Goodman. *European Society for Nuclear Methods in Agriculture, Physical Methods Newsletter*, 58-64, 1981. (Published 1982.)

48. An electron paramagnetic resonance study of copper(II)-diglycine complexes. By D. B. McPhail and B. A. Goodman. Submitted to *J. Chem. Soc. Dalton Transactions.*

49. TRIS buffer — a case for caution in its use in copper-containing systems. By D. B. McPhail and B. A. Goodman. Submitted to *Biochemical J.*

50. The nature of the copper(II) components of coeruloplasmin. By M. A. Syed, T. H. Coombs, B. A. Goodman and D. B. McPhail. *Biochemical J. Letters*, **207**, 183-184, 1982.

51. Application of a microcomputer system in an infrared laboratory. By M. J. Adams and I. Black. *J. Auto. Chem.*, **5**, 9-13, 1983.

4. SOIL ORGANIC CHEMISTRY

G. ANDERSON

Much of the work of the Department is concerned with the composition and properties of the organic components in soil, and their role in crop production. Investigations have continued on the nitrogenous components including amino acids, amino sugars and nucleic acid derivatives. Increasing use is being made of ^{15}N to follow the changes which occur following fertiliser application and the subsequent decomposition of crop residues. Further observations have been made regarding the role of plant and microbial polysaccharides in stabilising soil aggregates and on the factors which affect their resistance to decomposition. The reactions which occur near the soil root interface are of particular importance and studies have continued on the factors influencing trace element availability in this region. The release of nutrients from soil organic matter is dependent on the action of enzymes such as phosphatases and sulphatases and more work has been done on the effects of humic substances on soil enzyme activities.

Other research projects carried out by the Department include measurements of the effects of environmental forces on seedling growth, and a novel technique is being used to follow hypocotyl development. Field and laboratory studies have also continued on the conditions leading to the formation of iron ochre and consequent blockage of field drains, and on methods of ameliorating the problem.

Many of the experiments are collaborative, either internally with other Departments of the Institute, or externally with *inter alia,* the Scottish Colleges of Agriculture, the Department of Agriculture and Fisheries for Scotland, and various University Departments.

Soil Organic Nitrogen

Over 90% of the total nitrogen in surface soils is in organic forms and acid hydrolysis releases such compounds as amino acids, amino sugars, purines, pyrimidines and ammonia, the last being derived largely from amides, amino acids, etc. Although the figure varies with different soils, approximately half of the total soil nitrogen has so far not been identified. Some of the unknown forms may be artefacts produced during the extraction or isolation techniques and attempts to improve the preparative methods are being investigated. Studies are also being made of the effects of soil handling on the recovery of the various organic nitrogen forms.

Measurements have been made of the organic nitrogen content of humic and fulvic acid preparations obtained by the classical method involving alkali extraction followed by treatment of the extract with mineral acid,

and of the material obtained by resin acidification (Annual Report No. 52, 1981/82). In both procedures the acid-soluble polymers are purified by dialaysis. Data from four profiles under ancient woodland show that, as expected, the resin-acidified fractions contain higher proportions of the total soil nitrogen than the combined humic acid and fulvic acid fractions, probably due to the loss of low molecular size material produced by the action of the mineral acid. An additional benefit of the resin treatment is the recovery by the resin of free amino acids and peptides. Although these make only a small contribution to the total soil nitrogen, they may be important in terms of "availability." The range and amounts found in the resin parallel those found in the soil solutions.

The amounts of hydrolysable amino acids, expressed as a proportion of the total soil nitrogen, vary considerably within soil profiles. In podzolised soils, the eluviated horizons usually show the lowest proportions, with increases in zones of humus accumulations, such as B_h horizons, and C horizons above bedrock with lateral humus translocation.

One of the quantitatively less important forms of soil organic nitrogen occurs in nucleic acids or their derivatives. Recent observations by Canadian workers showed thato nly 15 to 30% of the nucleobases released on hydrolysis were in the humic acid, the remainder being in both the fulvic acid and humin fractions. The humic acid values, in relation to the total soil nitrogen, were broadly similar to those reported from this Institute previously. Although present in small amount, these bases are important components of microorganisms and are likely to cycle relatively rapidly. Further studies are, therefore, being carried out to establish their amounts and properties in different soils and their relationship to biomass values. Present work has resulted in a more efficient sample clean-up procedure and a rapid analysis of hydrolysates by HPLC. The effects of various acid concentrations, hydrolysis times and temperatures on the deamination of bases, e.g. guanine→xanthine, adenine→hypoxanthine, and cytosine→uracil, will allow more accurate measurements to be made of the initial quantities of nucleobases in the soil and an assessment of the extent to which such deamination reactions take place under natural soil conditions.

Two pot experiments have been set up to study nitrogen transformations in soil using ^{15}N techniques. The first involves growing successive crops of barley on three locally important arable surface soils with only one initial application of labelled nitrogen as ammonium sulphate. The crop residues are returned to the soil. In the second pot experiment, sub-soils corresponding to the surface samples in the first experiment are sown with creeping red fescue and treated with labelled fertiliser. Sub-samples are periodically taken, but the bulk of the shoots and roots are milled and composted in their respective soils prior to sowing a fresh crop. In this way it is hoped to build up ^{15}N labelled humic substances in the soil; once a sufficiently high level of organic carbon has been incorporated, the nature of the nitrogen compounds will be examined by ^{15}N nuclear magnetic resonance spectrometry and their rates of mineralization will also be studied. 4019

Soil Polysaccharides

Effects on Aggregation. The joint investigations with the Department of Microbiology examining the relationships between soil polysaccharides and aggregate stability (Annual Report No. 52, 1981/82) have been extended to a range of soils under various cropping regimes[1, 2]. In these studies the polysaccharide content and aggregation are measured after treatment of the soil with periodate, a reagent which rapidly destroys carbohydrate in other biological systems. With soils, however, some carbohydrate resists destruction and some stable aggregates remain. Possible factors contributing to this stability are being examined including pH and contents of clay, sand, carbon or nitrogen. Results obtained so far support suggestions that the stability of microaggregates, unlike that of macroaggregates, is not appreciably affected by cropping; microaggregates under old grassland, for example, were no more stable than those under short leys or arable crops such as barley or potatoes. In each soil the aggregate stability was related to the residual carbohydrate content, but each had its own characteristic relationship. Only with soils of the same series could a common equation be applied and this could be done even under different cropping regimes. Analysis of the soils after periodate treatment showed that glucose, xylose and, in particular, arabinose were more persistent than the other sugars. Initially this was attributed to the resistance of plant fragments, but other possibilities have also been investigated. By incubating soils with ^{14}C-labelled glucose, a labelled polysaccharide was formed entirely by microbial synthesis. In a parallel experiment, incubation with ^{14}C-labelled barley leaves produced labelled polysaccharide from both microorganisms and residual plant fragments. In both cases the sugars most resistant to periodate attack were arabinose, xylose and glucose, despite the fact that in the microorganisms, the two pentoses make up only a small proportion of the polysaccharide. The persistence of arabinose may lie in the chemical form in which it occurs in soil. Structural studies of polysaccharide from a Countesswells series soil, using a methylation technique, showed that over 70% of the arabinose existed in the furanose form, which lacks vicinal hydroxyl groups and should not, therefore, be so readily attacked by periodate as the pyranose form. A study has, therefore, been made of the structure of the polysaccharide remaining in soil after periodate oxidation, using a technique involving methylation of the whole soil[3]. Preliminary results indicate that terminal arabinose residues are predominantly in furanose form and that much of the glucose and xylose are in 1→4 linkage. These structures could be protected by the formation of hemiacetals. 4020, 6027

A book chapter discussing the contribution made by carbohydrates to soil fertility has been submitted for publication[4]. 4020

Carbohydrates in Root Exudates. Carbohydrate forms a significant proportion of the exudates and mucigel materials added to soil through the roots of living plants. It has been claimed that as much as 20% of the total plant photosynthate can reach the soil in this form so that it could be an important source of soil carbohydrate. Little is known of its composi-

tion, however, nor its ease of decomposition in the soil. It is difficult in practice to distinguish such material from the metabolic products of its attack by microorganisms because under natural conditions decomposition must proceed while the plant material is still being added. To study the contribution made by exudates, maize plants have been grown axenically in soil sterilised by autoclaving, with an atmosphere of $^{14}CO_2$. At harvest it was found that about 22% of the total activity was present in the roots and soil but when this was quickly extracted with water only about 2% was soluble. A longer extraction with water released much more and roots alone, extracted in the same way, released similar proportions. This process, however, is root lysis rather than exudation, which would be released from the living root. Similar results have been obtained in non-sterile soil and it has been concluded that with maize grown under these conditions, exudates must account for less than 1% of the whole plant carbon. Mucigel in contrast is not water-soluble and presumably, if detached from the root surface, would tend to become adsorbed on contiguous mineral surfaces. Its contribution is still not known. 4020, 6025

Humic Substances

A review paper giving an account of some recent ideas about the composition and properties of humus has been published[5]. 4021

A study has been initiated into the extent to which humified substances in peat resemble products of the Maillard reaction (the latter includes the "browning" reaction of foodstuffs). After incubation of the peat with various ^{13}C- and ^{15}N-labelled substrates, isolated fractions are being examined by nuclear magnetic resonance spectroscopy. The work is being carried out in cooperation with the Department of Peat and Forest Soils and the Canadian Chemistry and Biology Research Institute in Ottawa. 4020, 6027, 2055

Papers dealing with the effect of humic acid on the formation of cell wall-bound hydroxyproline[6] and on the relationship between humic acid and humin[7] have now been published. 3017, 4024, 4029

The transformations which occur in organic matter during the development of podzols are being examined by comparing a number of soils, including several from ancient woodland sites, at different stages of development. They range from classical iron podzols in the Loch Garton Nature Reserve to brown podzolic soils and brown forest soils in the Loch Lomond Nature Reserve. An account of this work is being prepared for publication. 4021

Plant and Soil Enzymes

Investigations have continued on the effects of humic acid on the activities of plant enzymes. Previous studies have shown that it usually inhibits the activities of enzymes by lowering the maximum velocity of reaction without changing the affinities of the enzymes for their substrates. This type of enzyme inhibition is referred to as non-competitive. It has now been shown that malic dehydrogenase, a Krebs cycle enzyme, is inhibited by humic acid, the extent increasing with increasing concentration

of the humate ion, but in this case the inhibition is partly competitive, partly non-competitive. The non-competitive inhibition is due to an interaction between the humic acid and the enzyme. The data also indicate that humic acid inhibits malic dehydrogenase competitively by capturing the protons removed from the malic acid substrate by the enzyme before they are transferred to the NAD acceptor molecules. This is in agreement with the postulate that humic acid participates in proton transfer mechanisms[8].

4024

A critical review of the techniques described in the literature for measuring the activities of soil phosphatases has now been published[9]. Another dealing with the assay of invertase activities in Scottish soils has been submitted for publication[10].

4024

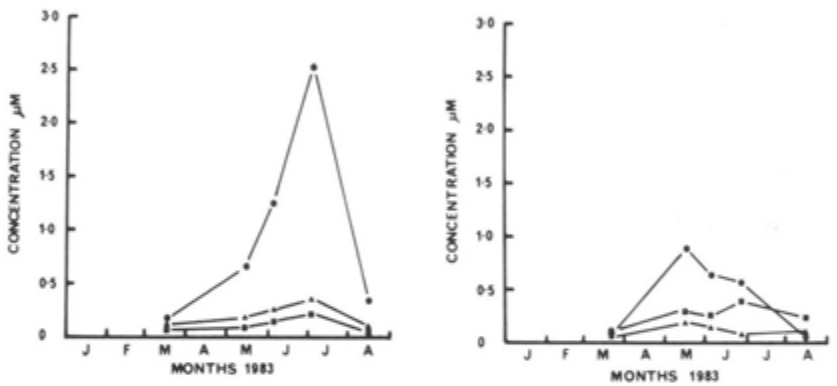


Fig. 4.1 (A) and (B)
Mobilization of manganese ●——●, copper ■——■ and zinc ▲——▲ near the root zone of spring barley in two contrasting soil types in 1983. (A) Stonehaven Association. (B) Corby Association.

Micronutrients

Further collaborative investigations with the Department of Soil Fertility have been carried out on the factors influencing trace element availability near the root surface. A method has been adopted for obtaining small quantities of soil solution by centrifuging field-moist soils and trace element analysis of these small volumes has been made possible by the use of electrothermal atomisation atomic absorption spectroscopy. Detailed observations were made at two sites, selected from conventional advisory analytical data as likely to produce manganese deficiency in spring sown barley. At both sites there was a substantial mobilisation of manganese, copper and zinc into the soil solution (Fig. 4·1). In a Stonehaven Association soil the concentration continued to increase until early July and then dropped sharply. Manganese deficiency was not observed in the barley at this site. In a Corby Association soil the mobilisation of manganese and zinc increased until May and had dropped considerably by mid-August when the barley was harvested, by which time the concentrations were comparable to those at the beginning of the season. The maximum concentrations

recorded were much lower than in the Stonehaven soil and spring barley at this site showed considerable symptoms of manganese deficiency. An explanation for the mobilisation of micronutrients during the growing season and for differences between sites is now being sought. It seems likely that microbiological action will play a large part. Such activity can be demonstrated by assaying the activity in the soil of microbial enzymes such as amylase. In a Countesswells Association soil this has been shown to increase to a maximum in early summer (Fig. 4·2) and decrease in mid and late summer. We do not have such data for either of the sites whose trace

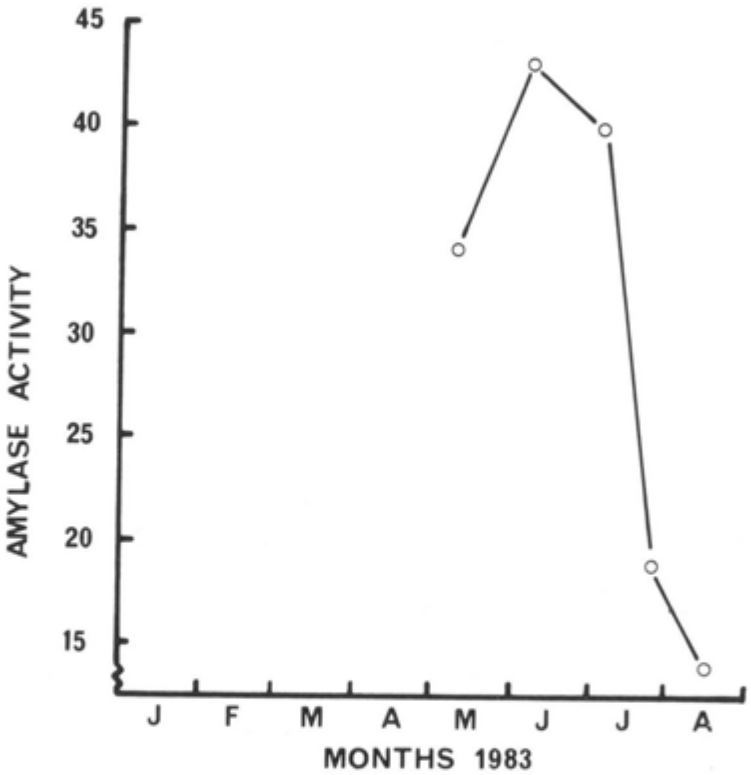


Fig. 4.2.
Amylase activity in a Countesswells Association soil in 1983.

element mobilisation we were investigating but the similarities between the patterns of mobilisation, especially at the Stonehaven site, and the amylase activity shown above are sufficiently close to warrant further investigation of the relationship between microbiological activities in soils and the availability of trace elements. 4023, 7042

Ochre in Field Drains

Collaborative work with the Departments of Microbiology and Soil Survey has continued on the ochre problem in field drainage systems (Annual Report No. 52, 1981/82).

The use of coniferous bark in field trials at a farm near Turriff has now kept drains open for 18 months at a site where ochre formation previously caused blockages twice per year. The bark, contained in nylon mesh sacks, was placed in the inspection pits which had earlier been installed to allow rodding or jetting. The only prerequisite is that the bark should be " weathered " in the open air for at least three months before placement in the drains. The weathering process prevents subsequent foaming of the drainage water.

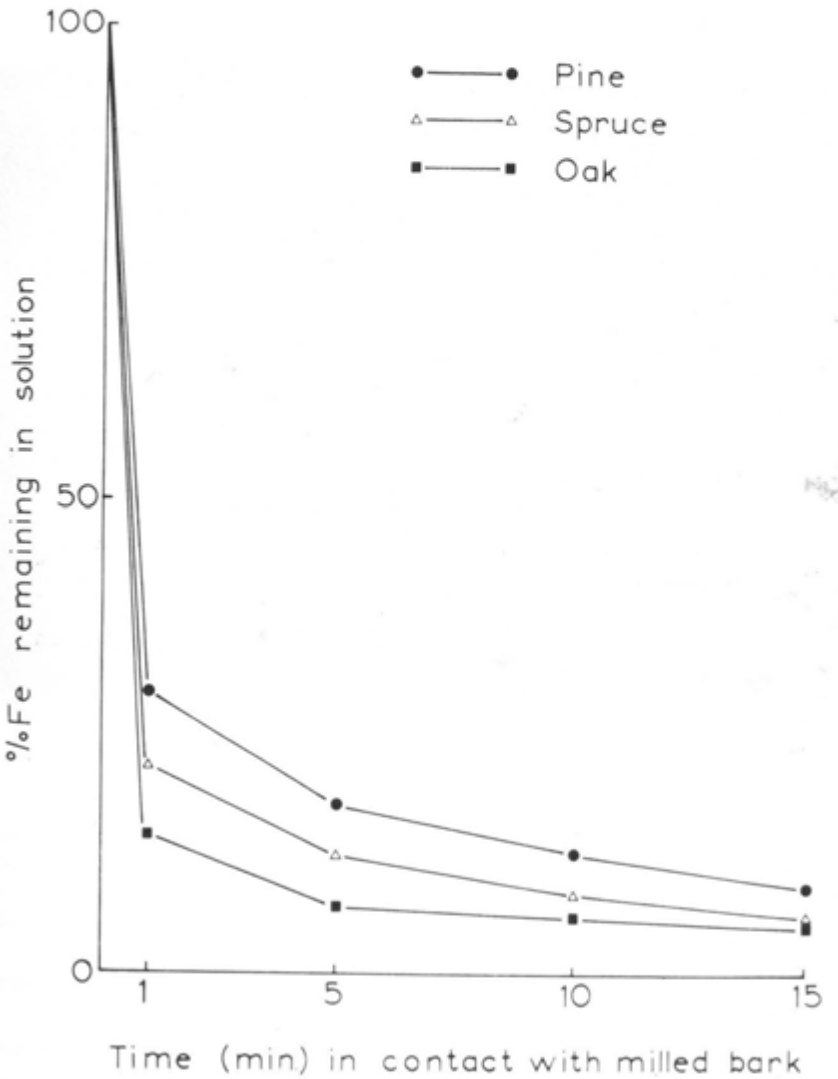


Fig. 4.3.
Absorption of iron by bark from a solution of ferrous sulphate. (5g bark in 100 ml solution containing 10 mg Fe.)

Laboratory experiments have shown that barks from all conifer (gymnosperm) species thus far tested should be suitable for use in the field because they rapidly absorb ferrous iron from solution. In the case of Scots pine and Norway spruce, for example, about 70 to 80% of the iron was absorbed after one minute from a solution of ferrous sulphate (Fig. 4·3) and this increased to over 90% after 15 minutes. In addition to removing ferrous iron, the bark will also remove other cations in the drainage water, such as copper, zinc and lead. This observation may have implications for the removal of cations from water courses in situations where they are present at toxic levels.

Dr D. Vaughan discussing iron ochre blockage of field drains with visitors to the Institute on the Subject Day, September, 1983. Mr B. Ord watches from behind the visitors.

With the cooperation of the Department of Agriculture and Fisheries for Scotland, field trials in other parts of Scotland are now under way. Experiments will be carried out to elucidate the most effective way of applying bark to different drainage systems. Three papers relating to the ochre problem have now been submitted for publication[11, 12, 13].

1801/4801/6801

Environmental Effects on Seedling Growth

Video Image Analysis of Growth. The video image analysis equipment assembled to provide a continuous record of growth rate changes in individual zones of a seedling hypocotyl (Annual Report No. 52) has entirely fulfilled its earlier promise. The equipment can be used not only

to record *in situ* experiments but also to analyse experiments recorded on cine film or still photographs. Digitization of analog video signals from a screened projection of film with direct transfer of data to a microprocessor has greatly speeded up the growth analysis of photographically recorded experiments and has led to a significant increase in productivity.

A new miniature growth chamber has been designed for use with the video camera, its larger cubic capacity accommodating more ambitious experiments. A further advantage with the new chamber is the facility to raise or lower two adjacent sides of the chamber thus giving maximum opportunity to bring into view or maintain in view any selected region of seedlings, orientated either vertically or horizontally, without having to manipulate the seedlings themselves. In the light of accumulating evidence that perturbation of seedlings can affect their growth rate this is an important consideration. But the major improvement incorporated in the new growth chamber is the inclusion of a bank of infra-red light-emitting diodes of wavelength 940 nm. The Extended Red Newvicon Camera is sensitive in this region of the spectrum and so transmits an image of seedlings growing in total " plant " darkness. 4053

Formation and Maintenance of the Apical Hook. Evidence from a variety of seedlings has been adduced to show that apical hook formation is dependent on the perception of gravity. When the seedling is rendered incapable of perceiving a unilateral gravitational stimulus, the hook fails to develop. From these findings it is deduced[14] that hook formation in dicotyledonous seedlings is a consequence of the development of a positive georesponse in the apical region of the hypocotyl as opposed to the normal negative geosensitivity of the hypocotyl. Correspondingly, light-induced hook-opening indicates the re-assertion of a negative geosensitivity to gravity throughout the entire length of the hypocotyl. This is a further intriguing illustration of the interaction of light and gravity in regulating the directional growth of plants. A proposal to test this hypothesis on the EURECA Microgravity Mission has been submitted to the European Space Agency.

Published reports of the influence of the adjacent tissue on apical hook-opening have drawn attention to the fact that decapitation of the cotyledons and the apical bud leads to an increased degree of hook-opening relative to control seedlings not similarly decapitated, from which is was concluded that apical tissues supply compounds influencing the degree of hook-opening. In these studies no attempt was made to observe the comparative development of the regions comprising the hook in both control and decapitated seedlings. Using resin beads as external markers on the hooked region of the hypocotyl it has been demonstrated that the region which opens and straightens in the decapitated seedling also straightens in the control seedling and that the maintenance of a hook in the latter is a consequence of continued expansion of tissue from the proximal end of the hook and not the result of a qualitative difference in the response of the hook itself in the two treatments. A report of this work has been submitted for publication[15]. 4053

Role of the Apex in the Regulation of Georesponse. The idea that there is a transmission of a hormonal message from the apex to distal geo-responding tissues has been an accepted component of plant growth regulation until quite recently when gaps in the corroborative evidence have been drawn attention to by other workers who have asserted that there is no evidence for a special role of the apex in geotropism. Work in this Department has demonstrated convincing evidence that the geo-response of the basal end of sunflower hypocotyls is dependent on the presence of the apical half. However, the basal half appears to have some self-awareness of its geo-environment and it is conceivable that in addition to a transmission of message from apex to base there may even be message transmission in the opposite direction. This work, which has been accepted for publication[16], has also demonstrated for the first time in dicotyledonous seedlings, a geo-stimulated resumption of growth in a tissue which had ceased to grow — a phenomenon which is well known in the nodes of grass stems subjected to lodging. An analysis of growth in different regions of the seedling hypocotyl undergoing geo-curvature has also been published during the year[17]. Investigations are continuing into the correlation of growth by the apex and the role of tranmissable factors and inter-organ effects in the regulation of seedling growth. 4053

Other Investigations

A paper dealing with the effect of benzyladenine and abscisic acid on the synthesis of the enzyme superoxide dismutase in *Lemna* gibba has now been published[18]. A paper describing the influence of some micro-organisms on the phytotoxic properties of high concentrations (10^{-3}m) of phenolic acids in the soil solution has been published recently[19]. 4024

References

1. The contribution of polysaccharides of plant or microbial origin to soil structure. By M. V. Cheshire, G. P. Sparling and C. M. Mundie. To appear in *ISSS Transaction, Biological Processes and Soil Fertility*. Reading, 1983.
2. Influence of soil type, crop and air drying on residual carbohydrate content and aggregate stability after treatment with periodate and tetraborate. By M. V. Cheshire, G. P. Sparling and C. M. Mundie. To appear in *Plant and Soil*.
3. The extraction and characterization of soil polysaccharide by whole soil methylation. By M. V. Cheshire, C. M. Mundie, J. M. Bracewell, G. W. Robertson, J. D. Russell and A. R. Fraser. *J. Soil Sci.*, **34**, 539-554, 1983.
4. Carbohydrates in relation to soil fertility. By M. V. Cheshire. To appear in *Soil Organic Matter and Biological Activity*. Ed. D. Vaughan, Martinus Nijhoff, The Hague.
5. Recent observations on humus composition and properties. By G. Anderson. Proc. Regional Colloquium on Soil Organic Matter Studies. *Piracicaba, SP-Brazil. Promocet*, 3-10, 1982.
6. Influence of humic acid on iron required for the formation of hydroxyproline in discs of *Beta vulgaris* L. storage tissue. By D. Vaughan and B. G. Ord. *Plant and Soil*, **73**, 27-34, 1983.
7. An IR spectroscopic study of soil humin and its relationship to other humic substances and fungal pigments. By J. D. Russell, D. Vaughan, D. Jones and A. R. Fraser. *Geoderma*, **29**, 1-12, 1983.

8. Influences of humic substances on biochemical processes in plants. By D. Vaughan, R. E. Malcolm and B. G. Ord. To appear in *Soil Organic Matter and Biological Activity*. Ed. D. Vaughan, Martinus Nijhoff, The Hague.
9. Assessment of phosphatase activity in soils. By R. E. Malcolm. *Soil Biol. Biochem.*, **15**, 403-408, 1983.
10. Influence of assay conditions on invertase activity in different Scottish soils. By D. Vaughan and R. E. Malcolm. Submitted to *Plant and Soil*.
11. Removal of ferrous iron from field drainage waters. By D. Vaughan, R. E. Wheatley and B. G. Ord. To appear in *J. Soil Sci.*
12. Easing the ochre problem. By D. Vaughan, B. G. Ord and R. E. Wheatley. Submitted to *Drainage Contractor*.
13. Amelioration of the ochre problem in field drainage systems using coniferous bark. By R. E. Wheatley, D. Vaughan and B. G. Ord. To appear in *Proceedings of the Seventh International Peat Conference*, Dublin, 1984.
14. The positive hook: the role of gravity in the formation and opening of the apical hook. By I. R. MacDonald, D. C. Gordon, J. W. Hart and E. P. Maher. *Planta*, **158**, 76-81, 1983.
15. The influence of adjacent tissue on hypocotyl hook opening. By I. R. MacDonald and J. W. Hart. Submitted to *Planta*.
16. Is there a role for the apex in shoot geotropism? By J. W. Hart and I. R. MacDonald. To appear in *Plant Physiology*.
17. Analysis of growth during geotropic curvature in seedling hypocotyls. By I. R. MacDonald, J. W. Hart and D. C. Gordon. *Plant Cell and Environment*, **6**, 401-406, 1983.
18. Effects of benzyladenine and abscisic acid on superoxide dismutase in fronds of the duckweed *Lemna gibba* L. By D. Vaughan, P. C. DeKock and B. G. Ord. *Physiol. Plant.*, **58**, 239-242, 1983.
19. Amelioration of the phytotoxicity of phenolic acids by some soil microbes. By D. Vaughan, G. P. Sparling and B. G. Ord. *Soil Biol. Biochem*, **15**, 613-614, 1983.

5. PLANT PHYSIOLOGY

A. E. S. MACKLON

Following a number of retirements and resignations, the Department has experienced something of a hiatus in the past year. There has been, nevertheless, some progress and some change of direction. Major emphasis is now being given to the study of trace element uptake and transport in plants, and studies on major nutrient transport are being curtailed. The study of trace element uptake and transport in plants is important not just for an understanding of plant nutrition, but also because the supply of trace elements in herbage can be a limiting factor in the health of grazing animals. Work on nitrogen uptake and transport, initiated last year, is also continuing. These two subjects are recognised as priority areas in agricultural research today.

Trace Element Studies

A start has been made on organising this work as part of a multidisciplinary study of trace element deficiencies in soil/plant/animal systems, involving other Departments and Institutes. The Institute's Subject Day in September was useful in establishing and extending contacts to this end.

Although correlations have been established between amounts of trace elements extractable from soil and amounts found in plants, little is known about mechanisms of trace element uptake, or the extent to which trace elements in plant roots are exchangeable with those in the root medium. Uptake (influx) at the cellular level and concurrent loss (efflux) of cobalt and iron have been measured and compared in root segments from wheat seedlings, using a solution complete for major nutrients, but containing only the trace element under study, at a concentration of 2μM. Cobalt is, of course, not essential for plant growth, but is important in animal diets. Iron is important for plants and animals, but is not usually deficient. It has been used in these experiments for comparative purposes.

Comparison of the efflux curves (Fig. 5.1) for radioactive cobalt from living root segments with those from roots killed by plunging into liquid nitrogen, prior to elution, shows that most of the cobalt is held in the living parts of the root, i.e. within the cortical cells. Analysis of the efflux curve indicates that absorbed cobalt is stored in the vacuole and tends, therefore, to be unavailable for transport to the shoot. Similar experiments with radioactive iron give a contrasting result (Fig. 5.2). No significant difference in the shape of the efflux curve, nor in the amount of ^{59}Fe washed out over nine hours, is apparent between dead and living roots. This suggests

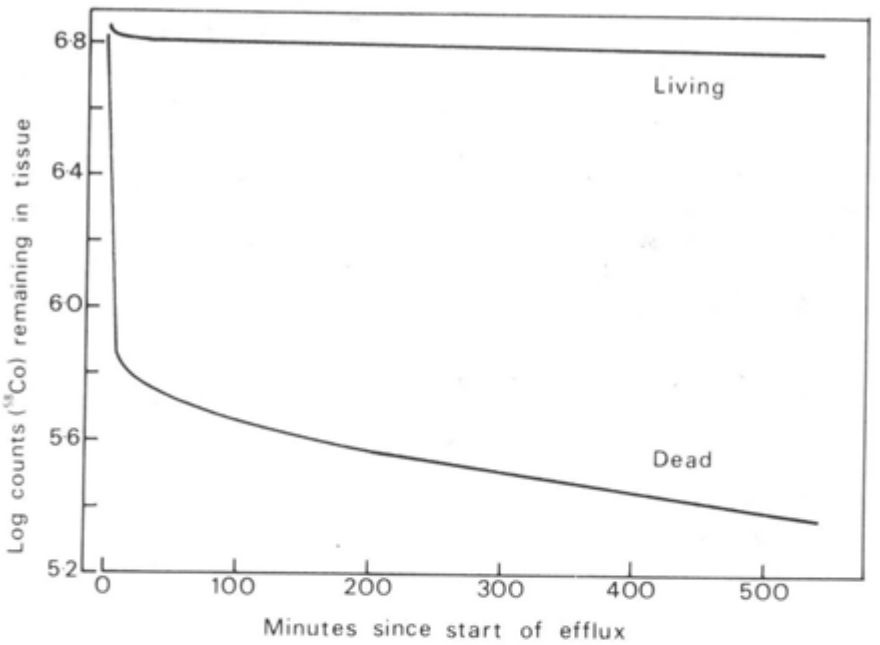


Fig. 5.1.
Efflux curves for ^{58}Co from dead and living root segments.

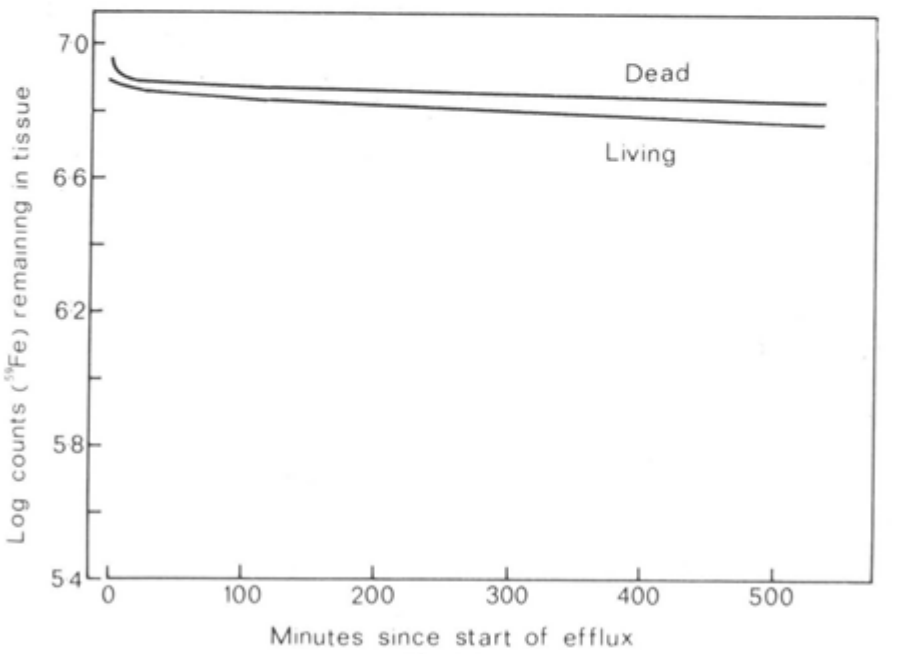


Fig. 5.2.
Efflux curves for ^{59}Fe from dead and living root segments.

that the bulk of the root iron is adsorbed onto exchange sites in the cell walls, and its retention is independent of living processes in the root. This trace element is also, therefore, largely unavailable for transport to the shoot, though for different reasons than in the case of cobalt. Slow release of iron from the cell walls masks the iron fluxes across the cell membranes, making any further conventional flux analysis virtually impossible for this element.

Simple uptake studies with ^{58}Co and ^{59}Fe reflect the large root content of these elements relative to amounts transported to the shoot in wheat seedlings (Table 5.1). 5052

Table 5.1

^{58}Co and ^{59}Fe (nmoles/gfw) in 7-day-old wheat seedlings after loading for 23 hours in nutrient solution containing 2μM of one trace element (pH 5·5)

	Co	Fe
Transported to shoot	2	0·7
Absorbed by root	80	65

Nitrogen Flux Studies

Staff and equipment limitations have held up the progress of this work but it has been possible to run a programme of experiments repeating those described in the previous Annual Report. In these more recent experiments, we have been able to prevent the rapid drift to very acid pH in solutions containing ammonium as the sole source of nitrogen. This was achieved by the addition of excess calcium carbonate, which allowed a constant pH of about 6·8 to be maintained, in both the solution used for growing the onion roots, and during incubation of root segments. This measure led to a small rise in the calcium concentration of the nutrient solution during incubation of the root segments in flasks, but this was considered more acceptable than a drift to very acid pHs. The NH_4^+ and NO_3^- uptake data, obtained using the Institute's microwave-excited optical emissions spectrometer to determine atom per cent ^{15}N in root samples, confirm our earlier findings concerning the time courses of NH_4^+ and NO_3^- uptake, but the many elution samples from these repeat experiments await the commissioning of a new mass spectrometer, dedicated to ^{15}N work, which is due to be delivered in November. 5051

Potassium and Calcium Absorption and Transport

A study of the effects of "crown" polyethers on uptake and transport of potassium in wheat and mung bean seedlings, carried out in collaboration with the Department of Molecular Structures, Rothamsted Experimental Station, and described in earlier Annual Reports, has now been completed with the publication of a paper[1] reporting the results.

Work on the effects of amino acid analogues on uptake and transport of K^+, Ca^{2+}, Na^+ and Cl^- in seedlings, described in Annual Reports 49-51, and supported by an ARC studentship, has been written up as a Ph.D. thesis[2], which was sustained. 5050

Work, funded by a DAFS research studentship, is proceeding on calcium relationships in the occurrence of internal browning of brussels sprouts. Attempts are being made to estimate values for calcium concentrations in the compartments of leaf cells within the buttons, leading to the establishment, or otherwise, of a correlation with the occurrence of the browning disorder. To this end, brussels sprout plants are being grown in ^{45}Ca-labelled nutrient solutions, containing nitrogen as sodium nitrate, ammonium nitrate or ammonium sulphate. In some of the treatments with nutrient solution containing solely ammonium nitrogen, calcium carbonate has been added to stabilise the pH. The specific activity of ^{45}Ca in buttons on plants grown in this way will be the same as the constant value maintained in the nutrient solutions, and using this value, calcium contents may be estimated, from elution of ^{45}Ca from fresh-cut button tissue, by conventional compartmental analysis. 5050

Active Iron and Related Studies

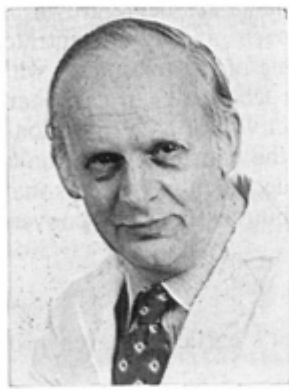
Further papers[3, 4], arising from the Department's earlier research programme, have now appeared, or are in press.

References

1. Effects of some Cyclic "Crown" Polyethers on Potassium Uptake, Efflux and Transport in Excised Root Segments and Whole Seedlings. By A. E. S. Macklon, A. Sim, D. G. Parsons, M. R. Truter and J. N. Wingfield. *Ann. Bot.*, **52**, 345-356, 1983.
2. Effects of Amino Acid Analogues on the Uptake and Translocation of some Nutrient Ions in Seedling Plants. By B. Tornton, Ph.D. Thesis, University of Aberdeen, 1983.
3. Effects of Benzyladenine and Abscisic Acid on Superoxide Dismutase in Fronds of the Duckweed *Lemna gibba* L. By D. Vaughan, P. C. DeKock and B. G. Ord. *Physiol. Plant.*, **58**, 239-242, 1983.
4. Studies on active ion. By P. C. DeKock and R. H. E. Inkson. Submitted to *J. Exp. Bot.*

6. MICROBIOLOGY

J. F. DARBYSHIRE



The current research of the Department is mainly concerned with the transformations of plant and microbial organic matter in soil and with the consequences of these transformations for plant roots. Particular attention is paid to the reserve of nutrients (N, P, S, minor and trace elements) in the soil microflora in both organic and mineral soil. Studies are also in progress on a wide range of secondary decomposer organisms concerned with the lysis or predation of the soil microflora and the subsequent release of nutrients for the roots of agricultural plants and tree seedlings. Such investigations should improve the understanding of the mode of transfer of nutrients from either inorganic or microbial fertilisers to plant roots. Recent appointments have strengthened the team concerned with this research topic and extensive collaboration now exists with most Departments of the Institute and with several other research organisations.

Interrelationships of Plant Roots and Microbes

Two papers dealing with the significance of free-living nitrogen-fixing bacteria to the nutrition of cereal plants have been published[1, 2]. As described in the previous Annual Report, these studies showed that the major factor limiting nitrogen fixation was the shortage of carbohydrate in the rhizosphere. In addition, these investigations also showed that nitrogen from microbial cells was rapidly mineralised and assimilated by wheat plants. The rates of mineralisation of phosphorus compounds from several microorganisms were also investigated. It was found that there is a similar rapid mineralisation of microbial phosphorus and that a wide range of agricultural and horticultural plants can obtain their phosphorus requirements from microbial cells[3]. A detailed account of these experiments is being prepared for publication. 6025

A collaborative study with the Department of Soil Organic Chemistry on the nature of the mucigel and other material released from cereal roots is discussed fully in Section 4. 6025, 4020

Fungi

Ultrastructure. A paper dealing with scanning electron microscopy of the soil fungus, *Stilbella bulbicola*, isolated during studies on the decomposition of phenolic acids in soil and discussed in the previous Annual Report, has been published[4]. 6026

Cryofixation has proved to be a valuable technique for preserving a range of biological specimens. This relatively new technique does not involve chemical fixatives or dehydrating agents and the specimens are frozen in liquid nitrogen at approximately −180°C. X-ray microanalysis of such frozen-hydrated tissue is likely to give a more natural distribution of elements than freeze or critical point dried material. Also, the distortion and shrinkage observed with some critical point or freeze-dried material, e.g. yeasts or aphids, does not occur with cryofixation (Fig. 6·1 in the previous Annual Report). Particularly good preservation of the basidiospores, basidia and cystidia of a soil fungus belonging to the Agaricales occurred on cryofixation. Promising results have also been obtained on fracturing frozen hydrated fungal and botanical specimens. A paper dealing with cryofixation has been accepted for publication[5]. 6026, 6028

Mycetozoa and Protozoa

The results of some cinemicrophotographical studies of amoeboflagellates of members of the Cavosteliidae have been published[6]. 6031

In collaboration with the Department of Soil Survey four methods have been compared for characterising the network of soil pores, which are inhabited by soil protozoa. One of these methods is a new technique and involves the use of a camera lucida and a microcomputer. The results of these comparisons are being prepared for publication and may be of interest to other soil scientists concerned with soil structure. 9014, 6031

Organic Matter

Microbial synthesis. A paper comparing fungal melanins with humin and other humic compounds using infra-red spectroscopy has been published[7]. This is a collaborative study with the Departments of Soil Organic Chemistry and Spectrochemistry. Further investigations are in progress. 3017, 6028, 4029

Crystals isolated from a culture of *Penicillium wortmanii* have been identified as the antibiotic vermiculine, which is active against pathogenic protozoa and bacteria. The identity of the *P. wortmanii* was confirmed by the Curator of the Commonwealth Mycological Institute. Vermiculine has not previously been isolated from cultures of *P. wortmanii*. Although it has a world wide distribution, *P. wortmanii* is still a rare fungus. It was originally isolated from Kaolin aggregates containing caffeic acid incubated on fallow soil during studies of the decomposition of phenolic acids by soil fungi in the rhizosphere. The yellow perithecia of this fungus were transferred with sterile glass needles to a range of agars, including Czapek Dox, malt extract and potato dextrose. Clusters of the antibiotic crystals were observed in Czapek Dox agar after three months' incubation at 20°C, but never in potato dextrose or malt extract agars. After several experiments it was found that the most satisfactory method to produce vermiculine was to grow the fungus in Fernbach flasks with 70 ml of Czapek Dox liquid medium. Large masses of the crystals were observed detached from the mycelium within three weeks of incubation without any agitation and they

were readily withdrawn from the culture with a fine pipette. The washed crystals were air-dried on colloidal carbon on aluminium stubs and examined under the scanning electron microscope. X-ray micro-analysis did not detect any elements. The culture filtrate from *P. wortmanii* grown on Czapek Dox agar inhibited the germination of *Botrytis allii* spores, but had no effect on *Aspergillus niger*. Cultures of *P. wortmanii* growing on agar with *B. allii* attacked the spores of the latter (Figs. 6·1, 6·2). Hyphal growth of *Rhizoctonia solani* was also inhibited by cultures of *P. wortmanii* on the same agar plate, but *Pythium debaryanum*, was unaffected.

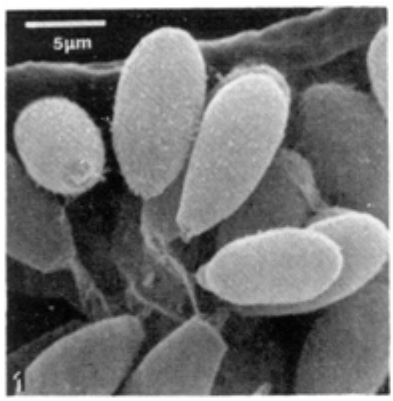


Fig. 6.1.
Scanning electron micrograph of spores of *Botrytis allii* without *Penicillium wortmannii*.

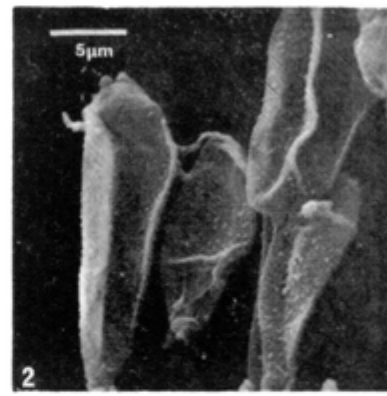


Fig. 6.2.
Scanning electron micrograph of spores of *Botrytis allii* with *Penicillium wortmannii*.

Further ecological studies of *P. wortmanii* in relation to other plant pathogens and saprophytes in the soil are in progress. The Departments of Soil Organic Chemistry, Spectrochemistry and Mineral Soils are involved in this research project. 3005, 3017, 6026, 4029

Polysaccharides. Studies of soil polysaccharides derived from plant and soil microbes have continued in collaboration with the Department of Soil Organic Chemistry. After it was demonstrated that the standard period of 6h with 0·02M sodium periodate followed by 6h of 0·1M sodium tetraborate was insufficient to destroy all the soil carbohydrate and water stability of soil aggregates in a local soil of the Countesswells series[8], 15 soils from eight soil series in Scotland were examined using a range of periods of treatment with periodate up to 168h. The resulting decrease in sugar content was correlated with the level of disruption of the microaggregates, although each soil had its own specific correlation. No consistent effect of particular crops or soil type was detected[9, 10]. A substantial proportion (15-20%) of the carbohydrate still appears to be resistant to periodate with glucose, arabinose and xylose as the most persistent sugars in the residues after periodate treatment. Soils amended with ^{14}C glucose or ^{14}C plant material were used in further experiments to determine the origins of these resistant sugars. It was concluded that these sugars could be derived from

either plants or soil microbes and that it was unwise to determine the origin of resistant polysaccharide from the composition of the sugar residues alone.

Biomass. Three papers dealing with microbial biomass and discussed in the previous Annual Report have been published[11, 12, 13]. 6027

The availability of microbial nitrogen and phosphorus to plant roots in peats and mor humus has been investigated in collaboration with the Department of Peat and Forest Soils. The methods of estimating biomass C, N and P in near-neutral soils were tested in acid organic soils[14]. Fumigating such organic soils with chloroform resulted in increased amounts of soluble-N and inorganic-P, extracted with 1M KCl and 0·01M $CaCl_2$ respectively, immediately after fumigation. The production of CO_2 during the subsequent 10 days of incubation was erratic and resulted in anomalous estimates of microbial biomass. More consistent correlations between biomass-C and the flush of inorganic-P were provided by measuring respiration of samples amended with glucose (Anderson and Domsch method) than with chloroform fumigation (Jenkinson method). 6027, 2055

The amounts of trace elements assimiliated by the microbial biomass have been investigated in a local arable soil in collaboration with the Department of Spectrochemistry. After chloroform fumigation, the amounts of trace elements released from the dead microbial cells were small and of minor significance to the exchangeable levels of these elements in soil, with the exception of manganese and cobalt. Similarly, when microbial activity was stimulated by amending soil with glucose, the exchangeable levels of Mn and Co were greatly increased[15]. 3007, 6027

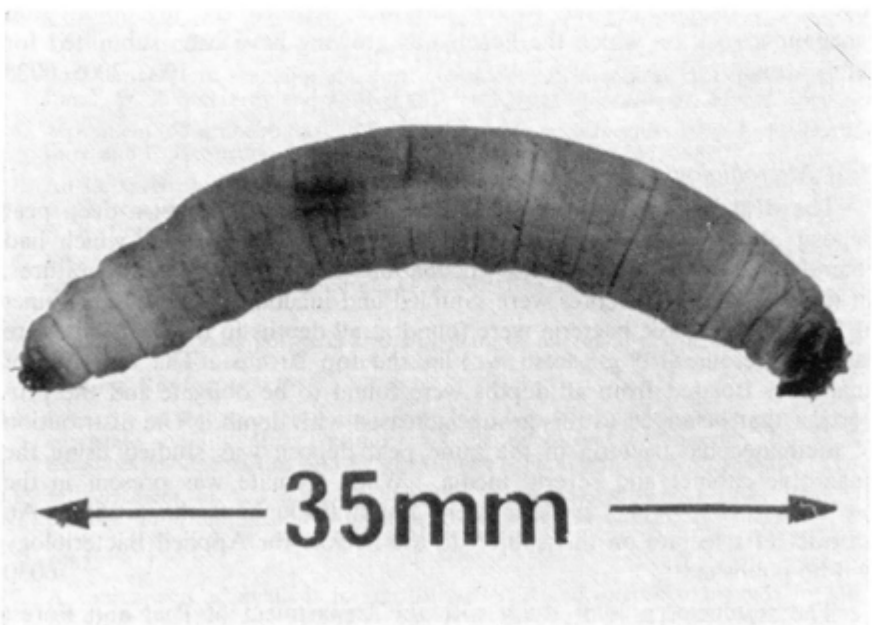


Fig. 6.3.
Larva of common leatherjacket, *Tipula paludosa.*

Soil invertebrates. Studies have begun on the role that phytophagous soil animals play in the decomposition of plant material. With the collaboration of the Department of Mineral Soils and using pyrolysis—mass spectrometry, the larvae of the common leatherjacket, *Tipula paludosa* (Fig. 6·3) were shown to digest nitrogen-rich compounds (e.g. amino-acids, proteins and chlorophyll), but leave the lignocellulose fraction of grass untouched. As a result of this selective digestion of nitrogenous compounds in the food, these larvae increased the C:N ratio from 11 in the grass to 23 in the excreta. Another unusual feature for insects is that the leatherjacket larvae excreted unusually large amounts of urea (17·4 μg N mg^{-1} dry wt.) and small quantities of uric acid (1·4 μg N mg^{-1}) and ammonia (0·3 μg N mg^{-1}). Urea-decomposing bacteria represent about 10% of the total microflora in the alimentary canal of *T. paludosa* and the significance of these bacteria in the transformation of nitrogen into forms that can be assimilated by plant roots is under investigation. 1018, 6027

Biological weathering

A collaborative study with the Departments of Mineral Soils and Spectrochemistry on biological weathering has continued with the publication of observations on the distribution and form of lead in the lichen *Stereocaulon vesuvianum*[16]. Another paper on lichen weathering of minerals and its implications for weathering processes in soil has been published[17]. The results of a study of the occurrence and significance of manganese oxalate crystals at the interface between the mycobiont and manganese rock on which the lichen was growing have been submitted for publication[18]. 1002, 3005, 6028

Peat Microbiology

The distribution of anaerobic bacteria was investigated in a deep peat deposit at Lyne of Skene using a Whitley anaerobic cabinet, which had recently been modified to allow incubations below ambient temperatures. In this study the peat cores were sampled and incubated within the cabinet at 20°C. Anaerobic bacteria were found at all depths in the peat, but were most numerous (10^4 g^{-1} fresh wt.) in the top 20 cm. The majority of anaerobes isolated from all depths were found to be obligate and the proportion that belonged to this group increased with depth. The distribution of methanogenic bacteria in the same peat deposit was studied using the anaerobic cabinet and several media. When formate was present in the medium, methanogenic bacteria were found throughout the profile. An abstract of a lecture on this subject to the Society for Applied Bacteriology will be published[19]. 6030

The results of a joint study with the Department of Peat and Forest Soils of the controlled water table experiment at Lon Mor near Fort Augustus are being prepared for publication. 6030, 2055

The study of iron ochre deposits in field drains has continued in collaboration with the Departments of Soil Organic Chemistry and Soil Survey. Coniferous bark in loose weaved polypropylene sacks has been placed in drainage inspection chambers in field trials in East, West and Central Scotland. This bark appears to be absorbing large amounts of ferrous iron from the soil solution and so prevents the formation of iron ochre deposits in the drains. Iron oxidising and precipitating bacteria were found in water samples from all the field sites. Some of the species isolated were *Gallionella* sp., *Leptothrix* spp. and *Thiobacillus* spp. Weathered coniferous bark appears to have little effect on the growth rate of such bacteria in laboratory cultures, but in field trials the numbers of these bacteria is reduced in drainage systems amended with sacks of bark. A paper on this research topic has been accepted for publication[20] and two others have been submitted[21, 22]. A paper on the amelioration of phytotoxicity of phenolic acids by some soil microbes has also been published[23].

1801/4801/6801/9801

References

1. The role of root-associated nitrogen-fixing bacteria in the nitrogen nutrition of wheat estimated by ^{15}N isotope dilution. By G. Lethbridge and M. S. Davidson, *Soil Biol. Biochem.*, **15**, 365-374, 1983.
2. Microbial biomass as a source of nitrogen for cereals. By G. Lethbridge and M. S. Davidson, *Soil Biol. Biochem.*, **15**, 375-376, 1983.
3. Microbial cells as a source of plant nutrients. By G. P. Sparling, M. S. Davidson, J. A. Leighton and G. Lethbridge. Transactions ISSS/BSSS meeting, Reading, 88, 1983.
4. Scanning electron microscopy of the soil fungus, *Stilbella bulbicola*. By D. Jones, *Trans. Br. Mycol. Soc.*, **80**, 541-543, 1983.
5. Low temperature scanning electron microscopy of biological specimens. By D. Jones, W. J. McHardy and J. M. Tait. To appear in *Trans. Br. Mycol. Soc.*
6. Movement of amoebo-flagellates of *Cavostelium bisporum*. By J. F. Darbyshire and E. B. Sneddon, *Trans. Br. Mycol. Soc.*, **80**, 356-357, 1983.
7. An IR spectroscopic study of soil humin and its relationship to other soil humic substances and fungal pigments. By J. D. Russell, D. Vaughan, D. Jones and A. R. Fraser, *Geoderma*, **29**, 1-12, 1983.
8. Effect of periodate treatment of soil on carbohydrate constituents and soil aggregation. By M. V. Cheshire, G. P. Sparling and C. M. Mundie, *J. Soil Sci.*, **34**, 105-112, 1983.
9. The contribution of polysaccharides of plant or microbial origin to soil structure. By M. V. Cheshire, G. P. Sparling and C. M. Mundie, Transactions ISSS/BSSS meeting, Reading, 47, 1983.
10. Influence of soil type, crop and air drying on residual carbohydrate content and aggregate stability after treatment with periodate and tetraborate. By M. V. Cheshire, G. P. Sparling and C. M. Mundie. To appear in *Plant and Soil*.
11. Measurement of the microbial biomass in composted wheat straw, and the possible contribution of the biomass to the nutrition of *Agaricus bisporus*. By G. P. Sparling, T. R. Fermor and D. A. Wood, *Soil Biol. Biochem.*, **14**, 609-611, 1982.
12. A comparison of methods for measuring ATP and microbial biomass in soils. By G. P. Sparling and F. Eiland, *Soil Biol. Biochem.*, **15**, 227-229, 1983.
13. Estimation of microbial biomass and activity in soil using microcalorimetry. By G. P. Sparling, *J. Soil Sci.*, **34**, 381-390, 1983.

14. Extractable N and P in relation to microbial biomass in UK acid organic soils. By B. L. Williams and G. P. Sparling. To appear in *Plant and Soil*.

15. Trace element mobilization by soil microbes. By G. P. Sparling and M. L. Berrow. Submitted to *J. Agric. Sci.*

16. Observations on the location and form of lead in *Stereocaulon vesuvianum*. By D. Jones, M. J. Wilson and J. R. Laundon. *Lichenologist*, **14**, 279-286, 1982.

17. Lichen weathering of minerals and implications for soil processes. By M. J. Wilson and D. Jones. *J. Geol. Soc.*, Special Publication, Residual Deposits, 5-12, 1983.

18. The occurrence and significance of manganese oxalate in *Pertusaria corallina*. By M. J. Wilson and D. Jones. To appear in *Pedobiologia*.

19. The anaerobic bacteria of a basin peat bog in Scotland. By R. E. Wheatley. To appear in *J. Appl. Bact.*

20. Removal of ferrous iron from field drainage waters. By D. Vaughan, R. E. Wheatley and B. G. Ord. To appear in *J. Soil Sci.*

21. Easing the ochre problem. By D. Vaughan, B. G. Ord and R. E. Wheatley. Submitted to *Drainage Contractor*.

22. Amelioration of the ochre problem in field drainage systems using coniferous bark. By R. E. Wheatley, D. Vaughan and B. G. Ord. Submitted to the Proceedings of Seventh International Peat Congress, Dublin, 1984.

23. Amelioration of the phytotoxicity of phenolic acids by some soil microbes. By D. Vaughan, G. P. Sparling and B. G. Ord. *Soil Biol. Biochem.*, **15**, 613-614, 1983.

7. SOIL FERTILITY

B. W. BACHE

One of the Department's objectives is to integrate soil physical, soil chemical and plant nutritional research into a better understanding of field crop production, and much of the work described below contributes to this. Changes in soil nutrient levels as a result of fertilizing and cropping provide important data for planning fertilization policy; these necessarily occur slowly and effects need to be studied in the long term. Work of this nature will be extended by acquisition of a 2·2 ha long-term field experiment site at Cross of Jackston on Foudland series soil rented from the Fyvie Estate Management Company. Two experiments have been laid down on this site: a nutrient balance experiment with a rotation of four crops, designed to measure the build-up/run-down of the major nutrients (P, K, Mg, S) under two nitrogen regimes, and a detailed nitrogen response experiment on spring barley within a six year grass/barley rotation. It will be a few years before these experiments produce the detailed information for which they are designed.

Co-operative work with outside organisations is becoming a more important feature of the Department's work. The Scottish Crop Research Institute (Mylnefield) has a large potato research programme and the Department has the main responsibility for mineral nutrition work within this programme, in addition to providing a routine crop analysis service. The Department is also involved in some of the soil aspects of the Department of the Environment Research Contract to the Institute for research on the effects of acid rain. In the winter barley programme co-operation takes place with the Botany Department of the North of Scotland College of Agriculture on the effect of growth regulators, which hold out considerable promise of yield improvements to this crop. A joint project with the Rowett Research Institute on the digestibility of straw in relation to its nutrient content is just beginning.

The Department's work is publicised to an increasing audience, apart from traditional publications in scientific journals, through more talks to farmers' discussion groups, exhibits at the Black Isle, Turriff and Keith agricultural shows, at the Royal Agricultural Society's Show at Stoneleigh, and the " Money from Grass " exhibits at Craibstone, Kelso and Ingliston.

As usual, the Department has been represented on a number of committees: the COSAC/MISR Liaison Committee and its Working Groups on yield constraints, advisory soil analysis (major and trace elements), the

soil fertility information system, and soil physical problems; the Scottish Standing Committee for the Calculation of the Residual Values of Fertiliser and Feeding Stuffs; the North of Scotland Grassland Society Committee; the Hill Land Use and Ecology Group; a Working Group on the co-ordination of R and D in potato physiology; the Biological Advisory Panel of the Central Electricity Research Laboratories; and the Convention on Long-range Transboundary Air Pollution of the UN Economic Commission for Europe.

Staff matters are still a major concern. Dr T. E. Edmonds resigned in December, 1982, to take up a lectureship in Chemistry at Loughborough Technological University, and has not yet been replaced. Dr W. M. Crooke retired at the end of 1982 after 33 years' service in the Institute, and Dr P. Millard has joined us to develop further the crop composition work that Dr Crooke began. Miss Sheila Law retired in October, 1983, after 41 years' service and both Dr J. W. S. Reith (40 years' service) and Mr A. H. Knight (33 years' service) retire in December, 1983. Appreciations of their contributions to the work of the Department are given elsewhere. Dr T. B. R. Yormah from the Department of Chemistry, Fourah Bay College, University of Sierra Leone, spent three months with us as a visiting worker learning radioactive techniques. Miss S. Fraser has completed her Doctorate studies on piezoelectric crystal gas monitors.

Field Crop Studies

Nitrogen for Winter Barley. A further seven experiments to determine the optimum nitrogen requirement for winter barley were carried out in 1982-83. The average maximum yield with optimum nitrogen was 6·4 t of grain dry matter/ha (7·5 t/ha at 15% moisture content), about 20% less than in 1981-82. The average optimum N rate was 170 kg/ha applied in spring. The weather in 1983 appeared to have both direct and indirect effects on the crops. April and May were much wetter and cooler than normal, with over 50% more than average rainfall and air temperatures about 3°C lower than normal. The main consequences of this were slow crop growth and great difficulty in controlling weeds and diseases, particuarly chickweed and *Rhizoctonia*. After near average weather in June, rainfall in July and August was only 22% of average, but this does not appear to have had a substantial effect on yield. For the third year in succession there were no gales or heavy rainstorms during the grain filling and ripening periods to induce lodging. Climatic conditions were, therefore, suitable for winter barley crops to respond to higher levels of fertilizer nitrogen.

On the basis of twenty-two experiments over three years on sites with a low to medium N status, an average spring nitrogen dressing of about 180 kg N/ha is recommended. In eleven of the experiments the optimum N rate fell within the range of N levels tested, and averaged 174 kg/ha (range 150-215 kg/ha N). In nine experiments the maximum yield was attained with the highest N rates tested, which averaged 196 kg/ha (range 160-240 kg/ha), and must therefore be presumed to be an under-estimate of the N requirement. In one experiment the lowest N rate, 130 kg/ha, gave

the highest yield. It is clear that there is a wide range of optima from <130 to >240 kg/ha N and more information is required to refine the average value.

A further experiment to test the interaction between date of sowing and spring N requirement was conducted in 1982-83. Optimum N for a crop sown on 30 August was 160 kg/ha and for crops sown on 22 September and 28 October the highest yield was given by 240 kg/ha, the highest rate tested. This confirms the results of the previous experiment (Annual Report No. 52).

The achievement of high yield seems to be neither fully understood nor totally under the control of crop management techniques. There is no indication from these experiments that more nitrogen is required when high yields are attained, only that higher yielding crops make more efficient use of nitrogen. Pest and disease control are obviously an important factor for nine experiments yielding 8·7 to 10·3 t/ha of grain (15% moisture) were virtually free of weeds or diseases, eight experiments yielding 6·5 to 7·9 t/ha had slight to moderate weed and/or disease infestations, and the remaining low (4·7 - 6·0 t/ha) yielding experiments had moderate to severe infestations of weeds and/or diseases.

An account of comparable work on spring barley described in previous Annual Reports, has been submitted for publication[1]. 7048

Growth Regulators on Winter Barley. A collaborative experiment with the Botany Department of the North of Scotland College of Agriculture has begun, with the object of studying the effects of N and 5C-Cycocel on the growth and yield of winter barley. Cycocel was applied as " Arotex Extra " in single or split applications of 0 or a total of 2·4 kg/ha at growth stages 13, 22 and 31 or 22 and 31, or 31 only. Details of the growth studies are not yet available but cycocel increased yields by about 12% at N rates of 80-160 kg/ha. With 200 kg/ha N there was little lodging where Cycocel had been applied whereas the untreated plots lodged very badly and were virtually unharvestable. There were no substantial differences between single or split applications of Cycocel. 7048

Trace Elements for Herbage Crops. The effect of pedological drainage conditions on trace element contents has been investigated by sampling soil and herbage collected three times per year for three successive years from 28 plots in fields where temporary leys had been established under a cereal crop the previous year. These plots were usually in the same field, from areas where the natural pedological drainage conditions were free, imperfect or poor, and in two instances very poor, usually occurring in the same field for a given soil association. The mean results for cobalt (Figure 3·1 of Annual Report No. 52, 1981-82) show that the practical significance of soil Co, extracted by 0·43M acetic acid, depends on the natural pedological conditions: a higher level of extractable Co is required on freely-drained than on poorly-drained land to produce herbage containing 0·1 mg/kg Co in dry matter. With Cu and Mo, the amounts extracted also increase as drainage changes from free to poor, but the drainage conditions

do not seem to have much effect on the relationship between herbage uptake and amount extracted for these two elements in contrast to Co. An abstract of this work has been published.[2]

Field experiments were carried out on three mineral soils and on a deep acid peat to investigate the effects of applying fertilizers, especially N, and trace elements on the contents of trace elements in herbage cut for conservation. The herbage was cut at the silage stage of growth, usually over 50% ear emergence in ryegrass, three or four times per year for at least three successive years.

The results for cobalt described earlier (Annual Report No. 52, 1981-82) have now been published[3]. The results for copper and molybdenum showed that without added Cu, applying N reduced the Cu content in herbage on two of the mineral soils and on the peat. Applying Cu at these three sites increased slightly both the yields of dry matter and the Cu content in the herbage, the increase in the latter being consistently greater with than without applied N. In the other mineral soil containing adequate Cu, applying N increased the Cu content in mixed herbage, ryegrass and cocksfoot, except with 56 kg/ha N per cut where the content in mixed herbage was reduced slightly by the elimination of clover. Where the soil was adequately supplied with Cu, either naturally or by Cu additions, clovers contained more Cu than grasses. The Cu content was higher in herbage from the October cuts than from the June cuts, mid summer cuts having intermediate contents, and this pattern was the same both with and without applied Cu. Applying P depressed the Cu content in herbage, the reduction being greater in clover than in grasses. Applying K at normal rates had no effect on Cu levels in herbage. Cu extracted from the soils by 0·05M EDTA generally reflected Cu contents of herbage, and varied from 0·6 - 3·6 mg/kg, but a higher level of extractable Cu may be required for herbage produced with high N applications than for optimum cereal yields.

Applying Mo had no effect on herbage yield, but produced a large increase in the Mo content in herbage on a mineral soil, the increase in clover being greater than in ryegrass. On peat, applied Mo had much smaller effects on herbage contents, giving similar increases in both clover and ryegrass. Applying N reduced the Mo content in herbage, both in the absence and presence of applied Mo, the effects of the latter gradually decreasing in successive years. Applying P, especially at high rates, tended to reduce Mo levels in herbage. As with Co and Cu, the Mo contents are higher in autumn than in summer herbage and this trend is also shown for S in other experiments. These higher levels of both Mo and S could be one of the reasons why the absorbability of Cu is lower in autumn than in summer herbage. This work has been accepted for publication.[4]

A paper illustrating how trace elements naturally present in soils, or applied to correct deficiencies, can meet the requirements of both herbage and animal production has also been published.[5] This summarizes the main results for cobalt and copper and gives some information about manganese, molybdenum, selenium and zinc.

A joint paper illustrating the effects of applying trace elements, lime and fertilizers on the contents of trace elements in crops and herbage has also appeared.[6]

The main results of the collaborative ADAS/ARC grass-white clover experiment (GM23) at Arbuthnott were described in Report No. 51, 1980-81. Three additional treatments added trace elements Co, Cu, Mo and Zn, with S100 and Blanca white clovers, without applied N, and with 400 kg/ha N per year with Blanca. Trace element determinations on samples of mixed herbage and of grass and clovers done by the Department of Spectrochemistry, agree with the results of the experiments described above. It is also noteworthy that S100 white clover consistently has a higher Co content than Blanca, especially with applied Co, and that mixed herbage and ryegrass from the plots with S100 also tend to have higher Co levels than with Blanca. 7042, 3008, 8059

Phosphatic Fertilizers for Reseeded grass. An experiment on reseeded grass, sown in early autumn, 1981, on a soil low in phosphate is comparing the effectiveness of supplementary applications of powdered, granular and chip forms of Gafsa (Tunisia) phosphate, and of calcined Senegal phosphate with the same amounts of phosphate applied as triple superphosphate or basic slag. All the plots received 20 kg/ha P as triple superphosphate at establishment. In 1982 only the triple superphosphate and basic slag treatments produced slightly higher yields than no supplementary phosphate. The 1983 results show that all the supplementary applications have increased yields, triple superphosphate and basic slag giving the highest responses. 7041

Phosphatic fertilizers for swedes. Two experiments on swedes, grown on soils low in phosphate, were carried out to compare the effectiveness of powdered, granular and chip forms of Gafsa (Tunisia) phosphate, both in the absence and presence of some water-soluble phosphate. The yields for these 1982 experiments agree with the results for similar experiments in 1981 (Annual Report No. 52, 1981-82) in showing that, without any water-soluble phosphate (triple superphosphate) powdered Gafsa was barely equal to half the phosphate in triple superphosphate, but, where the phosphate was applied as half triple superphosphate and half as Gafsa powdered (whether granular or chip) the yields of roots were practically identical to those obtained with the water-soluble phosphate alone. 7041, 8059

Cultivar differences in the Response of Swedes to Fertilizers. Two experiments carried out in both 1981 and 1982 determined whether there were differences in the need for, and response to, N, P or K with Doon Major and Ruta Øtofte swede varieties. The latter has a higher percentage of dry matter than the former. In all four experiments the differences in the response to applied N were small and far from significant, the mean increase with 90 kg/ha N being only 1·0 t/ha dry matter. The soils had moderate or high potassium status and the responses to applied K were small or negligible. In one experiment with moderately high phosphorus status, applied P significantly increased the yield of Ruta Øtofte but not of

Doon Major. At the other three sites with low or moderate phosphorus status, the yields of both cultivars were increased substantially by applied P, the increases being significantly greater with Ruta Øtofte than with Doon Major in two but not in the third experiment. These results show that the optimum rate of P for Ruta Øtofte is higher than for Doon Major.
7041, 8059

Nitrogen for Potatoes. The Department has assumed responsibility for work on potato nutrition in a collaborative programme with the potato physiology group at the Scottish Crop Research Institute (Mylnefield). Studies on the nutrient changes in the potato crop during the growing season have therefore been extended by the initiation of a field programme to study the nitrogen metabolism of potatoes. Eight rates of N were applied as nitrochalk (including split applications at planting and tuber initiation in two of the treatments) and the growth and nutrient composition of the crop were measured throughout the season. The tuber fresh weight yield response to nitrogen was from 31·7 t/ha with no nitrogen (N_0) to 46·2 t/ha with 250 kg/ha N (N_5) by 27 September. There was no increase in yield between 150-250 kg/ha N. In addition, plants from the N_0 and N_5 treatments have been sampled at each harvest by collecting several single stems from each plot and splitting them into successive leaf pairs, stems and laterals. This will enable nitrogen partitioning within the crop to be studied under deficient and luxury N conditions. Measurements of biomass partitioning and C:N ratios from different tissues will also be used to augment work currently in progress at the Scottish Croup Research Institute. 7047

Sulphur on Various Crops. Sulphur deficiency appears to be rather more widespread in the north-east of Scotland than was earlier thought due both to the relatively low inputs from the atmosphere and the lack of sulphur in many fertilizer mixtures. An appraisal of the situation has recently been published[7] and a review of sulphur in soils and plants has been accepted for publication[8].

The results of two grassland trials with sulphur have been published[9]. These trials were completed in 1982 when 20 kg/ha of S added as gypsum or as K_2SO_4 gave total oven-dry yield increases over three cuts of grass of 11·1% (on Laurencekirk series soil) and 19·0% (on Corby series soil) when 90 kg/ha N was added per cut. In each case the largest dry matter yield increases were in the third cut when the soils' sulphur reserves had been virtually exhausted. Grassland trials in 1983 on three more low S soils comparing micro-particulate sulphur sprays with fertiliser sulphate showed little difference between the two forms: both forms gave oven-dry yield increases at the second cut of between 15 and 20% and there was no consistent or significant difference between using 20 kg/ha or 40 kg/ha S over the two cuts. Two experiments to test sulphur effects on oilseed rape were performed on sandy soils in the Moray Firth area. On a soil with low extractable sulphate (4 mg/kg S), 20 kg/ha S sprayed onto the crop in spring increased the seed yield from 3·98 to 4·78 t/ha (a 20% increase) but a similar S application had no effects on a soil with moderate extractable

sulphate (13 mg/kg S). Cereals have been less sensitive than other crops to sulphur deficiency in pot experiments, but in a simple field trial comparing 8 kg/ha S sprayed on winter barley at growth stage 4, with no added S, on four sites low in extractable sulphate, the added S gave a significant overall grain increase of 0·6 t/ha dry matter above the nil-S yield of 5·1 t/ha. Detailed crop measurements at harvest show this yield increase was attributable to an increase in the number of grains per ear rather than any difference in the number of ears or the thousand grain weight. Varietal susceptibility to sulphur deficiency in spring barley was tested in a pot experiment using a sulphur-deficient soil. This placed the varieties in the following order of increasing susceptibiity: Celt, Klaxon, Tweed, Lina, Tasman and Triumph. Celt gave 22% grain yield response to added S whereas Triumph gave a 59% grain yield response and the others were intermediate (28, 31, 35 and 50%). 7038

Nitrogen Fertilizer

Collaborative work with the Department of Spectrochemistry on pot trials using ammonium treated vermiculite (ATV) as a slow release nitrogen fertilizer has shown that it might have advantages for the management of ryegrass[10]. Field trials are now being set up.

Crop Chemistry and Composition

Carbohydrates and the Winter-Hardiness of Swedes. Changes in the chemical composition of nine swede varieties of varying winter-hardiness were studied over the period October to March, in roots taken from the North of Scotland College of Agriculture's field trials. In the autumn, root dry matter samples contained 20-23% cell wall polysaccharides, 10-12% soluble phenolic acids, 3-5% inorganic nutrients and between 52 and 57% soluble carbohydrate, mainly glucose, sucrose and fructose. The main change in composition found in samples collected after the winter were in the soluble sugar levels: these increased in the high winter-hardiness varieties, while there was a decrease or no change in sugars in the low and medium winter-hardiness varieties respectively. Winter-hardiness may, therefore, be associated with prolonged canopy photosynthesis in the autumn, and protection of the roots from frost by the canopy. Preliminary work has started to study sugar accumulation, canopy development and frost resistance in swedes. 7047

Effect of Applied Nitrogen on Cereal Straw Digestibility. In a collaborative experiment with the Rowett Research Institute, the digestibility of barley and oat straw is being measured, to estimate the optimal N application rates that are necessary to produce the maximum digestible energy available to the animal. Considerable differences would be expected, because N application affects both carbohydrate and protein, and its partitioning between straw and grain (Annual Report No. 50, 1979-80). From the preliminary work it appears that N applications to spring barley have no effect on the digestibility at final harvest, although they increase

the N content of the straw. Further digestibility measurements are being made on samples harvested at earlier stages of growth, as well as on oat straw samples. 7047

Crop Composition: service facilities. Nearly 1000 plant analyses have been carried out for the Scottish Crop Research Institute on potato leaves, stems, tubers and sprouts and Blueberry leaves. This has also involved the development of methods to measure different calcium fractions in potato tubers. Lysimeter studies at SCRI have also involved about 100 analyses for No_3^- and NH_4^+ in solutions. 7047

Soil Physics

Preliminary studies of soil strength and compaction have investigated the relationship between unconfined compressive strength (UCS, measured as specified by the standard test ASTM D 2166) and soil matric water potential for a sandy loam and a clay loam soil. Soil cores were sampled at intervals during the season to give a range of moisture contents and the matric potential was calculated from a previously determined moisture release characteristic. For the clay loam soil, mean values of six replicate core measurements of UCS increased from 0·31 to 0·41 MN/m^2 as the soil dried from a potential of 0·10 bar to 0·37 bar; and for the sandy loam it is increased from 0·26 to 0·39 MN/m^2 as the soil dried from 0·11 to 0·33 bar. The relation between UCS and soil water potential was approximately linear over this range, but with a different slope for the two soils of contrasting texture. These results indicate that the sandy loam soil is less able than the clay loam to withstand compaction when it is moderately wet, but published data suggests that both would be at risk from structural damage by implements or animals. There is little difference between the behaviour of the two soils when they are somewhat drier. 7044

Soil Chemistry

Potassium. Further data comparing soil K and Na fractions released by electroultrafiltration (EUF) with conventional methods of extraction and grass growth have been calculated. Amounts of K extracted by EUF within 35 min (K_{35}) were lower than the contents of 1M ammonium acetate exchangeable K(K_{ex}); the decrease depended on clay content of the soils, and varied from 98% for a sand to 24% for a sandy clay loam. Amounts of Na (Na_{35}), were also lower than exchangeable Na (Na_{ex}), but were independent of clay content, and averaged 61% of Na_{ex}. Correlation coefficients of linear regressions of the reciprocal of soil K measurements on cumulative yield response of 3 cuts of ryegrass to a standard addition of K were 0·69 for K_{35} and 0·86 for K_{ex}. Correlation coefficients of linear regressions of Na removal after 3 cuts were 0·87 for Na_{35} and 0·74 for Na_{ex}. Clearly, electroultrafiltration is no improvement on conventional exchangeable K measurements for indicating soil K availability to crops. A summary account of this work is to be published[11].

The EUF technique was also used in collaborative work with Rothamsted Experimental Station, comparing rates of release of potassium from

soils from two long-term experiments, with yield and K offtake by winter wheat. The other laboratory methods used by the Rothamsted workers were: Boiling nitric acid extraction, Ca-cation exchange resin and HCl-extraction under reflux. All methods clearly distinguished between the differentially-fertilized plots of the two soil types, but the HCl reflux method gave closest correlations with long-term K offtake.[12] 7041

Manganese. Further experiments have extended the work relating the soil chemistry of manganese to Mn nutrition of the spring barley crop, by comparing pH and Mn solubility in rhizosphere and non-rhizosphere soil of Mn-deficient loamy sand (Corby series) and Mn-adequate sandy loam (Stonehaven series). As before the pH of the rhizosphere soil was lower than that of the bulk soil; this effect was greater for combine-drilled NPK fertilizer than for broadcast fertilizer and was noticeable only in the early part of the season. However, in the Corby soil, the higher Mn solubility that this effect produced, was confined to the early part of the season and it decreased later on. The Stonehaven soil had similar Mn concentrations to the Corby soil at the start of the season, but they gradually increased during the season. Thus Mn solubility cannot be explained by pH alone, but must depend on more complex processes, possibly relating to reducing conditions in this soil during the very wet spring. These effects are still under investigation. 7042

The effects of improved manganese nutrition on the spring barley crop are associated with improved development of adventitious roots and an increase in tillering, as shown in Figure 7·1(a).

The previous Report mentioned preliminary work on the use of the ^{54}Mn tracer to study the effectiveness of different methods of Mn supplementation for barley grain in pots. As indicated there, seed treatment seemed only to be effective in early growth. Soil amendment with 0, 15 and 30 μg/g Mn showed little effect on early growth, but effects were apparent by ear emergence, and at final harvest grain Mn content was 10·1, 11·4 and 12·2 μg/g for the three treatments. Spray treatments consisted of 6 cm^3 of 1% w/v solution of $MnSO_4$ at the 5-6 leaf stage, equivalent to a field dressing of about 10 kg/ha $MnSO_4$. New growth was analysed separately to show translocation of added Mn. At ear emergence, 3% of added Mn has been translocated to new growth, increasing Mn content of the upper leaves from 18 to 63 μg/g. Average grain Mn at the final harvest increased from 10·4 to 12·2 μg/g, about 5 μg/g of which had been derived from the spray, as shown by radiochemical measurements, representing 0·5% of the total addition. None of the plants showed any clinical symptoms of manganese deficiency, although the soil used was of marginal manganese status under field conditions. 7042, 7046

There has been a considerable increase in the number of plant samples both experimental and advisory, requiring analysis for manganese. The established formaldoxine colorimetric method has, therefore, been adapted for continuous flow automation. 7046

Sulphur. Sulphate was extracted from 26 calcareous soils using 0·1M hydrochloric acid, and the conventional 0·05M KH_2PO_4 solution used for

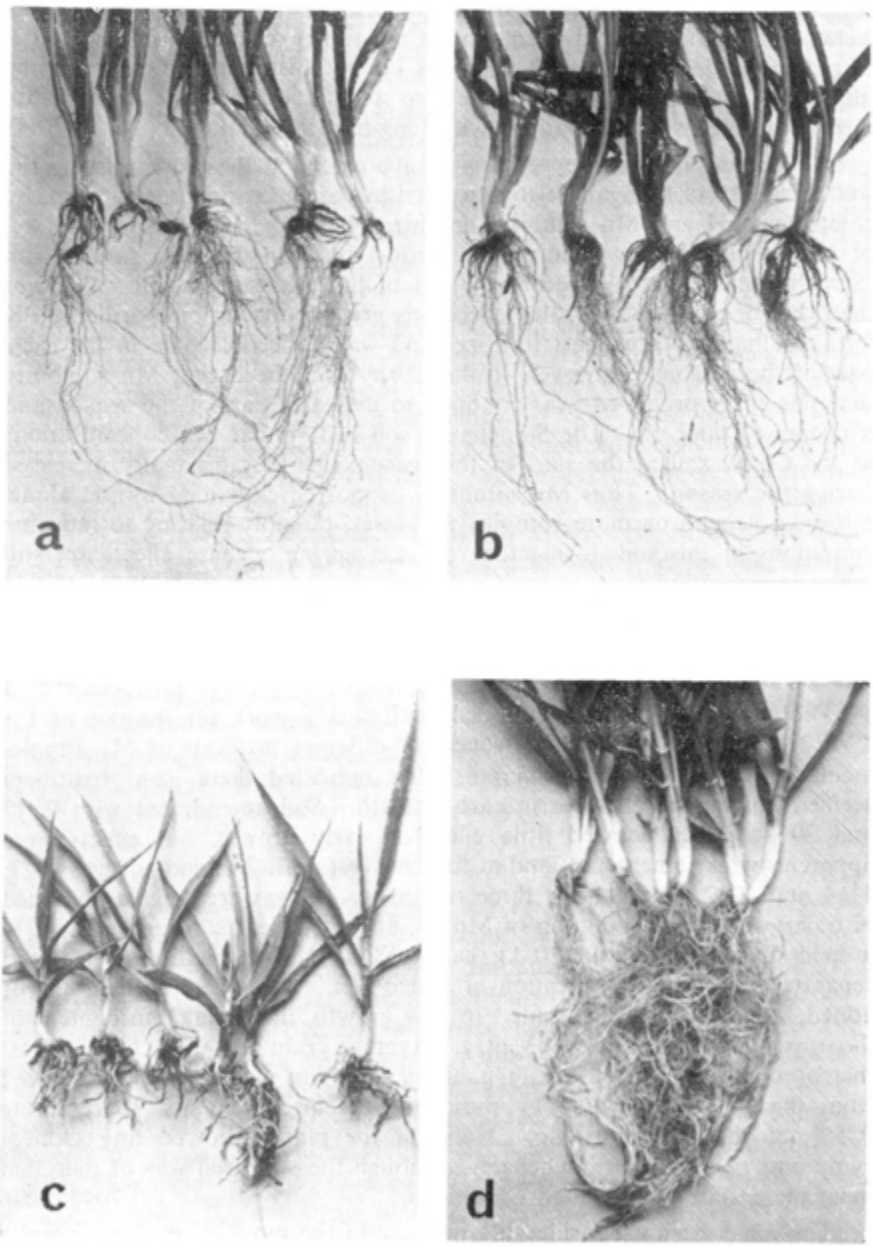


Fig. 7.1.
Effects of manganese and aluminium on root growth. (a) Manganese deficiency showing lack of adventitious roots and poor tillering compared to (b) adequate managenese. (c) Aluminium toxicity at pH 4.6 showing stunted root system compared to (d) normal plant at pH 6.2. All examples were from spring barley, variety Golden Promise.

acid soils. The amounts for the two methods varied from 17-161 and 3·1-16·4 mgs/kg respectively. Four of these soils, having KH_2PO_4-extractable sulphate values between 3·1 and 16·4 mgs/kg, were cropped with oats in a pot experiment with and without added sulphate. Yield responses to the S additions varied from 0 to 50% and gave a good inverse relationship to the KH_2PO_4 extractable values, similar to what would have been expected for acid soils, but gave a poor relationship to the HCl-extractable values. The phosphate extraction method is, therefore, equally suitable for calcareous soils as for acid soils, but the HCl extraction for total inorganic sulphate is obviously inappropriate for predicting availability of soil S to crops. 7038

Selenium. Modified instrumentation has been produced for the electrochemical analysis of selenium and other elements, which enables much greater flexibility in the form of the differential pulse waveform which is applied to the electrode. The parameters pulse-width, sample-width and amplifier time constant which were fixed on the unmodified PAR 174 instrument can now be varied over a wide range. The system clock has had its maximum frequency extended from 2 Hz to 10 Hz and differentiating circuitry has been added. When all these parameters are optimised an analytical scan at the hanging mercury drop electrode can be made at four times normal speed, with better reproducibility and approximately a twofold increase in sensitivity. Changes have also been made to the chemical methodology in the cathodic stripping method for selenium: Copper interference has been largely eliminated by swamping with excess copper and complexing it with EDTA, and the low concentration peak splitting effects have been eliminated by an electrode deposition mechanism involving a Se-Cu alloy rather than an $Se\text{-}Cl_6$ complex. 7045

Soil Acidity. A paper describing the interactions of acid rain with soils, and the consequent effects on the composition of surface water, has been presented to a Royal Society discussion meeting[13]. This showed that the composition of rainfall is modified by chemical interaction with the soil and rock that it passes through, mainly because of cation exchange, acid hydrolysis and oxidation-reduction reactions. At times of high flow rates, interaction with soil will be imcomplete, or may be short-circuited entirely. The need for on-site examination of detailed soil and hydrologic properties is emphasised, before accurate conclusions can be drawn about causes of surface water acidification. The influence of rock weathering in neutralizing acid rain, the effects of surface runoff and organic soils has been reviewed[14]. 7040

The complexation reactions of aluminium ions with soluble humus acids (" fulvic acid ") have been investigated. The affinity of fulvic acids for Al^{3+} due to chemical bonding appeared to be no greater than that of weak complexants such as adipic or acetic acids. The higher stability constants found at higher degrees of dissociation of the fulvic acids were therefore attributed to the electrostatic energy associated with the higher surface charge density of the fulvic acids. The results have allowed tentative calculation of the proportion of free and organically complexed Al

as a function of both the pH and the soluble organic matter levels in soil solution. An account of this work has now been written up[15]. 7040

Soil acidity parameters (pH, and soluble and exchangeable aluminium and calcium) have been determined on the soils fro mthree spring barley field experiments in 1982, on sites where different acidity/lime levels had been induced by previous treatments. The effects of soil pH on yild are summarized in Figure 7·2. The dramatic reduction in yield as soil pH drops below about 5·7 (Fig. 7·2a) is associated with increasing Al solubility, and the toxic effects of soluble Al on barley root systems is shown in Figure 7·1c. Where there were large differences in soil phosphate levels, higher P allowed barley to grow at somewhat lower pH (Fig. 7·2b) thus confirming in the field the results found earlier in pot experiments. Soluble Al measurements show that this is not an indirect effect of applied P in reducing Al solubility, as has been previously suggested, but is a direct effect of P nutrition on the growth of the crop. It has been known for some years that higher N additions can to some extent overcome the yield reduction due to acidity at marginal pH values. This is shown in Figure 7·2c, but in contrast to the P effect, higher N does not alter the critical soil pH below which yield reduction beings to be apparent.
7040, 7041, 7048, 8058

One of the experiments referred to above was cropped to winter barley (variety Igri) in 1982-83 after 5 years in spring barley (Golden Promise). The mean relative yields of the spring barley over five N levels were 83, 96 and 100, respectively, at the mean soil pH values of 5·0, 5·6 and 6·2. For the winter barley the relative yields at these three pH values were respectively 81, 97 and 100. This indicates that winter barley does not require a higher pH than spring barley, contrary to what has been previously suggested. 7048

Radioactive Tracers in Crop Sciences

In addition to routine projects within the Departments of Soil Organic Chemistry, Plant Physiology and Microbiology, the Radioactive Section of the Department has been involved in some unusual applications of radioactivity. The uptake and biochemical transformations of microparticulate elemental sulphur, when sprayed on to crop leaves, is being investigated by labelling the sulphur suspension with ^{35}S. Studies of the microbial decomposition of plant material in soils required an estimate of feeding turnover rates in insect larvae, and a method using ^{106}Ru, now widely used for farm animals, was adapted for this small scale purpose. The study of calcium efflux in Brussels Sprouts in relation to Ca-related disorders has required the growth of ^{45}Ca labelled sprouts, but the complication of using ammonium as well as nitrate in the culture solution necessitated adding ^{45}Ca as carbonate to maintain the solution pH to near 7. The need for high activity ^{45}Ca-labelled potato tubers to study Ca mobilization during sprouting, was achieved by letting the tubers develop in a layer of "Agrosoke" (a polyacrylamide gel) within the soil-sand culture medium

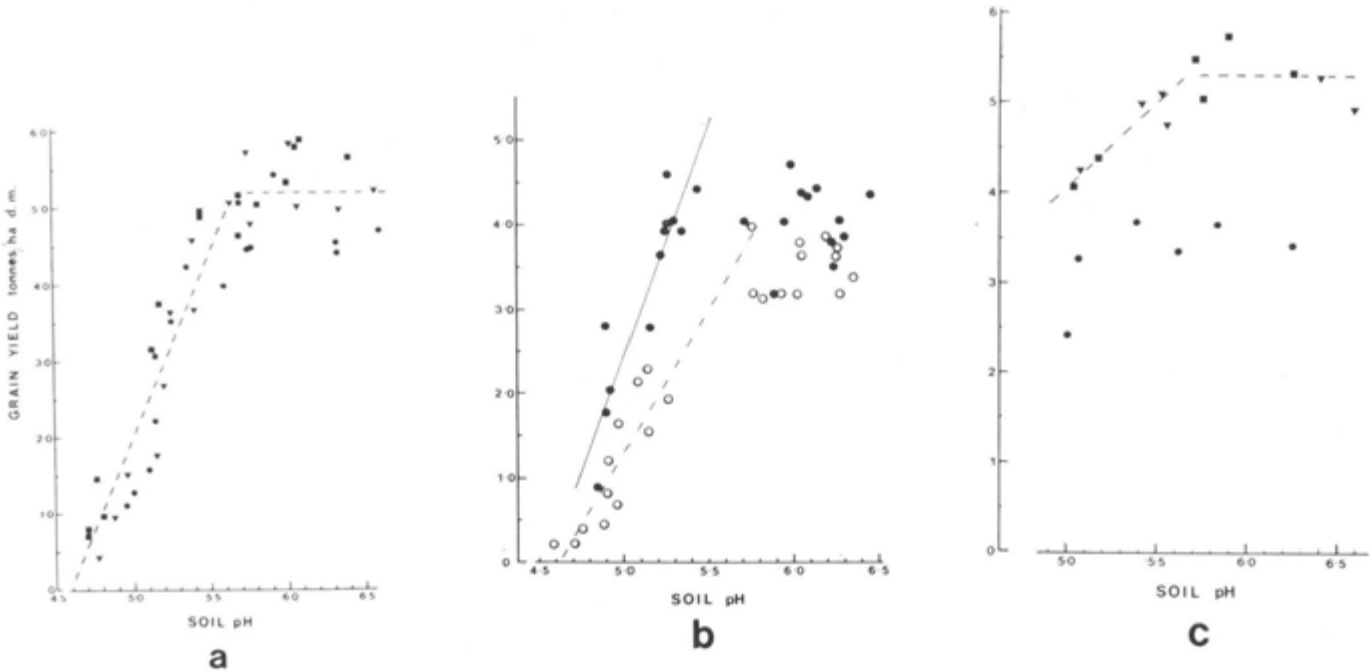


Fig. 7.2.

The effects of soil pH on oven-dry yields of spring barley (Golden Promise). (a) Soil of moderate P status, showing rapid yield decline as pH drops below about 5.7. (b) Effect of different phosphate levels: ○, no P added since 1967; ●, 2400 kg/ha P added in 1968, and none since. The intercepts of the two regression lines differ significantly at the 0.1% level. (c) Effect of nitrogen applications, with other inputs similar: ●, 25 kg/ha N; ▲, 75 kg/ha N; ■, 125 kg/ha N.

which held the ^{45}Ca against leaching. Specialised analytical expertise was needed to analyse ^{14}C in all parts of potato plants following $^{14}CO_2$ uptake by leaves. The two latter projects were done at the request of SCRI. 7049

Development and Advisory Work

Soil Test Methods. Discussions with soil chemists from the West of Scotland Agricultural College and the East of Scotland College of Agriculture are continuing under the auspices of a working group of the MISR/COSAC Liaison Committee, to decide on a common system of advisory analysis, both for major nutrients and for trace elements. To assist in this exercise, sub-samples of 144 soils, 12 each from 4 major soil series in each College area, have been analysed by all three laboratories for P, K, Mg and Ca by the methods currently in use and by the proposed ammonium acetate-lactate method, and the results have been statistically compared. 7041

A five category classification system for trace element levels in soils has now been agreed by this working group: Very low, low, moderate, high and excessive. In a detailed evaluation of soil trace element data, the ranges of extractable nutrients corresponding to these categories have been designated for copper, cobalt and molybdenum. 7042

The experimental work described earlier, together with advisory experience from all three college areas, has provided a better basis for the assessment of the Cu status of soils by EDTA extraction, of Co status by 0·43M acetic acid extraction, and of Mo status by 1·0M ammonium acetate extraction. Natural pedological drainage conditions of soil affect the significance of extractable Co levels, and should be taken into account in classifying the Co status of advisory soil samples in relation to the expected Co content of herbage. High or excessive levels of Mo in herbage can adversely affect Cu metabolism in ruminants and the ammonium acetate extraction is able to predict where this is likely to occur, which is generally in naturally poorly-drained fields. Peaty soils, with 30-90 per cent loss on ignition, have a much lower weight per unit volume than mineral soils, and in the assessment of the Cu status of soils this needs to be corrected for, when using a standard weight of soil for analysis. In contrast, it appears that for Co and Mo (but with only limited data for the latter) no adjustment is required for the lower density of peaty soil when relating the soil test to herbage uptake of these elements. 7042

Advisory Analyses. There has been a considerable increase in the number of advisory soil samples from the North of Scotland College of Agriculture, from 7,400 last year to 9,360 in the current year. Most of these were for major nutrients, pH and lime requirement, but 750 also included trace elements. 170 forest soil samples were also analysed. 120 crop samples were received for analysis, most of them for the investigation of possible trace element problems. 7043

Soil Fertility Information System. The field information and analytical results for more than 9,000 soils, sampled by the North of Scotland College

of Agriculture, have been recorded with a Commodore 700 series microcomputer (256 k bytes) and stored on discs. It is hoped in future to transfer the data directly to the Institute's mainframe computer to make use of its greaer storage capacity.

A Working Party of the Macaulay/COSAC Liaison Group has been set up to create a computerised Soil Fertility Information System for Scotland. Agreement has been reached on the additional data that needs to be collected at the time of sampling soiles for routine analysis, and on a standard form for supplying these data, which must accompany all requests for soil analysis. A common core of 41 variables are to be stored in the same format at three centres: The East of Scotland College of Agriculture, the West of Scotland Agricultural College and the Macaulay Institute. It is proposed that the East and West colleges send their core data to the Macaulay in order to produce an annual analysis on an all-Scotland basis. Examples of the information that could be obtained are: (i) trends in soil nutrient status by district, farm type, soil type and fertilizer usage; (ii) relationships between soil nutrient status and soil series so that a better picture can be built up of different series, and allow prediction of possible problems; and (iii) fertilizer practice by farm type and district.

7041

References

1. The nitrogen requirement of spring barley. By P. W. Dyson. To appear in *J. Sci. Food Agric.*, **35**, 1984.
2. Soil drainage conditions and related plant trace element contents. By M. L. Berrow, J. C. Burridge and J. W. S. Reith. *J. Sci. Food Agric.*, **34**, 53-54, 1983.
3. Effects of the application of fertilizers and trace elements on the cobalt content of herbage cut for conservation. By J. W. S. Reith, J. C. Burridge, M. L. Berrow and K. S. Caldwell. *J. Sci. Food Agric.*, **34**, 1163-1170, 1983.
4. Effects of the application of fertilisers on the copper and molybdenum contents in herbage cut for conservation. By J. W. S. Reith, J. C. Burridge, M. L. Berrow and K. S. Caldwell. To appear in *J. Sci. Food Agric.*, **35**, 1984.
5. Trace elements in soil and herbage. By J. W. S. Reith. *Norgrass*, **23**, 33-37, 1983.
6. Soil factors and treatments affecting trace elements in crops and herbage. By J. C. Burridge, J. W. S. Reith and M. L. Berrow. In Occasional Publication No. 7, pp. 00-00, "Trace Elements in Animal Production and Veterinary Practice," British Society of Animal Production, 1983.
7. Agricultural sulphur research and crop response to sulphur in the north of Scotland. By N. M. Scott. Proceedings "Sulphur 82," Vol. I, 579-586, British Sulphur Corporation, London, 1982.
8. Sulphur in soils and plants. By N. M. Scott. To appear in "Soil Organic Matter and Biological Activity," Martinus Nijhoff, The Hague.
9. Response of grassland to the application of sulphur at two sites in north-east Scotland. By N. M. Scott, M. E. Watson, K. S. Caldwell and R. H. E. Inkson. *J. Sci. Food Agric.*, **34**, 357-361, 1983.
10. Ammonia-treated vermiculite — an efficient controlled release nitrogenous fertilizer for a variety of crops. By N. M. Scott, A. K. Frazer and J. D. Russell. *J. Sci. Food Agric.*, **34**, 233-238, 1983.

11. Electroultrifiltration of soil potassium and sodium in relation to conventional methods and grass growth. By A. H. Sinclair and Grace Coutts. To appear in *J. Sci. Food Agric.*, **35**, 1984.

12. Assessment of potassium in soils. By K. D. Singh, K. W. T. Gouldlin and A. H. Sinclair. To appear in *Comm. Soil Sci. Plant Anal.*, **14**, 1983

13. Soil-water interactions. By B. W. Bache. Submitted to *Proc. Roy. Soc.*, B, 1984.

14. The implications of rock weathering for acid neutralization. By B. W. Bache. In *Ecological Effects of Acid Deposition*: Report of the Swedish Environment Protection Board, No. PM 1636, 175-187, 1983.

15. Aluminium-organic complexation: stability constants and a speciation model for soil solution. By S. D. Young and B. W. Bache. To be submitted for *J. Soil Sci.*, 1984.

8. STATISTICS

R. H. E. INKSON

The main aims of the work of the Department are to provide services to the rest of the Institute in both statistics and computing, and to develop the Institute's soil information system. The statistical service covers close collaboration at the planning stages of experiments and surveys, advice on the collection and recording of data, the choice of the appropriate method of statistical analysis, the interpretation and presentation of results, and a research capability in applied statistics. The computing service ranges from data entry and verification through programming to database management and both software and hardware development. Courses of instruction are given in the use of computer facilities, particularly terminals, and in programming.

Members of staff attended meetings of the Biometric Society, the Royal Statistical Society, the ARC Modellers' Group and the Forest Modelling Discussion Group, symposia on databases and experimental design, computer exhibitions and National Computing Centre demonstrations.

Computing

The Department provides the central computing facilities for the Institute and is responsible for the management, operation and development of the system. The Data General Eclipse network of terminals has now reached 15 and a further 14 lines are connected to various items of equipment, some via a local controlling microcomputer. The addition of a G300 graphics terminal with its own local printer has required a considerable programming effort to make it more " user friendly " and permit users to send their plot files to it rather than to the Benson graph plotter. A set of subroutines has been written so that users may display graphical output on the G300 and make any alterations necessary (such as improving a solution by a further cycle of iterations) before submitting a request for a hard copy on the graph plotter. The functions of these subroutines corresponds to those for the Benson plotter and thus no changes in the user's plotting program should be necessary apart from linking to it the G300 library rather than the Benson library of subroutines. Further testing and improvement of the G300 subroutines will continue. 8059

In addition to the service provided by the Department in data entry, verification and processing, and in the statistical analysis done by computer, there are now 34 registered computer user names, some used by more than one member of staff, from other Departments of the Institute. Their particular applications are described elsewhere in this report. 8059

Revisions of general statistical subroutines have been made and these then linked to mainline programs. Additional options have been included in some statistical programs, e.g. to FRECO which investigates the combination of regression lines fitted to a number of sets of data. The general correlation and regression program CORRG has been rewritten to provide greater flexibility in choice of independent variables, improved presentation of results, and the option to test the significance of the inclusion of an additional term in a regression equation. 8057, 8059

Increasing use is being made of the text editing and formatting programs as a word processing facility in the production of reports and drafts of papers for publication. The program package FAMULUS, designed to process personal reference collections maintained by research workers, has been obtained. Its basic structure renders it suitable for a large number of other applications. The 60 pages of source code are written in FORTRAN IV for another computer system and the machine-dependent code will have to be modified with Data General FORTRAN V software included. 8059

Soil Database. The Soil Inventory for Scotland has provided most of the input. From the systematic collection of profile descriptions at the 5 km national grid intersections 1218 out of a possible total of 3200 are now stored in the database. In addition, 178 selected profile descriptions relating to other investigations are stored. The database also contains the results of mineralogical analysis of sampled horizons of 314 profiles at 10 km intersections on the national grid and of 93 selected profiles. Data from the mineralogical and spectrochemical analyses of selected historical profiles are also stored. On-line interrogation of the database is now possible from computer terminals using any given key property to select the group of records required by means of the INFOS Query/Report Writer. An example of these facilities is given in a joint account[1] of the use of soil survey data from the site of a proposed opencast coal mine. 1802/8802/9802

Peat and Forest Soils. Regular use has been made of the service for processing LANDSAT MSS data from magnetic tapes and the results of chemical analysis of tree, rainfall and peat samples. 2035, 2054, 2055, 8059

Soil Organic Chemistry. An investigation of the relationships between chemical properties of the horizons of 173 soil profiles in a podzol chronosequence study has been undertaken using data retrieval and correlation programs. 4020, 8057, 8059

Soil Fertility. A plotting program was written to display three-dimensional graphs of soil moisture at different depths throughout the growing season. A soil fertility information system is being set up in the Data General Eclipse as a result of a working party decision that the annual analysis of soil advisory data for all three Colleges of Agriculture should be undertaken here. Data from the Department of Soil Fertility is transmitted to the Eclipse from an online Commodore microcomputer. Data from the East and West Colleges will be sent here on magnetic tapes. Thus online access to all Scottish advisory soil sample results will be provided. 7041, 7044, 8059

Soil Survey. The service in data entry, verification, processing and retrieval has been continued for plant phytosociological data from vegetation surveys. An additional retrieval and counting program has been written to provide a range of statistical information extracted from the soil and site data for the profiles on soil complexes at Ardnamurchan, Morven and the Isle of Mull. 9012, 9015, 8057, 8059

Statistical Advisory and Collaborative Work

Mineral Soils. Collaboration has been given in fitting a logarithmic type of curve to experimental data using a general program which allows the equation of the curve to be specified with up to 10 parameters. 1003, 8057, 8059

Peat and Forest Soils. Linear relationships between bands 4 and 7, and between the ratio of band 4 to band 7 and altitude, have been compared and combined where possible for LANDSAT satellite reflectance data obtained at a number of sites in two years. 2035, 8057, 8059

Sets of random co-ordinates for locating rainfall collectors and litter collecting bowls in a number of studies have been generated by GLIM using our RANDOM.SORT program. 2054, 8057, 8059

Further work has been done on data from the Glentanar acid rainfall project mentioned in previous reports. The collection of samples has now finished and the intial processing of data for separate sampling periods has been completed. Sample means for amounts and chemical contents of the rainfall have been plotted against time for the whole study period. 2054, 8057, 8059

As part of an investigation of nutrient cycling in birch, sample trees were selected for felling at two sites, Speyside and North Yorkshire. This whole tree sampling data has been processed, using some new computer programs and some existing programs, to provide weights of tree parts and regression relationships on a logarithmic scale between the various weights and section area. The regression lines were tested for equality of slopes and intercepts, and plotted along with data points. 2054, 8057, 8059

Litterfall data from the series of six experiments, of central composite design, on Sitka spruce has been received. They consist of weights of needles, twigs and other litter collected on plots receiving particular treatments in each block throughout the five-year duration of each experiment. Data entry to the computer and verification has been completed and work has begun on writing the necessary programs to process and analyse the data. Rainfall data from these same six experiments has been examined for seasonal cycles in pH level, deriving equally spaced data values as input for Fourier analysis methods. 2054, 8057, 8059

The examination of data from samples of natural and reseeded sites in Lewis, taken at regular depth intervals, and of basal area increments from a fertilizer experiment at Culbin, was done by analysis of variance and subsequent tests of significance. 2055, 2056, 8057, 8059

Soil Organic Chemistry. Highly significant linear relationships were established between residual carbohydrate, after progressively longer periods of treatments, and the microaggregate stability. Equality of the slopes and intercepts of lines for different soils was tested with the program FRECO, and combined equations produced for some groups of soils.
4021, 8057, 8059

Plant Physiology. Tomato experiments of factorial design tested moisture regime as one of the factors. A joint account[2] of part of this work and other data on active iron has been submitted for publication. Work has also been done on leaf composition data from factorial experiments on potatoes, on the assessment of damage by cavity spot of carrots, and on the contents and ratios of a range of elements in the roots and petioles of carrots. 5050, 8057, 8059

Microbiology. In a study of the distribution of pore size in a number of soils, tests of significance confirmed that the cross-sectional area measurements showed considerable skewness and kurtosis. The logarithmic transformation of the data was most successful in producing more normal distributions. To display the results and compare distributions for different soils, frequency tables were compiled and histograms on the logarithmic scale were plotted on the graph plotter. The same methods were applied to cross-sectional area measurements of organisms.
9014, 6027, 6031, 8057, 8059

In a soil drying experiment tests of significance were made on the effects of treatments on the proportions of undamaged roots. The program for processing, significance testing and interpreting dilution series data was used in a number of experiments with counts of amoebae and flagellates. Tests of homogeneity of variances were made and data from experiments combined in a comparison of different methods of extraction for several trace elements. A formula for the variance of the volume of fungal hyphae in soil was derived from length and diameter data. 6027, 6031, 8057, 8059

Soil Fertility. The regular collaboration in experimental design and the production of field plans has continued with a range of different designs in use for the current field experiment program. A service in the processing of the resulting data, statistical analysis and interpretation of results is also provided. 7038, 7039, 7040, 7041, 7042, 7048, 8057, 8059

Work has continued on the examination of regression relationships between crop response to added fertilizer and different laboratory measurements of soil phosphorus. A comparison of different methods of analysis by three laboratories on a set of 144 soils is being made to reach a uniform method of analysing advisory soil samples in Scotland. Linear regressions have been fitted to sets of data and plotted with the data points for all the properties, and this has been of considerable assistance in cleaning up the data for further analysis. 7041, 8057, 8058, 8059

Analysis of variance and regression methods have been applied to data on physical and chemical properties of plants and on growth rates in the

continuing study of the pattern of growth, mainly for barley crops. The results of the iterative fitting of exponential curves to barley yield and nitrogen fertilizer data for a group of experiments, conducted over a period of years, have been used in a joint account[3] submitted for publication. This work is continuing with further experiments and a method of fitting a series of two or more straight lines rather than a curve is also being applied.

7048, 8057, 8059

A joint account[4] of the results from two factorial experiments on grass with sulphur, nitrogen and potassium as factors has been published. Work has also been done on data from experiments with sulphur treatments on swedes and barley. Correlation analysis has continued in studies of the relationships between different chemical properties for a range of plants on several different sites. 7037, 7049, 8057, 8059

References

1. The application of soil survey data in opencast coal sites in Scotland. By J. H. Gauld and K. W. M. Brown. *Applied Geography*, **3**, 225-238, 1983.

2. Studies on active iron. By P. C. DeKock and R. H. E. Inkson. Submitted to *Ann. Bot.*

3. The nitrogen requirement of spring barley. By Peter W. Dyson, Ailsa C. Crowther and Robert H. E. Inkson. Submitted to *J. Sci. Food Agric.*

4. Response of grassland to the application of sulphur at two sites in north-east Scotland. By N. M. Scott, M. E. Watson, K. S. Caldwell and R. H. E. Inkson. *J. Sci. Food Agric.*, **34**, 357-361, 1983.

9. SOIL SURVEY

R. GRANT

The past year has seen the culmination of the Soil Survey's project to produce a series of soil maps, at 1:250 000 scale, covering the whole country, with a corresponding series of interpretative maps of land capability for agriculture. This project was commissioned in 1978 by the Department of Agriculture and Fisheries for Scotland on the recommendation of the Standing Committee on Rural Land Use in Scotland and work was started in 1979. The two sets of seven maps have been published and in March were given the honour of an official launch by the Minister of State at the Scottish Office, the Earl of Mansfield. The popular appreciation of the maps is reflected in the sales, to a wide range of customer, already approaching the 2000 mark.

Five of the descriptive handbooks to accompany the maps have been published; the two outstanding are in press.

With the completion of this project and the imminent replacement of the present Head on retirement, the Survey is undergoing a period or reorganisation and consolidation. Nonetheless, despite loss of staff and uncertainty about replacements, work has continued on the first priority task of completing the survey of the remaining sheet areas including important agricultural land. Some 1200 km^2 have been mapped. Work has also been carried out on the production of a new series of land capability for agriculture assessment maps in the priority areas requested by DAFS, using the revised classification. With the object of completing the medium scale soil map coverage of the whole of Scotland, a set of provisional maps at 1:50 000 is being prepared, based on the field-work carried out for the 1:250 000 survey. Progress on all of these maps is reported below.

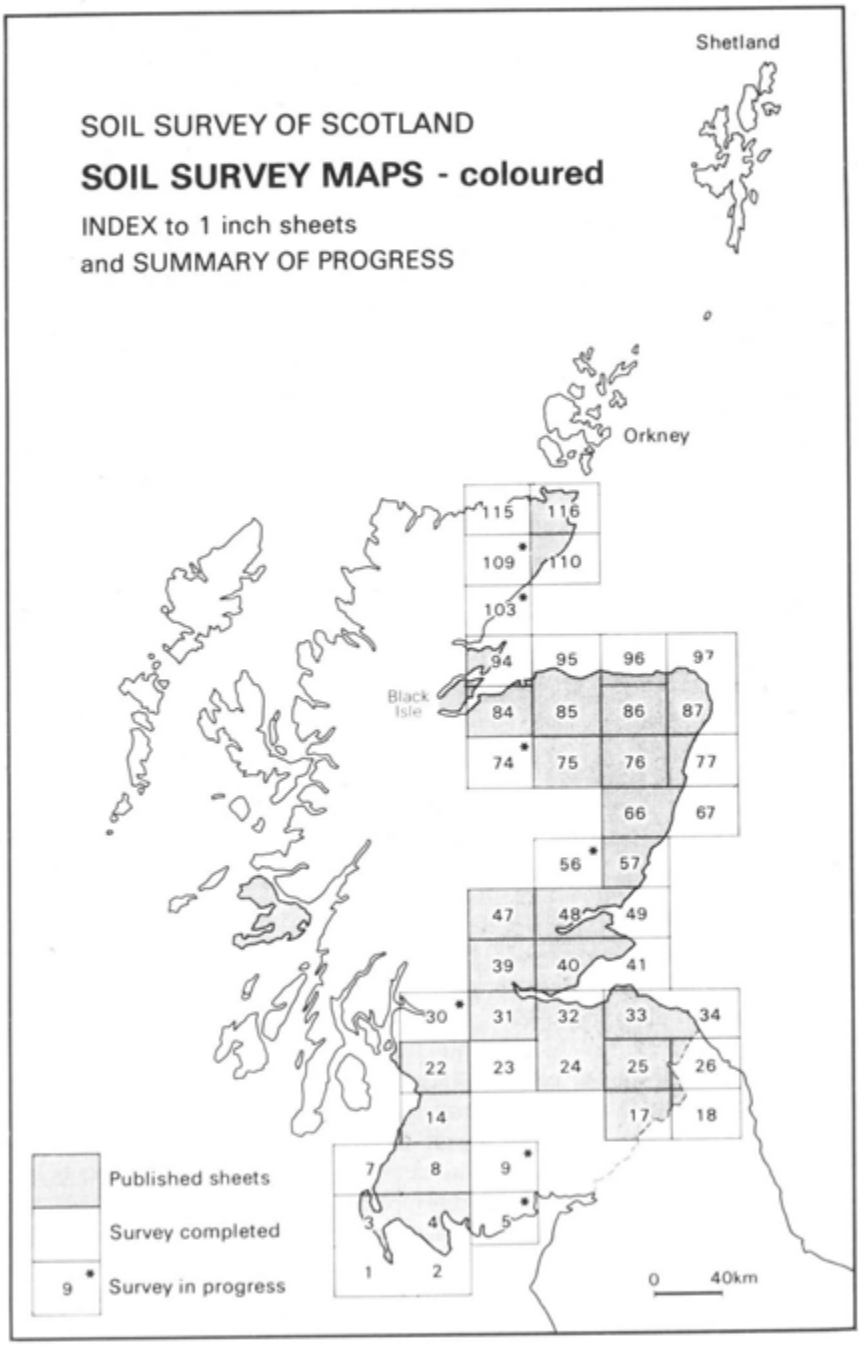
In addition to attendance at meetings abroad, listed elsewhere, members of staff have attended meetings of the British Society of Soil Science and the Hill Land Ecology Discussion Group. The Department has been represented on the DAFS Working Party on Hill Land Classification, the ARC Soil Survey Research Advisory Committee, the Ordnance Survey/Public Agencies Consultative Committee, the Scottish Agricultural Field Drainage Group and the MISR/COSAC Liaison Group.

The Soil Survey has welcomed the assistance of Ms Y. Geelan, Ms L. Schoot and Mr C. Pijs from the Agricultral University, Wageningen, who have spent three months attached to field parties to gain experience of soils and Soil Survey in Scotland.

Launch of new 1:250 000 scale maps and brochures. Lord Mansfield, Minster of State, addressing the press and invited guests in the auditorium of Craigiebuckler House. Professor West and Professor Keir look on from the left hand side.

Sheet 103 (Golspie)

Field-work during the period of this report concentrated on the completion of the hill ground, which accounts for most of the area; approximately 45 square kilometres were surveyed, 27 representative soil profiles were described and sampled and, in conjunction with the description of 20 soil inventory points (five of which were also sampled), previously surveyed land was revisited for the purpose of checking the map units and collecting further information on landforms and vegetation. Compilation of the final map legend is in progress and editing of the 1:25 000 field sheets for the production of the 1:63 360 soil map has begun. The remainder of the area, comprising the coastal lowland fringe, should be completed by the end of the 1983 field season.


Shetland
SOIL SURVEY OF SCOTLAND
SOIL SURVEY MAPS - coloured
INDEX to 1 inch sheets
and SUMMARY OF PROGRESS
Orkney
Black Isle
115
116
109
110
103
94
95
96
97
84
85
86
87
74
75
76
77
66
67
56
57
47
48
49
39
40
41
30
31
32
33
34
22
23
24
25
26
14
17
18
7
8
9
3
4
5
1
2
Published sheets
Survey completed
9
Survey in progress
0
40km

The area of hill land is underlain by Moinian and Old Red Sandstone rocks and there are two granitic masses. The Moinian rocks, dominantly quartz-granulites, form an undulating, mainly non-rocky, plateau. Nearer the coast, Lower and Middle Old Red Sandstone rocks, comprising sandstones and conglomerates with a local area of mudstones, form higher and more hilly ground. The Helmsdale granite forms a northern extension of this coastal range of hills, whereas the Rogart igneous complex, a zoned tonalite-granodiorite-granite body with outer migmatite complex, is geographically part of the Moinian plateau.

Apart from the drifts derived from mudstones, which have textures of silty loam or clay loam, all the soil parent materials have loamy sand or sandy loam textures and are stony. Many are indurated. Soils are predominantly peaty podzols, generally with a strongly gleyed E horizon above an iron pan, and peaty gleys, while organic soils are extensive.

Soils of the Arkaig Association are developed on drifts derived from the Moinian rocks. Common soil map units, described in previous reports, include the Pollie and Strathnaver Complexes, with the Assapol and Dalvina Complexes less common. Also common is a soil series, at present unnamed, comprising peaty podzols.

Soils developed on parent materials derived from the Lower and Middle Old Red Sandstone rocks have been separated into four soil associations. A mixed drift derived from sandstones and conglomerates, and often reddish in colour, gives rise to soils of the Berriedale Association. The main map unit is the Bogaig Complex, of peaty podzols and shallow peat found on non-rocky land with slopes in the gentle to moderately steep range.

The Kessock Association has been mapped on drifts derived predominantly from conglomerates. Such parent materials contain many Moinian stones and can resemble drifts of the Arkaig Association; many part of the conglomerate are, however, drift-free. Kessock Series (peaty podzols), Craggie Series (humus-iron podzols) and an unnamed series of subalpine podzols have been recognized, together with a number of new soil complexes of which a common one comprises peaty rankers and shallow peat on very rocky convex hills with slopes ranging from gentle to very steep.

Soils developed on drifts derived from sandstones of Lower and Middle Old Red Sandstone age have not yet been placed in a named soil association. The main map unit here is a complex of peaty podzols and shallow peat on non-rocky land with slopes up to moderately steep.

A small area of mudstones in Glen Loth has given rise to soils of the Braemore Association. Parent materials are reddish silty loams or clay loams and soils are brown forest soils, peaty podzols, peaty gleys and non-calcareous gleys.

The Countesswells Association occurs on the granite masses at Rogart and Helmsdale. On the Helmsdale mass, humus-iron podzols (Countesswells Series) occur extensively on the steep slopes bordering the narrow

coastal lowland fringe. Above, peaty podzols (Charr Series) are common, together with a complex of peaty podzols and shallow peat (Glutt Complex). At Rogart, brown forest soils are extensive on the lower ground, where they are mapped in a complex with rock outcrops.

Organic soils are widespread, mainly in the form of blanket peat of which shallow, deep and undifferentiated phases have been delineated, and cut-over areas indicated. Basin and valley peats have been mapped locally.

The vegetation of the area described comprises mainly moorland communities, the two dominant ones being moist Atlantic heather moor on peaty podzols, peaty gleys and shallow peat, and lowland blanket bog on deep peat. Dry Atlantic heather moor is less common and restricted generally to the steeper slopes. Common bog heather moor is common in the west of the area, but local elsewhere. On the higher hills, alpine azalea-lichen heath is present on the subalpine podzols, and mountain blanket bog on the peat. Grassland communities, associated with brown forest soils and humus-iron podzols, include acid bent-fescue grassland and meadow grass-bent pasture; bracken is commonly present and there are local areas of bracken scrub. 9012, 9013

Sheet 56 (Blairgowrie)

The systematic 1:63 360 soils and land capability for agriculture surveys of Sheet 56 (Blairgowrie) began this year. Approximately 250 km^2 have been surveyed and 24 profiles described and sampled. Mapping took place in three main areas, all of which lie in the eastern part of the sheet.

The first area lies in the north-east corner and comprises the valleys of Glen Clova, lower Glen Prosen and lower Glen Isla, together with the hill ridges between these valleys and the upland dissected plateau along the boundary with Sheet 57 (Forfar). In all valleys, the alluvial tracts vary in width, but despite the frequent occurrence of flooding, the land is amongst the most fertile in the area. The soils show little or no differentiation of pedologic horizons and comprise deep, dark brown loamy sands and loams. The internal drainage is generally imperfect. A complex arrangement of old meander channels is characterized by an infilling of poorly drained sand, with a thin silt band present at depths of 50 cm to 1 metre. Bordering the alluvial areas, spreads of fluvioglacial material, which form the parent material of the Corby and Boyndie Associations, are extensive, especially near Rottal in Glen Clova and on Pearsie Estate in lower Glen Prosen. The soils are mainly free-draining humus-iron podzols. On the lower concave slopes the soils are developed on a loam or sandy clay loam till derived from acid schists of the Strichen Association. Of particular interest is the sporadic occurrence of cultivated topsoil horizons on soils, previously under agriculture, but now supporting moorland communities. At the upper break of slope, the presence of series of spring lines results in the formation of poorly drained soils, which have been mapped as peaty gleys and flushed humic gleys. The complex arrangement of these soils may necessitate their mapping as a complex. Soils on the upper convex slopes are formed within a veneer of morainic drift overlying shattered rock.

Complexes of varying rock outcrop, rankers and podzols occupy parts of the hill summits or strongly glaciated upper hillslopes. Extensive hill peat occurs above 500 m, usually overlying a peaty podzol mineral profile with a well-developed iron pan. Associated with the hill peat on the upper plateau, north-west of Rottal Lodge, are the distinctive erosional pattern and isolated hill summits with subalpine soils.

Occupying the Highland Border Fault Zone, the second area extends south-east from Dykehead to the Loch of Lintrathen. In general, there is an intricate soil pattern with the array of parent materials being a consequence of the complex geology and glacial history of the area. On the highest land, shallow and stony soils of the Stonehaven Association are locally widespread, there being a variable thickness of colluvial drift overlying Lower Old Red Sandstone conglomerate rock. Slopes are often steep and their use is confined generally to rough grazing. A small area of soils developed on drift derived from porphyry has been provisionally included in the Knockskae Association. The soils of the Sourhope Association are of very limited extent, being developed on stony, loamy drift, which is frequently shallow. The most widespread association is the Gourdie, whose soils are mostly cultivated and freely or imperfectly drained. Such soils have been assigned to the brown forest soil subgroup, but podzolic soils have been identified and the latter may occupy a much greater area than previously anticipated.

The third district lies within the Vale of Strathmore, between Kirriemuir and Meigle, and includes the Dean Water flats and the undulating terrain around Craigton and Ruthven. All the soils mapped have been described previously. Most of the alluvium belongs to the Kaime Series, the imperfect drainage of the sandy subsoil resulting from the presence of silty clay or clay loam bands at depths between 75 and 125 cm. Peaty alluvial soils are associated with old meander channels and while intensive tile drains have tended to combat the poor internal drainage, such drainage schemes often suffer from iron ochre formation. On Arnbog and Drumkilbo farms soils of the Carpow and Carbrook Associations have been mapped along the margin of a denuded high terrace merging into the " 100 foot " raised beach. Soils of the Forfar and Balrownie Associations form an intricate pattern. The complex distribution of these and the alluvial soils was demonstrated during soil investigations along the B.P. gas pipeline installed between Kirriemuir and Meigle during the spring of 1983.

To the north of the Dean Water, some of the till deposits are overlain by fluvioglacial sands and gravels, the terrain being characterized by distinct undulations. 9012, 9013

Part Sheets 51, 52 and 53 (Ardnamurchan and Morvern)

The soil map was published in 1980 and field-work was completed this year by sampling 21 profiles and visiting 24 National Inventory points. 9012

Part Sheets 35, 36, 43, 44, 51 and 52 (Island of Mull)

Work, suspended during the 1:250 000 survey, was resumed this year on the memoir to accompany the published soil map. Samples were

collected from nine profiles, completing the soil sampling of the island and 37 National Inventory points were visited. 9012

Sheet 30 (Glasgow) and part Sheet 29 (Rothesay)

During the 1983 field season, priority has been given to this area and three field parties were engaged in its survey. The sheet is now complete and in the following account the field parties report individually.

North-West

Approximately 200 km^2 of soil and land capability mapping have been completed and 20 representative soil profiles sampled. All the associations encountered are described in previous annual reports and soil survey memoirs, though a full correlation has still to be undertaken.

One of the best known geological features of Scotland — the Highland Boundary Fault — traverses the area, separating the ancient metamorphic schists and slates of Dalradian age from the younger sediments and lavas of the Central Lowlands. Most of the soil parent materials owe their origin to glacial influences and comprise tills and fluvioglacial sands, gravels and silts. Raised beach, alluvial and organic parent materials are also represented.

To the north-west of the Fault the schists and slates give rise to soils of the Foudland Association developed on parent materials with a generally fine sandy loam texture. At lower altitudes the chief soils are poorly drained noncalcareous gleys (Fisherford Series), while shallow stony peaty gleys (Drumardoch Series) are prevalent on the hills, especially on the Rosneath peninsula and north of Helensburgh.

In the Central Lowlands soils of the Balrownie and Kippen Associations (parent materials derived from Lower and Upper Old Red Sandstone strata respectively) predominate. The texture of the unmodified tills is sandy clay loam, but widespread water-modification has resulted in a sandy loam or, in extreme cases, gravelly loamy sand texture. The most extensive soil of the Balrownie Association is the imperfectly drained brown forest soil (Balrownie Series) found mainly around Cardross and in the parish of Kilmarnock. The Kippen Association is also dominated by the imperfectly drained brown forest soil (Arnmore Series), mainly occurring between Alexandria and Croftamie. The peaty gley (Limpithill Series) has developed widely over the high rainfall areas of the Dumbarton and Cameron Muirs.

The Carboniferous rocks of the area have largely been overridden from the north by Old Red Sandstone drifts; however, north of Dumbarton the incorporation of Calciferous Sandstone shales has produced a red clay loam drift belonging to the Sorn Association. Due to the heavier textures the commonest soil is a poorly drained noncalcareous gley (Sorn Series). With increasing altitude an organic surface horizon becomes prevalent and the peaty gley (Weitshaw Series) is the main soil type of the moors.

Moundy fluvioglacial deposits are found in the valley of the Fruin Water where the sands and gravels derived from acid schists form the parent materials of the Corby Association, the humus-iron podzol (Corby Series)

constituting a major component of the main map unit, the Kildrummie Complex. In the valley of the Endrick Water a similar hummocky topography dissected by meltwater channels has sand, gravel and silt deposits derived from Lower Old Red Sandstone rocks giving rise to parent materials of the Carpow Association. The imperfectly drained brown forest soil (Carey Series) is the principal soil type. Nearby in Strathblane a level deposit of reddish brown silty clay, possibly of lacustrine origin, supports a poorly drained noncalcareous gley (Carbrook Series) of the Carbrook Association.

Raised beach terraces of sand and gravel of the Corby Association are seen on the southern tip of the Rosneath peninsula. Though most drainage classes are represented, the freely drained cultivated humus-iron podzol (Corby Series) predominates. Sands and gravels derived from Old Red Sandstone rocks (with some Dalradian schists) form raised beach terraces between Helensburgh and Dumbarton. Since sandy clay loam till often underlies these deposits, drainage is impeded and the main soil type is a poorly drained noncalcareous gley of the Panbride Association.

Alluvial soils cover only small areas and reach their maximum extent along the Endrick and Fruin Waters. The flood plains consist of loamy alluvium, freely drained (Peebles Series) in the former instance and imperfectly drained (Traquair Series) in the latter. Some low-lying hollows of alluvium interstratified with peat have been distinguished as peat-alluvium complex.

The major organic deposits are the blanket peat tracts of Stockie and Dumbarton Muirs, occurring on gently sloping terrain between 200 m and 300 m. Small hollows of basin peat are present throughout the low ground, the largest of these being near Caldarvan.

Climate imposes marked limitations on agricultural capability and in this area restricts even the most favourable soils to Class 3. These soils consist chiefly of the Corby, Balrownie and Arnmore Series around Rosneath, Gartocharn and Jamestown respectively. The aforementioned series are occasionally assigned to Class 4 because of steepness or shallowness. Soils of the Fisherford Series are similiarly considered as Class 4 land on account of greater workability problems engendered by their finer texture and poor drainage. Some mineral soils (e.g. Carey Series) occur on such irregular topography that they are placed in Class 5. Peaty gleys at moderate altitudes which are neither too steep or wet to preclude mechanized improvement are also included in Class 5. The northern footslopes of the Kilpatrick Hills provide such areas on Limpithill Series as does the Rosneath peninsula on Drumardoch Series. Class 6 is represented mainly by the blanket peat areas of the more exposed moors of the northern Kilpatrick Hills. In addition, there are local steep slopes in most of the soil map units that preclude cultivations or improvements.

Present land use is chiefly as grassland where stock-rearing and dairying are the main pursuits. Afforestation of less favourable agricultural areas is increasing, but much hill ground remains as rough grazing land with some grouse moors. 9012, 9013

North-East

An area of approximately 80 km² has been surveyed to the north of Glasgow.

The land to the north and west of Milngavie is dominated by soils of the Darleith Association, while the areas to the east of Duntocher, Milngavie and Strathblane have soils of the Rowanhill, Giffnock and Kilmarnock Associations.

The parent material of the Darleith Association is derived from basic igneous rocks of Carboniferous age. In this area the underlying rock strongly influences the landscape, resulting in an undulating or terraced topography. This has led to a consideration of soil complexes as the basic mapping units in the area. Three such complexes have been recognized:

(i) undulating topography with gentle to moderate slopes and occasional rock outcrops. The soils associated with the knolls are generally shallow, free draining brown forest soils, humus-iron podzols and rankers. In the intervening hollows the soils are mainly imperfectly drained noncalcareous gleys developed on colluvium. This unit has been provisionally correlated with an area of complex around Kilmacolm, Renfrew District.

(ii) ridged and hilly, moderately rocky topography with some steep rocky slopes. Brown forest soils and humus-iron podzols occur on the slopes and poorly drained noncalcareous gleys and humic gleys with some peaty gleys and peat occur in the intervening flats and hollows. This unit has also been correlated with an area of similar topography in the Marshall Moor area.

(iii) steeply sloping, often stepped and slightly rocky to rocky areas with brown forest soils, humus-iron podzols, rankers and rock with poorly draining noncalcareous gleys and humic gleys in flushes. This complex correlates well with the already established Knockan and Bennane Complexes.

The parent material of the Rowanhill Association is a till derived from Carboniferous age sediments and is mainly to be found around Duntocher and Bardowie.

The dominant soils of the association are imperfectly drained noncalcareous gleys (Caprington Series) which are derived from a brown to dark brown, sandy clay loam or clay loam till. The undulating till ridges and drumlins have gentle to strong slopes. Where the topography is more subdued, poorly drained noncalcareous gleys of the Rowanhill Series occur. In low-lying areas and between drumlinoid ridges, where the till has been modified by meltwater, imperfectly drained brown forest soils of the Macmerry Series are found. These soils have sandy loam or loam upper horizons overlying the unmodified till.

The drift comprising the Giffnock Association is derived mainly from sandstones of Carboniferous age. The dominant mapping unit of this association is the provisionally named Craigmaddie Complex. This complex is confined to the areas known as Craigmaddie, Craigend, Muirhouse and Blairskaith Muirs, occurring where the moderately dipping sandstone beds give rise to a stepped landscape with numerous rocky knolls. The component soils of this unit are freely drained brown forest soils, humus-

iron podzols and rankers, on rock, with peaty gleys and peaty podzols in the partially colluvium-filled hollows. Shallow peat occurs locally within this unit.

In areas where brown, sandy clay loam till occurs, both poorly drained and imperfectly drained noncalcareous gleys are found (Giffnock and Aberdona Series respectively).

The soils of the Kilmarnock Association are developed on a mixed till of Carboniferous age sediments and basic igneous rocks. The till forms a gently undulating landscape with some steep-sided drumlins and is generally reddish-brown with a sandy clay loam texture. The dominant soils are imperfectly drained noncalcareous gleys (Kilmarnock Series). In an area east of Strathblane, the Brownrigg Series has been mapped. These soils are noncalcareous gleys with partially sorted upper horizons.

Areas of poorly drained, silty alluvium (Bindal Series) have been delineated, while peat and fluvioglacial deposits occur locally.

Much of the area is considered to be of land capability Classes 3 and 4, with the main limitations being workability (due to the high rainfall in the area and slowly permeable subsoils) and pattern. Areas of Classes 5 and 6 are found on the more exposed moors and hills where pattern and wetness are the dominant limitations. 9012, 9013

South

The systematic 1:63 360 soils and land capability for agriculture survey of Sheet 30 (Glasgow) and part Sheet 29 (Rothesay) started this year.

The southern section of this area is bounded to the north by the Firth of Clyde and Glasgow City and extends south to Largs on the west coast and to Rutherglen in the east.

Approximately 550 km^2 have been surveyed of which approximately 180 km^2 were regarded as Built-Up Area.

The lowland area to the south and west of Glasgow is dominated by soils of the Rowanhill Association, and by an area provisionally mapped as Dreghorn Association. Further west the land is more broken and rock-controlled, soils of the Darleith Association being dominant, with a smaller area of Lanfine Association soils mapped in the Netherton area, east of Langbank. The coastal fringe north of Largs is occupied by soils of the Largs Association, while hill peat covers much of the higher plateau.

The soils of the Rowanhill Association occur in undulating topography and are developed on drifts derived from sediments of Carboniferous age. The drift is generally of clay loam or loam texture and the principal soils are imperfectly drained noncalcareous gleys (Caprington Series) with some poorly drained noncalcareous gleys (Rowanhill Series).

The level low-lying land between Renfrew and Houston, south to Linwood and north toward Bishopton, is considered to be an area of raised beach deposits, derived mainly from Carboniferous age sediments, with a very fine sandy loam to silty loam texture. These deposits are provisionally mapped as the parent material of the Dreghorn Association, the dominant

soils being imperfectly drained noncalcareous gleys (Peffer Series). Small, well-defined areas of basin peat overlying raised beach deposits were mapped, for example at Barrochan Moss and Linwood Moss, and were found to have very sharp boundaries, often along fences, suggesting that peat was once more extensive.

The soils of the Darleith Association are developed on drifts derived from basic igneous rocks of Carboniferous age, with topography ranging from gently undulating lowlands to hills with steep slopes, and from non-rocky to rocky. In some areas the nature of the parent material bore affinities to that of the Sourhope Association.

The principal soils of the Darleith Association are the imperfectly drained noncalcareous gley (Dunlop Series) and the freely drained brown forest soil (Darleith Series), with small pockets of the poorly drained non-calcareous gley (Amlaird Series). Due to the patterns of soils and their close relation to the rock-controlled topography, complex mapping units were delineated over much of the area. A range of textures was encountered varying from clay loam or sandy clay loam in those soils developed on glacial drifts, (e.g. Amlaird and Dunlop Series), to loams or sandy loams in those soils developed on locally derived thin drift or colluvium (e.g. Darleith Series and Glenaros Series).

Seven complex units were mapped:

(i) gently undulating rock-controlled lowland areas with brown rankers and occasional small rock outcrops on the tops of knolls, freely drained brown forest soils on the slopes, and imperfectly draining noncalcareous gleys with some peaty and humic gleys in the intervening hollows. This complex extends over a large area in Renfrew District and was provisionally named the Kilmacolm Complex.

(ii) steeply sloping, often stepped and slightly rocky to rocky areas with brown forest soils dominant and brown rankers, imperfectly and poorly draining noncalcareous gleys, humic gleys in flushes, and rock outcrops. This complex of soils correlates well with the already established Knockan Complex and Bennane Complex mapping units.

(iii) strongly undulating moderately rocky topography with peaty podzols, brown forest soils and intergrades on the steep slopes, peaty gleys on the lower slopes and occasional areas of peat or peat-alluvium in the intervening hollows. This unit has been mapped in the area around Loch Thom in the Inverclyde District.

(iv) gently undulating but ridged, non- to slightly rocky topography generally over 200 m above sea level with peaty gleys and peat with some peaty podzols, peaty rankers and rock outcrops. This unit was mapped on the slopes surrounding Misty Law and appears to have affinities with the previously mapped Cruchan Complex and Pinverains Complex.

(v) ridged and hilly, moderately rocky topography with some steep rocky slopes. Brown forest soils and humus-iron podzols with some rankers occur on the slopes, and poorly drained noncalcareous gleys and humic

gleys with some peaty gleys and peat occur in the intervening flats and hollows. This unit was mapped in the Marshall Moor area and has some affinities with Craig Complex as mapped on Sheets 7 and 8.

(vi) a small area of moundy morainic deposits with humus-iron podzols on the steeper slopes and humic and peaty gleys in the hollows was mapped on the eastern slopes of Queenside Muir above the River Calder. This unit is analogous to the Dalvina Complex of the Arkaig Association.

(vii) gently undulating non-rocky but rock-controlled topography with peaty gleys and peaty rankers and some brown forest soils and podzols. This unit was mapped on the south-western flanks of Whitelees Moor.

The soils of the Lanfine Association, developed on drifts derived from sediments mainly of O.R.S. age and basic igneous rocks, were confined to an area of drumlinoid topography near Netherton, and were mapped as imperfectly drained noncalcareous gleys (Lanfine Series) with a sandy clay loam to loam texture. The O.R.S. sandstone component of the glacial drift originates from rock outcrops north of the Clyde and this, together with the orientation of the drumlins, substantiates the established theory that the ice moved in a north-west to south-easterly direction.

The soils of the Largs Association are developed on drifts with sandy clay loam to sandy loam textures and derived from Upper and Lower O.R.S. sediments. They were mapped between Largs and Inverkip along the Clyde coast and east to Noddsdale Water. The Association is dominated by imperfectly drained brown forest soils (Largs Series), with small areas of poorly drained noncalcareous gleys (Kelburn Series) in depressions. Freely drained brown forest soils were identified but could not be delineated as they occurred in small irregular patches on the steeper slopes or where the glacial drift was shallow and/or of a coarser (sandy loam) texture. Imperfectly drained peaty podzols (Haupland Series) and poorly drained peaty gleys (Reoch Series) were mapped on the higher slopes.

Soils of the Sorn Association, developed on drifts derived from Carboniferous and O.R.S. sediments have been encountered east of Inverkip, the principal soil being the imperfectly drained noncalcareous gley (Glenpark Series).

Hill peat, much of it hagged, is extensively developed on the plateau areas to the west of Kilmacolm and Lochwinnoch, notably Duchal Moor, Queenside Muir and Ferret of Keith Moor.

Arable farming is practised principally in the area bounded to the east by the urban fringe of Glasgow and to the west by the Kilmacolm and Lochwinnoch areas, and also in the area between Largs and Gourock which is confined between the coast and the foothills of the plateau area.

Between Renfrew and Bridge of Weir the land is considered as Class 3. The imperfectly drained very fine sandy loam to silty loams of the provisionally mapped Dreghorn Association are capable of producing good yields of a narrow range of crops, the main limitations being climate and wetness. Structural stability in these soils is not considered to be a limiting factor under the type of management already dictated by the climate and wetness limitations.

In Kilmacolm area climatic considerations limit the land to Class 4·1—suitable for enterprises based primarily on glassland with short arable breaks, the main limitations other than climate being the pattern of soils and slopes. As the land rises and becomes more broken and rock-controlled, with occasional steep slopes and wetter soils, the land is classed as 4·2.

Further west increasing rainfall and exposure limit the land to Class 5, the division being determined by the degree to which patterns of soil, wetness or slopes affect grassland management.

The plateau area, generally above 225 m, is restricted by climate to Class 6, and mainly to division 3 by the moorland plant communities growing on peat and wet peaty soils.

Along the west coast there is a narrow band of Class 3·1 land downgraded to 3·2 in areas where the slope or pattern of slopes is too severe. There are equally narrow bands of Class 4 and 5 land rising to the Class 6 land of Ferret of Keith Moor.

Very steep hill and valley slopes were mapped as Class 6·1, e.g. the slopes on the east side of Noddsdale Water. 9012, 9013

Sheet 23 (Hamilton)

Approximately 85 square kilometres were surveyed around the Douglas Water, to the east of the A74 and to the south of the A70. The 1:63 360 soil mapping programme for Sheet 23 (Hamilton) is now complete.

The area mapped can be considered in three physiographic units: the valley of the Douglas Water, the undulating till-covered lowlands to the north-west of the small mining village of Douglas Water, and the hill ground to the south.

The valley bottom of the Douglas Water is occupied by alluvium, dominantly freely drained with a loamy texture (Peebles Series) while extensive deposits of sands and gravels occur on the valley sides and on the broad expanse of flood plain south of Lanark. To the north-east of the village the sands and gravels have a high content of sandstones of Old Red Sandstone age and are considered as comprising the parent materials of the Eckford Association; in general, the gravel content is low. The dominant soil series is the Eckford Series, a freely drained brown forest soil. To the south of the village, however, the sands and gravels are dominated by material of Carboniferous age and are mapped as the parent materials of the Darvel Association; again the principal soil is a freely drained brown forest soil, the Darvel Series.

The lowlands to the north-west of Douglas Water are dominated by the soils of two principal soil associations, the Sorn and the Giffnock Associations. The Sorn Association comprises soils developed on tills derived from sediments of Old Red Sandstone and Carboniferous age, while the parent materials of the Giffnock Association consist of tills derived mainly from sandstones of Carboniferous age. There is much evidence of water-modification of the till deposits and large areas of the imperfectly drained

Quothquan and Kennet Series have been mapped, the distribution of these soils being closely related to the present-day valleys of the Douglas Water and its tributaries. The soils become finer-textured and wetter towards the west and the A74 with the landscape being now dominated by poorly drained soils of the Giffnock and Scaurs Series. The area of Broken Cross Muir is dominated by the humus-iron podzol (Bath Moor Series) of the Giffnock Association. An area of basin peat has been mapped immediately to the north-west of the farm of Redshead: the peat deposits are presently being harvested for horticultural purposes.

The hill ground to the south of the Douglas Water consists mainly of soils of the Sourhope Association — soils developed on drifts derived from andesitic lavas.

The steepest hill and valley slopes are dominated by freely drained brown forest soils (Sourhope Series) with minor areas of Frandy Series (humus-iron podzols) and local brown rankers. On the more exposed and less severely sloping upper slopes and hill tops the landscape becomes dominated by peaty podzols (Cowie Series) and poorly drained gley soils, the Atton and Edgerston Series; small areas of peat occur locally.

Much of the arable land of the surveyed area is considered as Class 4— land that is suitable for enterprises based primarily on grass land with short arable breaks. Climate exerts a profound influence on farming practices, while in the more climatically favoured areas — in the vicinity of Lanark for example — the moundy nature of the landscape, a landscape dominated by sands and gravels, results in an overall downgrading to Class 4.

Broken Cross Muir and the hill ground to the south can be largely considered as Class 5 — land on which the grazing potential can be improved by mechanical means, but land that is not suitable for arable cropping apart from the occasional pioneer forage crop.

With the completion of the soil mapping programme, clean copies of field sheets and a soil map key were produced. The 1:63 360 soils map of Sheet 23 (Hamilton) is now in its final stages of production. 9012, 9013

Sheets 5 and 9 (Kirkcudbright and Maxwelltown)

Detailed survey in south-west Scotland has been resumed after the hiatus for the 1:250 000 mapping programme, with a total of 170 km² being surveyed in three areas.

The largest area, approximately 100 km², lies between the coastal villages of Auchencairn and Caulkerbush and extends inland to Dalbeattie. East of the valley of the Urr Water, in an area underlain by the Criffel-Dalbeattie granitic intrusion, intense glacial erosion has created a rugged landscape with abundant rock knolls. The soils, predominantly brown forest soils with some brown rankers, have been assigned to the Dalbeattie Association, with Aerie Complex being mapped extensively. This land is mostly improvable grassland, being too broken and bouldery to be cultivated regularly, while the bent-fescue vegetation of the rockier land provides good quality rough grazings. A large proportion of this area is afforested. Most

of the land lies below 100 m but on the higher hills, such as Bainloch Hill which rises to 280 m, soils with peaty surface horizons, mainly peaty podzols, occur and Loch Fleet and Garrary Complexes have been identified.

South-west of Dalbeattie a similar although often somewhat less rocky terrain occurs, but the underlying rocks here, Silurian greywackes with shales, give rise to soils of the Ettrick Association. Below 250 m freely draining brown forest soils are predominant and areas of the Linhope Series and Achie Complex are widespread. Above this altitude peaty gleys, peaty podzols and peaty rankers are abundant, rocky hills such as the prominent Screel Hill being mapped as Darnaw Complex.

Along the sheltered valley of the Urr Water, between Kippford and Dalbeattie, grey stone-free estuarine deposits carry soils of the Stirling Association, poorly drained gleys with textures mainly silty clay loam or silty clay. To the west, around Auchencairn Bay, low raised beach deposits are more coarse-textured, from silty loam to loamy sand. High raised beach gravels, occurring as localized coastal terraces, have been placed in the Yarrow Association, as for example at Rockcliffe.

A further 60 km^2 have been mapped in a belt stretching from Crocketford to Moniaive, an area underlain by Silurian greywackes and shales. Outcropping rock is widespread, but there is a substantial amount of rock-free terrain, including rock-controlled moundy topography and drift-covered hill slopes. A number of soil series and complexes of the Ettrick Association, all previously mapped, have been distinguished in this area, but the Linhope Series developed on stony sandy loam drift is the most widespread.

West of Shawhead reddish brown clayey till, deposited as drumlins, carries brown forest soils with imperfect drainage.

Alluvial and fluvioglacial gravel terrace on the valley bottom, accompanied by very stony, locally water-modified drift on the adjoining slopes, occupy the valley of the Cairn Water near Dunscore.

About 10 km^2 were surveyed between the villages of Haugh of Urr and Springholm. This is an area of classic drumlin topography with drumlins composed of a reddish brown till interspersed with pockets of shallow drift and rock. 9012, 9013

Land Capability for Agriculture 1:50 000

Sheet 38 (Aberdeen)

A draft map has been prepared with all land being assigned to a class, a division and a limitation type. Consultations on the interpretations are now in progress with DAFS and North of Scotland College of Agriculture staff.

Sheet 66 (Edinburgh)

A map, part of the programme to up-date existing Land Use Capability maps in accordance with the Land Capability for Agriculture guidelines of Bibby *et al.* (1982)[1], has been produced. The map is presently in its second draft and thanks are due to DAFS and the East of Scotland College of Agriculture for their co-operation and enthusiastic responses in the preparation of the map.

The map shows the distribution of land capability classes and divisions over an area of land extending from Edinburgh in the west to Haddington in the east and from Burntisland in Fife to the foothills of the Moorfoot Hills in the south.

Sheet 65 (Falkirk)

Sheet 65 represents the area immediately west of Sheet 66, extending from Edinburgh to near Cumbernauld in the west and from Cowie in the north to Carluke in the south. The map is presently in its first draft.

Sheet 70 (Ayr and Kilmarnock)

As part of the national project to prepare 1:50 000 maps based on the modified Land Capability Classification for Agriculture (Bibby *et al.* 1982), the soils of third edition Sheets 14 (Ayr) and 22 (Kilmarnock) were reassessed. Climatic data were assembled and integrated with soil parameters to formulate the capability classes and divisions. A draft map was prepared and consultations with the Department of Agriculture and Fisheries for Scotland and the West of Scotland Agricultural College were initiated.

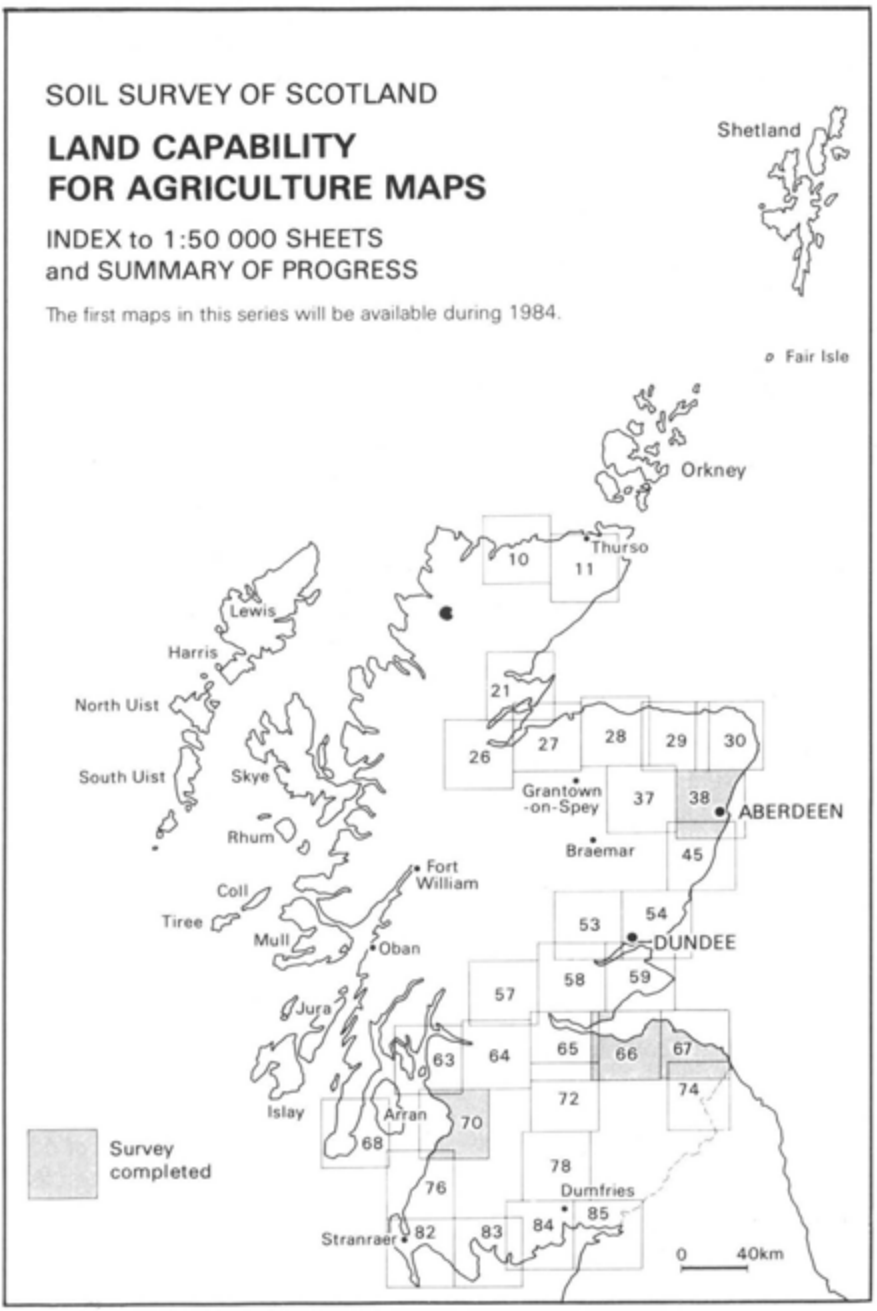
During field-work 43 National Inventory points were sampled, forming a brief introduction to the soils and landforms. Additional sites at selected farms were also examined. Particular attention was given to the best agricultural land, which occurs on the alluvium and raised beaches and on the gleyed brown forest soils. The noncalcareous gleys were also examined. The texture and drainage class of the alluvial soils were recorded in the larger areas and interpreted from aerial photographs in smaller alluvial straths and hollows. The brown forest soils, comprising 18 soil series, were grouped by texture into six categories for Land Capability assessments. Class 2 is confined to the Dreghorn Series and some alluvial soils. The bulk of Class 3 occurs below the 1000 mm rainfall isohyet extending up to the 1200 mm isohyet only on lighter-textured soils. Class 4 is restricted to the noncalcareous gleys and, in higher rainfall areas, to brown forest soils with gleying. Classes 5 and 6 are principally found where rainfall exceeds 1200 mm. 9013

1:50 000 Provisional Soil Map Series

Designed to complete medium-scale soil map coverage of Scotland, these maps are based on the field work carried out for the 1:250 000 survey. The map units have been stored in a small database from which individual map keys can be quickly extracted. So far, 14 maps out of a total of 53 in Scotland have been compiled, mostly in the west of Scotland. 9012

National Soils Inventory

Soil profile descriptions have been collected from a further 364 5 km National Grid intersect points, with samples from the 10 km intersects. Forty-three of these were from Sutherland and Caithness, 79 from the Moray Lowlands from Portgordon and Strathbogie to Inverness and Foyers with a further 10 from the Spey Valley and the Monadhliath Mountains to


SOIL SURVEY OF SCOTLAND
LAND CAPABILITY
FOR AGRICULTURE MAPS
INDEX to 1:50 000 SHEETS
and SUMMARY OF PROGRESS
The first maps in this series will be available during 1984.
Shetland
Fair Isle
Orkney
Thurso
10
11
Lewis
Harris
North Uist
South Uist
Skye
Rhum
Coll
Tiree
Mull
21
26
27
28
29
30
Grantown
-on-Spey
37
38
ABERDEEN
Braemar
45
Fort
William
Oban
53
54
DUNDEE
57
58
59
Jura
63
64
65
66
67
72
74
Islay
Arran
70
68
78
76
Dumfries
85
Stranraer
82
83
84
Survey
completed
0
40km

SOIL SURVEY OF SCOTLAND

SOIL SURVEY MAPS - provisional

INDEX to 1:50 000 SHEETS

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

*indicates part sheet

o Fair Isle

the north of Kingussie. The 37 from the Island of Mull and 24 from Ardnamurchan complete the Inventory for the Oban office area. 90 points were visited in Aberdeenshire, Kincardine and Angus and 43 in Ayrshire. This brings the total to 1619, 1218 of which have been included in the Institute's soil data base. 9012, 1802/8802

Vegetation Surveys

Descriptions of the vegetation and plant communities for inclusion in the 1:250 000 regional handbooks were completed and corrected for publication.

Standard survey of the natural and semi-natural vegetation of Sheets 30 (Glasgow), 56 (Blairgowrie) and 74 (Grantown-on-Spey) to establish relationships between plant communities and soils occupied a greater part of the year. Prominent communities recorded in these areas are the alpine azalea-lichen heaths on the summits of the Monadhliaths (74), the widespread juniper scrub on the slopes of the Spey valley (74), the limestone heaths and grasslands in the Angus glens (56) and the extensive sharp-flowered rush pastures on the flushed lower hill slopes of the west (30).

The experiment on heather regeneration in Glen Artney, Perthshire, was continued for a fourth year to obtain more comprehensive results and the report is now in preparation.

A special survey of the vegetation of the Gargunnock and Touch Hills and the Campsie Fells was carried out at the request of the Department of Agriculture for Scotland as part of an experiment in developing a structure plan for that area. The survey was based on aerial photograph interpretation with limited ground checking and a 1:25 000 map was produced as a transparent overlay.

Joint training meetings with DAFS Lands Branch officers have continued with field trips to study hill grazings in relation to bracken infestation, forestry and farm structure problems.

A paper on vegetation survey and mapping in Scotland has been published[2] and a joint paper on soils and their related plant communities on the Dalradian Limestone in Central Perthshire has been prepared for publication[3]. A paper on the species-rich scrub of Orkney has been published[4]. 9015, 9016

Due to staff reduction, it has proved necessary to limit the amount of soil thin section preparation carried out during the current year. However, soil thin sections have been prepared not only for micromorphological investigations within the Soil Survey Department, but at the request of the Departments of Mineral Soils, Microbiology, Spectrochemistry and Peat and Forest Soils.

Outwith the Institute a limited number of additional thin sections have been prepared for the Scottish Crop Research Institute in connection with nematode studies, and a short joint note, describing a micromorphological technique for studying the micro-distribution of nematodes in undisturbed

soils materials has been published[5]. At the request of the Scottish Development Department, Central Excavation Unit, soil thin sections were prepared to assist with archaeological investigations of a plaggen soil at the site of Iona Abbey.

In collaboration with Mr R. Connel, University of Aberdeen, the site at Kirkhill Quarry, near Mintlaw, Aberdeenshire, has been investigated further, and detailed micromorphological sampling completed. Previous examination of soil thin sections prepared from the 6·5 m exposure on the north face of the quarry, showing a sequence of fluvioglacial sand, tills and solifluction deposits has confirmed the presence of more than one palaeosol. The upper portion of the 8·5 m exposure on the south face of the quarry, which was previously inaccessible has now been sampled in detail, and micromorphological examination of soil thin sections prepared is being carried out, in an attempt to shed further light on the detailed stratigraphy of this unique site.

A joint paper on Optical, Scanning Electron Microscopic and Micro-analytical Study of Cementation in some podzols, presented by Dr W. J. McHardy at the Second Workshop of the International Working Group on Submicroscopy of Undisturbed Soil Materials, in Poitiers, France, in 1981, has now been published[6].

A paper entitled "The Environment of North Britain: Soils[7]" was presented at a conference on "Settlement in North Britain 1000 B.C.-A.D. 1000" held at the University of Newcastle upon Tyne in December, 1982, and has been published as part of a British Archaeological Research Report. An outline of the present day zonal sequence of soils in Scotland, with comments on the modifying effects of latitude, climate and soil parent material was presented, and some of the micromorphological features which have been found useful in the interpretation of buried prehistoric soils were discussed. These latter features include stone-rim weathering, patterns of oriented clay-lined pores, and the distribution of fossil spore cases of vesicular arbuscular mycorrhizae.

A paper on the general effects of early agriculture on the soil profile[8], presented at a symposium on the Impact of Aerial Reconnaissance on Archaeology, held at the University of Nottingham in December, 1980, is expected to be published in the near future.

At the request of the Department of Spectrochemistry, soil thin sections have been prepared for concretions derived from Australian podzols, in which the cementing material is believed to be proto-imogolite allophane. Micromorphological examination of the cementing material showed it to be only weakly anistropic under crossed polarized light, and fluorescent under ultra-violet light. A clearly defined layered micro-structure suggests deposition under successive drying episodes. A joint paper describing these features, and proposing that a proto-imogolite sol is the mobile phase that deposits Al and Si in these concretions, has been accepted by the Journal of Soil Science[9]. 9014, 3005

Collaboration with the Department of Microbiology on the macro- and micro-porosity of undisturbed soil materials has continued, and a system of

categorizing the micro-pore size distribution of selected soil materials has been further investigated, using serially-ground resin impregnated soil blocks. Results produced to date are currently being compared with results obtained using back-scattered scanning electron microscopy techniques and image analyses methods, and a paper describing these methods is in preparation. 9014, 6031

As an aid to the quantitative measurement of porosity and soil microstructure in general, the use of a relatively inexpensive Apple microcomputer and digitizing tablet has been investigated. Area measurements of two dimensional irregular shapes may be carried out, and with additional and modification to the supplied software, multi-area analysis on a percentage area basis may be carried out on simple source documents or photomicrographs.

Hardware modifications have been made, which greatly improve the ease with which such measurements may be made, and with the addition of a camera lucida attachment and specially designed flat-bed cursor with illuminated disc, permit micromorphological area measurements to be carried out on soil thin sections, while simultaneously viewing the microscope image directly. A paper discussing these techniques, describing the software and hardware modification and comparing the accuracy and efficiency of the method with more traditional area measurement techniques has been prepared[10].

Data Processing

Additional software and hardware have been acquired for the Department's Apple micro-computers, enabling software written for the CP/M-80 operating system to be used. A relational database system has been purchased (CP/M based), and is being used for several applications, including cataloguing of the Soil Monolith Library and micromorphologically related soil profile data.

A trial database, containing references and short abstracts of published micromorphological papers is being assembled, and is proving to be very efficient in terms of search and access facilities. It is likely that this system may well replace the more conventional card-index systems used at present, although the existing mass storage system available at present, could prove inadequate in some applications. To facilitate preparation of map keys for the new 1 : 50 000 series of soil maps being prepared, a database system has been set up which will contain all relevant information for the *ca.* 800 soil units and sub-units required. From this general database it is possible to choose a selection of map unit descriptions corresponding to an individual map, and to print out completely pre-formatted, camera ready map keys for each of the 53 1 : 50 000 maps being prepared. This will reduce considerably the cartographic effort required to prepare these documents.

Multi-area analyses using a digitizing tablet, coupled to a microcomputer, has been discussed under "Soil Micromorphology," and the techniques have proved to be of use where area and distance measurements

require to be derived from single soil and related maps. Software modifications have been carried out to enable such measurements to be stored on magnetic disc, while subsequent processing will produce on request, values for the total area of each map unit type, expressed as a percentage of the total map area considered. In many cases this system has considerable advantages over the more traditional planimetric methods. 9014, 9012, 9013

Other Work

Collaboration has continued at a highly satisfactory level with the Lands Branch of DAFS in the assessment of land capability for agriculture for map production and assistance has been given in respect of such assessments for a number of planning inquiries. Co-operation has also continued with DAFS and the National Coal Board concerning the reinstatement of existing and proposed open-cast extraction sites.

Collaboration with the three Scottish Agricultural Colleges has been maintained, locally in consultations on land capability assessments and the provision of soils information for drainage and reclamation schemes, and also through subgroups of the MISR/COSAC Liaison Group dealing with the provision of appropriate Soil Survey literature and the production of trace element distribution maps.

There has been continued co-operation with the Scottish Institute of Agricultural Engineering, particularly in the field texturing of soil samples, with the Scottish Crop Research Institute in supplying soil samples for a nematode census, and with the Hill Farming Research Organisation, the Forestry Commission, the Nature Conservancy Council and the National Farmers' Union of Scotland.

Within the Institute, collaboration with other Departments has continued, with the collection of soil and stream water samples for the Departments of Mineral Soils, Spectrochemistry and Soil Organic Matter for specific investigations, with the Department of Microbiology on exploration of techniques for examining microporosity of selected soils, and with the Department of Statistics in the compilation of the Institute soil data base. Excursions to demonstrate soils in the field have also been arranged.

The Survey has provided the convener of the Ochre Group set up in the Institute to co-ordinate the inter-departmental work concerned with the amelioration of the blockage of field drains by iron ochre, and supplied the transport to service the experimental sites producing data for the work in areas ranging from Aberdeenshire to Kintyre. 9012, 1801/4801/6801/9801

Assistance has been given to a number of Regional and District Councils, notably Grampian Region, in site investigations for the Lecht Ski Development Project, Highland Region on the A9 realignment and Argyll and Bute District Council with the Kintyre Local Plan.

Field demonstrations and talks on the work of the Soil Survey have been provided for various departments of Universities and Colleges and other parties of visitors to the Institute. Many requests for soils information

have been dealt with, from farmers and a widening range of other users, planners, developers, land agents, manufacturers to undergraduates and school pupils.

Professor J. S. Bibby has continued his role as visiting professor to Strathclyde University and Mr J. S. Robertson served as external tutor to the Department of Biological Sciences, University of Dundee.

Exhibits of maps and other publications have been prepared and manned for the Royal Highland Show, the Turriff, Black Isle and Keith Agricultural Shows and a number of relevant conferences and meetings. These were well received and succeeded in their purpose of increasing public awareness and interest in the work of the Soil Survey.

Papers on the soils of the Inner Hebrides[11], the application of soil survey data in opencast coal sites in Scotland[12], soils and related management problems in the Carses of Gowrie and Earn[13], and a chapter on the soils of Sutherland[14] have been published. A chapter on the soils has been written for inclusion in a Nature Reserve Record[15].

9012, 9013, 9014, 9015, 9016

Maps, Memoirs and Cartography

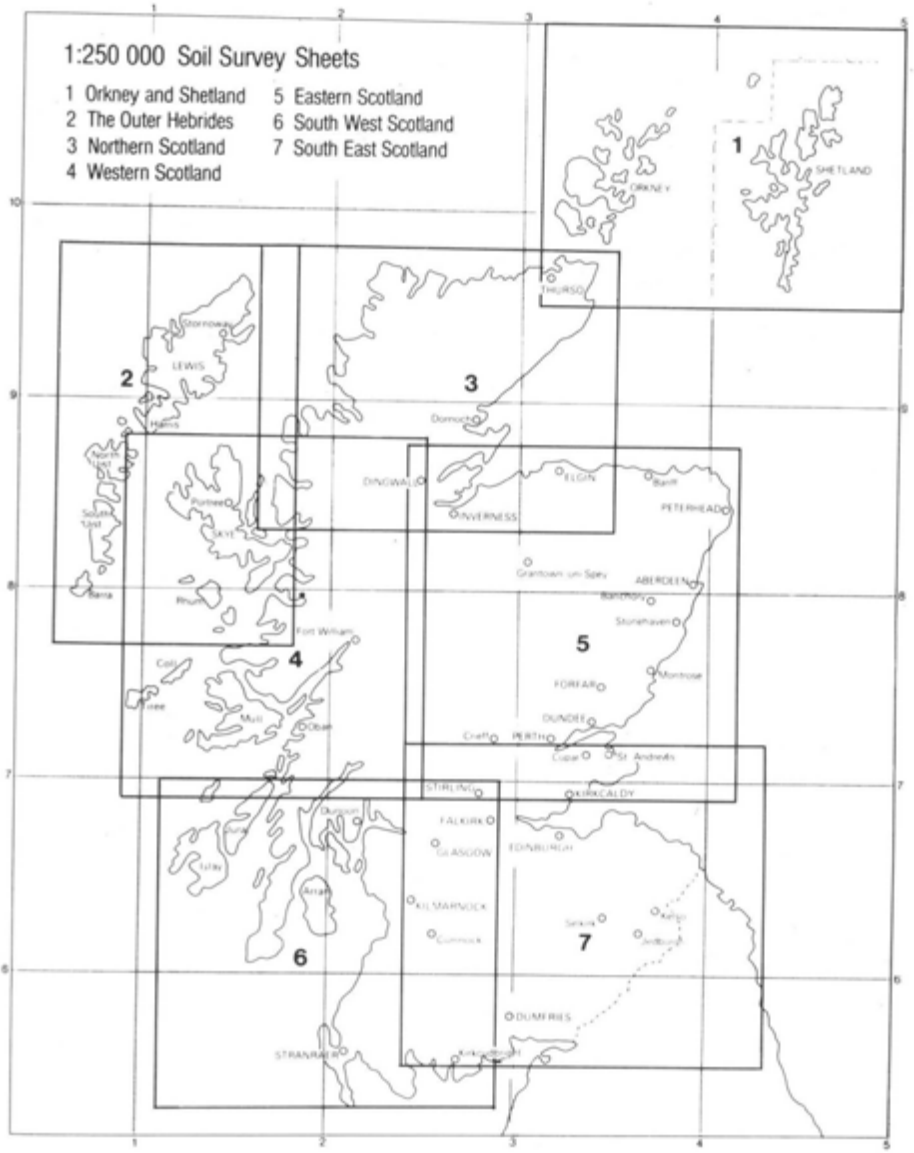
The following one-inch map has been published in both flat and folded version: Sheet 47 Crieff (Soil)[16]. Sheet 23 Hamilton (Soil) was scribed at the beginning of the year and colour proofs from Ordnance Survey are now being examined in preparation for final printing.

The seven 1:250 000 soil maps[17] and the seven 1:250 Land Capability for Agriculture maps[18], together with five of the seven explanatory handbooks[19-22, 24], have been published; the remaining two are in press[23, 25]. One of the soil maps, Sheet 6 South-West Scotland, received the Color Metal Print Award for 1983 in the annual competition organized by the trade journal " Printing World."

Work has started on the first priority 1:50 000 Land Capability for Agriculture programme. These maps will be published on the Ordnance Survey Landranger sheet lines. The base map will consist of a combination of the standard O.S. outline edition plus contours. The LCA information which is interpreted applying the revised (1982) guidelines will be overprinted using a slightly modified version of the three-colour printing scheme used on the 1:250 000 LCA maps.

Investigations into the digitizing of the 1:50 000 LCA series are being undertaken. Several commercial contractors are studying the Soil Survey's requirements in this area.

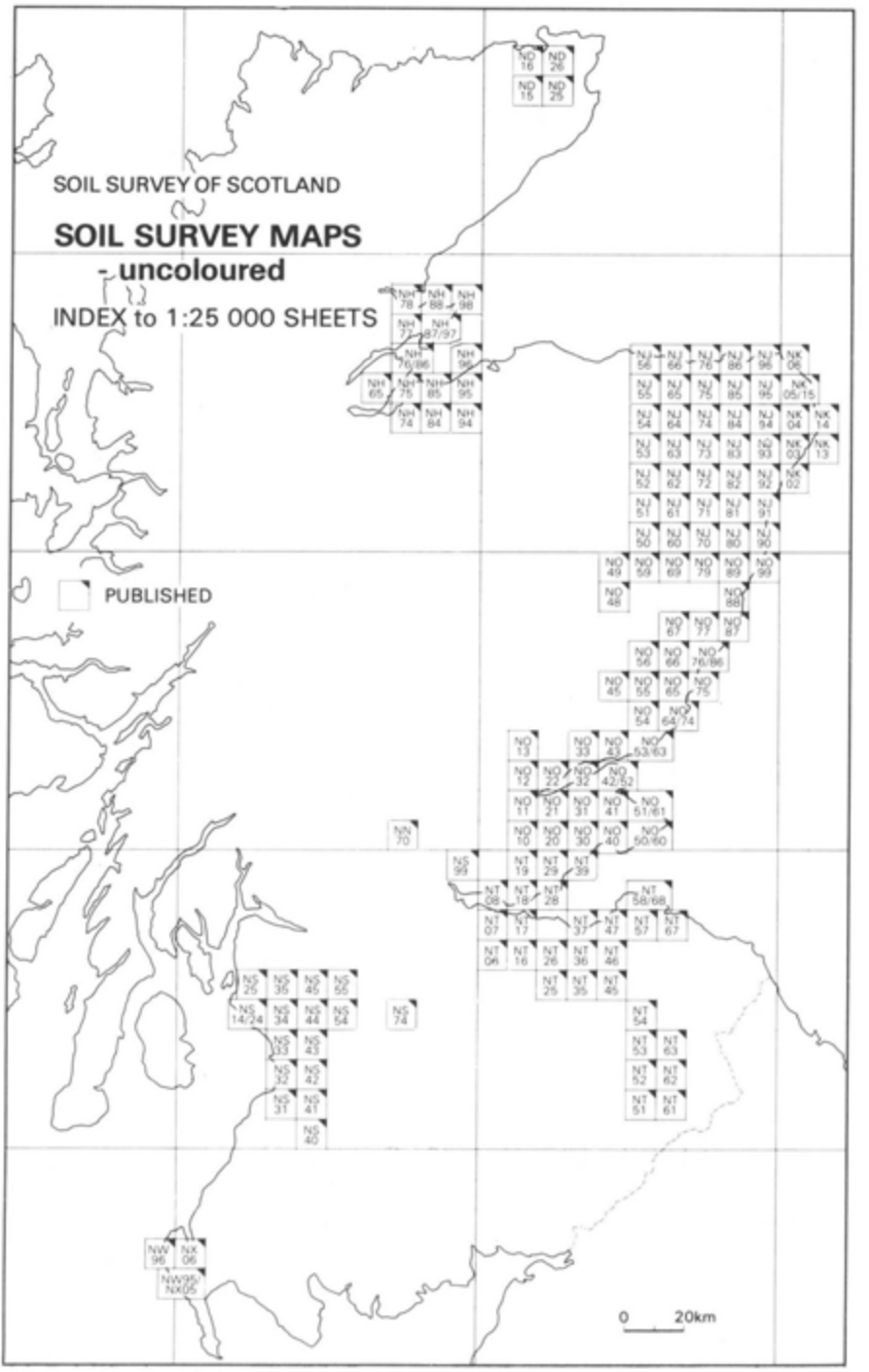
Production has started on a series of provisional 1:50 000 maps to provide soil map coverage of those areas not at present covered by coloured one-inch or 1:50 000 sheets (published or in progress). It is intended that these provisional sheets be produced inexpensively as single-colour dyeline prints on Ordnance Survey Landranger sheet lines using the same base map specification as the coloured 1:50 000 LCA series. There are 34 full sheets and 19 part sheets in the provisional map series; compilation work has been



completed on 14 of them. Work is proceeding on the preparation of a provisional legend based on that used on the 1:250 000 soil maps.

Exhibitions of Soil Survey work were prepared for the Royal Highland Show, Ingliston, Edinburgh, and the British Cartographic Society annual technical symposium at Exeter University.

Cartographic techniques were demonstrated at the Carto-Tech Workshop organized by the British Cartographic Society at the University of Aberdeen. 9012, 9013, 9015


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

References

1. Land Capability Classification for Agriculture. By J. S. Bibby, H. A. Douglas (Meteorological Office), A. J. Thomasson (Soil Survey of England and Wales) and J. S. Robertson. *Monogr. Soil Survey Scotl.*, Macaulay Institute for Soil Research, 1982.

2. Vegetation Survey and Mapping in Scotland. By J. S. Robertson. *Cartographica*, **19**.2, 74-81, 1982.

3. Soils and their related plant communities on the Dalradian Limestone in Central Perthshire. By J. H. Gauld and J. S. Robertson. Submitted to *Journ. Ecol.*

4. Species-rich Scrub Communities and their Soils on Hoy, Orkney. By E. L. Birse. *Trans. Bot. Soc., Edinb.*, **44**, 65-72, 1982.

5. A technique for studying the micro-distribution of nematodes in undisturbed soils. By B. Boag (Scottish Crop Research Institute) and L. Robertson. *Revue Nematol.*, **6**.1, 146-148, 1983.

6. An optical scanning electron microscopic and microanalytical study of cementation in some podzols. By W. J. McHardy and L. Robertson. *Geoderma*, **30**, 161-170, 1983.

7. The environment of North Britain: Soils. In Proceedings of The George Jobey Conference: Settlement in North Britain, 1000 B.C.-A.D. 1000. By J. C. C. Romans and L. Robertson. *Brit. Archaeol. Rep.*, **118**, 55-80, 1983.

8. The general effects of early agriculture on the soil profile. In: The impact of aerial reconnaissance on archaeology. By J. C. C. Romans and L. Robertson. CBA Res. Rep., **49**, 136-141, 1983.

9. Proto-imogolite allophane in podzol concretions in Australia: Possible relationship to aluminous ferrallitic (lateritic) cementation. By V. C. Farmer, A. R. Fraser, L. Robertson and J. R. Sleeman. To appear in *J. Soil Sci.*

10. Multi-area analyses using a micro computer. By L. Robertson. Submitted to *J. Soil Sci.*

11. Soils of the Inner Hebrides. By G. Hudson and D. J. Henderson. *Proc. Roy. Soc. Edinb.*, 83B, 107-119, 1983.

12. The application of soil survey data in open-cast coal sites in Scotland. By J. H. Gauld and K. W. M. Brown. *J. Appl. Geogr.*, **3**, 225-238, 1983.

13. Soils and their management problems within the Carses of Gowrie and Earn. By J. H. Gauld and J. S. Bell. *Scot. Geogr. Mag.*, **99**.2, 77-88, 1983.

14. The Soils. By D. W. Futty. In The Sutherland Book. Ed. D. Omand. Golspie: The Northern Times Limited, 62-73, 1983.

15. Soils. Chapter in "Loch Lomond Nature Reserve Record." By J. H. Gauld and J. S. Bell. To be published by Nature Conservancy Council.

16. Soil Survey Map of Crieff (Sheet 47). Scale 1:63 360 Soil. By B. M. Shipley *et al.* Ordnance Survey, 1983. £1.20. Folded £1.50.

17.* Soil Survey Staff: Soil Maps of Scotland. Scale 1:250 000 Maps (Soils). Sheet 1 (Orkney and Shetland), Sheet 2 (The Outer Hebrides), Sheet 3 (Northern Scotland), Sheet 4 (Western Scotland), Sheet 5 (Eastern Scotland), Sheet 6 (South West Scotland), Sheet 7 (South East Scotland). Ordnance Survey, 1982.

18.* Soil Survey Staff: Land Capability for Agriculture Maps of Scotland. Scale 1:250 000 Maps. Sheet 1 (Orkney and Shetland), Sheet 2 (The Outer Hebrides), Sheet 3 (Northern Scotland), Sheet 4 (Western Scotland), Sheet 5 (Eastern Scotland), Sheet 6 (South West Scotland), Sheet 7 (South East Scotland). Ordnance Survey, 1982.

19. Orkney and Shetland. 1:250 000 Handbook. By F. T. Dry. *Soil Surv. Scotl.* Macaulay Institute for Soil Research, 1982.

20. The Outer Hebrides. 1:250 000 Handbook. By G. Hudson, W. Towers, J. S. Bibby, and D. J. Henderson. *Soil Surv. Scotl.* Macaulay Institute for Soil Research, 1982.

21. Northern Scotland. 1:250 000 Handbook. By D. W. Futty and W. Towers. *Soil Surv. Scotl.* Macaulay Institute for Soil Research, 1982.

22. Western Scotland. 1:250 000 Handbook. By J. S. Bibby, G. Hudson and D. J. Henderson. *Soil Surv. Scotl.* Macaulay Institute for Soil Research, 1982.

23. Eastern Scotland. 1:250 000 Handbook. By A. D. Walker, C. G. B. Campbell, R. E. F. Heslop, J. H. Gauld, D. Laing, B. M. Shipley and G. G. Wright. *Soil Surv. Scotl.* Macaulay Institute for Soil Research. In press.

24. South West Scotland. 1:250 000 Handbook. By C. J. Bown, B. M. Shipley and J. S. Bibby. *Soil Surv. Scotl.* Macaulay Institute for Soil Research, 1982.

25. South East Scotland. 1:250 000 Handbook. By C. J. Bown and B. M. Shipley. *Soil Surv. Scotl.* Macaulay Institute for Soil Research. In press.

*These maps are available for purchase only in packages for each area containing soil map, LCA and accompanying descriptive handbook. £7.50 per package.

10. TECHNICAL SERVICES

A. W. STUART

The past year has again been a very busy one for all four sections of Technical Services.

Several new items of equipment have been acquired, including a Bead-Blast Cabinet for the fine finishing of a variety of components manufactured in the Instrumentation Section and a Double Density Disk unit to be used in the Electronics Section for microprocessor development work.

A summary of the work undertaken by the individual sections is given in the following paragraphs.

Instrumentation

Numerous items of work have been carried out (over 150 completed between January and August 1983) and the Section is now overcoming the backlog of work experienced during the previous year.

Peat and Forest Soils. In conjunction with the acid rain experiment at Balquhidder, a second rotating and tilting boom, to carry specialised sampling tubes, was constructed for use in a non-forested catchment area.

A special auger was constructed to contain solid carbon dioxide, thus enabling loose lake sediment to be frozen to the auger's surface before the unit is withdrawn.

Spectrochemistry. Further development to the nebulizing chamber and partial development on a constant temperature gas controller has been carried out for the Inductively Coupled Radio Frequency Spectrometer.

Soil Organic Chemistry. Modifications to a spectrometer involved the design and construction of a beam chopper, slit unit and an adjustable optical mirror.

A barrel assembly and growth chamber was fabricated to assist in the study of seedling growth using Video Image Analysis techniques.

A portable lifting unit was also constructed for the quick changeover of bark-filled bags used in field drain ochre pit experiments.

Electronics

Much work has been done on major constructional projects during the year, the interface between the HP-85 computer and the Philips X-ray fluorescence spectrometer in the Department of Mineral Soils now being complete. Work continues on the N analyser for the Department of Soil Organic Chemistry.

Development of microprocessor software has been greatly facilitated by the acquisition of a Double Density disk drive for the existing Intel Development System, and good progress has been made on the Continuous Flow Analysis instrument for the Forest Soils Department. Mr Alan Milne, a post-graduate student of Robert Gordon's Institute of Technology has spent some time at the Institute assisting in this project.

Considerable demands continue to be made on the Section's facilities for routine maintenance of laboratory equipment, some 40 items being repaired or modified in the course of the year.

Photography

The routine of the Photographic Unit continued very much along the lines of previous years in providing illustrations in black and white and in colour for the various Departments.

In particular, the use of colour prints for demonstration and record purposes has increased considerably, two notable items being the illustration of Cartography, Soil Survey Department and the colour differences of crops in the fields for the Department of Soil Fertility.

The Photographic Unit entered the " Video Age " with the acquisition of a U-matic portable recorder and editing suite as well as a three-tube colour camera and a mobile dolly, and is now in the process of evaluating the potential of the system for the various Departments that have shown an interest in video, namely, Soil Organic Chemistry (iron ochre in field drains), Forest Soils (acid rain), and the Remote Sensing Unit (aerial survey).

Some short sequences were recently taped at New Pitsligo to demonstrate various peat harvesting techniques.

Joinery/Building Maintenance

This section has again been very active during the past year, mainly with refurbishing various rooms and laboratories throughout the Institute. *Spectrochemistry:* Refurbishing part of Outbuilding 'F' to laboratory specification.

Mineral Soils: The refurbishment of Room 264 to accommodate the recently acquired Electron Spectrometer.

Administration: The refurbishment of Rooms 232, 321B and 226, the latter now houses the Administration computer. The old telephone exchange room was entirely refurbished and now houses the Off-set Litho, copying equipment and the Mainframe for the new computerised telephone switchboard.

General Maintenance: The exceptional summer weather assisted greatly in the good progress made with resealing and painting the external windows.

The two coal-fired boilers used for heating Outbuilding 'G'/new soil store and Outbuilding 'F' respectively, have now both been replaced

with gas-fired units and both boilerhouses were refurbished to accommodate the new boilers.

Additional garage accommodation was provided by refurbishing the old coal bunker site and the old soil store adjacent to the existing double garage. These garages are used by the Department of Soil Survey to house their vehicles during the winter months.

At the present time work is in progress on a further garage, situated at the rear of Outbuilding 'F,' which will provide accommodation for the Institute's Display Caravan during the winter months.

11. LIBRARY

A. H. W. DICKIE

The library holds an extremely comprehensive collection of literature on all matters relating to soil research. The service is primarily for members of staff, but loans can be obtained by individuals and institutions, preferably through the inter-library lending scheme. This year 124 items were lent to other libraries, and a total of 847 items were borrowed, including 509 through the British Library Lending Service.

Additions to the bookstock totalled 554 and one new journal was also bought, but only by cancelling another. Two further journals are being donated by the Director.

Lists of Available Publications can be obtained from the Librarian. In response to the last list 497 reprints were distributed, and a further 420 in direct applications.

Two Current Awareness Bulletins are produced — the Periodicals Bulletin weekly and the Book Bulletin monthly. Both are circulated internally, and are also sent to other Scottish Agricultural Research Institutes, and to local research establishments.

A new microfiche reader — an NMI 90 — has been bought, and new heating has also been installed.

APPENDIX I

EIGHTH

T. B. MACAULAY LECTURE

25th November, 1983

by

Mr J. I. SMITH, C.B.

Chairman:

Professor H. M. Keir, B.Sc., Ph.D., D.Sc., F.I.Biol., F.R.S.C., F.R.S.E.

EIGHTH T. B. MACAULAY LECTURE

Aberdeen, 25th November, 1983

SCOTTISH AGRICULTURAL IMPROVEMENTS IN THE POST-WAR YEARS

Mr J. I. SMITH, C.B.
Secretary

Department of Agriculture and Fisheries for Scotland,
Chesser House, Edinburgh

Presentation of Macaulay Scroll on occasion of Eighth T. B. Macaulay Lecture, 25th November, to Mr J. I. Smith, Secretary of DAFS, on the left, by Professor T. S. West and Professor H. M. Keir (right hand side).

INTRODUCTION

I was honoured if somewhat surprised at the invitation to give this lecture, honoured to follow the distinguished lecturers who have preceded me but surprised that the Council should have chosen an administrator rather than a scientist. I hope, however, that their choice reflects the close association for over 50 years now between the Institute and my Department, and reflects also the fact that we have managed despite the inevitable problems of the relationship between a paymaster and a contractor to stay on very good terms. For our part we in the Department think of our relationship with the Macaulay as being more than that between paymaster and contractor; we have seen it rather as sharing in a common enterprise to further the well-being of the farming industry.

Thomas Macaulay gave his name to this Institute and was indeed its father, but my Department can perhaps claim to have been the midwife at the birth. Mr Macaulay's first approach in 1928 was to the Department and we can claim a good part of the credit for extending his interest, and for that matter his benefaction, beyond the improvement of farming in Lewis to the wider purposes of the pursuit of soil science. Since those early days the Department's interest in the Institute has grown steadily closer, some would no doubt say too close, but that is the inevitable consequence of the fact that the taxpayer has taken over the financial responsibility for the baby which Mr Macaulay fathered and the baby of course has grown out of all recognition.

Since this is by way of being my swan-song I thought the audience would bear with me whilst I reflect on the main changes in Scottish Farming during my time with the Department. This puts me on much safer ground, of course, than seeking to look forward. Attempts to predict the future of agriculture anyway have been notoriously unsuccessful. An exception might be found in the Bible — Joseph was able to forecast seven years of plenty followed by seven years of famine. He was right, but of course he had inside information and from a more reliable source than I have been able to tap so far. When I started in my present job one of my predecessors gave me the advice that I should decide what was going to happen and make that my policy objective. Despite that prudent policy, we can still be taken by surprise by developments in Agricultural Policy, particularly since we became involved with the Common Agricultural Policy of the European Community and our fate is linked with that of very different farming economies. However, I shall venture later, on a personal basis — as befits a Civil Servant — into some crystal gazing and I shall have something to say about a subject close to the heart of the scientific community — that of the problems of administering publicly-financed research and development.

Inevitably I have to begin with some statistics about post-war developments in Scottish farming. Statistics are nearly always boring, but perhaps I can be allowed to rattle through some basic measures of increased output and efficiency before commenting on their significance.

The period has been one of exceptionally rapid technical evolution and indeed, in some respects *revolution* might be a more appropriate term.

The most striking change has been in the substantial increases in the level of output per animal or per hectare. Milk yields, for example, have risen by over 50% since 1950 and egg yields are up by three-quarters. In the cropping sector, barley yields and potato yields have increased by about 80%.

In many instances where there have been sharp increases in yields, there has been a reduction in either the numbers of livestock kept or the area devoted to the crops in question. The dairy cow herd has fallen in size by one-quarter, and the area devoted to potatoes is down by more than half. Cereals initially followed this pattern, but latterly both area and yield have risen together, and the cereals area is now 10% above the 1950 level. On the other hand, in areas where yield improvements are either less obvious or less easily measured there have been substantial increases in productive numbers. The beef cow herd has increased to over three times its earlier size, pig population is up by over 80%, sheep numbers are up by over 10%, and numbers of table fowl are at three times the level of even 20 years ago.

This greatly increased productive efficiency has been accompanied by substantial changes in the structure of the industry.

There has been a continuous trend to fewer and larger businesses. In parallel, and at least as important, specialisation has increased. For example, over the past 20 years the number of milk producers has fallen by over 60% and the average size of herd has doubled. Despite increasing pig and beef cow numbers, the numbers of farms with each type of stock has fallen by 80% and 50% respectively. The most extreme case has been the poultry sector where production is no longer widely dispersed but is to a large extent controlled by only a handful of major companies.

Much more than the reduction in the number of farmers has been the fall in the number of workers they employ. The number of employees is down by 60% since 1950, but the 40% who remain are much more highly skilled as is evidenced by a substantial increase in the proportion of specialists and in the proportion of farm workers who now receive formal education and training through attendance at full or part-time courses.

On the other side of the coin there has been a dramatic increase in mechanisation. This does not always take the form of more machines. Part of the trend has been to much larger and more sophisticated machines. For example, whilst there has been a twenty-fold increase in the number of combine harvesters and forage harvesters, threshing machines and binders have all but disappeared.

So much for a broad measurement of increasing technical efficiency. How has it been made possible?

In the first place, there have been huge strides in plant and animal breeding. The cereal and potato varieties of the immediate post-war period have been all but completely replaced by new generations of varieties. More recently, varieties of winter barley and oilseed rape suitable to Scottish conditions have been introduced. The poultry industry's application of breeding and selection methods based on advances in population genetics have resulted in spectacular improvements in productivity, and the pig industry, through adoption of performance and progeny testing programmes and selective breeding, has shared many of the genetic advances exploited in poultry. The technique of artificial insemination (AI) and progeny testing programmes have contributed to the great improvement in milk yields, and with AI, and now embryo-transfer, the search for improvement constitutes an internationl trade.

Secondly, there have been very significant advances in plant and animal health. The chemical control of diseases, not to mention weeds, has become commonplace in crop production. Improvements in the standards of health of seed potatoes have become possible as a result of the introduction of new techniques associated with the production of virus-tested stem cutting material. The largest growth area in the sheep sector has probably been in the upland areas where intensification has been made possible in no small measure by the advances made over the years in the field of preventive veterinary medicine.

The third major contribution has come from the introduction of new techniques, often involving increased investment and capital intensification. The methods of producing and handling cereal crops have changed dramatically over the last three decades. Practices such as broadcasting seed and fertilisers have given way to combined seed and fertiliser drilling. The use of the binder and the practices of stooking and stacking have disappeared in favour of the combine harvester with associated drying and storage facilities. There have been similar developments in potato production, and the realisation that grass is a valuable fodder crop has resulted over the years in greatly improved conservation methods.

Dairy production has benefited from improved grassland management and more precise levels of nutrition, and from capital investment in large purpose-built loose housing systems, parlour milking and self-feeding silage, bulk collection and refrigeration. The rapid increase in beef numbers in the 1960s was assisted by the increased use of dairy crossbreds as cows. The most notable development since then has perhaps been increased understanding of the nutritional needs of the breeding ewe at critical times of the year and ways in which these can be met. There has been some rationalisation in the number of sheep breeds used. There have been sweeping changes in pig and poultry production techniques ranging from housing systems, feeding regimes, automation and controlled environment to strict health and hygiene regimes.

I need hardly tell this audience that all this increased efficiency of production is based on increased productivity from the soil and it is evident that increases have occurred on all soils ranging from the most productive to

the most marginal. These increases have resulted from greater understanding of the chemistry and physics of the soil as a medium for plant growth coupled with increased and more efficient use of fertilisers to meet the nutrient requirements of crops. There have also been substantial improvements in our knowledge of how to improve marginal soils covering factors such as drainage, liming, fertiliser requirements and trace element problems in animals and grassland. In general, our soils have had to sustain the production of a changing pattern of cropping with higher and higher yields and these requirements, along with the associated changes in farming practice, are continually posing new problems which need resolution, e.g. problems caused by greater intensity of production such as effects on soil structure and compaction.

The overall effect of all these developments has been an increase of 70% in the contribution of agriculture to the Scottish economy since 1950 (as measured by the gross domestic product). In the face of the continuous loss of hill land to forestry and of arable land to other development, this implies an even greater intensification of the use of the national farm. I said earlier that this might well be termed a revolution and this can be illustrated by contrasting developments in the post-war period with those in the first half of the century. For example, most 1950 yield levels were not substantially higher than those achieved several decades earlier. Cattle numbers were little different in 1939 from 1900, and the tillage area had fallen over 20% over that period. Between the wars, worker numbers fell by little more than 1% per year on average. The tractor made its mark during the Second World War, but much other agricultural machinery was still relatively unsophisticated in 1950.

In the nature of things it is not always easy to prove a direct correlation between expenditure on R & D on one hand and agricultural improvement on the other. Clearly, not all of the changes I have outlined have arisen directly and solely as a result of research and development; social and economic factors and for that matter political factors have also been very important. The introduction of legislation on guaranteed prices and assumed markets gave the industry a tremendous boost to confidence. It is clear beyond any doubt, however, that research and development has been a major factor in the remarkable transformation in Scottish agriculture in the post-war years. Indeed, I do not think it can be simply coincidence that the agricultural revolution since the war matches the massive growth in the amount being spent by Government on agricultural R & D in Scotland over the same period. For example, in 1948 the grant given by my Department for the running costs of the Scottish agricultural research institutes amounted to £180,000; the corresponding figure for the current year is over £18 million. Allowing for inflation over the period, in real terms we are now spending about six times as much on agricultural research in Scotland today as we spent in 1948. This pattern of growth is also illustrated by a comparison of the numbers of scientific staff employed in the Scottish Research Institutes in this period. In 1948 there were 186 scientific staff, today there are 820.

I think we should keep this growth in mind now that we are in a period of retrenchment, minor retrenchment so far. Institute budgets have been cut back in real terms. I cannot be precise about the likely level of expenditure on R & D over the next few years, but the Government has made it clear its determination to reduce public expenditure, and agricultural research and development cannot be altogether exempt from the Government's general policy. However the statements by the Agriculture Ministers last week made it clear that the reduction in expenditure next year will not be severe. Nevertheless the prospect of a reduced level of funding makes it all the more necessary for us to ensure that our organisational arrangements are efficient, our priorities are right and that the taxpayer is getting value for money.

The post-war period also saw major changes in the organisation and management of agricultural research. In the early days the Director of an Institute was given a great deal of freedom. Your present Director will affirm that this is no longer true. Admittedly some guidance was provided by Agricultural Improvement Councils in Scotland and in England, which assessed an extensive list of possible research topics and awarded priority classifications to them; but by and large the received wisdom was that the Directors of Institutes were best placed to determine their own priorities within their own particular fields. However, this laissez-faire approach to the organisation and control of agricultural research could not survive with an era of heavy public investment in R & D. A framework was needed and it found tangible expression in a Government White Paper published in 1971 under the title " A Framework for Government Research and Development " which included a report by Lord Rothschild in his capacity as head of the Central Policy Review Staff. Lord Rothschild's report represented a watershed in the organisation of Government-sponsored research and development in this country. In the introduction to his report, Lord Rothschild identified the objective of R & D organisation and management as being to achieve a logical, flexible, humane and decentralised system with each person in the system having clearly defined responsibilities. The whole of his report was, in his own words, " based on the principle that applied R & D, that is R & D with a practical application as its objective, must be done on a customer/contractor basis ". The Government of the day accepted the principle on the Rothschild report, and the customer/contractor relationship which is recommended has been the main principle in our administration of R & D over the last decade or so.

One consequence of the implementation of the new customer/contractor arrangements was that it became necessary to revise the system by which the customers for agricultural R & D represented by the Ministry of Agriculture, the Agricultural Research Council and my Department — now known as the Sponsors — received advice on the priority needs of the different sectors of agriculture. A Joint Consultative Organisation was set up consisting of five Boards representative of the interested parties in the major sectors of agriculture. The Boards carried out a detailed urvey of the R & D needs in each sector and produced extremely useful reports for

the Sponsors, setting out guidelines for agricultural R & D for several years to come. Now we have moved on to a simpler consultative organisation with a single Consultative Board, but with provision for the setting-up of special committees, each for a limited period and for a clearly defined subject.

While the Joint Consultative Organisation had, and still has, a remit for the whole of Great Britain, we also felt the need for a separate body to deal with the particular needs of Scottish agriculture. The Secretary of State therefore appointed the Scottish Agricultural Development Council in 1971 and gave it the remit of overseeing all agricultural research and development work in Scotland, with particular emphasis on development work. I do not think I would be giving away any secrets if I say that this body had more than its fair share of teething problems and in 1976 it was decided to change the status of the Council to make it a purely advisory body to the Secretary of State instead of the limited company wih executive powers it had originally been. I do not think that in my experience I have known a more effective advisory body than the present SADC and we rely very heavily on its advice.

The final development which I should mention as flowing from the Rothschild report has been the establishment within the Department of a Scientific Adviser's Unit. The Unit is responsible for advice on the R & D programmes undertaken by the institutes and colleges; for advice on the educational and advisory work of the colleges; for liaison with the ARC and MAFF, and in general for advising the Department on the R & D needs of agriculture.

The arrangements for the organisation and funding of agricultural R & D are undoubtedly complex; particularly, I think it is fair to say, south of the Border. The way in which Institutes have come into being has largely been by way of historical accident. Certainly if we were starting from scratch to set up an agricultural research service for Great Britain I do not think anyone would contemplate the creation of 30 separate institutes. As you will know, the arrangements have recently been the subject of much critical comment from various quarters, in particular the JCO Board and the House of Commons Select Committee on Agriculture. It is gratifying to note, however, that neither Report has any criticism to make of the Scottish system; indeed the House of Commons Report in particular goes out of its way to commend the Scottish system, particularly as regards the close links that exist between the various organisations involved. The scale of the exercise in Scotland is no doubt in our favour and it may be that the Scottish practice cannot readily be replicated elsewhere. However, the Government is still considering its response to these reports and it would clearly be improper for me to speculate as to what changes in the system might be made. I am sure, however, that everyone involved in this sphere of activity in Scotland in whatever capacity would hope that the Secretary of State will still retain his present responsibility for the Scottish institutes and the Scottish colleges.

During the thirty years or so during which I have been involved in agricultural administration we have been constantly reviewing and changing

the arrangements for the organisation and funding of R & D. And I doubt whether we have yet reached the end of the road. In this context I thought you might be interested in a comment I came across recently:

> " We trained hard, but it seemed that every time we were beginning to form up into teams we would be reorganised. I was to learn later in life that we tend to meet any new situation by reorganising; and a wonderful method it can be for creating the illusion of progress while producing confusion, inefficiency and demoralisation."

You might be forgiven for thinking that this comment was penned by a disgruntled member of one of our research institutes; in fact, it was written by the Roman writer Gaius Petronius in A.D. 65. Perhaps nothing has changed all that much.

I have referred to the various sources of advice which the Department has in determining priorities for research. The question may well be asked, however, how is that mass of advice (perhaps conflicting advice) translated into decisions on actual research programmes. There is no simple answer; a great many factors are involved and have to be weighed against each other. For example, value of the commodity is one factor, but by no means a conclusive one; even if the current value of a commodity is low there are many examples of R & D leading to an improvement of the market and, of course, some areas of research such as that on soils cannot sensibly be reviewed on a commodity basis. A further factor is the likelihood or otherwise of success at the end of the day. Obviously we must also have regard to whether any other organisation (and not necessarily within Great Britain) is also at work in a particular subject area. Then there are political and social considerations which may influence our choice of priorities; for example the public concern in recent years over some aspects of intensive livestock farming has led to an increased emphasis not only on alternative husbandry systems (for example, for poultry), but also on fundamental research into animal ethology. All these and other considerations come together at the customer reviews of each R & D sector which are held on a cyclical basis so that each sector is reviewed every four years. At these Reviews the Department considers with the contractors the progress being made in that sector and discusses what changes in commissioned research should be made over the next four-year period. A key element in our procedures for determining priorities is our dialogue with Institute Directors; in our view the formal customer/contractor relationship must not be allowed to get in the way of a full dialogue between the two; there is no more important factor in this business than scientific initiative and vision and we attach major importance to the judgement of those at the frontiers of knowledge. What we are constantly trying to do is to strike the right balance between scientific freedom and public accountability; whether we are successful or not in our endeavours is perhaps for others to judge, but I would subscribe to the sentiment of the notices which I understand use to be hung in Wild West saloons — " Please don't shoot the pianist, he is doing his best."

Although the theme of my talk has been primarily to outline the massive changes which have taken place in Scottish agriculture in the post-war years and to relate these changes in our R & D effort, I think I might chance my arm a bit as where we go from here. Undoubtedly, we will continue to see changes in farming practices; the trend towards greater specialisation will no doubt continue with the uptake of new and improved technology. Whether we will see continuation of the same high level of capital investment that has been apparent in recent years is more doubtful.

There are currently a number of pressures which are bound to affect farming in varying degrees. There is, for example, the impact of the environmental-cum-conservation lobby, with its criticisms that the increased use of fertilisers and pesticides is destroying the ecological balance and that prairie-type farming is leading to the destruction of hedgerows and wildlife (though this problem is more acute in parts of England than in Scotland). There are the demands from a largely urban public in this country for freer access to agricultural land for leisure and recreation. The potential conflict between these urban claims and the agricultural interest is particularly acute not only in the immediate area of our cities and towns, but also in our hill and upland areas to which the town dwellers, now more mobile than ever before, seek to escape. Another major difficulty, of course, is the problem (particularly in an EC context) created by the production of some commodities in quantities greater than the consumer is able or willing to purchase. Clearly too our agriculture will need to take account of changes in the pattern of consumer demand for food; to quote just one example of this, if consumers generally respond to the advice from some dietary experts to cut down the amount of fat they consume, this could have a marked effect on both our dairy producers and beef producers. In addition, as I said earlier, there is the increasing public concern for more acceptable and humane ways of intensive livestock production. Finally, and underlying all that I have just said, there is the need to husband and improve our soil resources.

I think that there can be little doubt that at present farmers in this country are being attacked more fiercely than they have been for some time. They are regularly pilloried in the press and on television on a wide variety of counts, some of which I have just mentioned. Some of this criticism is undoubtedly misconceived and sometimes grossly exaggerated. Some of it, however, is thoughtful and well-founded and I know that many leaders of the industry are well aware that in some respects the industry needs to put its house in order. A particular example, of course, is the widespread public anger in recent months over the sometimes indiscriminate burning of straw.

Amid all these conflicting pressures and criticisms one key role of research and development is to provide the industry with information on options so that farmers can choose which course to follow. To do this our R & D establishments must be flexible in their approach. For example, to meet some of the criticisms I have referred to, our R & D might perhaps be directed to find production techniques which have a less damaging

ecological impact, but still maintain farm profitability. This might involve, for example, the need to make energy savings in cultivations, greater precision in the application of fertilisers and chemicals and in animal feeding and more emphasis on the recycling of wastes. It may also be desirable, in view of the problems of commodity surpluses, to give more attention in R & D work to possibilities for reducing the cost of inputs as a means of further improving efficiency. This could provide useful information about lower cost systems of production as an alternative option to the high input/high output systems which are generally being pursued at the present time.

There will certainly be no lack of problems for the Agricultural Research Service in this country over the next few decades. Could I finish this talk with a personal comment about the role of those, like most of this audience, who are employed in grant-aided bodies concerned with agricultural research and development? Only the scientist can define his objectives but his freedom to do so has to be reconciled with the need to justify public spending to the public. Someone has to say what the needs of society are and to square that with the research worker's own objectives. That is the paymaster's function. But the investment in R & D is really in people, not in programmes, and whether we get the best return on public funds is always going to depend on the research workers themselves.

APPENDIX II

VISITS ABROAD — 1982-83

	Place/Event	*Lectures*	*Date* — 1983	*Financed by*
1. G. Anderson	University of Sao Paulo, Piracicaba, Brazil	1	October	Centro de Energia Nuclear na Agriculture (CENA) and British Council
2. H. A. Anderson	Estes Park, Colorado (U.S.A.) 1st Meeting of International Humic Substances Society	1	August	DAFS
3. B. W. Bache	Brussels (Belgium) World Phosphate Institute 3rd International Congress	1	October	DAFS
4. D. C. Bain	Prague (Czechoslovakia) Euroclay 1983 5th Meeting European Clay Groups	1	September	DAFS
5. J. S. Bibby	Wageningen (The Netherlands) Seminar on Soil Survey and Land Evaluation	—	September	DAFS
6. V. C. Farmer	Prague (Czechoslovakia) 5th European Clay Group Conference	1	September	Self
7. B. A. Goodman	Lectures in U.S.A. at various Universities and Research Laboratories during Sabbatical Year at Indiana University	10	January/May	DAFS, NATO, Civil Service and Nuffield and Leverhulme Fellowships
8. P. D. Hulme	Helsinki/Jyvaskyla/Oulu (Finland) Geological Survey of Finland, State Fuel Centre and University of Oulu	1	July/August	DAFS/Self
9. R. C. Mackenzie	Prague (Czechoslovakia (Euroclay 1983 5th Meeting European Clay Groups	2	September	Charles University, Prague/DAFS
10. H. G. Miller	Oslo (Norway) IEA Forestry Energy Meeting	1	October, 1982	IEA
11. H. G. Miller	Uppsala (Sweden) Evaluation of Environmetal Research	—	December, 1982	Swedish Agricultural University
12. H. G. Miller	Uppsala (Sweden) ESF Workshop on Dynamics of Forest Ecosystems	1	March	NERC
13. H. G. Miller	Quebec (Canada) USDA/Environment Canada Conference on Acid Rain and Forest Resources	1	June	Environment Canada/DAFS
	Knoxville (U.S.A.) 6th North American Soils Conference	—		
	Visits to Coweeta Experimental Forest and Oak Ridge National Laboratory	1		

		Place/Event	*Lectures*	*Date* — 1983	*Financed by*
14.	H. G. Miller	Brussels (Belgium) Contractors Meeting, European R & D Programme — Wood as a Renewable Raw Material	1	October, 1982	EEC
15.	J. S. Robertson	Lund (Sweden) Third European Ecological Symposium on Plant Animal Interactions	1	August	DAFS
16.	R. A. Robertson	Leningrad (U.S.S.R.) Working Group on Peat Terminology	—	March	IPS
17.	R. A. Robertson	Munich (F.R.G.) Meeting of Executive of International Peat Society	—	June	DAFS
18.	J. D. Russell	Prague (Czechoslovakia) 5th European Clay Group Conference	1	September	DAFS
19.	J. D. Russell	U.S. Clay Minerals Soc. IR Workshop U.S. Clay Mineral Meeting Seminars, Purdue University	4 2	September	USCMS and Purdue University
20.	N. M. Scott	Paris (France) Sulphur in European Agriculture	1	April	Sandoz Chemicals
21.	B. L. Sharp	Stockholm (Sweden) Doctoral *viva* examination	—	May	Swedish Royal Institute of Technology
22.	G. P. Sparling	Adelaide (Australia) CSIRO Division of Soils and Waite Institute	1	December	DAFS
23.	A. M. Ure	Aarhus (Denmark) FAO Consultation on Trace Elements	—	May	FAO
24.	A. M. Ure	Lyngby (Denmark) General Assembly, International Union of Pure and Applied Chemistry.	—	August	DAFS
25.	T. S. West	Tokyo (Japan) Executive Committee, International Union of Pure and Applied Chemistry	—	April	IUPAC
26.	T. S. West	Amsterdam (Netherlands) Int. Co-op Res. Project Characterization of Environmental Traces	—	June	DAFS
27.	T. S. West	Lyngby (Denmark) General Assembly, International Union of Pure and Applied Chemistry	—	August	IUPAC
28.	B. L. Williams	East Lansing, Michigan (U.S.A.) 3rd International Symposium on Microbial Ecology Ottawa (Canada) Land Resource Research Centre and the Chemistry and Biology Research Institute	1	August	DAFS/Self
29.	M. J. Wilson	Prague (Czechoslovakia) Euroclay 1983 5th Meeting European Clay Groups	1	September	Clay Minerals Group

APPENDIX III

LECTURES GIVEN IN THE U.K. BY MEMBERS OF STAFF

	Place	*Event*	*Date* — 1983
Department of Mineral Soils			
W. J. McHardy	Cambridge	Clay Minerals Group/Petroleum Exploration Soc. Conference on Clay Diagenesis	April
	Glasgow	NASA Workshop and Symposium on Clays and Origin of Life	July
E. Paterson	London	Clay Minerals Group	November, 1982
M. J. Wilson	Cambridge	Clay Minerals Group/Petroleum Exploration Soc. Conference on Clay Diagenesis	April
	Sawley, Yorks.	X-ray Diffraction Users' Group	May
Department of Peat and Forest Soils			
R. V. Birnie	London	Remote Sensing Soc. / Roy. Soc. Chem. Meeting on Field Reflectance	February
	Dundee	Remote Sensing Course for Offshore Industries	July
	Malvern	Microwave Radar Workshop	July
	Aberdeen	Int. Peat Soc., Commission I. Symp. on Remote Sensing Applications	September
	Silsoe	Remote Sensing Soc. Annual Conference	September
	Farnborough	Agrispine Workshop	October
P. D. Hulme	Durham	British Ecological Society, Mires Research Group	December, 1982
H. G. Miller	London	Royal Society Workshop on Ecological Effects of Deposited Sulphur and Nitrogen Compounds	December, 1982
	London	Royal Society Discussion Meeting on Ecological Effects of Deposited Sulphur and Nitrogen Compounds	September
	York	BES Meeting on Ecology and Upland Land Use	September
P. F. S. Ritchie	Aberdeen	Int. Peat Soc., Commission I. Symp. on Remote Sensing Applications	September
R. A. Robertson	Edinburgh	SPALDA Conference — Back to the Land — A Strategy for Rural Repopulation	November, 1982
	Harrogate	U.K. Peat Producers' Association	February
G. C. Stove	London	Royal Society Discussion Meeting on the Study of Ocean and Land Surfaces from Satellites	March
	Aberdeen	Int. Peat Soc., Commission I. Symp. on Remote Sensing Applications	September
	Silsoe	Remote Sensing Soc. Annual Conference	September
B. L. Williams	Reading	Joint Meeting of Int. and Brit. Soc. Soil Science	July
Department of Spectrochemistry			
M. J. Adams	Edinburgh	SAC '83 Roy. Soc. Chem.	July
V. C. Farmer	Edinburgh	Infrared Discussion Group	July
	Aberystwyth	Clay Minerals Group	March

D. B. McPhail	Aberdeen	Inorganic Biochem. Discussion Group	April
J. D. Russell	London	Clay Minerals Group	November, 1982
B. L. Sharp	Manchester	ICP Workshop UMIST	March
	Edinburgh	SAC '83 Roy. Soc. Chem.	July
A. M. Ure	Aberdeen	Varian Techtron Users' Group	September
	Edinburgh	SAC '83 Roy. Soc. Chem.	July
Department of Soil Organic Chemistry			
M. V. Cheshire	Reading	International Society of Soil Science (Comm. II and V) and British Society of Soil Science	July
B. G. Ord	Alnwick	Demonstration at "Farmers Weekly" International Drainage Event	May
D. Vaughan	Alnwick	Demonstration at "Farmers Weekly" International Drainage Event	May
Department of Microbiology			
J. F. Darbyshire	Cambridge	British Society of Protozoology, Cambridge University	April
	Alnwick	Demonstration at "Farmers Weekly" International Drainage Event	May
D. Jones	Aberdeen	Aberdeen Electron Microscopy Group	June
	Exeter	Society for Experimental Biology Meeting on "Cryotechniques in Electron Microscopy" Poster	July
G. P. Sparling	York	Association of Applied Biologists at York University	March
	Reading	International Society of Soil Science / British Society of Soil Science Meeting	July
R. E. Wheatley	Edinburgh	Society of Applied Bacteriology	July
Department of Soil Fertility			
B. W. Bache	London	Royal Society Discussion on "Ecological Effects of Deposited Sulphur and Nitrogen Compounds"	September
N. M. Scott	London	"Sulphur '82"	November, 1982
A. H. Sinclair	London	SCI Symposium "Sodium and Potassium in Soils and Crops"	October
Department of Soil Survey			
J. S. Bibby	Stirling	University Department of Geography	November, 1982
	Glasgow	Strathclyde University Department of Geography (3)	November, 1982
R. E. F. Heslop	Aberdeen	Symposium on Remote Sensing, IPS	February and March
J. S. Robertson	St Andrews	Friends of University Botanic Gardens	September
	St Andrews	University Open Association	February
W. S. Shirreffs	Exeter	British Cartographic Society Symposium	March
			September
Director			
T. S. West	Aberdeen	Royal Society of Chemistry and Aberdeen University Chem. Soc.	February
	Aberdeen	University Inaugural Lecture	December
	Place	*Event*	*Date* — 1983

PUBLICATIONS

The numbers appearing on the left-hand side of this list are the MISR serial numbers for the items. Please quote these numbers when asking for reprints, which are available free from the Librarian, Macaulay Institute for Soil Research, Craigiebuckler, Aberdeen, AB9 2QJ. *Reprints with no serial numbers are only available if priced.* Items marked † are publications which can be bought from the Department of Soil Survey, at the above address.

1240 ADAMS, M. J. and BLACK, I. Application of a microcomputer system in an infrared laboratory. *J. Automatic Chem.*, 1983, **5**, 9-13.
An Apple microcomputer has been interfaced to dispersive and Fourier spectrometers for the acquisition of infrared spectral data. Extensive data-manipulation software has been produced and the results compared with instrument manufacturers' dedicated microcomputers.

1256 ADAMS, M. J., MITCHELL, M. C. and EWEN, G. J. A microcomputer system for processing data from a three-channel atomic absorption spectrometer. *Anal. Chim. Acta.*, 1983, **149**, 101-106.
A microcomputer system has been interfaced to a three-channel atomic absorption spectrometer, remote from the computer, with the aid of a multi-channel analogue-to-digital interface unit. Data recording, and subsequent data analysis, are under operator control *via* a microterminal.

ANDERSON, G. Recent observations on humus composition and properties. *Proc. Regional Colloq. on Soil Organic Matter Studies, Piracicaba, SP-Brazil.* Promocet, 1982, 3-10.
A paper reviewing some recent investigations on soil organic matter. There is no evidence as yet of any marked difference in the nature of humus in different climatic zones, but the rates at which transformations occur are higher in tropical than temperate regions. New techniques have shown that the proportion of aromatic ring structures is much lower than formerly believed and that many of the acidic functional groups are associated with aliphatic chain structures. In particular, the characteristic properties of fulvic acids and water-soluble organic polymers are due to the presence of clusters of aliphatic carboxylic acid groups. The importance of aluminium and iron-containing gels in stabilising organic matter against rapid decomposition is stressed, and examples given of the effects of organic matter on the uptake of trace metals by plant roots. Recent measurements of the aggregated stability of soils before and after chemical degradation of the carbohydrate components have indicated that the stabilising effects of polysaccharides have often been underestimated in the past.

1242 BACHE, B. W. The implications of rock weathering for acid neutralization. In *Ecological Effects of Acid Deposition: Swedish Environment Protection Board Rept.* PM 1636, 1983, 175-187.
The processes involved in rock weathering, and experimental studies in the laboratory and in catchments, indicate that weathering rocks have an extremely large capacity to neutralize acid inputs from precipitation. Only when rapidly moving waters avoid the weathering residium, either by surface run-off or when flowing through organic surface horizons, are the acids in precipitation unlikely to be neutralized.

1229 BACON, J. R., WELCH, K. H. and URE, A. M. Analysis of plant materials by spark source mass spectrometry directly and following preconcentration by cementation. *Inter. J. Mass Spectrom. Ion Physics*, 1983, **47**, 307-310.
The applicability of spark source mass spectrometry to the analysis of plant materials is demonstrated using direct analysis of plant ashes and analysis following preconcentration. Direct analysis gives an overall assessment of the element composition of a sample and quantitative results for about 30 elements. Preconcentration removes the major elements, which are a source of molecular interference on some elements, and increases the concentration of some elements usually below the detection limit of direct analysis.

1234 BAIULESCU, G. E., MOLDOVEANU, S. and WEST, T. S. Nicolae Teclu (1839-1916); a pioneer of flame spectroscopy. *Talanta*, 1983, **30**, 135-137.
A brief account is given of Teclu's career and his contributions as a pioneer of the study of flames.

1236 BERROW, M. L. and STEIN, W. M. Extraction of metals from soils and sewage sludges by refluxing with aqua regia. *Analyst*, 1983, **108**, 277-285.
The effectiveness of several acid digestion procedures for dissolving metals in soils and sewage sludges was investigated. The objective was to establish a simple method, using flame atomic absorption, for the determination of the total contents of cadmium, chromium, copper, lead, manganese, nickel and zinc in such materials. Boiling under reflux for two hours was highly effective in extracting metals from sludges and sludge treated soils. This procedure also removed on average 60 to 100 per cent of the total contents of cadmium, chromium, copper, iron, lead, manganese and zinc from uncontaminated soils.

BERROW, M. L., BURRIDGE, J. C. and REITH, J. W. S. Soil drainage conditions and related plant trace element contents. *J. Sci. Fd. Agric.*, 1983, **34**, 53-54.
The effects of soil drainage on the mobilization and uptake of cobalt, copper and molybdenum by herbage are reported in this summary. The value of acetic acid, EDTA and ammonium acetate respectively in assessing the amounts of these elements taken up by herbage is described.

†BIBBY, J. S., DOUGLAS, H. A., THOMASSON, A. J. and ROBERTSON, J. S. Land capability classification for agriculture: Soil Survey of Scotland Monograph. Aberdeen, Macaulay Institute for Soil Research, 1982, £7.50 (with map).

†BIBBY, J. S., HUDSON, G. and HENDERSON, D. J. Western Scotland: 1:250 000 handbook. Aberdeen, Macaulay Institute for Soil Research, 1982, £7.50 (with maps).

BIRNIE, R. V. Monitoring crop development in N.E. Scotland from Landsat MSS data: Results of the Agrispine experiment. *Proc. Int. Conf. Remote Sensing for Rangeland Monitoring and Management*, Silsoe, Bedford, 1983, 178-190.
The AGRISPINE experiment was conducted in 1982 as a joint venture between the European Space Agency, RAE Farnborough and a number of remote sensing data users in the U.K. The object was to establish a communications network for rapid dissemination of LANDSAT MSS data, and to test the value of real-time satellite data for agricultural monitoring. This paper presents the results for the East Grampian test area and discusses the potential role of LANDSAT data for agricultural monitoring in the U.K.

BIRNIE, R. V., HULME, P. D. and ROBERTSON, R. A. The peat resources of the Island of Yell, Shetland. *Report of Survey and Evaluation for the North of Scotland Hydro-Electric Board*. Aberdeen, Macaulay Institute for Soil Research, 1983.
Report prepared on behalf of the North of Scotland Hydro-Electric Board presenting the results of a peat survey on Yell. The major peat deposits are identified. Estimates of peat volume, peat quality and potential number of annual peat harvests are presented.

BIRNIE, R. V. and STOVE, G. C. Use of Landsat data to monitor iceberg production: Results from the Agrispine experiment for the Jakobshavns Isbrae. Macaulay Institute for Soil Research/National Remote Sensing Centre, Farnborough, 1983.
Reports upon the results of part of the AGRISPINE experiment and illustrates that it is possible to use LANDSAT data to monitor iceberg production from West Greenland glaciers.

BIRNIE, R. V., STOVE, G. C. and RITCHIE, P. F. S. Mapping the distribution of bracken in Scotland by remote sensing techniques: Interim report for the Department of Agriculture for Scotland. Aberdeen, Macaulay Institute for Soil Research, 1983.
Summarises the results of a pilot study, conducted on behalf of DAFS, to assess the role of remote sensing techniques in determining the area of bracken infestation in Scotland. The paper highlights the relative advantages/disadvantages of various air photograph/satellite image-based techniques.

1230 BIRSE, E. L. Species-rich scrub communities and their soils on Hoy, Orkney. *Trans. R. Soc., Edinb.*, 1983, **44**, 65-72.
The species-rich scrub of Hoy, Orkney, is briefly described and classified according to the scheme for the woodland of North Scotland. The soils are classified by the system of the Soil Survey of Scotland and a new unit, *plagisols*, is proposed for colluvial soils under the World Classification.

1270 BOAG, B. and ROBERTSON, L. A technique for studying the microdistribution of nematodes in undisturbed soil. *Revue de Nematol.*, 1983, **6**, 146-148.
Undisturbed soil samples were inoculated with nematodes and their subsequent microdistribution investigated by optical examination of thin sections of the resin impregnated soil materials. The technique has possible applications in identifying the ecological niche occupied by nematodes in different soil types.

†BOWN, C. J. and SHIPLEY, B. M. South East Scotland: 1:250 000 handbook. Aberdeen, Macaulay Institute for Soil Research, 1984, £7.50 (with maps).

†BOWN, C. J., SHIPLEY, B. M. and BIBBY, J. S. South West Scotland: 1:250 000 handbook. Aberdeen, Macaulay Institute for Soil Research, 1982, £7.50 (with maps).

1278 BURRIDGE, J. C. and HEWITT, I. J. The determination of $^{14}N:^{15}N$ isotope ratios by using the (3,0) and (4,1) bandheads of the N_2 second positive system. *Anal. Chim. Acta*, 1983, **153**, 347-350.
Bandheads of two transitions, not previously studied, were examined for their possible application to the determination of nitrogen isotope ratios by optical emission spectroscopy. They were found to be less suitable than the (2,0) and (1,0) transitions at present in general use. The results demonstrated that the emission source previously developed (see Annual Report No. 50, 1979-80) operates with very reproducible excitation conditions.

BURRIDGE, J. C., REITH, J. W. S. and BERROW, M. L. Soil factors and treatments affecting trace elements in crops and herbage. In *Trace Elements in Animal Production and Veterinary Practice*, Occasional Publication No. 7 of the *Brit. Soc. An. Prod.*, 1983, 77-85.
Results from field experiments are used to demonstrate effects of liming, NPK fertilizer application and the addition of trace elements to the soil, on trace-element contents of crops and herbage. The four elements, Co, Cu, Mn and Mo are discussed in detail because of their significance for agricultural problems in North-East Scotland.

CHESHIRE, M. C., SPARLING, G. P. and MUNDIE, C. M. The contribution of polysaccharides of plant or microbial origin to soil structure. *Trans. ISSS/BSSS Meeting, Reading*, 1983, 47.
The polysaccharide component of a range of soils was selectively destroyed using a periodate followed by tetraborate treatment, leaving the soil microaggregates unstable; this suggested an important role for polysaccharides in maintaining soil structure. The periodate treatment appears to attack preferentially polysaccharide typical of microbial sources. A small residue of polysaccharide, resistant to periodate attack, is possibly of plant origin.

1239 CHESHIRE, M. V., SPARLING, G. P. and MUNDIE, C. M. Effect of periodate treatment of soil on carbohydrate constituents and soil aggregation. *J. Soil Sci.*, 1983, **34**, 105-112.
Treatment of soil with sodium periodate-tetraborate over short periods up to 48 hours has previously been assumed to destroy all the aggregation caused by polysaccharide. Studies on the effect of different periods of treatment of soil with periodate show that a considerable proportion of the carbohydrate survives the treatments, but is progressively destroyed. A linear relationship was observed between the carbohydrate content of the soil and the degree of aggregation, implying that soil carbohydrate make a consistent contribution over a very wide range of aggregate stabilities.

1274 CHESHIRE, M. V., MUNDIE, C. M., BRACEWELL, J. M., ROBERTSON, G. W., RUSSELL, J. D. and FRASER, A. R. The extraction and characterization of soil polysaccharide by whole soil methylation. *J. Soil Sci.*, 1983, **34**, 539-554.
Repeated methylation of whole soil forms chloroform-soluble methylated products which contain about 70 per cent of the soil sugars as poly- or oligo-saccharides. Hydrolysis and analysis shows that 1→4 linkages between sugars predominate, but there are considerable proportions of 1→3 linkages for both hexoses and pentoses. The material is highly branched and/or substituted.

1243 COWKING, A., WILSON, M. J., TAIT, J. M. and ROBERTSON, R. H. S. Structure and swelling of fibrous and granular saponitic clay from Orrock Quarry, Fife. *Clay Minerals*, 1983, **18**, 49-64.
The swelling capacity of some clay minerals strongly influences many important physical properties of soils. A full understanding of such swelling can, however, only be achieved by the study of pure minerals. In this investigation the structure and swelling of a fibrous and granular form of the clay mineral saponite were examined mainly by X-ray diffraction and electron microscopy. The results indicate that the granular saponite swells more readily than the fibrous form because the latter possesses a higher degree of structural order resulting in stronger layer-to-layer bonding.

1251 DARBYSHIRE, J. F. and SNEDDON, E. B. Movement of amoebo-flagellates of *cavostelium bisporum*. *Trans. Brit. Mycol. Soc.*, 1983, **80**, 356-357.
Many plasmodial slime moulds (myxomycetes) and their close relatives, the protostelids, have motile flagellate phases that can be readily induced by a sudden dilution of the liquid environment of the soil, such as occurs during rain. Cinemicrophotographic analysis of the movement of one protostelid, *cavostelium bisporum*, suggests that amoeboid movements rather than flagella propel the cells forward while the organism is in contact with the substrate. As most of the prey is attached to soil particles and not floating in the soil solution, these amoeboid movements ensure that the amoebo-flagellates can rapidly explore adjacent new micro-environmental niches while still remaining close to the main source of food.

†DRY, F. T. Orkney and Shetland: 1:250 000 handbook. Aberdeen, Macaulay Institute for Soil Research, 1982, £7.50 (with maps).

1246 FARMER, V. C. Significance of the presence of allophane and imogolite in podzol Bs horizons for podzolization mechanisms. A review. *Soil Sci. Pl. Nutr.*, 1982, **28**, 571-578.
The widely held view that Al and Fe are transported from A2 to B horizons in podzols in the form of fulvate complexes cannot account satisfactorily for the formation of Bs horizons rich in allophane, although this can be the dominant illuvial horizon in Iron Podzols, and a major feature of the B horizon of Iron Humus Podzols and Peaty Podzols. It is argued that the presence of imogolite and of allophanes with imogolite-like structures in such horizons can be explained only by their deposition from hydroxyaluminium silicate (proto-imogolite) sols, which are known to have the necessary chemical and colloidal stability to act as the agent

of transport of Al and, in part, Fe. Evidence is reviewed that indicates that Bh horizons form by the migration of organic colloids through the A2 horizon, and their subsequent precipitation on previously deposited allophane and hydrous iron oxides at the top of the B horizon. Further processes that could lead to the formation of Peaty Podzols with thin iron pan and other podzol types are briefly sketched.

1224 FARMER, V. C. and FRASER, A. R. Chemical and colloidal stability of sols in the Al_2O_3-Fe_2O_3-SiO_2H_2O system: Their role in podzolization. *J. Soil Sci.*, 1983, **33**, 737-742.
Levels of dialysable silica in equilibrium with synthetic hydroxy-aluminium silicate sols indicate that equilibrium between imogolite-type materials and aluminium hydroxides will tend to buffer silica levels within the range 2-6 $\mu g/cm^3$ in drainage water from acidic soils. The constancy with depth of the Al to Fe ratio in oxalate extracts from podzol Bs horizons can be explained only if Al and Fe migrate as mixed hydroxide-silicate sols, which are shown to be nearly as colloidally stable as iron-free sols for Fe:Al ratios up to 1.5.

1275 FARMER, V. C., RUSSELL, J. D. and SMITH, B. F. L. Extraction of inorganic forms of translocated Al, Fe and Si from a podzol Bs horizon. *J. Soil Sci.*, 1983, **34**, 571-576.
A range of extractants commonly used in soil studies both to clean up the crystalline clay minerals by dissolving poorly ordered phases, and to assist in the classification of soils, has been used to assess their efficiency in extracting inorganic forms of translocated Al, Fe and Si from a podzol Bs horizon. A fourth extraction with ammonium oxalate pH 3 is the most efficient single procedure for these phases. It is concluded that a satisfactory characterization of a podzol B horizon requires the use of two extractants: acid oxalate to assess the total amounts of Al, Fe and Si in non-crystalline weathering products, and pyrophosphate or EDTA to assess the amounts in organic forms. Dithionite-citrate-bicarbonate gives a measure of total free iron oxides, but extracts only an ill-defined fraction of the allophane-imogolite complex.

1267 FARMER, V. C., SKJEMSTAD, J. O. and THOMPSON, C. H. Genesis of humus B horizons in hydromorphic humus podzols. *Nature*, 1983, **304**, 342-344.
Hydromorphic humus (or humic) podzols are characterized by the presence of thick, frequently humus-cemented, Bh horizons, dominated by aluminium humate precipitates, which form at around the level of the water-table in quartzose sands. It is proposed that these Bh horizons form as the result of co-precipitation at the interface between organic-rich surface waters and aluminium-bearing groundwater.

1271 FU, B., URE, A. M. and WEST, T. S. Column cementation on aluminium powder as a preconcentration technique for trace element analysis by spark source mass spectrometry. Part I: Copper, lead, ruthenium and the noble metals. *Anal. Chim. Acta.*, 1983, **152**, 95-104.
The technique of column cementation on aluminium powder for pre-concentration form solution of the elements copper, lead, ruthenium and the noble metals is shown to be quantitative over a wide range of concentrations. Optimum conditions of pH, temperature and solution flow-rate are established. In conjunction with final analysis by spark source mass spectrometry of the aluminium powder concentrate, detection limits of well below $1\mu l^{-1}$ and concentration factors of >1000-fold are readily obtainable. Interference effects are discussed and a method of eliminating the principal one, that of iron, by masking with fluoride is described. The development of the technique for other elements and its application to the analysis of natural waters and soil extracts will be presented in Part II.

FUTTY, D. W. The soils. In *The Sutherland Book*. Edited by D. Omand. Golspie, the Northern Times Ltd., 1983, 62-73.
Soil-forming factors, with particular reference to Sutherland, are discussed and the soils of Sutherland described under major soil subgroup headings.

†FUTTY, D. W. and TOWERS, W. Northern Scotland: 1:250 000 handbook. Aberdeen, Macaulay Institute for Soil Research, 1982, £7.50 (with maps).

1276 GAULD, J. H. and BELL, J. S. Soils and their associated management problems within the Carses of Gowrie and Earn, Perthshire. *Scott. Geogr. Mag.*, 1983, **99**, 77-88.

The soils located in the Carses of Gowrie and Earn and developed on raised beach deposits have been investigated with due regard to problems which are associated with their management. Through intense drainage and attention to crop rotation, these soils have been converted into rich arable land, where the current trend is for continuous cereal cropping. However, due to the fine texture of the soils, severe management problems are often encountered and these have been discussed in relation to current cultural practices, modern management techniques and trends in soil drainage. To extend the usefulness of soil maps and to focus attention on possible changes in soil condition, there is an urgent need to undertake soil physical measurements.

1281 GAULD, J. H. and BROWN, K. W. M. The application of soil survey data in opencast coal sites in Scotland. *Appl. Geogr.*, 1983, **3**, 225-238.

A commitment by the National Coal Board Opencast Executive to restore opencast coal areas to agricultural use as efficiently as possible recognises the need for continual improvement in techniques. The Department of Agriculture and Fisheries for Scotland, as agents to the National Coal Board Opencast Executive, share a similar objective. Both organisations appreciate the need for a comprehensive soil survey, but experience has shown that general-purpose maps and reports are not always adequate for use in opencast mining operations. A soil survey of a proposed site at Keirsbeath is described and, on the basis of results from the use of improved survey methodology, and computer techniques to analyse the data, interpretative maps have been produced. The procedures, together with an examination of soil quantities available for restoration, and of critical moisture levels in soil stripping, are an improvement with significance for the planning and development work stage. A scheme of soil operations has been presented and the relevance of soil data to the forthcoming restoration and rehabilitation stages is discussed.

GOODMAN, B. A. and DeKOCK, P. C. Applications of Mössbauer spectroscopy to the study of iron in plants. *European Society for Nuclear Methods in Agriculture, Physical Methods, Newsletter*, 1981, 16-27.

A brief description is given of the principal features of Mössbauer spectra that are relevant to investigations of the forms of iron in plants. The usefulness of the technique is illustrated with examples from studies on garden pea and duckweed, in which the iron was enriched with the ^{57}Fe isotope.

HELSEN, J. A. and GOODMAN, B. A. Characterization of iron(II) — and iron(III) — exchanged montmorillonite and hectorite using the Mössbauer effect. *Clay Minerals*, 1983, **18**, 117-125.

The absorption of transition metals in the interlamellar spaces of clay minerals may be an important factor in determining their mobility in the soil and their availability to plants. In the present paper, the forms of iron on the exchange sites of montmorillonite and hectorite have been characterized by Mössbauer spectroscopy. Ferrous iron was shown to be present as the solvated cation Fe^{2+}_{aq} in both minerals. In contrast, the spectra of clays saturated with ferric iron had components characteristic of ferric iron bound directly to the surface of the minerals, although with monmorillonite, but not hectorite, an additional component was observed which is probably a hydrated cation, such as $Fe(OH)^{2+}_{aq}$ or $FeCl^{2+}_{aq}$, but definitely not Fe^{3+}_{aq}.

1265 HUDSON, G. and HENDERSON, D. J. Soils of the Inner Hebrides. *Proc. R. Soc. Edinb.*, 1983, **83B**, 107-119.
The field mapping of the soils of the Inner Hebrides has revealed a range of major soil subgroups including calcareous regosols, brown forest soils, humus-iron podzols, peaty podzols, peaty gleys and peat. The parent materials, vegetation communities and Land Capability for Agriculture of the soils are described, and the distribution of soils in relation to various factors controlling their formation discussed

†HUDSON, G., TOWERS, W., BIBBY, J. S. and HENDERSON, D. J. The Outer Hebrides: 1:250 000 handbook. Aberdeen, Macaulay Institute for Soil Research, 1982, £7.50 (with maps).

1228 HULME, P. D. and BLYTH, A. W. The annual growth period of some *sphagnum* species on the Silver Flowe National Nature Reserve, South-West Scotland. *J. Bryol.*, 1982, **12**, 287-291.
The length of the growing season of five *Sphagnum* (bog moss) species was investigated in south-west Scotland. A mechanism of hollow and pool enlargement is proposed.

1257 JONES, D. Scanning electron microscopy of the soil fungus *Stilbella Bulbicola*. *Trans. Brit. Mycol. Soc.*, 1983, **80**, 541-543.
This paper describes the fine structure of critical point-dried spores and spore-bearing organs of the soil fungus, *Stilbella bulbicola*, as seen in a scanning electron microscope. The information supplements the first light microscope observations made on a similar fungus in Germany in the early part of the century. The information presented here is important in determining the taxonomic status of a fungus which is proving of interest in views of its antagonism towards other soil fungi and its ability to decompose certain phenolic acids in soils.

1226 JONES, D., WILSON, M. J. and LAUNDON, J. R. Observations on the location and form of lead in *Stereocaulon vesuvianum*. *Lichenologist*, 1982, **14**, 279-286.
Some lichens appear to thrive in environments polluted with potentially lethal metals such as lead. However, the precise location and form of this metal in such lichens has not hitherto been established. This note describes the use of scanning electron microscopy and X-ray powder diffraction in studying these aspects with reference to lead in *Stereocaulon vesuvianum*, a rock-encrusting lichen often associated with lead-polluted environments. A basic lead carbonate was identified and shown to be associated mainly with the mycelium of the lichen fungus (mycobiont).

1247 LAU, C. M., URE, A. M. and WEST, T. S. Atom trapping absorption spectrometry. *Anal. Proc.*, 1983, **20**, 114-117.
The principle and apparatus of atom-trapping atomic absorption spectrometry are described. The experimental parameters, interference effects and the mechanism of trapping and atomization of analyte species from the surface of a silica tube atom trap are discussed. For most elements an increase in sensitivity of 10-50 times compared with the conventional flame technique can be found. Some of the practical applications of the atom trapping technique are summarized.

1233 LAU, C. M., URE, A. M. and WEST, T. S. The determination of lead and cadmium in soils by atom trapping atomic absorption spectrometry. *Anal. Chim. Acta.*, 1983, **146**, 171-179.
The technique of atom trapping atomic absorption spectrometry for trace element analysis has been applied to the determination of total and extractable lead and cadmium in soils. The optimum experimental parameters were established for both elements and the interference effects of some cations present in over five hundred fold excesses were assessed. Extractions of twelve typical Scottish topsoils by 0.05 M EDTA and 0.5 M acetic acid were made for the analysis of extractable lead and cadmium, and total lead and cadmium were determined in aqua regia digests of these soils.

1253 LETHBRIDGE, G. and DAVIDSON, M. S. Microbial biomass as a source of nitrogen for cereals. *Soil Biol. Biochem.*, 1983, **15**, 375-376.
Wheat and maize grew well on microbial biomass as a sole source of N in sand culture. In a low N soil ^{15}N labelled microbial biomass was equally as effective as $^{15}NO_3$-N in supplying N to wheat, whereas in a higher N soil it was only 68% as effective as NO_3-N. In both soils, plant fertilized with microbial biomass took up to 20-30% more N from the soil pool than those fertilized with NO_3-N and there was a corresponding increase in yield in the biomass fertilized plants. The results are discussed in terms of the indigenous soil microbial biomass as a source of plant nutrients and the possibility of adding microbial biomass to soil as an organic fertilizer.

1255 LETHBRIDGE, G. and DAVIDSON, M. S. Root-associated nitrogen-fixing bacteria and their role in the nitrogen nutrition of wheat estimated by ^{15}N isotope dilution. *Soil Biol. Biochem.*, 1983, **15**, 365-374.
Nitrogen-fixing bacteria are frequently found in close association with the roots of wheat. The ability of these microorganisms to supply the host plant with agriculturally significant quantities of nitrogen from the atmosphere was investigated using ^{15}N isotope dilution. The results indicated that nitrogen fixation in the root zone of wheat is negligible in temperate climates. There appears to be too little carbohydrate available to the root-associated bacteria to allow them to fix enough nitrogen to benefit the host plant.

1260 MACDONALD, I. R., HART, J. W. and GORDON, D. C. Analysis of growth during geo-tropic curvature in seedling hypocotyls. *Plant, Cell and Environment*, 1983, **6**, 401-406.
The kinetics of the growth of seedling plants curving to regain a vertical orientation, have been analysed using time-lapse photography. The results indicate that gravity has two distinct effects on the growth of the horizontal stem, promoting growth on the lower side and inhibiting growth on the upper side. These events are discussed in relation to current theories on the regulation of plant growth.

1259 MACDONALD, I. R., GORDON, D. C., HART, J. W. and MAHER, E. P. The positive hook: The role of gravity in the formation and opening of the apical hook. *Planta*, 1983, **158**, 76-81.
A crucial stage in the development of dicotyledonous seedlings is the formation of the hypocotyl hook which occurs prior to the emergence of the seedling through the soil surface. This study shows that gravity plays a major role in the formation of the hook and that the normal reversal of polarity in respect of geo-sensitivity between stem and root is mirrored at the apical end of the hypecotyl.

1263 McHARDY, W. J. and ROBERTSON, L. An optical, scanning electron microscopic and microanalytical study of cementation in some podzols. *Geoderma*, 1983, **30**, 161-170.
The use of scanning electron microscopy with associated microanalysis has been examined as a means of extending conventional optical observations on polished soil thin sections in connection with studies on the nature of the material responsible for cementation in certain podzolic soil horizons. The optical microscope shows that skeleton grains are heavily coated and bridged by monomorphic organic matter, while X-ray microanalysis indicates aluminium to be the dominant inorganic element present. This suggests that the cementing agent in these materials is an Al-organic complex.

MACKENZIE, R. C. Nomenclature in thermal analysis. In *Treatise on Analytical Chemistry*. Edited by I. M. Kolthoff, P. J. Elving and C. B. Murphy. Second ed., Pt. I, Vol. 12. New York, Wiley Interscience, 1983, 1-16.
The three published reports and one report as yet unpublished of the Nomenclature Committee of the International Confederation for Thermal Analysis have been integrated to give a logical system of thermal analysis nomenclature. This system allows for possible subsequent extension and addition of detail.

1252 MACKENZIE, R. C. Origin of thermal analysis. *Isr. J. Chem.*, 1982, **22**, 203-205.
Thermoanalytical techniques are often used in soil science, but their origin is vague. Recent international acceptance of a definition of "thermal analysis" should enable the originator to be located. A search of the literature suggests that the first to use a technique that could be so classified was Jakob Fredrik Emanuel Rudberg (1800-1839) in Sweden, who observed inverse cooling-rate pheonomena in 1829; he was succeeded by Moritz Ludwig Frankenheim (1801-1869) in Germany, who determined cooling curves in 1837, John Ballantyne Hannay (1835-1931) in Scotland, who introduced mass-charge curves in 1877, and Henry Louis Le Chatelier (1850-1936) in France, who devised quasi-isothermal heating curves and heating-rate curves in 1883 and 1887, respectively. As all of these studies were probably intially independent of the earlier work, perhaps the honour should be shared.

1273 MACKLON, A. E. S., SIM, A., PARSONS, D. G., TROTTER, M. R. and WINGFIELD, J. N. Effects of some cyclic "crown" polyethers on potassium uptake, efflux and transport in excised root segments and in whole seedlings. *Ann. Bot.*, 1983, **52**, 345-356.
Three synthetic potassium-complexing compounds were tested for their effects on potassium absorption by roots, both at the cellular level and in whole seedling plants, with a view to their possible utilization in making more efficient use of nutrients in the soil. Two of the compounds reduced net potassium absorption, but a third had a stimulatory effect on potassium uptake when used at concentrations sufficiently low to approach commercially viable application.

McPHAIL, D. B., LINEHAN, D. J. and GOODMAN, B. A. The use of EPR spectroscopy as a tool in the investigation of the uptake of trace metals by plants. *European Society for Nuclear Methods in Agriculture, Physical Methods, Newsletter*, 1981, 58-64.
Results from an investigation of the uptake of cupric and vanadyl ions by wheat have been used to illustrate the potential application of EPR spectroscopy in the *in vivo* study of the uptake of metal ions by plants. A brief account of the basic theory required for interpretation of the spectra is given.

1269 MALCOLM, R. E. Assessment of phosphatase activity in soils. *Soil Biol. Biochem.*, 1983, **15**, 403-408.
In many of the publications dealing with the measurement of phosphatase activities in soils the basic rules governing assays have, at best, been only partially obeyed. This review article concentrates on the measurement of phosphatase activity, draws attention to the wide discrepancies in its assay and urges the adoption of a more uniform technique obeying the rules of simple enzyme kinetics.

MILLER, H. G. Nutrient cycling in alder. *Rept. 2 of Program Group B., I.E.A./Forestry Energy Agreement.* Stockholm, National Swedish Board for Energy Source Development, 1983.
The literature on growth and the accumulation, uptake and release of nutrients by alder species, including their ability to fix atmospheric dinitrogen, is reviewed. On the basis of the available information models of nutrient cycling are developed for *Alnus rubra* grown as energy plantations on rotations of 2, 5 and 20 years. The annual demands made on soil nutrient reserves did not differ greatly between rotation lengths, but the nutrient cost per unit of biomass harvested is very much less in the longest rotation.

1245 MILLER, H. G. Studies of proton flux in forests and heaths in Scotland. *Proc. Workshop on the Effects of Accumulation of Air Pollutants in Forest Ecosystems, Gottingen, May, 1982.* Edited by B. Ulrich and J. Pankrath, 1983, 183-193.
The role of the vegetation, and associated soil organic layers, in the production and consumption of acidity is being examined as part of a

continuing study of element cycling in forests and heaths. Nutrient uptake by tree roots introduce to the soil equivalent amounts of acidity to that in acid rain, but because rainwater acidity is accompanied by mobile anions this is the more likely to reach streams, provided that drainage over or through the soil is so rapid that neutralization reactions are not completed. In polluted regions, tree crowns appear to accentuate the episodicity of hydrogen ion input to the soil.

MILLER, H. G. Wood energy plantations — diagnosis of nutrient deficiencies and the prescription of fertilizer applications in biomass production. *Rept. 3 of Program Group B, I.E.A./Forestry Energy Agreement.* Maple, Ontario Tree Improvement and Forest Biomass Institute, 1983.
The literature on tree nutrition and forest fertilization is discussed in the light of particular requirements for short-rotation energy-biomass forests. It is suggested that soil analysis is not a useful guide, but that both foliar symptoms and foliar analysis could be used. Deficiency symptoms are described and an attempt made to derive generalised critical and optimum foliar nutrient levels, including suggestions of how these change with tree size. Provisional schedules are drawn up of cultural operations, including applications of both weedicides and fertilizers, for short-rotation forests on six main soil types.

MILLER, H. G. and MILLER, J. D. The interaction of acid precipitation and forest vegetation in Northern Britain. *Water Quality Bull.*, 1983, **8**, 121-126.
Rainwater acidity is shown to be considerably modified by tree canopies, both acidification and neutralization occurring dependent on the acidity of the incoming precipitation. The extent of such changes, however, vary both with site for a particular species and between species at a particular location. There may also be a pronounced seasonal effect, with trees in polluted regions apparently increasing the episodicity of hydrogen ion input to the soil.

ODELL, A. W., STOVE, G. C. and WRIGHT, R. Aspects of coastal terrain and estuarine hydrography in north-east Scotland interpreted from sequential Landsat data. In *N.E. Scotland Coastal Field Guide and Geographical Essays for the IGU Coastal Commission Symposium.* Edited by Professor W. Ritchie. Aberdeen, University of Aberdeen Department of Geography, 1983, 126-140.

1279 REITH, J. W. S. Trace elements in soil and herbage. *Norgrass*, 1983, **23**, 33-37.
The paper reviews the main factors that influence the availability in soils and the uptake by herbage of trace elements, mainly cobalt, copper, manganese and molybdenum, based on experimental work on temporary leys. The factors considered are the natural drainage conditions of the soil, its trace element status, and the effects of applying lime and nitrogen and of cobalt and copper additions to correct deficiencies.

1282 REITH, J. W. S., BURRIDGE, J. C., BERROW, M. L. and CALDWELL, K. S. Effects of the application of fertilisers and trace elements on the cobalt content of herbage cut for conservation. 1. Experimental details and results for cobalt. *J. Sci. Fd. Agric.*, 1983, **34**, 1163-1170.
Field experiments were carried out on three mineral soils and on a deep acid peat to measure the effects of fertiliser applications, especially N, on the uptake of trace elements. The experimental treatments, including the quantities of trace elements applied, are recorded. The Co contents in mixed herbage, grass and clover were determined in samples cut at the silage stage of growth, three or four times per year for at least three successive years. Applying N and Co had appreciable effects on the Co content of herbage, which was normally lowest in the first and highest in the last cuts. The effectiveness of the Co supplements varied with soil type, especially after the second year following their application. Some data are given for Co extracted from the soils.

RITCHIE, P. F. S. and STOVE, G. C. Interpretation and automated mapping of airborne and satellite imagery using the Macaulay MAPIPS system. In *Ecological mapping from ground, air and space: I.T.E. Symposium No. 10.* Edited by R. M. Fuller. Monkswood, I.T.E., 1981, 113-124.

ROBERTSON, J. S. Vegetation surveying and mapping in Scotland. *Cartographica,* 1982, **19**, 74-81.
The methods used to survey and map vegetation in Scotland by the Botanical Section of the Soil Survey are discussed. The Section has a basic requirement to consider vegetation in relation to soils and so the techniques of gathering soils information are also considered as a means of establishing statistically acceptable soil/vegetation links. Soils and vegetation information can be represented in the form of maps, but might be more profitably used in the construction of an eco-topographic database from which information would be extracted to suit a variety of specific requirements.

1272 ROMANS, J. C. C. and ROBERTSON, L. The environment of North Britain: Soils. *Proc. "George Jobey Conf.: Settlement in North Britain 1000 B.C.-A.D. 1000."* B.A.R., **118**, 1983, 55-80.
In Part I the present-day soil zonal system is briefly described and an outline of soil profile development is presented. In Part II micromorphological features found useful in the interpretation of archaeological soil samples are described.

ROMANS, J. C. C. and ROBERTSON, L. The general effects of early agriculture on the soil profile. *Proc. Symp. on the Impact of Aerial Reconnaissance on Archaeology. British Archaeology Res. Rept.,* 1983, **49**, 136-141.
The macro and micromorphological trends of soil profile development in early cultivated soils are described and discussed in relation to inferred cultivation procedures, with special reference to buried palaeosoils from two lowland sites on terraces of the River Earn at North Mains Strathallan and Strageath Mains, and to a prehistoric land holding at Scord of Brouster in Shetland.

1268 RUSSELL, J. D., MILODOWSKI, A., FRASER, A. R. and CLARK, D. R. New IR and XRD data for leadhillite of ideal composition. *Mineralog. Mag.,* 1983, **47**, 371-375.
The infrared spectrum and X-ray powder pattern of a chemically-analyzed specimen of leadhillite, a lead carbonate sulphate hydroxide mineral from Leadhills, Scotland, are shown to be different from those in the literature. The IR spectra of several specimens suggest that mutual replacement of SO_4^{2-}, CO_3^{2-} and OH^- may occur in this mineral, and it is thought that this might be responsible for the observed variation in X-ray spacings. The IR spectrum also suggests that the anions may be partly segregated in the structure, an observation which may help to explain the mechanisms by which leadhillite is formed during the weathering of galena.

1235 RUSSELL, J. D., VAUGHAN, D., JONES, D. and FRASER, A. R. An IR spectroscopic study of soil humin and its relationship to other soil humic substances and fungal pigments. *Geoderma,* 1983, **29**, 1-12.
Humin, relatively free from mineral components, has been isolated from a sandy soil, and shown by IR spectroscopy and by chemical analysis to be similar to humic acid derived from the same soil. It is also similar to the dark melamin pigments from the soil fungi *Rhizoctonia solani, Coniothyrium minitans* and to some extent *Aspergillus niger.* This observation suggests that humin (and humic acid) may be derived at least in part from the pigments produced by such organisms and, therefore, that humic substances are to a considerable extent microbial in origin. Although humin is, by definition, not extractable from soil and might therefore be considered to be inactive, it was shown that, when ^{13}C-labelled humin was incubated with fresh soil, about 20% of the radio-

activity was lost after three months and 25% after six months, a result similar to that obtained using humic acid. This indicates that humin, despite its insolubility, is an active component in the soil, and that the rates of turnover of humin and humic acid in the soil are similar.

1250 SCOTT, N. M., FRASER, A. R. and RUSSELL, J. D. Ammonia-treated vermiculite — an efficient controlled-release nitrogeneous fertilizer for a variety of crops. *J. Sci. Fd. Agric.*, 1983, **34**, 233-238.
The flake size of ammonia-treated vermiculite (ATV) has been shown to control the release of ammonium ions to plants, the smaller the flake the more rapid the release. The N released from fine ATV (0.25-0.5 mm) is sufficient to produce a yield of oats superior to that obtained using either ammonium nitrate or ammonium sulphate; it also gave a 10% greater oven-dray weight of potatoes than did either ammonium nitrate or IBDU, the slow release N fertilizer, and 7% greater than sulphur-coated urea. Coarse ATV (2.8-4.0 mm) gave significantly smaller yields of oats and potatoes than did all of the other N fertilizers. The importance of the flake size is further demonstrated with ryegrass where the slower release of nitrogen from the coarse ATV gives three relatively constant intermediate yields over the season compared with two high and one low for ammonium nitrate, ammonium sulphate and fine ATV. This observation suggests a possible practical application to grazing conditions.

1254 SCOTT, N. M., WATSON, M. E., CALDWELL, K. S. and INKSON, R. H. E. Response of forage crops to sulphur fertilisation at two sites in north-east Scotland. *J. Sci. Fd. Agric.*, 1983, **34**, 357-361.
Herbage yields were increased with added S in two contrasting soils which had low amounts of available sulphate. The yield increases occurred mainly in cuts two and three and at one site amounted to an increase of 2.39 tonnes/ha at the third cut, and to 3.75 tonnes for three cuts compared to the S_0 treatment. Added S also affected the S uptake and S composition of the crop and intial results indicate that plant SO^{2-}_4-S is the most promising parameter to predict S deficiency in crops.

SHAND, C. A., AGGETT, P. J. and URE, A. M. Preparation of biological samples for multielement analysis by spark source mass spectrometry. In *Trace Element Analytical Chemistry in Medicine and Biology, Vol. 2.* Edited by P. Bratter and P. Schramel. Berlin, W. de Gruyter, 1983, 1025-1037.
The problems associated with the comprehensive trace element analysis of biological materials by Spark Source Mass Spectrometry are elucidated with particular regard to sample preparation and contamination. The methods of dry ashing versus oxidative digestion procedures are considered. A preconcentration procedure for elements occurring below the normal detection limit is illustrated. The trace element contents of bovine liver samples determined by these methods are given.

†SHIPLEY, B. M., *et al.* Soil survey map of Crieff (Sheet 47). Scale: 1:63 360. Ordnance Survey, 1983, £2.50.

1262 SMITH, B. F. L., MITCHELL, B. D. and MACKENZIE, R. C. Susceptibility to weathering of some Scottish rocks and their derived soils. *Trans. R. Soc. Edinb., Earth Sci.*, 1983, **73**, 191-203.
In an attempt to assess the weatherability of rock types giving rise to the main soil Associations in north-east Scotland and the soils derived therefrom, methods based on chemical composition, the nature and amount of poorly ordered aluminosilicate materials and the degree of polymerization of silica have been applied to a series of essentially residual soils and their parent rocks. While chemical methods tend to give results consistent with field observations, the amount of monomeric silica released on acid attack is more closely related to the nature and amount of poorly ordered aluminosilicate present than to weatherability. Only the two chemical methods tested gave a reasonable idea of the susceptibility to further weathering of the parent rocks and the soils.

†SOIL SURVEY STAFF. Land Capability for Agriculture Maps of Scotland. Scale: 1:250 000. Sheet 1 (Orkney and Shetland); Sheet 2 (The Outer Isles); Sheet 3 (Northern Scotland); Sheet 4 (Western Scotland); Sheet 5 (Eastern Scotland); Sheet 6 (South West Scotland); Sheet 7 (South-East Scotland). Southampton, Ordnance Survey, 1982. (Price: see below.)

†SOIL SURVEY STAFF. Soil Maps of Scotland. Scale: 1:250 000. Sheets as above.

(Please note: These 1:250 000 maps are available for purchase only in packages for each area, containing soil map, LCA map and accompanying descriptive handbook. £7.50 per package.)

1258 SPARLING, G. P. Estimation of microbial biomass and activity in soil using microcalorimetry. *J. Soil Sci.*, 1983, **34**, 381-390.

All organisms evolve heat when they are growing, and the growth and activity of microbes are largely responsible for organic matter turnover and mineral cycling in soil. The heat output from soils was measured in a microcalorimeter and used to estimate the activity of the soil microbial biomass. In many soils the bulk of the biomass was found to be dormant, but soon became active if readily available substrates were added. There was a consistent relationship between the rate of heat output and the biomass in amended soils, so that the biomass can be predicted by measuring the heat output.

1248 SPARLING, G. P. and EILAND, F. A comparison of methods for measuring ATP and microbial biomass in soils. *Soil Biol. Biochem.*, 1983, **15**, 227-229.

Many different methods and types of equipment are available for measuring the biochemical activity of microbes in soil, and it is sometimes difficult to make comparisons between soils analysed in different laboratories. Three laboratories collaborated in a study to measure the soil ATP content and the soil biomass. In general there was good agreement between laboratories using similar methods, and minor changes such as instrumentation had little effect, although other factors, such as the reagents used to extract ATP, could result in large differences in the results of analyses performed by the different laboratories.

SPARLING, G. P., DAVIDSON, M. S., LEIGHTON, J. A. and LETHBRIDGE, G. Microbial cells as a source of plant nutrients. *Trans. ISSS/BSSS Meeting, Reading*, 1983, 88.

Soil microorganisms form a comparatively large and labile pool of predominantly organic nutrients which are potentially available for plant growth. In a series of pot experiments, the responses of a wide range of crop plants to additions of various types microbial cells was measured. The plants all showed large growth responses and higher N and P contents when cells were added. The size of the response depended on the crop species, soil and the amount and type of microbial cells added.

1232 SPARLING, G. P., FERMOR, T. R. and WOOD, D. A. Measurement of the microbial biomass in composted wheat straw and the possible contribution of the biomass to the nutrition of *Bisporus Agaricus*. *Soil Biol. Biochem.*, 1983, **14**, 609-611.

Edible mushrooms are grown commercially on composted wheat straw, and it has been previously suggested that the microbial biomass of the compost could influence the yield of mushrooms. The biomass of composts was, therefore, measured and although estimated to contribute a maximum of about 10% to the carbon requirement of the mushroom it may be more important as a concentrated source of nitrogen and minerals.

1261 STOVE, G. C. Current use of remote sensing data in Scotland. *Phil. Trans. R. Soc., Lond.*, 1983, A**309**, 271-281.
The remote sensing methodology developed at the Macaulay Institute for natural resource surveys is introduced and some recent mapping and environmental monitoring projects are reviewed. The current use of remote sensing data by the Peat Survey Section and the Soil Survey Department is reviewed for peat, soil and vegetation mapping. Current projects include the DAFS Bracken Survey of Scotland, the AGRISPINE Experiment for the U.K. National Remote Sensing Centre at RAE Farnborough and the SAR 580 Experiment for the European Space Agency.

SYED, M. A., COOMBS, T. L., GOODMAN, B. A. and McPHAIL, D. B. The nature of the copper(II) components of ceruloplasmin. *Biochem. J. Letters*, 1982, **207**, 183-184.
In collaboration with the Institute of Marine Biochemistry, ceruloplasmin, a copper oxidase that occurs in vertebrate plasma, has been studied in detail by electron paramagnetic resonance (EPR) spectrometry. The results show that with plaice ceruloplasmin the oxidase activity is located at one type of Cu(II)-containing site, and that the other type of Cu(II)-containing site, reported by other workers for mammalian ceruloplasmin, is probably in an impurity phase.

1244 TAIT, J. M., VIOLANTE, A. and VIOLANTE, P. Co-crystallization of gibbsite and bayerite with nordstrandite. *Clay Minerals*, 1983, **18**, 95-99.
Gibbsite, bayerite and nordstrandite — the three polymorphs of aluminium hydroxide, $Al(OH)_3$ — occur naturally in soil clays and clay deposits. During a study of the crystal morphology of nordstrandite synthesized under various conditions, small amounts of gibbsite and bayerite have been identified, in different samples, and are shown to be frequently co-crystallized with the nordstrandite. The gibbsite occurs either as individual hexagonal prisms or as tapered prisms co-crystallized with tabular nordstrandite crystals in a hammer-shaped configuration. Some ovoidal nordstrandite crystals, synthesized in the presence of montmorillonite, have roughly cone-shaped crystals of bayerite projecting from their centres.

THORNTON, B. Effects of amino acid analogues on the uptake and translocation of some nutrient ions in seedling plants. *Ph.D. Thesis, Aberdeen University*, 1983.

URE, A. M. Atomic absorption and flame emission spectrometry. In *Soil analysis: modern instrumental techniques*. Edited by K. A. Smith. N.Y., Marcel Dekker, 1983.
The basic principles of atomic absorption and flame emission spectrometry are outlined and current developments of these techniques reviewed in terms of their relevance to the analysis of soils and soil extracts. Comprehensive references are given to recent (1971 *et. seq.*) applications of these methods to the analysis of soils.

1266 VAUGHAN, D. and ORD, B. G. Influence of humic acid on iron required for the formation of hydroxyproline in discs of *beta vulgaris L.* storage tissue. *Plant and Soil*, 1983, **73**, 27-34.
It has previously been shown that humic acid affects plant metabolism but the mechanism is not yet clear. When slices of beetroot storage tissue are washed in water there is a 100% increase in the amino acid hydroxyproline found in their cell-wall proteins. Humic acid enhances the increase in hydroxyproline formation, but has not effect on the uptake by the tissue or the incorporation into proteins of the hydroxyproline precursor proline. A comparison of the effects of humic acid with those of chelating agents such as 2,2′-dipyridyl, or 8-hydroxyquinoline on the formation of hydroxyproline suggest strongly that humic acid enhances the hydroxylation of proline by rendering more ferrous iron available to the hydroxylation process or by increasing the activity of the hydroxylating enzyme.

1264 VAUGHAN, D., DeKOCK, P. C. and ORD, B. G. Effects of benzyladenine and abscisic acid on superoxide dismutase in fronds of the duckweed *lemna gibba L. Physiol. Plantarum*, 1983, **58**, 239-242.
Previous work has shown that the enzyme superoxide dismutase (SOD) is present in the fronds of *Lemna gibba L.* SOD protects plant tissues from oxygen toxicity and low levels of its activity are associated with tissue senescence. The growth promoting (benzyladenine) and growth inhibiting (abscisic acid) plant hormones affect the development of SOD activity in opposite ways, the former decreasing the activity and the latter increasing it. The effect of benzyladenine can be ascribed to its inhibitory effect on Zn uptake because this metal is necessary for SOD activity.

1277 VAUGHAN, D., SPARLING, G. P. and ORD, B. G. Amelioration of the phytotoxicity of phenolic acids by some soil microbes. *Soil Biol. Biochem.*, 1983, **15**, 613-614.
The phenomenon of allelopathy is one example of the influence of plants on their environment. This influence can be exerted by the release of phytotoxic concentrations of organic substances, for example phenolic acids, from a variety of plant species. This report shows that the phytotoxicity of ferulic, caffeic, p-coumaric and p-hydroxybenzoic acids towards the growth of winter wheat can be ameliorated by soil bacteria and fungi capable of using these phenolic acids as their sole source of carbon. It is suggested that under field conditions, soil microorganisms can play a vital role in controlling phytotoxicity.

1231 VIOLANTE, P., VIOLANTE, A. and TAIT, J. M. Morphology of nordstrandite. *Clays and Clay Minerals*, 1982, **30**, 431-437.
In continuation of studies on the occurrence of aluminium oxides and hydroxides in soils, the crystal morphology of nordstrandite synthesized under different conditions was investigated by transmission and scanning electron microscopy, and by electron riffraction. The synthetic nordstrandite exhibited a morphological variation similar to that observed in soils and sediments.

1237 VIOLANTE, P. and WILSON, M. J. Mineralogy of some Italian andasols with special reference to the origin of the clay fraction. *Geoderma*, 1983, **29**, 157-174.
The mineralogy of four Italian soils derived from volcanic ash has been investigated by a variety of techniques. In all profiles the clay fraction is dominated by halloysite and amorphous materials (imogolite and protoimogolite allophane) with moderate illite and smectite-vermiculite, minor kaolinite and occasional gibbsite. Evidence is presented to show that, with the exception of illite, these minerals are of pedogenic origin, deriving from the decomposition of volcanic glass and weatherable primary minerals like leucite, clinopyroxene and calcium-rich plagioglase feldspar.

†WALKER, A. D., CAMPBELL, C. G. B., HESLOP, R. E. F., GAULD, J. H., LAING, D., SHIPLEY, B. M. and WRIGHT, G. G. Eastern Scotland: 1:250 000 handbook. Aberdeen, Macaulay Institute for Soil Research, 1984, £7.50 (with map).

1238 WILLIAMS, B. L. The nitrogen content of particle size fractions separated from peat and its rate of mineralization during incubation. *J. Soil Sci.*, 1983, **34**, 113-125.
Particle size fractions, varying from 5 to 0.005 mm, were separated from samples of several peat types using a wet sieving technique. In all the types, the nitrogen content was highest in the fine fraction (<0.05 mm and >0.005), accounting for around 27-47 per cent of the total nitrogen. During incubation, peats from blanket bogs and raised bogs behaved differently in their patterns of inorganic nitrogen release and carbon dioxide evolution with particle size, thus giving some indication of the nature and location of readily decomposable carbon and nitrogen compounds.

1249 WILLIAMS, B. L. Nitrogen transformations and organic matter decomposition in litter and humus from beneath closed canopy Sitka spruce. *Forestry*, 1983, **56**, 17-32.
Growth and nitrogen requirements of coniferous trees, planted on soils of low nutrient status, depend very much on the release of inorganic nitrogen from decomposing litter and humus. In the present study, rates of inorganic nitrogen production in surface organic horizons beneath Sitka spruce growing on a brown forest soil have been measured under field and laboratory conditions. Annual release under field conditions amounted to 50 and 17 kg N ha^{-1} in litter and humus respectively. An application of nitrogen, phosphorus and potassium fertilizers, 18 months previously, decreased these values slightly but stimulated the production of nitrate-nitrogen in both litter and humus.

WILSON, M. J. and JONES, D. Lichen weathering of minerals: Implications for pedogenesis. In *Residual Deposits: Surface Related Weathering Processes and Materials*. Edited by R. C. L. Wilson. Special Pub. No. 11 of the Geological Society. London, Blackwell, 1983, 5-12.

1241 WILSON, M. J. and RUSSELL, J. D. Melanosiderite is siliceous ferrihydrite. *Min. Mag.*, 1983, **47**, 85-87.
Melanosiderite was first described as a hydrated basic iron silicate and claimed as a new mineral species, although it was later regarded as a mixture of hydrous iron oxide with colloidal silica or silicate. X-ray diffraction and infrared spectroscopic studies prove that melanosiderite is, in fact, siliceous ferrihydrate in a fairly pure, but highly unsual form.

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, KA6 5HL.
Hill Farming Research Organisation	Bush Estate, Penicuik, Midlothian, EH26 0PH.
Macaulay Institute for Soil Research	Craigiebuckler, Aberdeen, AB9 2QJ.
Rowett Research Institute	Bucksburn, Aberdeen, AB2 9SB.
Scottish Institute for Agricultural Engineering	Bush Estate, Penicuik, Midlothian, EH26 0PH.
Scottish Crop Research Institute	Invergowrie, Dundee, DD2 5DA. and Pentlandfield, Roslin, Midlothian, EH25 9RF.

State-aided Institutes (England and Wales)

Animal Virus Research Institute	Pirbright, Woking, Surray, 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.
Rothamstead Experimental Station	Harpenden, Herts., AL5 2JQ.
Welsh Plant Breeding Station	Plas Goggerddan, Aberystwyth, Dyfed, SY23 3EB.
Wye College, Department of Hop Research	Ashford, Kent, TN25 5AH.

S.U.N. Print Division, 113 High Street, Galashiels.