THE MACAULAY INSTITUTE FOR SOIL RESEARCH

FOUNDED 1930

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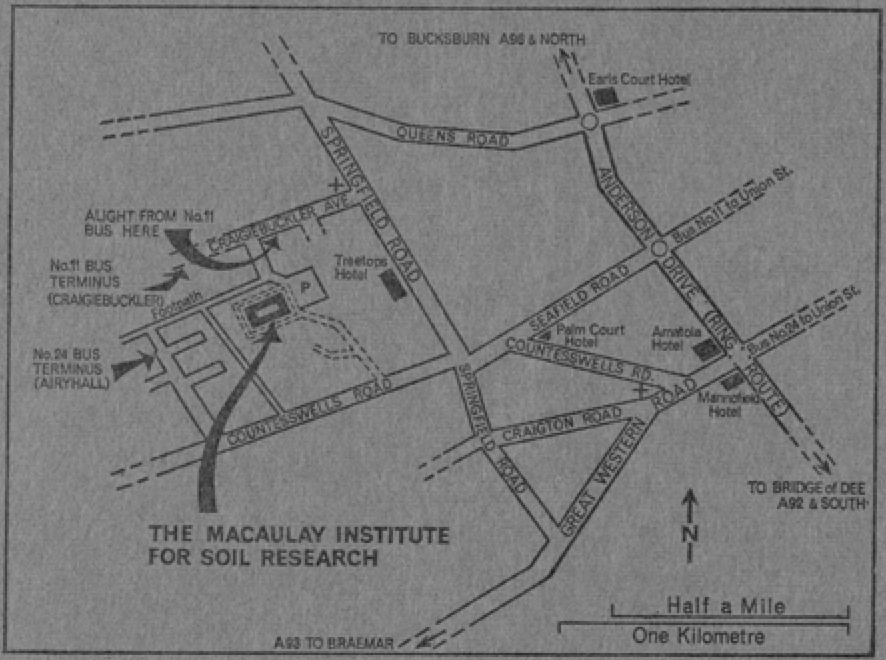

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

(Founded 1930)

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1970-1971

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Mrs B. B. Mackie—resigned 31/1/71.
Miss N. I. MacWilliam.
Miss S. E. Masson—appointed 1/9/71.
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Miss C. A. Ross—1/10/70-31/7/71.
Miss M. Sinclair—resigned 31/8/71.
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A. G. Gall.
S. A. Duncan—retired 22/12/70.
J. A. M. Anderson—appointed 15/2/71.
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S. Harris.

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Miss F. M. Strachan, B.Sc.—resigned 30/6/71.
Mrs D. E. G. Paterson, B.Sc.—appointed 1/7/71.
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	A. I. A. Wilson.
	R. Riddell.
Photographer	J. Mitchell.

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	G. A. Reid.
	J. Shaw.
	H. Shaw.
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VISITING RESEARCH WORKERS

N. A.-A. ALI (Geological Centre, Regional Planning of Asswan, Asswan, U.A.R.).

A. CARVALHO (Department of Soil Science and Soil Survey, Institute of Agronomy, Sao Paulo, Brazil).

CATHERINE DOUKA (Department of Agriculture, Nuclear Research Centre "Democritus," Aghia Paraskevi-Attikis, near Athens).

H. K. EL-KHOLY (7 Al-Shaik Al-Amir Street, Kobba Gardens, Cairo, U.A.R.).

A. S. DE ENDREDY (F.A.O., Rome, Italy).

H. HANI (Station Fédérale d'Essais de Chimie Agricole, 3097 Liebefeld, Bern, Switzerland).

Y. HENIS (Department of Plant Pathology and Microbiology, Faculty of Agriculture, Hebrew University, Rehovot, Israel).

G. W. JONES (Agricultural Chemistry Department, The Queen's University, Belfast, Northern Ireland).

IRENE KUCZYNSKA (Institute for Land Reclamation and Grassland Farming, Bydgoszcz, Poland).

*JUDITH E. LONGLAND (Trent Polytechnic, Nottingham).

*N. S. MCGREGOR (Napier College, Edinburgh).

M. E. F. VAN MENSVOORT (Department of Soil Science, Agricultural University, Wageningen, Netherlands).

H. W. MORGAN (I.C.I. Post-Doctoral Fellowship).

A. NEGRO (Faculty of Architecture, Institute of General and Applied Chemistry, Turin Polytechnic, Turin, Italy).

Y. OHTA (Faculty of Agriculture, Tokyo University of Education, Komaba, Japan).

L. P. RAIKOV (Nikola Pushkarov Institute of Soil Science, Sofia, Bulgaria).

*C. A. SHAND (Robert Gordon's Institute of Technology, Aberdeen).

*S. J. THOMPSON (Nottingham Regional College of Technology).

W. VAN DE WESTERINGH (Department of Soil Science, Agricultural University, Wageningen, Netherlands).

**Sandwich-Course student.*

CONTENTS

INTRODUCTION

It is now over forty years since a benefaction from the late Dr T. B. Macaulay, at that time President of the Sun Life Assurance Company of Canada, led to the foundation of the Institute. Dr Macaulay's forebears stemmed from Uig in the Island of Lewis and, having visited the Highlands and Islands in the 1920's and seen the conditions then prevailing, he expressed a desire to do something to further Scottish agriculture, particularly in the crofting areas. The plan for a soil research institute followed consultation with Sir Robert Greig of the Department of Agriculture for Scotland and Dr W. G. Ogg, then working on soils at the Edinburgh and East of Scotland College of Agriculture. Their far-sighted recommendations radically influenced the history of soil research in Scotland, and indeed in Britain. W. G. Ogg became the first director of the Macaulay Institute and subsequently director of Rothamsted Experimental Station, from which, as Sir William Ogg, he retired in 1958. The staff of the Institute were happy to be able to congratulate Sir William on the occasion of his 80th birthday on 2 November 1971.

Dr Macaulay, in addition to founding the Institute, provided a Trust, the income from which is administered by the Council of Management of the Institute, for the encouragement and extension of agriculture and of good agricultural methods, for agricultural education or for work of any kind intended to improve agriculture or agricultural conditions in the Island of Lewis.

In the application of the Lewis Endowment Fund the Council has had the wholehearted co-operation and collaboration of the North of Scotland College of Agriculture and has relied on the advice and services of Mr J. W. Grant, Regional Director of the Highland Region County Advisory Staff of the College, without whose assistance the developments in Lewis would not have been possible. The policy has been to provide quite small grants to support a series of projects affecting selected townships or individual crofters, and this has, in the conditions prevailing in Lewis, proved most successful. These small projects have had widely differing objectives, including hill-land pasture improvement, township development, croft improvement after land apportionment, small farm intensification, improvement of croft buildings and appliances, improvement of sheep husbandry and study of infertility in cattle.

The cumulative effect of such schemes, involving land improvement covering some 12,000 acres, has been to further a most marked change in agricultural conditions in Lewis, particularly in the whole concept of sheep husbandry and cattle raising on crofts. Previously the sheep economy was based on three-year-old wethers, now it is on eighteen-month wethers and fat lambs. In pre-grassland-improvement days crossing the Lewis ewe to produce fat lambs was uncommon. Until quite recently few fat bullocks were killed in Stornoway; now up to 1000 per annum are slaughtered and at cattle sales this year a large proportion of the animals were bought to fatten locally. These changes reflect, within the changing pattern of the crofting economy, the considerable influence of pilot schemes sponsored by

Macaulay Lewis Endowment Funds and supervised by the staff of the North of Scotland College of Agriculture in Lewis, to whom much of the credit is due. At a recent meeting the Council of Management considered various means of utilizing the Macaulay Funds and decided that the purpose of the Endowment could best be furthered by a continuation and extension of the present policy.

The glasshouse facilities for Plant Physiology, Pedology (Peat and Forest Soils), Biochemistry, Microbiology and Spectrochemistry were completed early in 1971 and have been brought into service. Plans for the modernization of Craigiebuckler House to provide accommodation for Soil Survey have been approved in principle by the Department of Agriculture and Fisheries for Scotland and funds to enable the work to proceed are available, but commencement has been delayed pending a decision on the form of heating to be employed. Plans have been approved for the erection of an extension to the Institute Library to provide much-needed stack-room accommodation, and work should commence before the end of 1971.

During the year, short-term visitors from twenty-seven different countries visited the Institute and facilities were provided for longer-term workers from Bulgaria, Egypt, Greece, Israel, Italy, Japan, Poland, The Netherlands and Switzerland.

In May 1971, His Excellency Sonomdorjiin Dambadarjaa, The Mongolian Ambassador, visited the Institute and made a brief tour of the laboratories.

In March 1971 the Presidium of the International Peat Society held a meeting in Scotland, in the course of which the following members visited the Institute: Professor E. Kivinen (President), Rector, University of Helsinki, Finland; Mr A. K. Dergunov (Secretary General), International Peat Society, Helsinki, Finland; Mr J. Filipowicz, Chief of Peat Division, Ministry of Agriculture, Warsaw, Poland; Dr M. Gordon, Director, Peat Institute, Hanover, German Federal Republic; Dr R. Kadner, Director, Peat Institute, Rostock, German Democratic Republic; Mr D. C. Lawlor, Managing Director, Bord na Mona, Dublin, Ireland; Mr A. M. Matveev, Deputy Minister of Fuel Industry, Moscow, U.S.S.R.

The Director accepted an invitation from the American Association for the Advancement of Science to participate, as a guest of the Association, in a Symposium on Minor Metals of the Geochemical Environment, Health and Disease, at the AAAS Annual Meeting in Chicago in December 1970. Dr Mitchell also visited the U.S. Geological Survey Laboratories at Federal Centre, Denver, Colorado, and the Department of Chemistry of the University of Louisiana, Baton Rouge. Dr V. C. Farmer (Spectrochemistry) accepted an invitation from the Director of the Institute of Soil Science and Plant Biology of the Spanish Superior Council for Scientific Investigations to visit Madrid to present two lectures and to take part in various discussions during June 1971. The Spanish authorities met the costs of this visit.

With the aid of grants made available by the Agricultural Research Council and the Department of Agriculture and Fisheries for Scotland, several members of staff were able to make profitable visits to centres or meetings abroad. Dr R. Glentworth (Soil Survey) attended the eighth session of FAO Working Party on Soil Classification in Europe in Helsinki and participated in a seven-day Post-Conference tour through Finland and Sweden to Copenhagen. Dr R. C. Mackenzie (Pedology) attended the third International Conference on Thermal Analysis and a meeting of the Standardization Committee of the International Confederation for Thermal Analysis in Davos, Switzerland. Mr B. M. Shipley and Mr D. Laing (Soil Survey) attended the International Society of Soil Science Commissions V and VI Symposium on Pseudogleys and Gleys and participated in Pre- and Post-Conference tours in West Germany. Dr D. J. Linehan (Biochemistry) attended the fifth Humus et Planta Symposium in Czechoslovakia. Dr M. J. Wilson (Pedology) attended the eighth International Sedimentological Congress in Heidelberg, and Dr A. M. Ure (Spectrochemistry) attended the third International Conference on Atomic Absorption and Atomic Fluorescence Spectrometry in Paris.

The development of the scientific work of the Institute has proceeded steadily, as is shown by the departmental reports, prepared by the Heads of the respective departments, which follow. Particular mention should be made of the improved facilities provided by the scanning electron microscope and electron probe unit recently installed in Pedology and already being utilized by several other departments. It is perhaps appropriate to emphasize the importance that is attached to inter-departmental co-operation in much of the work of the Institute. In many instances such interdependence exists even if it is not specifically mentioned. For example, Soil Survey advice is sought by most departments in the selection and designation of the soils used in their investigations, the statistical and computing facilities provided in Statistics are widely employed, several departments make use of radioactive techniques based on equipment in Plant Physiology, the electron microscopes in Pedology find applications in work in Microbiology, Biochemistry and Plant Physiology, and the expertise and analytical services available from Soil Fertility, Spectrochemistry and Pedology are extensively utilized by other departments.

External collaboration with University Departments and other organizations is mutually helpful and the assistance the Institute derives therefrom is much appreciated. Members of staff have served on various technical committees appointed by the Department of Agriculture and Fisheries for Scotland, the Agricultural Research Council and the Forestry Commission, as well as on other scientific panels and groups.

PEDOLOGY

The aim of the work of the department continues to be a better understanding of the complex soil system through fundamental studies on the soil and its components.

The importance of mixed inorganic gels associated with the surfaces of soil particles has been stressed in previous Annual Reports and during the year the department has been fortunate in acquiring two instruments that will yield much information on these somewhat intractable materials. The first is a scanning electron microscope and electron microprobe system that not only enables direct observation of surface morphology at very high magnification (up to $\times 50{,}000$) and with great depth of focus, but also permits non-destructive chemical analysis of very small areas of, and observation of element distribution on, surfaces. Although only exploratory investigations have so far been performed, the versatility of the equipment in enabling detailed observations of surface features of both mineral and biological materials has been clearly demonstrated and a considerable fund of information has already been accumulated. The second instrument is a flow microcalorimeter which enables relative energy relationships at particle surfaces to be measured, thus giving information of value in assessing soil properties: this equipment is now yielding excellent results.

From the biological aspect, the main advance during the year has been the commissioning of the new glasshouse unit in which one section is set aside for peat and forest soils studies. This facility, which enables much more accurate control over environmental conditions than was previously possible, has already shown its worth and it is clear that more ambitious experiments with growing plants will be possible once its capacity is fully developed.

Collaborative studies with other departments of the Institute have continued and samples have been examined for various outside bodies, including the Forestry Commission, Colleges of Agriculture in Scotland, the Scottish Horticultural Research Institute, the Agricultural Development and Advisory Service, the British Standards Institution, the Universities of Aberdeen, Glasgow, Newcastle, Leeds, Belfast, Istanbul and Cairo, Lincoln College (New Zealand) and the Food and Agricultural Organization of the United Nations. Close collaboration has been maintained with the Forestry Commission in studies on forest soils and with the Department of Agriculture and Fisheries for Scotland, the Highlands and Islands Development Board, the North of Scotland Hydro-Electric Board and the Scottish Council for Development and Industry on aspects of the survey and utilization of peat. Requests for information and advice on matters concerning peat have come from many bodies and individuals, including County Development Departments, the Natural Environment Research Council, the Building Research Station and various landowners and tenants.

The department was pleased to welcome during the year a number of postgraduate workers. Dr H. Häni, Station Fédérale d'Essais de Chimie Agricole, Berne, Switzerland, has been examining the complexing of synthetic silica alumina gels with simple organic molecules, Mr A. Carvalho, Institute of Agronomy, São Paulo, Brazil, and Mr G. W. Jones, Department of Agricultural Chemistry, Queen's University, Belfast, have received training in the mineralogical techniques in use in the department, and Professor A. Negro, Istituto di Chimica applicata, Facoltà di Architettura, Politecnico di Torino, Italy, has commenced thermoanalytical and X-ray diffraction studies on some compounds of lime with ferric oxide. Dr A. S. de Endredy, F.A.O., Rome, and Mr N. S. McGregor, a sandwich-course student from Napier College of Science and Technology, Edinburgh, have also assisted in the work of the department.

Members of staff have attended, *inter alia*, meetings of the British Ecological Society, the Royal Scottish Forestry Society, the Thermal Analysis Group of the Society for Analytical Chemistry and the British Standards Institution Panel M79/2/5 on propagation pots.

In March 1971 the Institute acted as hosts to the Presidium of the International Peat Society for part of their annual meeting; later in the year Mr R. A. Robertson attended a meeting of the Council of this body and a symposium on the classification and utilization of peat at Helsinki, Finland. Dr M. J. Wilson participated in the eighth International Sedimentological Congress at Heidelberg, Germany, at which he read a paper, and Dr R. C. Mackenzie presented two papers at the third International Conference on Thermal Analysis at Davos, Switzerland.

CHEMISTRY AND MINERALOGY

Analytical Studies

Because of the wider range of systematic analyses now being undertaken and the greater number of soils being submitted for examination by Soil Survey (1800 in 1970; 2200 to September 1971) it has proved essential to increase the number of samples that can be handled each year. Since fully automated methods are not entirely suitable for many of the determinations involved, increased throughput has had to be achieved by introducing improvements in technique and in methods of handling without altering the methods themselves to any great extent; a laboratory manual with details of the analytical techniques employed has now been compiled for internal use.

A number of analyses of soil air have been carried out by withdrawing samples into gas pipettes from probes buried permanently in the soil, the gas samples being examined in the laboratory by mass spectrometry. The state of aeration of each soil horizon is reflected in the content of carbon dioxide, since poor exchange with surface air leads to a build up of this gas. In a hydrological sequence of soils a higher carbon dioxide content relative to oxygen occurs in the poorly drained members; a seasonal variation has also been observed, in that increased carbon dioxide contents were present in the wet autumn and winter months, even in freely drained soils. No minor constituents other than argon and carbon dioxide could be observed at the sensitivity available. In other experiments, carried out in collaboration with Peat and Forest Soils, anaerobic incubation of peat samples has been found to produce a gas mixture containing nearly 50 per cent methane.

Differential thermal analysis coupled to mass spectrometry, which has proved of value for the detection and semi-micro estimation of simple carbonate minerals in soils, has also been used successfully to elucidate the temperature pattern of carbon dioxide evolution from a series of complex carbonates. The effect of admixture of one carbonate mineral on the differential thermal curve of another has been described[1], and a chapter dealing with the applicability of thermoanalytical methods in soil science[44] has been compiled.

Recently the Standardization Committee of the International Confederation for Thermal Analysis has been developing a set of standards for temperature calibration of differential thermal analysis equipment; these standards are all pure inorganic materials that display well defined solid-phase transitions at particular temperatures. While examining these materials the opportunity was taken to check their value for energy standardization of differential thermal equipment and, despite the fact that the technique adopted was not the optimum for energy measurement, encouraging results have been obtained[45].

Soil Mineralogy

The minerals present in the soil not only provide a source of plant nutrients that are released during weathering but also influence soil properties. The clay fraction, which consists of particles less than 0·002 mm in size, has an enormous area of surface the behaviour of which towards moisture, plant nutrients, etc., depends on the nature and structure of the minerals present. The origin of these minerals is therefore of considerable interest. Consequently, investigations in soil mineralogy are concerned with (a) general studies aimed at obtaining a better understanding of pure minerals, (b) studies on parent materials and (c) studies on the clay fraction.

The thermal characteristics of Na- and Mg-saturated samples of vermiculite and hectorite have been examined using principally a semi-micro thermogravimetric technique. Differences are attributable not only to the nature of the saturating cation but also apparently to the extent of isomorphous substitution in the crystal structure.

In conjuncion with the Railway Technical Centre, Derby, some subsoil clays, on which stabilization tests are being conducted, have been examined by X-ray diffraction, electronoptical and thermoanalytical techniques; these techniques have also been used to characterize montmorillonite samples from South Africa.

The study of crystallographically poorly ordered inorganic materials in soils continues to be a major subject of research. Thermoanalytical and selective chemical tests show these materials to be present in significant amounts in Scottish soils—particularly in those with free internal drainage. The position as regards imperfectly and poorly drained soils is less clear, since the clay fractions of these soils frequently contain finely particulate material which cannot be unambiguously distinguished from poorly ordered aluminosilicate components. It has been demonstrated, however, that poorly ordered gibbsitic material in soils can be determined by differential thermal analysis in conjunction with alkali dissolution techniques[2]. A rapid method, using buffered sodium dithionite solution and ultrasonic agitation, has been developed for removing and estimating free ferric oxide and associated silica and alumina from soils and soil clays[3].

Reviews of the electronoptical characteristics of sesquioxide minerals[4] and of imogolite[5], a fibrous aluminosilicate occurring in many soils developed on volcanic ash, have appeared and laboratory studies are continuing on the ageing of inorganic gels. Whereas alumina gels produce bayerite, gibbsite and boehmite at atmospheric temperature and pressure[6], there is no evidence of development of structure in aluminosilicate gels ageing under these conditions.

The scanning electron microscope is currently being applied to the study of inorganic gels in soils. Following preliminary trials to ascertain optimum methods of specimen preparation, results obtained for the 2-6 μm fraction of samples of entisols and vertisols (non-cracking and cracking soils, respectively) indicate that the particles of the former are well defined and have extremely smooth surfaces, whereas those of the latter are less well defined and the surfaces are very fluffy. A coarse-textured soil from Caithness, which from selective chemical dissolution tests contains an appreciable amount of aluminosilicate gel, is also being examined. A preliminary correlation of scanning electron-micrographs of soil thin sections with optical microscope observations for the same thin sections in transmitted light is also being undertaken. Although the electron probe accessory is not fully operational for quantitative work, tests of a qualitative nature have been encouraging.

Parent Materials. As a preliminary investigation to pedological studies on soils derived from Scottish Carboniferous sediments, the clay mineralogy of the rocks themselves has been established[46]. Although kaolinite is common throughout the succession, it is highly crystalline in arenaceous rocks but poorly crystalline in other types of sediment. Analysis for major elements by X-ray fluorescence indicates some variation in $SiO_2 : Al_2O_3$ ratio between the kaolinite types, but the occurrence of variable amounts of quartz precludes a firm conclusion being drawn. Unusual phosphate minerals of the plumbogummite group in Cretaceous greensands have been examined[7].

In collaboration with Spectrochemistry the weathering pattern of hornblende in a residual soil on biotite-hornblende rock[8] and the mechanism of the oxidative weathering of biotite and vermiculite[9] have been deduced. From X-ray diffraction, optical and electronoptical evidence it has been concluded that the weathering of granite and granulite boulders in an Upper Old Red Sandstone conglomerate occurred in an almost closed alkaline system[47].

Clay Fractions. Systematic examination of soil clays by X-ray diffraction, thermoanalytical and electronoptical methods represents an appreciable portion of the year's work. Mineralogical investigations on the clay fractions from the principal soil series of the Stirling and Latheron/Wick areas (Sheets 39, 110/116) have been completed; the fine sand fractions of these soils have also been examined. The clay mineralogy of soils and rocks from Brazil, Egypt, Greenland, Northern Ireland, South Africa and Turkey has been determined.

Following a study of the clay minerals present in Old Red Sandstone rocks[48], an investigation of the clay fraction of soils derived from Lower Old Red Sandstone in eastern Scotland has been undertaken. The strong influence of parent rock on soil-clay mineralogy has been established, clay minerals inherited by the soil often including unusual trioctahedral expansible minerals such as saponite, interstratified vermiculite-chlorite and smectite-vermiculite. Weathering of the clays to non-crystalline products is well advanced throughout the B and even the C_1 horizons in freely drained acidic soils but this alteration is minimal in soils of pH$>$6 and in poorly drained soils. The ready weathering of the trioctahedral expansible minerals results in high values for exchangeable magnesium in the basal horizons.

The clay fractions of two gley soils developed on glacial till derived from chloritic schists in the Loch Awe area are dominated by diochtahedral illite and chlorite at the base of the profiles. The illite becomes vermiculitized towards the surface but the chlorite, as in the freely drained soils of the area, is stable throughout. The fact that clay fractions composed predominantly of chlorite from freely drained soils do not yield differential thermal curves similar to those for the chlorite in the parent rock is due to oxidation, since artificially oxidized rock chlorite yields a curve similar to that for the soil chlorite. In the gley soils reducing conditions prevail for most of the year and the differential thermal curves for the clays show the normal chlorite features.

An improved method, employing boehmite as an internal standard and a new means of specimen preparation by deposition of the clay on polyester foam, has been developed for quantitative determinations by X-ray diffraction. Attempts are also being made to separate clay minerals using a suitably modified electromagnetic separator with a specially designed and fabricated cell for introduction of clay and silt suspensions. Some degree of success has been achieved in separating mixtures of chlorite and illite.

Clay Organic Complexes

A series of complexes have been prepared from relatively simple organic molecules and synthetic aluminosilicate gels of composition varying from pure silica to pure alumina. According to infrared absorption evidence, pure silica combines with acetyl chloride through an ester type linkage, whereas with increasing alumina content a salt linkage similar to that in basic aluminium acetate appears. Infrared adsorption bands of the ester linkage are not observable at aluminium contents above $Al/(Al+Si)=0{\cdot}5$. Since gaseous butylene is the thermal decomposition product obtained from all complexes formed between these gels and *n*-butanol it has been possible to study the kinetics of the decomposition using a pyrolysis unit coupled to a mass spectrometer. The activation energy for decomposition varies with gel composition reaching a minimum for gels of composition approximately $Al/(Al+Si)=0{\cdot}2$—the point at which cation-exchange capacity and reactivity towards sodium fluoride attain a maximum. An incidental discovery was that volatile components containing boron are released from borosilicate glass by the action of water or alcohol vapours at 140°C and that these volatile compounds subsequently react with silica gel surfaces.

Complexes formed between ethylene glycol and various clay minerals, accessory minerals and aluminosilicate gels have been examined by pyrolysis to 600°C *in vacuo* followed by mass spectrometric identification of the volatile products. The compounds formed from complexes with poorly ordered aluminosilicates resemble those from the soil–organic complex more than do those formed from complexes with well ordered clay and accessory minerals.

In collaboration with Microbiology the same combined pyrolysis and mass spectrometer unit has been used to examine the organic components on the surface of montmorillonite samples exposed to the soil environment. It has also been shown by X-ray diffraction that montmorillonite–adenine complexes are resistant to microbial attack[49]—a behaviour that contrasts with that observed for montmorillonite–nucleic-acid complexes, where the progress of the degradation can readily be followed by X-ray diffraction[10].

Surface Properties of Soils and Clays

The acquisition of automatic titration equipment has enabled the fluoride reactivity technique for assessment of poorly ordered inorganic material in soils (reported last year) to be applied on a systematic basis to Soil Survey samples. The results obtained have been compared with the amounts of silica and alumina extracted by 5 per cent sodium carbonate solution and the amount of free ferric oxide extracted by buffered sodium dithionite solution for a considerable number of Scottish soils. For freely drained soils high multiple correlations have been obtained between fluoride activity as measured by the amount of hydroxyl ions released on the one hand and silica, alumina and ferric oxide contents on the other, whereas for poorly drained soils correlations were lower but significant.

A method for determining pore-size distribution has been developed from the low-temperature nitrogen adsorption technique used for measurement of the specific surface area of finely particulate material. Preliminary measurements of the heat of sorption of liquids by fine powders in a flow microcalorimeter having proved satisfactory, the system is now being used to assess the energies of sorption of polar liquids on synthetic aluminosilicate gels.

Organic and Biological Materials

The pyrolysis and mass spectrometer unit previously used in soil horizon characterization[50] has been modified to accommodate a commercial Curie-point pyrolyser. This has improved both the reproducibility of results and speed of operation and the system is currently being used to examine a wide range of soil humus forms.

The effect of the saturating cation on the complete-combustion characteristics of humic acid is being examined by differential thermal analysis and derivative thermogravimetry. Various constituents of fungal cell walls have been successful characterized by X-ray diffraction; chitin and β-(1-3)-glucan are readily identifiable[51].

PEAT AND FOREST SOILS

Peat Survey and Evaluation

Survey, classification and evaluation of Scottish peat resources[52] have continued to provide information of practical as well as scientific value. Results of this work are incorporated in appropriate Soil Survey memoirs and in detailed maps and reports on selected areas that have development potential. Survey techniques and expertise are also employed to support field and laboratory investigations concerned with drainage[53], cultivation[11] and afforestation[54] of peatlands and with the use of peat for horticultural and other purposes.

During the past year, work in the Kinross/Elie area (Sheet 40/41), including a close-grid topographical and stratigraphical survey of Moss Morran near Cowdenbeath, has been completed. In the Latheron/Wick district of Caithness (Sheet 110/116), multiple-line traverses ranging in length from 3000 to 8000 metres have been employed to characterize approximately 10,000 hectares (22,000 acres) of deep blanket bog. Ground survey combined with air photo interpretation has been widely used to establish regional patterns and to assist in differentiating blanket bog and basin and valley bogs on the Caithness plain. Peat deposits in the Peebles/Edinburgh area (Sheet 24/32) have been examined and classified in collaboration with the local Soil Survey officer, and following the completion of survey work around Stranraer (Sheet 1/2/3/4) sampling of selected profiles is in progress.

In North Uist, a detailed topographical survey of 50 hectares (110 acres) of blanket bog has been undertaken in order to establish basic drainage requirements for a proposed reclamation scheme.

Cartographic work and documentation have progressed satisfactorily and survey maps are now being standardized to a scale of 1:5000. Physical and chemical determinations on peat samples taken in the course of field survey have continued as previously reported and the possibility of using the scanning electron microscope to advance palaeobotanical studies is being investigated.

The close liaison established with national and international organizations concerned with peat science and technology has been of great value in dealing with the increasing volume of enquiries on many aspects of peat research and development.

Pollen Analysis and Quaternary Research

Pollen analysis of selected deposits in areas where peat surveys are in progress has continued to provide information for purposes of chronology and stratigraphical correlation. Pollen-analytical studies on profile samples from different geographical regions of Scotland have indicated that, so far as the history of the heath groups of plants since the Weichselian period (approximately 7000 B.C.) is concerned, the high proportion of *Empetrum* pollen in the oldest peat samples is more widespread than was previously supposed and the later dominance of *Calluna* is particularly associated with eastern districts of the country. Investigations on three buried peats in the Aberdeen area[12] and on the Flandrian history of Wooler Water[13] have been concluded.

Sample series from peat deposits at Elsick Heath, Kincardineshire, and in the vicinity of Corby Loch, Aberdeenshire, are being examined on behalf of the Department of Botany, University of Aberdeen. The results of pollen analysis will be employed to elucidate certain aspects of peat-bog ecology.

Samples from the long barrow at Dalladies, near Edzell, Angus—which is being excavated under the direction of Professor Piggott, Department of Archaeology, University of Edinburgh—and from a nearby peat bog have been taken for examination. In collaboration with archaeologists from the Universities of Cambridge and Glasgow, material has been collected from a dig at Udal in North Uist and a contribution has been made to a study on a hut circle in Sutherland[55], respectively.

Root and Moisture Studies in Peat

Studies on the moisture and aeration characteristics of peat and other organic substrates in relation to root development of forest trees and to standards for horticultural soils[14] have continued along the lines previously reported.

At Lon Mor, Inverness-shire, where investigations on the response of lodgepole pine to water-table height are still in progress, further detailed examination of root morphology has been followed by extensive sampling of the peat on a volume basis from selected profiles in all five plots. Analysis of these samples has shown that air : water ratios have increased in response to the lowering of the water-table—an effect that has been more marked in the planted than in the unplanted areas of each plot, demonstrating the drying effect of a tree crop on deep peat. A technique based on sulphide staining of silver rods has provided information on aerobic limits within the peat profiles and redox potential measurements have been used to indicate the progressive improvement in oxidizing conditions in response to drainage.

Investigation of the moisture-retention and other physical characteristics of natural peat and organic soils from experimental sites in north-east Scotland has been undertaken in collaboration with the Botany Departments of the Universities of Aberdeen and Dundee. A comparison of a range of horticultural peats of different degrees of decomposition has shown that, although the moisture content at wilting point (pF 4·2) is relatively constant at approximately 100 per cent (on an oven-dry basis), moisture contents at moisture equivalent (pF 0·7) can vary between 600 per cent and 1300 per cent.

In collaboration with Plant Physiology, glasshouse experiments have been initiated to assess the value of certain peats and peat composts in horticulture.

Nutrient Uptake from Forest Soils

The emphasis in nutrition studies is now moving from pine to Sitka spruce, reflecting the predominant role that this species has attained in British forestry. Three new experiments are soon to be laid out in pole-stage stands of Sitka spruce to investigate the relationship between tree growth and nutrient uptake in this species: a start on this project has been made with a field investigation into the distribution of dry weight and nutrients in a 21-year-old stand at Fetteresso forest, Kincardineshire, and a glasshouse experiment on the response of seedlings to different rates and forms of nitrogen using hydroponics. The seedlings showed maximum total growth, and exhibited minimum root:shoot ratio, when the concentration of nitrogen in the needles was maintained at about 2·5 per cent of oven-dry weight. This optimum nitrogen level is much the same as that found for seedlings of Corsican pine, but the associated concentrations of phosphorus and potassium in the spruce—about 0·30 and 1·25 per cent, respectively—are much higher than those in the pine.

The large growth variation that can occur in pot experiments between trees in the same treatment has stimulated interest in the production of clonal Sitka spruce for future experimentation. During the year 100 to 150 cuttings have been taken from each of seven different source trees and, by using soil heating and intermittent misting, it has been possible to root a number of these, the success rate varying from 7 to 80 per cent according to clone. Eventually it is planned to establish, within the Institute grounds, banks of the more successful clones to act as a sufficiently large source of cuttings for envisaged nutrition experiments.

Preliminary tests of the methods of handling vegetatively reproduced material, and of the advantages to be gained from its use, have been carried out with cuttings taken from a clone of Western red cedar known to root profusely. Propagation was successful and 198 of the rooted cuttings were experimentally subjected to the same range of rates and forms of nitrogen treatments as had previously been used in experiments with seedlings of Corsican pine and Sitka spruce. Survival has been high and the pattern of growth response is similar to that obtained with seedlings of the other two species. Also in the glasshouse, cuttings of Western red cedar, together with one-year-old seedlings of Sitka spruce, are being used in an experiment designed to provide, for mineralogical examination, micas 'weathered' by tree roots under controlled conditions.

During 1970, needle samples have been taken at monthly intervals from young Western hemlock, grand fir, Douglas fir, Sitka spruce and lodgepole pine planted beneath an over-canopy of larch thinned to densities of 100, 200, 300 and 500 stems per hectare and also planted in areas from which the larch had been entirely removed. These have now been analysed for chlorophyll (on fresh samples) and nutrients, while material frozen at the time of sampling has been used for determination of free amino-nitrogen and, in collaboration with Biochemistry, of soluble sugars, both total and reducing.

In all species chlorophyll concentrations varied both with season of the year and with shade—the pattern of response to shade, however, differing between species. Of the nutrients examined, only nitrogen concentrations changed in all species in response to shade, the trend being an increase with increasing shade density. Since maximum change on shading was typically of the order of 0·3 per cent nitrogen, it is sufficiently large to be of concern should foliar analysis be used as a diagnostic technique for underplanted trees. Phosphorus, potassium, calcium and magnesium concentrations, on the other hand, were with few exceptions relatively unaffected by shade and showed a similar pattern of variation with season for all species—i.e. nitrogen, phosphorus, potassium and magnesium concentrations were at a minimum in July whereas calcium showed less variation.

Concentrations of both amino-nitrogen and soluble sugars showed some response to density of shade, the nature and extent differing with species. Seasonal variations followed similar patterns irrespective of species or shade density: thus, amino-nitrogen exhibited two maxima, in March and May, with a small secondary peak in October, whereas soluble sugars yielded two main peaks in February-April and November, with a small secondary peak in August. Concentrations of amino-nitrogen ranged, according to species, from maximum values of 0·014 to 0·022 per cent of oven-dry weight to minimum values of 0·004 to 0·008 per cent; for soluble sugars maximum values were 9 to 10 per cent and minimum values 6 to 7 per cent.

A careful examination has been made of changes in the pattern of stem wood production, both within a single tree and between trees, in a pole-stage stand of Corsican pine following heavy application of nitrogen fertilizer. Little or no change has occurred in distribution of growth up the stem. Growth response to fertilizer appeared to be mainly concentrated in large trees, but careful examination of growth distribution before and after fertilizer application has revealed that within any one treatment there is no significant difference between trees sizes in the *proportional* increase in relative growth brought about by the fertilizer.

Nitrogen Mineralization in Peat and Mor Humus

Incubation techniques continue to be used for measuring rates of production of mineral nitrogen in samples of peat and mor humus collected from field experiments; recently the rate of evolution of carbon dioxide during incubation of these samples has also been assessed.

Examination of the effects of a range of fertilizers on the chemical nature and course of decomposition of humus taken from a Scots pine experiment at Culbin forest, Morayshire, has continued. Despite the fact that fertilizers were last applied three years ago, humus samples from the various treatments are still behaving very differently on incubation. Thus, for material from limed plots, the pH of which remains high, there is enhanced evolution of carbon dioxide but net production of mineral nitrogen is very low, whereas for humus given urea, ammonium sulphate or ammonium nitrate the production of mineral nitrogen is high but carbon dioxide evolution is little affected.

Peat samples from the drainage experiment on deep peat at Inchnacardoch forest, Inverness-shire, have been incubated under both partially aerobic (wet) and anaerobic (waterlogged) conditions. For samples from the flooded and the intensively drained plots, mineral nitrogen production was most rapid under anaerobic conditions, whereas for samples from intermediate drainage treatments rates of nitrogen production were more rapid under partially aerobic conditions. Rate of carbon dioxide evolution in samples incubated under partially aerobic conditions showed no distinctive pattern, but the high variability observed may have been due to differential production of methane. Certainly, large quantities of this gas are produced under waterlogged conditions (p. 13).

To supplement field observations, studies on the effect of adding phosphate and potassium to peat on mineralization of nitrogen are being made under controlled laboratory conditions. Under partially aerobic conditions, phosphate addition has stimulated production of mineral nitrogen during incubation, but under anaerobic conditions neither phosphate nor potassium has had any influence; the effect of potassium addition during partially aerobic incubation has yet to be tested.

Experiments have been initiated with a view to fractionation and identification of the organic nitrogen compounds in peat and mor humus. Results suggest that under optimum conditions (boiling with 6 M HCl under reflux for 12 hours) more than 90 per cent of the organic nitrogen in peat and humus can be hydrolyzed. Analysis of the hydrolysate has shown that approximately 12 per cent of the total nitrogen was present as ammonium, 10 per cent as hexosamine and 50 per cent as α-amino nitrogen.

SOIL SURVEY

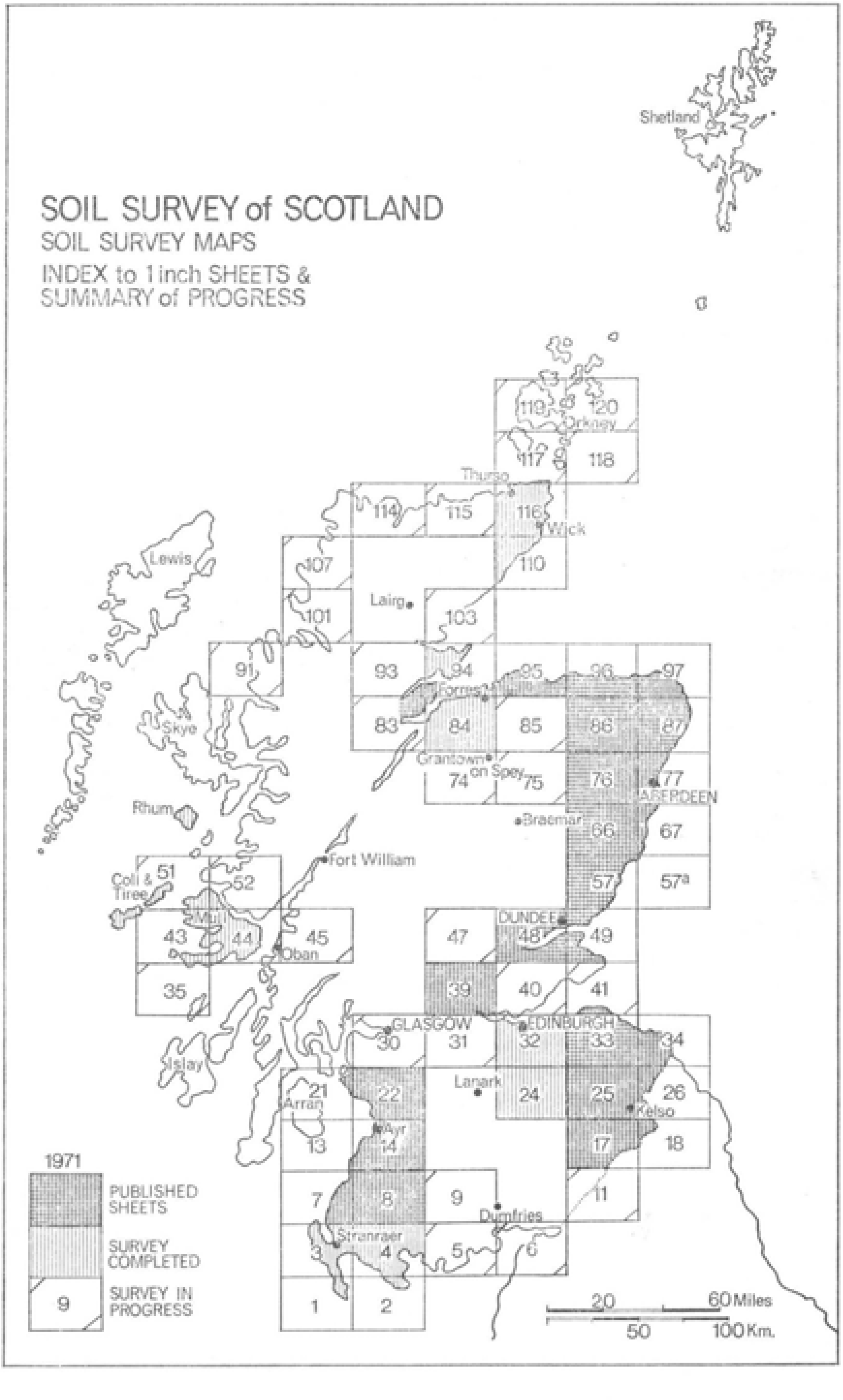
Systematic soil survey is being conducted from six regional centres—Kirkwall, Thurso, Grantown-on-Spey, Edinburgh, Oban and Dumfries—as well as from headquarters in Aberdeen. Decentralization has been in operation since 1966 and all centres will shortly have office accommodation for two officers. Eight members of staff have been decentralized. This decentralization has facilitated the survey of areas at a distance from headquarters and appears to have stabilized the staffing position; it has also improved collaboration with the staffs of the Scottish Colleges of Agriculture, the Forestry Commission, the Department of Agriculture and Fisheries for Scotland and the Nature Conservancy, and with landowners and farmers.

Mapping now covers the greater part of the agriculturally important areas of the lowland and a large amount of soil information is available. Considerable time is spent in dealing with relevant enquiries, some of which are referred to below. The classification of soils is helping to provide a basis of comparison and correlation for investigations by the specialist disciplines in the departments of Pedology, Spectrochemistry, Soil Fertility, Biochemistry and Microbiology; the results of these investigations will help in turn to improve the classification of Scottish soils.

Systematic survey on a scale of 2·5 inches to 1 mile has continued in the eleven areas listed below. During the six months from April to September 1971 approximately 445 square miles (1150 km^2) have been surveyed, 40 on 1 inch to 1 mile Sheets 117, 118, 119 and 120 (Orkney), 65 on Sheets 109 and 115 (Auchentoul and Reay), 20 on Sheet 85 (Rothes), 50 on Sheet 75 (Tomintoul), 40 on Sheet 74 (Grantown), 20 on Sheets 51 and 52 (Ardnamurchan), 35 on Sheet 47 (Crieff), 38 on Sheets 40 and 41 (Kinross and Elie), 87 on Sheet 31 (Airdrie), 6 on Sheets 24 and 32 (Peebles and Edinburgh) and 45 on Sheets 5 and 9 (Kirkcudbright and Maxwelltown).

Four hundred and fifty-seven profiles have been described and sampled for analysis, mostly with the aid of the Smalley excavator. Seven soil monoliths have been added to the Soil Survey Library.

In July Dr R. Glentworth attended a meeting in Helsinki, Finland, of the European Commission on Agriculture Working Party on Soil Classification and Survey, for consultation and correlation in connection with the legend of the 1:1 million Soil Map of Europe, and afterwards participated in a post-meeting study tour in Finland and southern Sweden. In September Mr D. Laing and Mr B. M. Shipley attended the Joint Meeting of Commissions V and VI of the International Society of Soil Science in Stuttgart-Hohenheim when Mr Laing read a paper on the gley soils of the Midland Valley of Scotland. Members of staff attended the Annual Meeting of the Ordnance Survey Committee on Survey and Mapping, meetings of the British Society of Soil Science and a conference on drainage in grassland organised by the South-West Scotland Grassland Society, at which a talk on soil structure and drainage in south-west Scotland was given. There has been consultation with the Soil Survey of England and Wales to compare systems of data retrieval and to discuss methods of analysing field data.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Mull
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60 Miles
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Mr W. van de Westeringh and Mr M. E. F. van Mensvoort of the Department of Soil Science, Agricultural University, Wageningen, Holland, visited the Survey for a period of four weeks to study 'Plaggenboden' (deep infield soils). Most of this time was spent in the field with various Survey officers who demonstrated likely soils in different parts of the country.

A Zeiss Stereotope which has been brought into use should improve the precision of transfer to base maps of recorded field information from aerial photographs of areas of high relief.

A joint Soil Survey Conference and Field Meeting with the Soil Survey of England and Wales was held in Stirling in June. Soil drainage was the main theme of the meeting, which was attended by 49 surveyors. The programme included one whole day and two half-day field excursions, with morning and evening paper-reading sessions to which a number of guest speakers contributed. Six papers were presented by the members of the Scottish Survey.

Sheets 118, 119, 120, 121, 122, part 117 (Orkney Islands)

The systematic survey of the soils of the Orkney Islands commenced in May. Approximately 40 square miles (104 km²) have been surveyed, with the aid of aerial photographs, in Deerness, Tankerness and Holm in the East Mainland and in South Ronaldsay and Burray.

The soils mapped are mainly developed on a reddish brown sandy clay loam to clay loam till derived from sandstones and flagstones of the Eday Beds and Rousay Flags of the Middle Old Red Sandstone. Peaty gleys and non-calcareous gleys are the most common soils of this provisionally named Kirkwall Association. The peaty gleys are largely cultivated, sometimes to such a degree that nearly all evidence of their former peaty nature has disappeared and they resemble in all characteristics the non-calcareous gley. Small areas of peaty podzols and podzols with stony, compact or indurated, sometimes mottled, B horizons have also been mapped.

In the Holm district soils of the Bilbster series of the Thurso Association occur. In South Ronaldsay a small area of complex consisting of rock ridges with soils of the Bilbster series (shallow phase) and till-filled hollows has been mapped around Cleat. Soils of the Fraserburgh Association occur around some of the bays.

Thirty-five profiles have been described and sampled.

Sheets 109 (Auchentoul) and 115 (Reay)

Approximately 65 square miles (168 km²) have been mapped to date in three separate districts, and 33 profiles have been described and sampled.

In the Shurrery and Shebster district of Western Caithness 25 square miles (65 km²) have been covered. The soils mainly belong to the Berriedale Association and comprise podzols (Ramscraigs series) and peaty podzols (Berriedale series) together with peaty gleys on indurated till. A new complex of peaty podzols and peat has been delineated on an area of moraines. Other soils present in this district are peaty podzols (Camster series) and peaty gleys (Olrig series) of the Thurso Association and peaty podzols (Gaerlie and Charr series) of the Strichen and Countesswells Associations. Blanket peat, mapped either as shallow or deep peat, is widespread, while deep basin peat occurs locally at Shebster.

A further 35 square miles (40 km²) have been completed in the Strath Halladale district. Peaty podzols of the Strichen and Countesswells Associations and blanket peat are predominant. A common mapping unit is a complex of peaty podzols and thin peat with some rock outcrops. Along the strath freely drained sandy soils are developed on recent alluvium, with humus-iron podzols (Corby series) and peaty podzols (Tarbothill series) of the Corby Association occurring on sand and gravel deposits.

Five square miles (13 km²) have been surveyed in Strath Naver to the west of the River Naver. The soils developed on alluvium are similar to those of the Strath Halladale district, but humus-iron podzols (Corby series) predominate on the sand and gravel deposits. Brown forest soils occur on the steeper slopes of the valley above the gravels, frequently under birch, and peaty podzols, often in soil complexes with peat, are present on the upper slopes and on the plateau above the valley. These soils are similar to those of the Strichen Association, but contain a proportion of hornblende-schist; pending correlation, they could be placed in the Tarves Association. Deep blanket peat has also been mapped in this district.

Sheet 94 (Cromarty)

Ten soil profiles were collected from the north-western corner of Sheet 94 following upon a revision of the mapping of the Sabhail Association which was carried out during the 1970 field season.

To clarify the correlation between the recently published Geological Survey drift map of Sheet 95 (Elgin) and the soil map of Sheet 94 (Cromarty), approximately five square miles of the raised beach complex east of Findhorn have been revised in detail. The bulk of this area consists of raised beach stratified sands and gravels overlain by aeolian sand. Several distinct shingle ridges up to 12 feet thick trend in an east to west direction. Usually a well developed humus podzol profile lies beneath a thin veneer of windblown sand. Similar buried profiles are occasionally observed at the junction of the raised beach sands and a variable thickness of dune sand. Much of this aeolian sand is now stabilized.

Sheet 85 (Rothes)

Approximately 20 square miles (52 km²) have been surveyed and 22 soil profiles collected. The greater part of the mapping was done in the north-west quarter of the sheet in two localities. The smaller includes the north-facing slopes of Tomechole Hill with Romach Hill and parts of Newtyle Forest. The ground is mostly moorland or afforested moorland lying between 500 and 1100 feet. This parcel of land joins up the ground on the west side of the sheet mapped in recent seasons with an area mapped earlier around Forres and Rafford. The soils, the parent material of which is generally derived from acid schists, are included within the Strichen Association. They include peaty podzols, peaty gleys and podzols, the last making a significant appearance on the lower ground of Newtyle Forest. Hill peat is developed on the higher ground and on north-facing slopes. The larger area lies farther to the east and includes part of Dallas Estate east of the Dallas-Knockando road, together with Pluscarden and Auchtertyre

Estates. The altitudinal range here is from about 200 to 1200 feet. The soils of the Strichen Association together with hill peat dominate the higher ground, but over a small area on the south-west-facing slopes of the Hill of Wangie the soil parent material is a mixture of sandstone and schist and the soils have been included within the Orton Association. Soils developed on fluvio-glacial and morainic sands and gravels on the low ground between Pluscarden and Auchtertyre have been mapped in the Boyndie and Corby Associations.

Sheet 75 (Tomintoul)

About 50 square miles (130 km^2) have been surveyed and 27 profiles described and sampled. The mapping has been done in two areas of approximately equal extent, one in the north-east of the sheet near Grantown-on-Spey, and the other in the Dee catchment area near Ballater.

In the area near Grantown the Strichen Association was found to be widespread, most parent materials being coarse-textured (loamy sand to sandy loam) drifts derived from quartz-schists and mica-schists. On lower ground some of these drifts were difficult to distinguish from gravels, but examination of deep profiles revealed by the excavator proved helpful. Outcrops of granite and diorite near Dorback Lodge give rise to parent materials of the Countesswells and Tarves Associations respectively, while mounds and terraces of fluvio-glacial gravels and sands derived from acid schists and granites form the parent materials of the Corby and Boyndie Associations. The soils found in the area are cultivated brown forest soils, gleys, iron and peaty podzols, and peat and alluvial soils. Many of the brown forest soils and podzols have an indurated B_3 horizon which can also occur, sometimes partly softened, in gleys on 'shedding' sites.

Most of the parent materials in the area mapped near Ballater are derived from granite and norite, forming soils of the Countesswells and Insch Associations respectively. Soils of the latter association which occur in the Morven district are capable of supporting many more sheep, cattle and grouse than the granite soils to the south and west of the basic igneous mass. Soils of both associations tend, with increased elevation, to follow the sequence iron podzols—peaty podzols and peat—sub-alpine podzols—alpine soils, although the first-named soil extends to higher altitude on basic igneous parent materials. The alpine soil of the Insch Association differs from those formed on less basic parent materials in its lack of a distinct A horizon containing bleached mineral grains and in having a lower layer containing coated grains which is thicker and has a higher organic matter content; samples from alpine soils of this and other associations are being analysed to compare the levels of pyrophosphate-extractable iron in the latter layer with those in other horizons. The country round Morven proved suitable for access by means of a Gnat cross-country vehicle, both for the transport of soil samples and for surveying.

Sheet 74 (Grantown)

Approximately 40 square miles (104 km^2) have been surveyed in three areas, the northern Cairngorm and Monadhliath plateaux and the fluvio-glacial outwash plain of Mid Strathspey.

The soil patterns previously described around Abernethy are repeated in the Rothiemurchus region. On the open moorland the dominant profile is a peaty podzol with a well developed iron pan overlying a strongly cemented gravelly B_2 horizon. The combination of these two soil properties undoubtedly contributes to the poor growth performance of the Scots Pine plantations planted 20 years ago near Loch Morlich. These soils belong to the Corby Association.

Between 1200 and 1500 feet, in depressed and flushed sites, a thin veneer of outwash gravels frequently overlies an intensely indurated till derived from acid schists and granites. In this peaty fragogley profile a well developed iron pan is situated directly on the upper surface of the induration. The position of the iron pan and the absence of a friable B_2 horizon have been used to distinguish this profile from that of a peaty gleyed podzol. These soils have been included within the Aberlour Association.

Residual mountain top detritus covers most of the Monadhliath and Cairngorm plateaux. The derived soils belong respectively to the Strichen and Countesswells Associations and reveal a distinct altitudinal zonation.

At about 2000 feet the typical peaty podzol with iron pan is replaced by a profile transitional to an alpine podzol. This zone is characterized by a stunted Callunetum with *Arctostaphylos uva-ursi* colonizing eroded areas on exposed or steep sites. Above 2500 feet this vegetation is gradually replaced by an *Empetrum-Vaccinium-Rhacomitrium* zone where the soil profile is an alpine podzol. The characteristic alpine 'A' horizon seldom exceeds ten inches in thickness and usually overlies a B horizon in which there has been an accumulation of silty material. Around 3500 feet in the Cairngorms the increasing severity of climate leads to a patchy vegetation cover, mainly of a *Juncus trifidus-Carex bigelowii* community. The organic A_1 horizon becomes vestigial and is frequently overlain by one or two inches of granitic grit, except in sheltered areas of persistent snowfields, where there is usually an accumulation of mineralized peaty humus up to ten inches thick under a closed vegetation mat of *Nardus stricta.*

Whereas peat development on the northern flanks of the Cairngorms is confined to the upper reaches of shallow gullies, there is extensive hill peat on the Monadhliath plateau. Pronounced radial drainage lines are associated with the individual projecting summits but in saddles and local basins the pattern is intensively dendritic.

Sheets 51 and 52 (Ardnamurchan)

Soil survey on the Ardnamurchan peninsula was started in July 1971. Exploratory survey on the gabbro of the Ardnamurchan intrusion revealed soils similar to those of the Insch series, but the majority of the soils belong to the organic and ranker groups. Mineral and organo-mineral soils are thin and bare rock is widespread. Raised beach soils which form the major agricultural areas are dominantly coarse gravels, indurated on upper beach levels.

Further exploratory survey was carried out in the Acharacle district on the moraines, outwash deposits and raised beaches of Loch Shiel and on the metamorphic rocks surrounding the loch. In the former areas soils with affinities to those of the Boyndie and Corby Associations were found, dominantly peaty gleys and iron podzols, with occasional peaty podzols. In the latter, soils of the Strichen Association were recognized, dominantly peaty gleys and rankers. Organic soils occupy large areas.

Approximately 20 square miles (52 km²) have been mapped.

Sheets 43, 44, 51 and 52 (Isle of Mull)

The systematic survey of Mull, including major revisions, was completed during October 1970. A draft key has been compiled and correlation with other areas carried out. The punching-up of field data and some preliminary analysis of the results was undertaken during the winter period. Sampling commenced in April 1971 and 81 profiles were sampled, the majority with the aid of the Smalley excavator. The Gnat cross-country vehicle proved versatile in use and materially aided collection of samples from otherwise difficultly accessible areas.

Sheet 47 (Crieff)

A further 15 square miles (40 km²) have been mapped in the Highland Border Fault Zone to the west and south-west of the area reported in 1966. In middle and upper Glen Artney, to the south-west of Comrie, the soil pattern is as complex as the geology, and soils included in the Gourdie, Callander, Balrownie, Strichen and Foudland Associations have been encountered. They have all been described in previous reports.

The dominant soils on the lower slopes are acid brown soils, and compacted subsoil layers are common. On the hills north-west of the fault-zone rankers and rock outcrops are common on the plateau tops and steep glaciated valley sides: peaty podzols are here limited in extent and often ranker-like in profile development, having been truncated by the presence of shallow rocks in this very rocky terrain. The steeper slopes of the hills support well developed podzols while the gentler slopes of the northern side of Glen Artney support well developed peaty podzols and peaty gleys, the latter usually in the hollows between the podzolic morainic mounds. The southern slopes are of less rugged terrain, underlain by steeply dipping Old Red Sandstone sediments partly covered with deep drift, with a complex pattern of gleys and acid brown soils on the lower slopes, succeeded at higher altitudes by podzols, peaty gleys, peaty podzols, peat and some rankers.

Sheet 40 and part 41 (Kinross and Elie)

Approximately 38 square miles (98 km²) have been mapped and 24 profiles have been described and sampled. In east Fife, 20 square miles (52 km²) were surveyed in the district between Ceres and Anstruther. Till derived mainly from Lower Carboniferous sediments covers much of the area and constitutes the parent material of soil series within the Rowanhill Association. Residual soils of the Darleith and Drumain series are developed on the igneous intrusions which pierce the till cover at frequent intervals. The former series is derived from basaltic rocks, the latter from quartz dolerite.

In central Fife, 18 square miles (46 km^2) have been mapped around Cowdenbeath where the soils form a mixed pattern with series from both the Giffnock and Rowanhill Associations developed on Carboniferous till, Drumain series on the igneous intrusions and Reidston series on till derived from mixed Carboniferous sediments and igneous rocks. In addition, there are frequent areas of basin peat. The most extensive peat deposit, covering approximately 1¼ square miles (3·2 km^2), occurs near Cowdenbeath at Moss Morran, where peat-cutting is still in operation.

As this was formerly an extensive coal-mining district, the soil pattern is further complicated by frequent occurrences of made-up ground produced by levelling former coal-bings or reinstating open-cast coal sites. These areas, at present, are limited in use to pasture.

Survey of the Ochil Hills has been completed with the mapping of an area of 3 square miles (7·8 km^2) north-west of Kinross.

The survey of Sheets 40 and 41 together with the small area of Sheet 32 north of the Forth estuary is nearing completion and it will now be possible to prepare a soil key showing the associations and series represented. While the map will include many of the soils shown on the published sheets 48 and 49 lying immediately to the north, there will be no soils derived from Highland rocks and those from Lower Old Red Sandstone rocks will occupy a very small area. Soils derived mainly from Lower Carboniferous sediments will be much more extensive and will include four additional associations, Giffnock, Darvel, Hindsward and Dreghorn, not mapped on the sheets to the north.

Sheet 31 (Airdrie)

Mapping in the north-western part of Sheet 31 has been continued in the valley between Kilsyth and Larbert and in the Kilsyth Hills and their footslopes to the north. Similar soils to those described in 1969 and 1970 have been encountered. They have been included in the Sorn, Darleith, Rowanhill, Giffnock and Darvel Associations. Some 20 square miles have been surveyed.

South of the Forth-Clyde canal soil mapping has been confined to the Cumbernauld and Slamannan area where 67 square miles (173 km^2) have been surveyed. Most of the soils belong to the Rowanhill and Giffnock Associations, but soils of the Darleith Association, together with alluvial and organic soils, have also been distinguished.

Sheets 24 and 32 (Peebles and Edinburgh)

Some 6 square miles (15 km^2) have been mapped around Linlithgow and 50 soil profiles sampled. This completes the survey and soil sampling of this area.

Sheets 5 and 9 (Kirkcudbright and Maxwelltown)

A further 45 square miles (112 km^2) have been surveyed in two areas. In the south the parishes of Borgue and Twynholm are underlain by Silurian greywackes and the pattern of geomorphology and soils is similar to that reported in previous years (Annual Reports 38, 1967/68 and 40, 1969/70).

Erosion by ice has given rise to a microtopography dominated by irregular rock outcrops, and the soils developed on frost-shattered rock debris form the Achie complex. Till deposits are confined to scattered drumlins and have developed freely and imperfectly drained brown forest soils, some of which show close affinities to soils of the Rhins Association and others to those of the Ettrick Association, while intergrades between these types are of very common occurrence.

In the hill areas of the north-western part of the region the underlying rocks are greywackes and shales of the Ordovician system and the soils have been mapped with the Ettrick Association. A new series has been recognized, the Garryhorn series, formed on very shallow rock debris occurring on the tops and upper slopes of hills between about 1500 and 1900 feet in altitude. The soil is a type of peaty podzol but differs from the well established Dod series in its extreme stoniness and weakly developed and differentiated horizons, the most prominent of which is usually the thin iron pan which often occurs in the disintegrating upper part of the rock.

Special Surveys.

Auchtertyre and Kirkton Farms, Tyndrum, West Perthshire. The properties of soils occurring on the Kirkton Face of the Kirkton Experimental Unit of the West of Scotland Agricultural College Farms were evaluated on a statistical basis with a view to substantiating the visual estimate made during the initial survey and providing information to assist in decisions on the future improvement of the hill. This involved inspecting 200 randomized pits (selected with the help of appropriate statistical tables from 800 grid intersections) on the hillside and recording soil properties at these points. From this information it was possible to provide more precise percentages of soils occurring in the soil complex than with a visual assessment. The method is time-consuming and justified only in special surveys. The soil types and their possible problems were demonstrated to the hill farms adviser and soil chemists of the College.

Loch Morlich, Inverness-shire. A detailed soil map (1 : 10,000) was prepared for 600 acres around Loch Morlich to aid the re-afforestation of the area.

Cumbernauld, Dunbartonshire. A land use capability map of 1:25,000 Sheet NS 77 was prepared at the request of the Cumbernauld Development Corporation.

Vegetation Surveys

Further revision of the plant communities of lowland Scotland has been carried out in the light of comment by Professor R. Tüxen, Arbeitsstelle für Theoretische und Angewandte Pflanzensociologie at Todenmann, Rinteln, West Germany.

The sampling of the vegetation of Mull by plant sociological methods has been completed. The vegetation of Sheets 24 (Peebles) and 32 (Edinburgh) was also sampled by the same methods.

A third climatic map, Bioclimatic Sub-regions of Scotland, has been prepared, together with a short explanatory pamphlet[57]. These should be published early in 1972. This map, based on thermal zonation, moisture status and oceanicity, will provide a useful categorization of the climate for surveys of soil, vegetation, etc., based on medium and small scale maps. The terms used are such that they can be readily related to conditions in North America and Europe.

As an aid to data retrieval in connection with the vegetation survey, computer programs have been devised dealing with both field and analytical information. This information is being assembled and punched on cards, the resulting decks being regarded as a data bank from which sites satisfying 35 individual factors, or ranges or combinations of these factors, can be extracted under program control. A further program, which will produce a distribution map of sites satisfying the requested factors, has also been written.

Soil Micromorphology

Sampling of soils for micromorphological work has been greatly reduced this season and more time has been spent on examining and interpreting material in hand and on producing detailed descriptions of soil thin section fabrics. In particular emphasis has been placed on bench mark soils from Sheet 24/32 (Peebles/Edinburgh). Photographic records in the form of 35 mm transparencies have been made so that a reference library of characteristic soil fabrics and pedological features may be built up.

Laboratory work on the preparation of soil thin sections and soil monoliths has been reduced: some 100 sections have been prepared and seven additions to the Soil Monolith Library have been made.

Other Work

Collaboration has been maintained with the three Scottish Colleges of Agriculture, the Department of Agriculture and Fisheries for Scotland, the Nature Conservancy, the Forestry Commission, the Highlands and Islands Development Board and the Institute of Geological Sciences and with other departments of the Institute. Information on soils in connection with drainage problems and experiments has been supplied in each of the College areas and assistance given in the selection of sites for field trials. A sampling programme has been carried out in Glen Artney for the investigation of probable trace element deficiencies.

A report has been supplied to the Nature Conservancy on the soils and related erosion hazards in the Coire Cas area of the Cairngorms. A profile from Glenlochy, Banffshire, has been described and sampled to aid an experiment by the Grouse and Moorland Ecology Unit of the Conservancy.

Consultations have been held with the Hunterian Museum and the Department of Extra-Mural Studies, University of Glasgow, concerning archaeological sites at Kintraw and Benderloch, Argyllshire.

A detailed survey of an area ear-marked for a botanical garden was made for the Department of Biological Sciences, University of Dundee, and a map and report supplied.

Maps, Memoirs and Cartography

Colour proofs of both the soil and land use capability maps of combined Sheet 110/116 (Latheron/Wick) and the soil map of combined Sheet 1/2/3/4

BIOCHEMISTRY

The scope of the departmental facilities has been extended by the installation in August of an automated amino acid analyser. It is to be used primarily to study the distribution of amino acids in soil profiles, both between horizons and between the organic constituents of particular horizons, but will be available for other types of material. The machine is able to accept up to 20 samples and to analyse these in succession without further manual intervention. This facility will be offered to other departments, subject only to the safeguard that the samples shall not contain substances that could damage the ion-exchange resins that are the basis of the separation.

This acquisition marks a further stage in the automation of analytical procedures which began in 1964 with the purchase of a Technicon Auto-Analyzer. A large proportion of the analyses needed in the department are now carried out by two of these machines, which can be changed quickly from one procedure to another so that, for example, iron, protein and reducing sugars may be determined in quick succession. Samples are analysed at up to 70 an hour, a rate so greatly exceeding that of manual methods that experiments may be designed that would not previously have been considered feasible. The equipment is also capable of continuous monitoring of processes, and is particularly useful for following the progress of liquid chromatograms, which were partly automated 20 years ago by the introduction of automatic fraction collectors.

The use of plunger-operated micro-pipettes and a pedal-operated dilutor has increased the speed of those analyses which do not lend themselves to complete automation. Automatic equipment using electrically operated syringes is now coming on the market and will make possible the automation of enzyme assays.

While these developments demand a greater effort, particularly in the maintenance of more complex apparatus, and a greater expenditure, chiefly in replacements of minor components, the increased research capacity more than compensates for this, and it would now be difficult to contemplate returning to the older methods.

Enzymic Degradation of Fungal Cell Walls

Recent work in this department has shown that when easily decomposed carbohydrate is incubated with soil the most abundant sugar in the polysaccharides newly synthesized by the soil microflora is glucose. Little of this glucose can be extracted by water and some of it, like cellulose, requires the use of 72 per cent sulphuric acid to remove it. Two other hexoses, galactose and mannose, also appear in the new polysaccharides, but little pentose[23].

This sugar composition is consistent with what is at present known about the composition of the cell walls of the fungi, and it is worth noticing that glucosamine and glucuronic acid, both common soil constituents, are often found in fungal polysaccharides. There are therefore grounds for believing that soil organic matter contains appreciable proportions of polysaccharides derived from fungal cell walls.

Since 1963 this department, in close collaboration with Microbiology and Spectrochemistry, has been studying the degradation of fungal cell walls by soil micro-organisms. The earliest results (referred to in Annual Report 36, 1965/66) showed the complexity of wall structures, and subsequent work has deepened this impression.

Of particular interest is the multiplicity of forms in which glucose occurs. The glucose molecule lends itself to the construction of polymers, which may be either simple chains or, more commonly, branched structures. The degree to which regions of these large molecules can form close-packed arrangements with regions of the same or other molecules determines whether they are almost completely insoluble, exist as gels, or dissolve freely in water. In general a high degree of branching prevents close association of the molecules and confers solubility on the polymer.

In the course of work $\alpha(1\rightarrow3)$-, $\beta(1\rightarrow3)$-, and $\beta(1\rightarrow6)$-linked glucans, all of which occur in forms that are insoluble in cold water, have been encountered. The first two dissolve with difficulty even in aqueous alkali, and so approach the insolubility of native celluloses, which are $\beta(1\rightarrow4)$-linked glucans. It is thus evident that several types of glucan polymers could serve usefully as cell wall components, conferring insolubility with varying degrees of permeability. Such substances, if also incorporating structural features designed to resist attack by enzymes from other soil organisms, could clearly be among the polysaccharides that reside for long periods in soil.

The glucans as a class are hydrolysed by enzymes called glucanases, and the complexity of glucan structures finds a parallel in the existence of a multiplicity of glucanases. However, these are not matched to particular glucans but are distinguished by requiring different structures in the neighbourhood of the glycosidic bonds they attack; a particular enzyme may, therefore, find a few suitable points for attack in two molecules that elsewhere differ considerably in structure.

Methods now exist for separating enzymes by chromatography, and these have been applied in the department to culture fluids derived from organisms known to be capable of lysing various fungal cell walls. In the case of the myxobacterium, *Cytophaga johnsonii*, which attacks yeast cell walls, it was discovered that at least three glucanases were present, but that the dissolving of the walls was mainly due to one, which contributed relatively little to the total glucanase activity[24]. From this it is evident that crude measurement of total glucanase activity is unlikely to give any indication of the relative lytic abilities of a series of microbial cultures.

When considering the place of cell wall degradation in the sequences of transformation of soil organic matter it is probably satisfactory to use isolated cell wall preparations or killed cells; many cells must be moribund or dead before their walls are attacked. However, the processes by which the walls of living cells are attacked are of special interest and have a bearing on the control of soil-borne pathogenic fungi.

Attack on the cell wall is not the only way in which micro-organisms could threaten fungi (they could, for instance, secrete antibiotics to disrupt their metabolism), but quite small modifications of the strength and permeability of the cell wall can have serious consequences for the fungus, and might be achieved by a single enzyme, even perhaps by one already playing a part in the metabolism of the attacking organism.

Some of our recent experiments are relevant to this situation. For example, living yeast cells of the species and strains examined are not attacked by *Cytophaga johnsonii*, although cell wall preparations are. The situation is not changed when the glucanases are used at higher concentrations than those that occur naturally, so the resistance of the living cells must be qualitative in nature, and probably depends upon some so far undiscovered structural feature of the cell wall. From studies elsewhere this is thought to be connected with the mannan constituent of the cell walls, which is not attacked by the cytophaga. Recent work at the Heriot-Watt University has shown that living cells of other strains of the same yeasts lose their walls when exposed to Cytophaga glucanases. It thus seems that quite small differences in wall structure may confer resistance. Hence, presumably, the effectiveness of the attacking organism may also be subject to intra-specific variation, and until cell wall structure can be described more accurately in chemical terms there will remain plenty of scope for exploring the more biological aspects of relation between pathogenic fungi and their likely enemies in soil.

Recent collaboration with Microbiology has centred round straightforward instances of parasitism of the sclerotia of a plant pathogen, *Sclerotinia sclerotiorum*, by two soil fungi *Coniothyrium minitans* and *Trichoderma viride*[51]. Once again the chief cell wall constituent is a glucan, but one that so far has been found only in sclerotia-forming fungi. Although it belongs to the same general class of glucans that is so widespread in fungal walls, the $\beta(1\rightarrow3)$-glucans, it has a repeating structure in which a single glucose residue is attached to every third glucose residue of the main $\beta(1\rightarrow3)$-chain.

This structure impedes the action of the glucanases of many organisms, including those of Cytophagas, which are of the endo-$\beta(1\rightarrow3)$-glucanase type, designed to attack the middle of long chains of unsubstituted $\beta(1\rightarrow3)$-linked glucose residues. The structure is, however, susceptible to exo-$\beta(1\rightarrow3)$-glucanases, which work along the $\beta(1\rightarrow3)$-chain from the non-reducing end and ignore the side groups. In accord with this it is found that both the *Coniothyrium* and the *Trichoderma* species produce glucanase mixtures in which exo-$\beta(1\rightarrow3)$-glucanases predominate.

Experiments have shown, however, that the exo-glucanase acting on its own is not very effective in attacking either a glucan preparation isolated from the sclerotia, or cell wall preparations, or the walls of living cells. In each case the simultaneous presence of an endo-$\beta(1\rightarrow3)$-glucanase enhances its activity. This suggests that the chemical structure proposed for this glucan does not fully describe it. The glucan is notable for its capacity to form a gel, and the possible relations between this and its resistance to enzymic degradation are at present being investigated.

This study, like previous research, emphasizes the complexity of the problem, even when a single wall component is involved. Until a fuller description can be written of cell wall structures and of the enzymes needed to degrade them it will be difficult to decide which soil organisms play a leading role in the decomposition of fungal residues. When that time comes a better understanding of the processes that limit the survival of pathogenic fungi in soil should also have been obtained.

Other Topics

Investigations of the effects of soil organic matter on plant tissue[25] continue. In September, Dr Linehan attended the fifth Humus et Planta Symposium in Prague, at which an international committee was set up to summarize and record, using computer techniques, all information relating to humus research. A study of the minor sugar constituents of plant cell walls[26], begun in 1960 (*see* Annual Report 30, 1959/60), has been completed and published. Two further publications describe the results of collaboration with Plant Physiology on copper deficiency in oats[27, 28]. A preliminary report on the organic constituents of the Glentanar podzol profile[29] has appeared.

PLANT PHYSIOLOGY

The improvement of the mineral nutrition of the plant is the essential aim of the work of the department. Special emphasis is given firstly to the investigation of processes by which plant cells absorb nutrient ions, secondly to the effects of interactions between major and trace elements on the health and nutrient balance of the plant, and thirdly to the effect on the mineral nutrition of plants of soil organic constituents.

Dr Yasusada Ohta from the Faculty of Agriculture, Tokyo University of Education, completed a further five months of study leave in the department. More recently the department has welcomed, for a period of six weeks, Mr L. P. Raikov, Deputy Director of the Nikola Pushkarov Institute of Soil Science, Sofia, Bulgaria. The exchange of information and experience resulting from such visits is mutually advantageous.

Mechanisms of Nutrient Uptake

Ion Flux Studies. To understand the mechanism of ion absorption in plant roots, it is necessary to establish, at the cellular level, the concomitant influx and efflux of the major nutrient ions. This can be most meaningfully achieved when the fluxes measured relate to an ambient solution containing all the major nutrient ions in concentrations of the order found in soil solutions. Measurements of ion fluxes in cortical cells of onion root segments, grown and incubated in a balanced nutrient solution, have therefore continued. Analysis of K^+, Na^+ and Cl^- isotope elution data has resolved efflux into the three phases commonly found—associated with vacuole, cytoplasm and wall compartments of the cells. However, for Ca^{++} a fourth phase, with an exchange rate intermediate between the rates characteristic of cytoplasm and wall, has been found. Comparison of turnover times in each cell compartment for the three cations studied has revealed some interesting differences. The half-time of exchange ($t\frac{1}{2}$) for vacuolar K^+ is about 100 hours, whereas for Na^+ it is up to five times this value; for vacuolar Ca^{++}, $t\frac{1}{2}$ is only one-third of the K value. In the cytoplasm $t\frac{1}{2}$ for K^+ and Ca^{++} is of the order of one hour, whereas for Na^+ it is as little as 15 minutes.

Further evaluation of the flux data for fresh-cut storage tissue, obtained using beetroots grown in nutrient solutions with radioactive Na^+ or Cl^-, requires comparisons with data for similar tissue which has been aged for 24 hours and in which a progressive reduction in vacuolar efflux, apparent in fresh-cut tissue, is avoided. Culture of further beets for this purpose is in hand.

Ion Absorption, Protein Synthesis and Energy Supply. In addition to the measurement of ion fluxes across the cell membranes discussed above, the characterization of active ion transport requires an understanding of the energy supply to the transport mechanism, of the exergonic reactions in the cell from which active ion transport derives its energy, and of the mechanism of its transfer. Although there are several mechanisms of energy transfer in plant cells, by far the most important is linked to the synthesis and hydrolysis of adenosine triphosphate (ATP) which can be produced either oxidatively in respiration or, in green tissue, photochemically as a by-product of photo-synthesis. Reference was made in last year's report to some preliminary experiments on the ion uptake properties of greening wheat laminae initiated as a follow-up to an investigation of the relation between ion uptake and protein synthesis in storage tissue. This work has been continued and developed with a view to characterizing the energy sequences involved in ion uptake by photosynthetic cells of higher plants, i.e. whether they are powered by oxidative phosphorylation or photophosphorylation.

The investigation of ion uptake processes by leaf tissue is hindered by the impermeable nature of the leaf surface. The difficulty is generally overcome experimentally by slicing the tissue to give thin sections allowing the rapid diffusion of ions to all the mesophyll cells through transverse cut surfaces. As an alternative to slicing the use of vacuum infiltration of the tissue has been investigated; the effect of this is to fill the intercellular spaces with solution and thus facilitate the diffusion of ions to all the leaf cells. Experiments have shown that this treatment is not injurious to the tissue and that it permits a rate of uptake by whole wheat laminae comparable to the maximum rate attained by chopped tissue. A study of the effect of segment length on ion uptake by wheat laminae has shown that in non-infiltrated tissue uptake is related to the number of cut edges per unit length and rate-limited by diffusion of the solution to the absorption sites, whereas in infiltrated tissue uptake is uniform along the length of the lamina and rate-limited by metabolic processes. An account of this work[73] has been accepted for publication.

Comparative studies of the effect of some inhibitors on ion uptake by root and leaf cells of wheat have yielded results which indicate that ion uptake by photosynthetic cells can be supported by energy derived from photochemical reactions. For example, carbonyl cyanide m-chlorophenylhydrazone (CCCP) is a very effective inhibitor of Cl^- uptake by root cells and by non-illuminated leaf cells, but in the light Cl^- uptake by leaf cells can proceed normally in the presence of the inhibitor. This indicates that Cl^- uptake by photosynthesizing cells is supported by electron transfer reactions rather than by ATP formation. Confirmatory evidence is obtained from dichlorophenyl dimethylurea (DCMU), which disrupts the light-driven electron transfer reactions. This compound has no effect on Cl^- uptake by green cells in the dark, but in the light it obliterates the light-stimulated component.

Experiments have been continued on the specificity of protein synthesis inhibitors in relation to ion uptake by storage tissue.

Major and Trace Element Interactions

Copper/Phosphate. The effect of phosphate on the severity of the copper deficiency symptoms of oat plants growing in peat of a low copper content has been studied[28]. Copper deficiency becomes more intense when phosphate is added and this is ascribed to the more effective utilization of nitrogen in the synthesis of protein with which the copper is associated in the plant. Earlier work on this problem[27] has been published.

Calcium/Potassium. Following completion of the new glasshouse in late spring, extensive experiments have been laid down in conjunction with Pedology on the growth of tomatoes in different types of peat. Particular attention has been paid to calcium nutrition and to potassium-calcium relationships as being fundamental to the blossom-end rot problem in peat culture. It has been demonstrated that excessive potassium in the nutrient solution causes blossom-end rot and that the content of potassium shows a linear relationship with citric acid. Electron micrographs have shown that calcium-deficient cells of these tomatoes contain neither chloroplasts nor mitochondria. Similar results have been obtained with calcium-deficient cells of the duckweed *Lemna*.

In collaboration with the Scottish Horticultural Research Institute, experiments have been carried out on a similar disorder of carrots, cavity spot. It has been determined that this disorder can be induced by high potash fertilizer applications. A study of the carrots showed high correlations between the potassium-calcium ratio and the citric acid-malic acid ratio. A related malady of lettuce called tip burn can be readily induced by spraying with a solution of tenth-normal potassium acetate. The metabolic changes are under study.

Dr Ohta has continued his work reported last year on the mechanism of absorption of calcium with Lemna in sterile culture. Using radioactive isotopes, it has been demonstrated that the oxalate ion is readily absorbed from solution and that the absorption of calcium is increased by the absorption of oxalate. When EDTA is present in the medium in amounts equivalent to those of calcium, uptake of calcium is prevented and the young fronds which develop are colourless. Examination of these colourless cells under the electron microscope has shown that they, like the calcium-deficient tomato cells, are devoid of structural contents. A brief report of this work[30] has appeared.

Soil Organic Compounds and Ion Uptake

A paper reporting collaborative work with Biochemistry on the effects of humic acids on ion absorption by storage tissue[25] has been published. This investigation is now being extended to include sterile wheat roots.

Radioactivity

The use of isotopes as tracers has been continued by workers in various departments. Work with Biochemistry on the incubation in soil of plant material labelled with ^{14}C and on a simple method of counting ^{14}C labelled soil in a liquid scintillation counter has been completed.

The use of the liquid scintillation spectrometer for analytical methods, other than measurement of radioactivity, in which a small amount of light must be measured, has been investigated. Thus bioluminescence produced by the luciferin-luciferase enzyme technique enables the assay of very small amounts of ATP. Several workers have made measurement of ATP the basis for obtaining counts of micro-organisms, and this technique may be applicable to estimations in soil and peat.

In the collaborative work with Soil Fertility on the cation exchange properties of plants it was found that there were interrelationships between C.E.C., Ca, and Ca/K ratio and other factors in parts of the plant, including floral parts. Two reports of these findings[74, 75] have been submitted for publication and two on other aspects of the C.E.C. of plants[32, 33] have appeared.

MICROBIOLOGY

The general aim of the work of the department is to investigate the role of soil micro-organisms in the decomposition of organic matter in soil and their influence on the healthy development of plants of economic importance. The main lines currently being pursued include studies on interrelationships between soil micro-organisms and the roots of higher plants, on the interactions between groups of soil micro-organisms, and on the effect of clay minerals on the breakdown of organic matter in soil. Work is also in progress on the microbiology of peat. Collaboration with various departments of the Institute and with organizations with allied interests has continued.

Dr H. W. Morgan, an I.C.I. Postdoctoral Fellow, joined the department in October 1970 for two years. An I.A.E.A. Fellow, Miss Catherine Douka of the Department of Earth Sciences, Nuclear Research Centre, Democritus, Athens, Greece, spent six months studying techniques for handling soil micro-organisms—particularly those involved in oxidizing manganese. Professor Yigal Henis of the Department of Microbiology, Rehovot, Israel, came to the department in September 1971 for two months.

During the year members of staff attended meetings of the British Society of Soil Science and the Society for General Microbiology, the fifth International Symposium and Study Group on Continuous Culture of Micro-organisms, and the first International Mycological Congress. Visits were also made to organizations with allied interests.

Dr D. M. Webley served on a small group set up by the Agricultural Research Council to recommend a programme of work for the Microbiology Section of the Weed Research Organization in Oxford. He also accepted an invitation to join the Editorial Committee of the journal Soil Biology and Biochemistry.

Interrelationships between Plant Roots and Micro-organisms

The results of a study of the invasion of pea roots by a *Pseudomonas* sp. and *Acanthamoeba palestinensis*[34] have now been published. During this study it was observed that inoculation of pea roots with *Pseudomonas* sp. changed the appearance of the mucigel on the root surface. These changes have been examined in more detail, using the electron microscope, and the study has been extended to include several plant species and an additional micro-organism, the non-fruiting myxobacterium *Cytophaga johnsonii*. Generally, inoculation of plant roots grown in nutrient solution or sand results in the formation of larger amounts of mucigel than are found on axenic roots. The granular and fibrous components of the axenic mucigel disappear during microbial colonization of the roots. Similar results were observed when the plants were grown in soil. It was noted that the mucigel on soil-grown roots frequently contained large numbers of minute mineral particles. Preliminary results from electron diffraction studies suggest that these particles are clay mineral platelets. The infection of roots by the *Pseudomonas* sp. has been studied further and shown to occur in pea, mustard, timothy, tomato and wheat. A demonstration of the above work was presented at a Conversazione during a meeting of the Association of Applied Biologists in Dundee.

Influence of Soil Protozoa on Nitrogen Fixation

Recent experiments with the nitrogen fixing bacterium *Azotobacter chroococcum* and the soil ciliate *Colpoda steini* have established that environmental temperatures can significantly influence some interrelationships between protozoa and bacteria. At incubation temperatures between 15°C and 25°C the mixed cultures of the colpoda and azotobacter fixed more nitrogen than equivalent pure cultures of azotobacter. At 10°C and 5°C very little nitrogen fixation occurred in either the mixed or the pure cultures. When the cultures were incubated at 28°C, which is approximately the optimum temperature for nitrogen fixation by pure cultures of *A. chroococcum*, the mixed cultures fixed less nitrogen than the pure cultures. Several reports have been published by other workers in the past on increased nitrogen fixation by azotobacter in the presence of soil protozoa, but the influence of temperature has been neglected. When gently shaken (60 revs/min) and incubated at 28°C the mixed colpoda/azotobacter cultures fixed slightly more nitrogen (5μg N/ml) than the pure azotobacter cultures in the first two weeks of incubation, but after three and four weeks of incubation there was little difference in the quantities of nitrogen fixed. The actual mechanism whereby ciliates stimulate nitrogen fixation is still not clear, but in view of the known oxygen sensitivity of azotobacter during nitrogen fixation, it is possible that the protozoa helps to reduce the dissolved oxygen concentrations in mixed cultures to more suitable levels for nitrogen fixation by azotobacter. Two reports[76, 77] of findings indirectly supporting this new hypothesis have been submitted for publication, and confirmatory experiments are in progress designed to substantiate this.

Lytic Soil Micro-organisms

The work on the study of the lytic micro-organisms present on the root surface of winter wheat has been continued using the cultivar Joss Cambier. Samples from the field were taken periodically throughout the life cycle of the plant and the total number of organisms and the percentage that lysed the walls of *Saccharomyces cerevisiae* estimated. The selective medium with antibiotics was used to encourage growth of non-fruiting myxobacteria by suppressing fungi and actinomycetes. The number of myxobacteria fluctuated, being predominant on the young roots. Lytic actinomycetes became more numerous as the plant aged.

Organisms showing lytic activity were isolated and tested on the walls of *Saccharomyces cerevisiae*, *Fusarium culmorum* and colloidal chitin. All were attacked. The morphology of the isolates was noted. All the myxobacteria examined were *Cytophaga* sp. When tested on antibiotics, *Cytophaga johnsonii* was found to be capable of adapting to high concentrations, suggesting that myxobacteria are able to survive even when lytic actinomycetes are the dominant group.

Recently it has been shown that the culture fluid from *C. johnsonii* possesses a polygalacturonate *trans*eliminase and that there is a reduction in viscosity of sodium polygalacturonate when this substrate is incubated with the culture fluid. Further work is in progress in collaboration with Biochemistry.

Both the review of the biological transformation of microbial residues in soil[35] and the description of the separation of β-glucanases produced by *C. johnsonii*[24] have now appeared.

Fungal Parasites of Plant Pathogens

During the last three years, with the aid of the Division of Mycology of the School of Agriculture, Aberdeen, a large number of sclerotia of the pathogen *Sclerotina sclerotiorum* have been collected from diseased plants, including potatoes, carrots, lettuce and peas, and from soil in various areas of north-east Scotland. The object was to examine these sclerotia for fungi which could parasitize them. It is interesting to note that only two such species, *Coniothyrium minitans* and *Trichoderma viride* have been isolated throughout these studies. *C. minitans* has been found to be moderately widespread in south-east England, but has not previously been encountered so far north.

The sclerotia of a range of plant pathogenic fungi have been tested for their susceptibility to the two parasitic fungi. Since last year's report, it has been found that spores of *T. viride* parasitize sclerotia of *Botrytis cinerea* when applied to their external surfaces; *C. minitans*, however, proved ineffective. A study of the length of time the sclerotia of the various pathogenic fungi persist in soil is being carried out. It has been shown that sclerotia of *S. sclerotiorum* are still viable and capable of producing many more sclerotia on agar plates after being buried for over two and a half years in soil. In collaboration with Biochemistry it has been possible to fractionate, from culture filtrates of *C. minitans*, the enzyme responsible for degrading the sclerotial and hyphal walls of *S. sclerotiorum*. The different $\beta(1\rightarrow3)$-glucanases isolated do not bring about much lysis when acting individually, but two acting in combination bring about significant lysis of the walls. Attempts are also being made to fractionate the lytic enzyme from *T. viride* culture filtrates.

Ultrastructure of Fungi

Work continues on comparing the ultrastructure and chemical components of the cell walls of various plant pathogens (*see* Annual Report 40, 1969/70): these, with one exception, form sclerotia. This study was undertaken with the collaboration of Spectrochemistry, Biochemistry and Pedology in an attempt to relate cell wall composition to susceptibility of sclerotia to parasitism by the above fungi and to fungal classification, and the results[51] have been prepared for publication. Infrared spectra, sugar analysis of hydrolysates and lytic experiments indicated that the wall composition of *Sclerotium tuliparum* differs markedly from that of other *Sclerotium* spp. but is similar to *Rhizoctonia solani*. By the same criteria the *Sclerotium* spp. other than *S. tuliparum* are similar in composition to the *Sclerotinia* spp.

Work with the Commonwealth Mycological Institute on spore surface ornamentation of the rust fungi *Aecidium balansae* and *A. fragiforme*[78] has been completed. The spores were examined by optical microscopy and by transmission and scanning electron microscopy. Freeze-etching has been used to reveal the ultrastructural features of spores of various soil fungi, and a description of observations on *T. viride*[79], a species which parasitizes sclerotia, is in press.

A collection of highly magnified electron micrographs illustrating some of the above results, together with infrared spectra and micrographs of fungal cells walls, has been prepared for exhibition and teaching purposes.

Microbial Decomposition of Soil Organic Matter

The results of the investigation of the microbial degradation of nucleic acids and nucleic acid: montmorillonite complexes[10] have now been published. This investigation has continued, in collaboration with Pedology, with a study of the effects of soil micro-organisms on adenine: montmorillonite complexes. Adenine is released during the degradation of nucleic acids and is adsorbed in the inter-layer spaces of montmorillonite. Analysis of adenine: montmorillonite complexes during incubation on several soils, using X-ray and mass spectrometric techniques, suggests that adsorption protects the adenine against microbial enzymes. It appears that the interlayer spacing (12·5Å) of the complex is too small to allow penetration by the proteinaceous enzyme molecules, and thus prevents enzyme-substrate combination. This work has been submitted for publication[49]. In addition, a study of the adsorption of polysaccharides by clay minerals and its effect on their microbial degradation has commenced, in collaboration with Pedology, Biochemistry and Spectrochemistry. For this investigation, mannan, an important constituent of the cell walls of soil fungi, has been chosen and yeast mannan, from *Saccharomyces cerevisiae*, has been purified and used as a substrate for the isolation of organisms capable of utilizing it as the sole source of carbon. A micro-organism similar in morphological characteristics to the genus *Arthrobacter* was isolated from a soil percolated with the mannan. This isolate produced an extracellular enzyme capable of splitting 60-70 per cent of the mannose units off the mannan, leaving a resistant polymeric mannose residue. The enzyme, an α-mannosidase, was purified by ammonium sulphate precipitation, gel filtration and ion exchange chromatography, and appeared to be similar to an α-mannosidase isolated in 1969, also from a soil *Arthrobacter*, by American workers in California. The enzyme differed only in its stability on D.E.A.E. sephadex ion exchange columns, requiring a lower elution pH to prevent loss of activity.

Preliminary results show the enzyme to be strongly adsorbed to montmorillonite, with little or no adsorption of the mannan substrate. The effect on the activity of the enzyme of its adsorption to clays is being studied, and for this purpose a substantial amount of the purified enzyme has been prepared. The enzyme is unable to attack mannan in intact or heat treated cell walls of *S. cerevisiae*. The mannan residue remaining after enzyme attack has also been used as a substrate for the isolation of organisms capable of decomposing it. Several isolates are currently being tested for mannase activity.

Microbiology of Peat

The bacteriology of a basin peat at the Lyne of Skene near Aberdeen is under investigation. Bi-weekly samples are being taken at half metre depths, using a modification of a Russian designed sampler. Sampling is based on random co-ordinates in a three metre square grid divided into one hundred squares.

Twenty different media have been used in the past for counting aerobic peat micro-organisms. To date, a soil extract plus mineral salt medium has proved the most suitable for both the most probable number (M.P.N.) and plate dilution techniques. Predominant organisms isolated from the dilution plates are being further investigated. Counts of aerobic spore-forming bacteria indicate that from one to fifty per cent are present as spores, the proportion increasing with depth. Techniques for counting anaerobic bacteria are under investigation. Direct counts of bacteria are also being made, using the fluorescein isothiocyanate (F.I.T.C.) technique mentioned in last year's report. Both the F.I.T.C. and the M.P.N. counts reveal a wide numerical fluctuation in populations with depth and time. Another method of population enumeration, by determination of adenosine tri-phosphate (A.T.P.) content of samples, is under investigation in collaboration with Plant Physiology. Preliminary results are similar to those given by the F.I.T.C. and M.P.N. techniques. Chemical analyses of the peat samples are being carried out by Pedology. Examination of the peat by scanning electron microscope has revealed the presence of what appear to be bacterial cells and fungal hyphae to a depth of over two metres.

Other Investigations

The microbial production of the potassium salt of 2-ketogluconic acid has continued and its use as an extractant for certain trace elements is under investigation in collaboration with Spectrochemistry.

Experiments on the growth of mixed cultures of bacteria and protozoa in batch culture under strictly controlled conditions are under way. With the acquisition of a half-litre fermentation vessel and equipment for monitoring dissolved oxygen further parameters can be measured during continuous culture.

Pigments synthesized by certain soil fungi are being examined in association with Biochemistry to ascertain the conditions under which they are formed and their relevance to soil organic matter.

SOIL FERTILITY

The main objective of the research programme continues to be improvement of manurial practices and crop production, through better understanding (a) of the influences of pedological factors, soil properties and environmental conditions on nutrient supply and soil productivity, (b) of the immediate and residual effects of lime and fertilizers, including form, rate, frequency, time and method of application, on the growth and mineral composition of crops, and (c) of the factors which affect the selection, calibration and practical usefulness of laboratory methods for evaluating the nutrient status of soils, as a basis for adjusting fertilizer dressings. The overall experimental approach therefore remains the concurrent development and integration of field, pot and laboratory investigations based on a selection of contrasting soil series mapped in the Soil Survey of Scotland and covering the different plant nutrients and the main agricultural crops. In addition to clarifying the operation of the various soil properties and processes which regulate soil-nutrient-plant relationships, and which underlie the effects of pedological factors, this approach is designed also to provide practical information about the performance and fertilizer requirements of the different soils and crops.

Importance continues to be attached to practical application of research findings through consultative activities, especially advisory soil testing carried out in collaboration with the North of Scotland College of Agriculture. Collaboration has also been maintained with other research organizations and various technical committees. Under the latter head come the Technical Committee on Soil Fertility of the Agricultural Research Council, the Working Party on Soil Analysis set up by the Soil Survey Research Board, the Scottish Sub-Committee of the Sugar Beet Research and Education Committee, the Scottish Standing Committee for the Calculation of the Residual Values of Fertilizers and Feeding Stuffs and, more recently, the Working Party on the Evaluation of Manurial Residues set up by the Ministry of Agriculture, Fisheries and Food. A paper on soil type and soil fertility was contributed to a meeting of the Agriculture Group of the Society of Chemical Industry on Soil Survey in Agriculture.

At the invitation of the Faculty of Agriculture and Forestry, Dr E. G. Williams acted as Scientific Assessor for the appointment of a new Professor of Agricultural Chemistry and Physics in the University of Helsinki.

Fertilizer Requirements of Crops

The results of 33 field experiments on potatoes on farms in north-east Scotland between 1953 and 1969 have been used to assess the effects of various rates of ammonium sulphate, superphosphate and potassium chloride, arranged in factorial or central composite designs, on the yield, size and dry-matter content of the tubers. The size limits were 1·25 to 2·25 inches for seed and above 2·25 inches for ware.

With reasonably adequate phosphate and potassium, the responses to nitrogen were very variable, ranging from 0 to 6 tons tubers per acre, while the optimum dressing varied from 0 to 160 lb N per acre. These variations were associated to some extent with the intensity of arable cropping, the largest responses being obtained on farms with a high proportion of crops to temporary leys. Yield increases from applied nitrogen were greater for ware than for seed-size tubers. Optimum seed production was normally obtained with about two-thirds of the nitrogen required for the most profitable yields of ware and total tubers. Dry matter content was consistently reduced by the nitrogen treatments, 120 lb N per acre giving an average of 20·7 per cent compared with 21·5 per cent when none was applied. Since high rates may produce rather soft tubers more susceptible to damage during harvesting and dressing, somewhat less nitrogen should be applied than is required for optimum yield.

Phosphate rates up to 240 lb P_2O_5 per acre were used, and with reasonably adequate nitrogen and potassium the total yields of tubers showed responses in 32 out of the 33 experiments, the mean response to 160 lb P_2O_5 being 1·7 tons per acre. The yield of ware showed a response in only about half the experiments whereas seed yields were consistently increased. The indications are that it is profitable to apply quite high rates of about 160 lb P_2O_5 per acre on most soils in north-east Scotland, especially if the crop is being grown for seed production. Added phosphate had practically no influence on the percentage of dry matter.

Potassium rates up to 250 lb K_2O per acre were used and with reasonably adequate nitrogen and phosphate the total yields showed a response in 31 experiments, the mean response to 200 lb K_2O being 1·6 tons per acre. The yield of ware was increased at all the responsive sites, and for both total tubers and ware it is normally profitable to apply about 160 lb K_2O per acre. The yield increases for seed were much smaller and optimum production seems to be obtained with about 70 lb K_2O per acre. Added potassium normally reduced the dry matter content of the tubers, 200 lb K_2O per acre giving a mean of 20·5 per cent compared with 22·2 per cent when none was applied.

For ware production it seems profitable to apply about 80 lb N, 160 lb P_2O_5 and 160 lb K_2O per acre. For seed production slightly less nitrogen and much less potassium are required, average optimum rates being about 70 lb N, 160 lb P_2O_5 and 70 lb K_2O per acre.

An account of joint work with Pedology on lime and fertilizer requirements for establishing grass on deep peat[11], summarized in last year's report, has now been published.

Effects of Fertilizers, Soil Characteristics and Environmental Factors on Crop Yields and Composition

As explained in the reports for 1968/69 and 1969/70 a series of annual factorial NPK experiments is in progress to study in detail the growth and development of swedes and barley at each of four contrasting sites, representing the Countesswells, Foudland, Insch and Laurencekirk soil series. Each centre is equipped to measure soil and air temperatures, rainfall, humidity, wind speed and soil moisture, in order to assess the implications of site, environment and season, as distinct from soil characteristics.

The indications are that the main factor determining the yield of barley was the number of ear-bearing tillers, grain number per ear and grain size being little affected by site or treatment. Nitrogen increased the number of ear-bearing tillers on all sites and hence increased yield. The phosphate and potassium treatments had no measurable effects on growth or yield, all four soils having adequate contents of both nutrients. Yield was measured as combine-harvested grain and as yield of ears from sub-plots of 1 square metre. The four sites gave different responses to nitrogen but when 90 lb N per acre was applied they gave similar yields of ears, indicating that they had a similar production potential. Uptake of nitrogen, potassium and calcium proceeded rapidly up to ear emergence, but after this stage little more nitrogen was taken up and the contents of potassium and calcium decreased. Uptake of phosphate continued to maturity, the rate decreasing only slightly in the later stages of growth.

The main factor determining the yield of swedes appeared to be the time of onset of rapid root growth.

Trace Elements

Samples of herbage and soil continue to be taken from a series of plots representing different soil parent materials and pedological drainage categories to study, in collaboration with Spectrochemistry, the relationship between laboratory soil values and the contents of trace elements, especially molybdenum, in the herbage. The effectiveness of various sources of manganese, including a chelate form, is being tested in an experiment on oats on a manganese-deficient calcareous sand.

Inorganic Phosphorus

Attention has been concentrated mainly on a series of annual projects, started in 1969, on the evaluation of soil phosphate status. These have two main objectives: one is to examine more deeply the implications of phosphate Quantity, Intensity and Buffer indices; the other is to assess to what extent correlations between laboratory values and field responses can be improved by taking account of relevant soil properties and minimizing disruptive effects of site and seasonal variations. To these ends each project is based on 20 field sites confined to a single soil series in one season, and field response measurements with swedes are supplemented with parallel measurements with oats under uniform conditions in pot cultures. Coverage is being given to a selection of soil series representing contrasting parent materials and soil properties.

An account of a major series of experiments on the residual effects of phosphate and the relative effectiveness of annual and rotational dressings[36], summarized in the 1967/68 report, has now appeared. A paper mentioned in last year's report, on the development of an improved index for rapid characterization of the phosphate sorption properties of soils[37], has also been published.

Organic Phosphorus and Sulphur

Fractionations, using gel chromatography, are being carried out on the organic matter extracted from soils with aqueous acetylacetone. The distribution and nature of the phosphorus in the fractions is being examined, and it is hoped that this approach may give an insight into the nature of the esters which are mineralized or otherwise altered during extraction with sodium hydroxide. The sulphur contents of the fractions are also being measured.

A study has been made of the sorption of inositol hexaphosphate by a range of soils, to clarify the reasons for its extreme stability in soil and to examine the effects of enrichment with inositol phosphate on the retention of inorganic phosphate.

Publication of chapters on soil organic phosphorus[80] and organic sulphur[81] prepared six years ago for an Encyclopedia of Soil Science is still awaited.

Nitrogen

Further work has been done on the effects, mentioned in last year's report, of phenyl phosphonic acid in increasing the yield and nitrogen content of oat and barley grain in pot cultures, with particular reference to the implications of soil type and of the rate and timing of nitrogen and phosphonic acid dressings. Investigations have also been continued on laboratory methods for evaluating the nitrogen status of soils and on changes in NO_3^- and NH_4^+ in field plots receiving contrasting nitrogen treatments.

The colorimetric method for routine AutoAnalyzer estimation of NH_4^+ in Kjeldahl digests, summarized in last year's report, continues to give very satisfactory results and the details[38] have now been published. An account of joint work with Statistics on the interpretation of response curves in estimating optimum rates of nitrogen was presented at a meeting of the Agriculture Group of the Society of Chemical Industry and the Fertilizer Society and a paper has been prepared for publication.

Soil Acidity and Cation Exchange

Quantitative investigation of relationships between the degree of saturation of the cation exchange complex with Ca + Mg, Al being the complementary ion, and the pH of equilibrium suspensions of acid soils continues to be a major theme.

In dilute salt suspensions of acid mineral soils the pH appears to be governed mainly by the first stage hydrolysis of aluminium ions in solution: $Al^{3+} + H_2O \rightleftharpoons AlOH^{2+} + H^+$. The pH values of different soils, and of a given soil with varying salt concentrations, are accordingly determined by the aluminium concentration in solution. Different soils with the same proportion of exchangeable Ca + Mg to Al, however, do not necessarily give similar pH values because the equilibrium constant for the exchange reaction varies with soil composition, and in some cases a small contribution from protons dissociated from surface OH groups is also involved. These principles have been found to apply also to clay mineral suspensions, but not to highly organic soils which contain little aluminium.

A closely associated problem is that of finding a physicochemically acceptable index of aluminium solubility to assist in the diagnosis of infertility in acid soils. The activity product of aluminium hydroxide, which can be expressed as pH-$\frac{1}{3}$pAl, would be expected to remain constant as the acidity of a soil is reduced by liming because of the establishment of an aluminium hydroxide solubility equilibrium. The fact that it is not constant is not at present understood and the implications are currently being investigated. Even so, the function pH-⅓pAl is of deeper significance and more general applicability than a simple measure of soluble aluminium in an arbitrary extractant, and since it is not constant it may provide the required index.

Cation-Exchange Properties of Plants

Work in India with sugarcane varieties has shown a relationship between the cation-exchange capacity (CEC) of the roots at an early stage of growth and the yield of cane at harvest, while short-term pot experiments in the Netherlands have shown that changes brought about by fertilization in the organic acid content of barley, expressed as C-A, the difference between total cations and total inorganic anions, can also be related to yield. A connection between these observations lies in the finding in this laboratory that measurements of excess base, which corresponds to organic acid content, correlate well with root CEC over a wide range of species and varieties.

Tests using leek varieties have confirmed these yield relationships. The correlation between root CEC and yield ($r=0.91$) is higher than that between excess base or C-A and yield ($r=0{\cdot}80$), and a paper embodying these findings[33] has been published. Varietal trials of barley, oats and swedes have been sampled to test whether these relationships are of more general applicability, and in particular to see whether they hold for the dicotyledonous plant.

The work on effects of soil pH and root CEC on crop composition[32], mentioned in last year's report, has now been published, and accounts of collaborative work with Plant Physiology on pollen composition[74] and on the composition of floral parts[75], in relation to cation-exchange properties, have been submitted for publication.

Advisory Work

During the year about 12,000 soil samples have been tested for lime requirement and phosphate and potassium content to assist the Advisory Officers of the North of Scotland College of Agriculture in making lime and manurial recommendations for agricultural and horticultural crops. Collaboration has been continued with Pedology in examining soil samples from forest nurseries, and with Spectrochemistry in assessing the magnesium, cobalt, copper and molybdenum contents of soil and crop samples from areas with problems concerning animal health or crop production.

Experimental work on grassland has shown little or no yield response of herbage to phosphate, but in problems involving animal performance the advisory services have found that the phosphate content of rations, particularly those based on hay and silage, is sometimes below the required level Analyses of herbage samples from experimental plots with different phosphate status and varying phosphate dressings have shown that the phosphate content of the dry matter depends more on the status of the soil than on the amount applied. To produce herbage containing over 0·3 per cent P, especially when high rates of nitrogen are used, it is necessary to ensure that the soil has good reserves of phosphate. This may require extra amounts of phosphate, in addition to the dressings normally considered adequate to produce satisfactory yields, and illustrates the desirability of raising the phosphate status of the soil to a satisfactory level.

STATISTICS

Provision of advice on the design of experiments and statistical analysis of results continue to be the main activities of the department. Members of staff have attended meetings of the Royal Statistical Society and of the Biometric Society, and an Agricultural Research Council Working Party on model-building in crop and plant science, and a joint paper with Soil Fertility on fitting and interpreting response curves for estimating rates of nitrogen was presented to a meeting of the Agriculture Group of the Society of Chemical Industry and the Fertilizer Society.

Computing Service

Use of the IBM 1130 Computer and card and tape punches is open to authorized members of staff, training and supervision in programming and operating being provided. The department, however, continues to program and run work for those who prefer to have this done.

The library of statistical programs has been extended and a number of other programs and subroutines revised to be of more general use. A new output subroutine for analysis of variance tables combines a number of functions, thus reducing the number of calls required from a mainline program. It was developed initially to meet the requirements of the analysis of covariance program for factorial experiments and has been incorporated into analysis of variance programs. An optional call is now available to a subroutine which performs multiple range tests on a specified group of treatment means. The program for the analysis of central composite designs has additional options available for output, and improvements have been made to input to avoid repetition of design information when several variables from the same experiment require analysis. Revisions and extensions have been made to programs for the calculation of correlation coefficients, partial correlation coefficients and multiple correlation coefficients.

Advisory and Collaborative Work

Further series of experiments on cereal and swede crops, concerned with the rate of accumulation of dry matter and of nutrient uptake, have been designed for Soil Fertility using confounded and partially confounded factorial arrangements. Other field experiments have randomized block, lattice square, central composite or factorial arrangements. Four response equations were compared for their ability to predict the optimum economic rate of nitrogen from the results of 200 field experiments. The equations were the simple quadratic, the square root form of the quadratic, the Mitscherlich and the Mitscherlich with a linear term added. Computer programs were written to evaluate the parameters in the four equations and to maximize the financial gain, expressed as the difference between the value of the crop and the cost of the fertilizer. Mitscherlich response curves have also been used to make comparisons between different forms of phosphate fertilizers in terms of crop yield and uptake of phosphorus.

Collaboration with Pedology has included the continued use of a program for the processing of the results of X-ray silicate analysis and the translation to FORTRAN of an ALGOL program for the evaluation of pore size distribution. Comparisons have been made of the reproducibility of results. Tabulations of solid state decomposition functions have been made by computer. In the kinetic analysis of thermogravimetric data the logarithmic integral had to be evaluated. FORTRAN programs were written, using two different series, one absolutely convergent and the other semi-convergent, to tabulate the required values of $-\log p(x)$ for different temperatures and activation energies. Agreement was obtained where parts of this tabulation overlapped previously published results. Further programs and subroutines have been written for the experiment on the nitrogen nutrition of pines to process and analyse data on tree girth, height growth, ring width, basal area and volume. Data processing was carried out tree by tree and results tabulated by treatments and by tree size categories. A frequent requirement was for log/log regressions of increments in a size measurement on a previous value of the basal area. These regressions were then solved for a ditribution of stems by basal area classes with the results expressed as estimated totals per hectare with confidence limits. Analyses of variance have also been carried out on cumulative growth and relative weekly growth rates derived from girth measurements of trees, and on chemical and physical properties of peat samples taken from a number of depths in a water level experiment.

Experiments have been designed and data analysed for further work by Plant Physiology on the growth of lemna. In addition to correlation analyses and analyses of variance for greenhouse experiments, a larger project was concerned with the uptake of phosphate and chloride ions in wheat lamina in a 2×2 factorial arrangement of treatments. For each of the four treatments and for a number of experiments four time-response curves were compared—linear, quadratic, log/log and exponential.

In collaboration with Soil Survey, properties of six horizons of profiles for 12 soil series from Mull have been summarized, and in another survey the percentages of occurrence with confidence limits were obtained for soil types from a random sample of points on a grid.

The analysis of results from NPK manuring trials in collaboration with the Crop Husbandry Department of the West of Scotland Agricultural College continues. The combined analysis and the presentation of the results of a series of NPK manuring trials on early potatoes have been completed.

LIBRARY

The library holds an extensive collection of literature of soil science and related subjects and, although the service is primarily for members of staff, loans can be obtained by individuals and institutions either on direct application or through the inter-library lending schemes. A list of periodical holdings is available on request.

It proved possible this year to take out subscriptions to 16 additional journals; 101 books were purchased and 31 received by donation. As in previous years, reports and reprints came in from many countries.

Co-operation with other libraries in the provision of books and information continues. Borrowing from outside sources is still heavy, involving this year 947 books and journals; 335 items were lent.

The Institute maintains a mailing list of individual scientists and institutions interested in the various branches of the research work, and lists of staff papers of which reprints are available are sent out periodically. This year 5374 reprints were distributed. No charge is made for reprints and anyone interested in receiving lists should apply to the librarian.

Volume 9 of The Collected Papers, covering the years 1967/69, was prepared for publication and is now in the hands of the binder.

PUBLICATIONS

(A) *Published*

1. The thermal dissociation of some carbonate minerals. By S. St. J. Warne and R. C. Mackenzie. (*J. therm. Analysis*, **3**, 49-55, 1971.)

   In view of the occurrence of carbonate minerals in soils, a recent report that admixture of one carbonate mineral with other carbonates reduces the peak temperature on DTA curves has been checked. There is no evidence that a solid-state reaction occurs in such carbonate mixtures, and the observed effect is attributed simply to dilution. When magnesite is admixed with siderite no reduction is observed in the magnetite peak temperature because the peaks of the two minerals are additive.

2. Assessment of gibbsitic material in soil clays by differential thermal analysis and alkali dissolution methods. By S. S. Jørgensen, A. C. Birnie, B. F. L. Smith and B. D. Mitchell. (*J. therm. Analysis*, **2**, 277-286, 1970.)

   Differential thermal analysis and sodium carbonate dissolution methods have been employed in the investigation of the clay fractions of a wide range of soil groups containing free hydrated oxides of aluminium. These two methods combined provide an arbitrary means of differentiating free crystalline aluminous material in soils from poorly-ordered assemblages containing alumina.

3. The effect of buffered sodium dithionite solution and ultrasonic agitation on soil clays. By B. D. Mitchell, B. F. L. Smith and A. S. de Endredy. (*Israel J. Chem.*, **9**, 45-52, 1971.)

   A rapid method for removing free ferric oxides from soil clays with sodium dithionite solution buffered with sodium bicarbonate solution is described. Effective dispersion of the clay suspension during the extraction treatment is obtained by use of ultrasonic agitation.

4. The oxides of iron, aluminium and manganese. By R. C. Mackenzie, E. A. C. Follett and R. Meldau (Gütersloh, Germany). (pp. 315-344 of *The Electron-optical Investigation of Clays.* Edited by J. A. Gard. London: Mineralogical Society. 1971.)

   A review of electronoptical data currently available on the oxides and hydroxides of iron, aluminium and manganese.

5. Imogolite. By W. J. McHardy. (pp. 359-364 of *The Electron-optical Investigation of Clays.* Edited by J. A. Gard. London: Mineralogical Society. 1971.)

   Electronoptical and electron diffraction observations on imogolite, a fibrous aluminosilicate found in volcanic ash soils, are reviewed.

6. Conditions for the formation of bayerite and gibbsite. By W. J. McHardy and A. P. Thomson. (*Mineralog. Mag.*, **38**, 358-368, 1971.)

   Since the formation of crystalline alumina hydrates in soils is an important pedogenic process, the conditions conducive to the crystallization of gibbsite and bayerite from alumina gels have been investigated. Two methods of preparing such gels free from adsorbed inorganic anions have been devised and the products of crystallization examined by electron microscopy, X-ray and electron diffraction. Bayerite forms in neutral or alkaline solutions whereas gibbsite crystallizes in the presence of dilute carboxylic acids.

7. Plumbogummite-group minerals from Mull and Morven. By D. C. Bain. (*Mineralog. Mag.*, **37**, 934-938, 1970.)

   The rare minerals of the plumbogummite group of phosphates, which have been reported in soils, have been detected in very small amounts in the $< 1{\cdot}4\ \mu m$ fraction of sandstones from Mull and Morven, most of which are from the

Greensand formation. By means of X-ray and spectrochemical techniques, individual minerals were found to have a complex composition consisting of different amounts of the various end-members of the group. Electronoptical observations indicate that they are disseminated throughout the rocks as particles with an estimated size of between 0·1 and 0·25 μm.

8. A study of weathering in soil derived from biotite-hornblende rock. Pt. II. The weathering of hornblende. By M. J. Wilson and V. C. Farmer. (*Clay Minerals*, **8,** 435-444, 1970.)

The weathering of biotite and hornblende in a sedentary soil developed on appinite at Rehiran Farm, Inverness-shire, was studied by a variety of methods. The hornblende contains discrete lamellar intergrowths of another amphibole which in the lower horizons is selectively weathered to interstratified swelling chlorite-saponite. This clay mineral becomes unstable in the upper part of the profile and could not be detected in the A horizon.

9. Evidence for loss of protons and octahedral iron from oxidized biotites and vermiculites. By V. C. Farmer, J. D. Russell, W. J. McHardy, A. C. D. Newman (Rothamsted Experimental Station), J. L. Ahlrichs (Purdue University, Lafayette, Indiana, U.S.A.) and J. Y. H. Rimsaite (Geological Survey of Canada). (*Mineralog. Mag.*, **38,** 121-137, 1971.)

Natural weathering in soils oxidizes iron in biotites to the ferric state. This process has been studied by infrared spectroscopy, electron microscopy and X-ray diffraction, and has been shown to be associated with conversion of hydroxyl groups to oxide ions, and subsequently with ejection of ferric ions from the biotite structure. These ferric ions either form interlayer hydroxides in the weathered biotites, or diffuse out of the biotite to form a separate oxide or hydroxide phase.

10. The degradation of nucleic acids and montmorillonite–nucleic acid complexes by soil micro-organisms. By M. P. Greaves and M. J. Wilson. (*Soil Biol. Biochem.*, **2,** 257-268, 1970.)

It has been shown that nucleic acids, which probably enter soils in greater amounts than any other organic phosphorus compounds, are readily attacked by soil micro-organisms, the ultimate degradation products including inorganic phosphate. Microbial attack was not prevented when the nucleic acids were adsorbed by montmorillonite. X-ray diffraction showed that a contraction of the basal spacing occurred when montmorillonite–nucleic acid complexes were attacked by microbial enzymes. The role of clay minerals in the degradation of nucleic acids in soil is discussed.

11. Lime and fertilizer requirements for the establishment and growth of grass on deep peat. By J. W. S. Reith and R. A. Robertson. (*J. Agric. Sci., Camb.*, **76,** 89-95, 1971.)

The lime and fertilizer dressings required to establish agricultural grasses and clovers on deep acid peat in central Scotland has been assessed by field experiments. Lime at rates to supply 1, 2 and 4 metric tons Ca per ha gave good yields, and even 0·25 ton Ca produced moderate growth. At 49 and 98 kg P per ha basic slag was inferior to superphosphate. Ground mineral phosphate was inferior to basic slag in the first and second years, but in the fourth, fifth and sixth seasons its residual effect was greater than that of slag and equal to superphosphate. Dressings of N and K had appreciable effects on establishment and initial growth, and produced considerable increases in yield in the second year. To establish a satisfactory sward on deep peat about 3 metric tons Ca, 35 kg N, 100 kg P and 140 kg K per ha should be applied.

12. Pollen diagrams from three buried peats in the Aberdeen area. By S. E. Durno. (*Trans. Proc. bot. Soc. Edinb.*, **41**, 43-50, 1970.)

Pollen analysis of three buried peats uncovered in the Aberdeen area has produced evidence about dating and chronological correlation. The time span covered by the three peats together stretches from the late-Weichselian (probably zone II) to the late Flandrian (zone VIII).

13. Flandrian history of the Wooler Water, Northumberland, provided by pollen analysis. By C. M. Clapperton (University of Aberdeen), S. E. Durno and R. H. Squires (University of Aberdeen). (*Scott. geogr. Mag.*, **87**, 14-20, 1971.)

A basin peat buried 3·5 m beneath the Wooler Water gravel plain was exposed as a waterfall on the river bed in 1963; the peat outcrop is now much reduced in extent and will ultimately disappear. Pollen analysis of the peat suggests that it belongs to the Atlantic period (ca. 6000-3000 B.C.). The peat appears to have grown in a kettle hole within a complex of glacial meltwater deposits. Erosion of these deposits by the Wooler Water allowed the river to inundate the kettle hole after Atlantic times and bury the basin peat with gravels.

14. Moisture characteristics of some peat–sand mixtures. By Robert Boggie. (*Scient. Hort.*, **22**, 87-91, 1970.)

The physical properties of five peat and sand mixtures suitable for use as horticultural " no-soil " growth media were studied and compared with a John Innes potting compost. Very considerable differences in moisture-holding capacities, moisture-release characteristics and porosities were revealed. Mixtures containing up to 50 per cent sand exhibit poor moisture retention, whereas pure peat and a mixture containing 25 per cent fine sand and 75 per cent peat have a high pore volume with attendant good air-moisture proportionment. The best is peat which, from a physical viewpoint, has much to commend it as a mono-ingredient substrate.

15. Assessment of climatic conditions in Scotland. 2. Based on exposure and accumulated frost. By E. L. Birse and L. Robertson. (Map and explanatory pamphlet issued by the Soil Survey of Scotland. Aberdeen: Macaulay Institute for Soil Research. 1970. £0.75.)

A map of the climatic conditions prevailing in Scotland, based on exposure and accumulated frost, has been constructed on the scale 1:625,000. When the map is used in conjunction with the tables of exposure and accumulated frost presented in the accompanying pamphlet a reasonably accurate categorization of the suitability of the climatic conditions to plant growth is attained.

16. Podzolization in a zonal and altitudinal context in Scotland. By J. C. C. Romans. (*Rep. Welsh Soils Discuss. Grp.*, **11**, 88-101, 1970.)

Podzolization is described as a temperature controlled weathering and leaching process in which colloidal humus with a high carbon/nitrogen ratio progressively attacks the surface mineral horizons of the soil and forms soluble compounds with the iron and aluminium oxides produced in the initial reaction. These soluble complex compounds are subsequently leached down the profile where they accumulate and form the B horizon of the podzol profile. The process shows optimal development in the north-east of Scotland from near sea level to about 2300 feet (700 metres) and the soils can be sub-divided altitudinally into podzol, peaty podzol and sub-alpine podzol zones, with an alpine zone above, morphologically and genetically related to the lower zones. The variations in process intensity and profile morphology within these altitudinal zones are described with reference to temperature, time and parent material. A brief description is given of the geographical distribution of soil zones in other parts of Scotland.

17. Copper and molybdenum in sub-cellular fractions of rat liver. By C. F. Mills (Rowett Research Institute) and R. L. Mitchell. (*Br. J. Nutr.*, **26**, 117-121, 1971.)

An investigation of the content of copper and molybdenum in various fractions of rat liver by spectrochemical methods has indicated that the mode of action of Mo on Cu-dependent processes may involve the formation of an unavailable Cu/Mo complex with an atomic ratio of 3:2, corresponding to the formula $2CuMoO_4 \cdot Cu(OH)_2$.

18. Analysis of EDTA extracts of soils for copper, zinc and manganese by atomic absorption spectrophotometry with a mechanically separated flame. By A. M. Ure and M. L. Berrow. (*Anal. Chim. Acta*, **52**, 247-257, 1970.)

The atomic absorption analysis of EDTA extracts of soils for copper, zinc and manganese using a mechanically separated air:acetylene flame shows an improvement in sensitivity and detection limit over a normal non-separated flame. This is studied in detail for copper. Interference effects are small or negligible. The method is compared with an optical emission spectrometric method using the porous-cup solution technique and high-voltage spark excitation. The results agree well for copper and manganese. A statistical comparison of the results for copper in 200 soil extracts shows little significant difference between the two methods. For zinc analysis, atomic absorption has a distinct advantage in sensitivity and accuracy.

19. Replacement of OH by OD in layer silicates, and identification of the vibrations of these groups in infrared spectra. By J. D. Russell, V. C. Farmer and B. Velde (Laboratoire de Petrographie, Paris, France). (*Mineralog. Mag.*, **37**, 869-879, 1970).

The hydroxyl groups of the expanding layer silicate family of clay minerals are shown to be rather unreactive in that they undergo exchange reactions with heavy water only at elevated temperatures. Complete exchange occurs at 350°-400°, giving deuterated forms of these minerals. Comparison of the infrared spectra of deuterated and normal forms of layer silicates permits identification of hydroxyl bending vibrations whose frequencies are shown to distinguish different clay minerals according to their composition.

20. I.R. spectroscopic evidence for interaction between hydronium ions and lattice OH groups in montmorillonite. By J. D. Russell and A. R. Fraser. (*Clays Clay Miner.*, **19**, 55-59, 1971.)

Hydroxyl groups of acidic montmorillonites undergo interaction with exchangeable hydronium ions at low levels of hydration. Infrared spectroscopy shows that in acidic clays treated with heavy water, this interaction results in H-D exchange of hydroxyl groups adjacent to some of the sites which give rise to the cation exchange capacity of the clay. The reactivity of lattice OH groups makes it difficult to distinguish them from interlayer hydroxide species.

21. The characterization of adsorption bonds in clays by infrared spectroscopy. By V. C. Farmer. (*Soil Sci.*, **112**, 62-68, 1971.)

Infrared spectroscopy has shown that, in montmorillonite, the exchangeable cation is the dominant influence in interlayer adsorption and that interactions between adsorbed molecules and the surface oxygens of the mineral is weak. The evidence for these conclusions is summarized in this review, and the justification for their extension to other soil minerals is considered.

22. Interlayer complexes in layer silicates: the structure of water in lamellar ionic solutions. By V. C. Farmer and J. D. Russell. (*Trans. Faraday Soc.*, **67**, 2737-2749, 1971.)

The expanding layer silicates present in clay, silt and sand fractions of soils can trap organic substances, including added pesticides: consequently, factors which determine the strength of adsorption are of some practical importance. Examination of the infrared spectrum of water in layer silicates, either alone or in association with organic molecules, indicates that the properties of the clay surfaces are determined largely by the distribution of negative charge over the silicate surface. This distribution, together with the nature of the exchangeable cation, determines the hydration and absorptive properties of expanding layer silicates.

23. The origin of the pentose fraction of soil polysaccharide. By M. V. Cheshire, C. M. Mundie and H. Shepherd. (*J. Soil Sci.*, **22,** 222-236, 1971.)

The origin of soil polysaccharide has been investigated by incubating soil with easily metabolized substrates such as glucose or xylose labelled with radioactive carbon. Transformations occur which could account for the hexoses and 6-deoxyhexose in soil polysaccharide but relatively little pentose is synthesized even after 1-2 years of incubation. Therefore it is suggested that if soil pentose originates by such microbial synthesis it is through a long process of selection in which the more heterogeneous polysaccharide molecules, some of which will contain pentose, prove to be more stable to enzymic hydrolysis and so predominate.

24. The separation of β-glucanases produced by *Cytophaga johnsonii* and their role in the lysis of yeast cell walls. By J. S. D. Bacon, A. H. Gordon, D. Jones, Irene F. Taylor and D. M. Webley. (*Biochem. J.*, **120,** 67-78, 1970.)

Cytophaga johnsonii is abundant in the root region of grasses. It has the ability to solubilize the cell walls of certain yeasts and filamentous fungi, when these contain a β-(1→3)-glucan as a major constituent. In order to examine this lytic action in more detail the organism was grown in media containing yeast cell walls, and the enzymes in the culture fluid fractionated by chromatography. Of several partly purified glucanases obtained, only one was capable of lysing yeast cell walls. It is hoped that further study of preparations of this enzyme will cast a further light on the structure of fungal glucans and the ability of various soil organisms to lyse cell walls which contain them as major constituents.

25. Effects of humic acid on protein synthesis and ion uptake in beet disks. By D. Vaughan and I. R. MacDonald. (*J. exp. Bot.*, **22,** 400-410, 1971.)

Ageing beet disks in humic acid solutions for up to four days stimulated the development of phosphate uptake, but inhibited chloride uptake. Amino-acid uptake was not affected by humic acids, nor was protein synthesis in general as measured in terms of amino-acid incorporation and phosphatase activity. The stimulation of invertase development, however, indicates a more specific effect of humic acid on protein synthesis, possibly linked to growth, with which invertase activity is often closely associated.

26. Apiose and mono-*O*-methyl sugars as minor constituents of leaves of deciduous trees and various other species. By J. S. D. Bacon and M. V. Cheshire. (*Biochem. J.*, **124,** 555-562, 1971.)

Earlier research at the Institute showed that the polysaccharides of soil contained small amounts of various uncommon sugars. At first these were thought to be microbial products, but subsequent studies have shown that some of these sugars are present in plants. In the present report several are identified and their abundance measured in various plant materials, particularly leaves. These results strengthen the view that the soil polysaccharide fraction contains a substantial proportion of partly degraded substances from plant cell walls.

27. The fine structure of leaf cells of copper-deficient oats. By P. C. DeKock, Marjorie Rutherford and M. V. Cheshire. (*Ann. Bot.*, **35,** 193-199, 1971.)

Copper-deficient oat plants show abnormal growth and this has been studied with the electron microscope. Copper-deficient and normal oat leaves showed only minor structural differences; there were reduced numbers of compartments in the chloroplast stacks, with no differences in stromacentres, plastoglobuli, mitochondria, nuclei or cell walls. The cells of the white withered tip characteristic of copper-deficient oat leaves were found to be full of fibrous masses.

28. A comparison of the effect of phosphorous and nitrogen on copper deficient and sufficient oats. By P. C. DeKock, M. V. Cheshire and A. Hall. (*J. Sci. Fd. Agric.*, **22**, 437-440, 1971.)

The effect of phosphate applied to oats growing in a peat medium of low copper content in increasing the severity of copper deficiency is ascribed to the more effective utilization of nitrogen in the synthesis of protein with which the copper is associated within the plant.

29. Some aspects of the chemistry of the Glentanar podzol profile. By H. A. Anderson. (*Rep. Welsh Soils Discuss. Grp.*, **11**, 124-133, 1970.)

The study of the Glentanar podzol profile forms part of a general study of various soil types in an effort to apply modern analytical techniques to clarify the organic chemistry of fractions isolated by traditional means. Milder methods of extraction are being developed in order that degradation of organic matter may be minimized. The process of podzolization may be due to the presence of certain types of polysaccharides.

30. Calcium in plant nutrition. By P. C. DeKock and Y. Ohta. (*What's New in Plant Physiology*, **3**,(6), 1-4, 1971.) *No reprints.*

A review of calcium metabolism stressing its importance in relation to organic acids and reporting the most recent findings.

31. Absorption of iron from chapatti made from wheat flour. By P. C. Elwood, I. T. Benjamin, D. Newton, F. A. Fry, J. D. Eakins, D. A. Brown (M.R.C. Epidemiology Unit, Cardiff), P. C. DeKock and J. U. Shah (M.R.C. Epidemiological Unit, Cardiff). (*Am. J. clin. Nutr.*, **23**, 1267-1271, 1970.) *No reprints.*

Wheat grown in nutrient culture with radio-iron was used in a study of iron availability in normal flour and flour enriched with an iron salt. It was found that the availabilities in both were low, but the wheat iron appeared to have been better absorbed than the iron salt.

32. Crop composition in relation to soil pH and root cation exchange capacity. By W. M. Crooke and A. H. Knight. (*J. Sci. Fd Agric.*, **22**, 235-241, 1971.)

The effect of liming on the mineral composition of five farm crops has been studied. In cereal leaves, total cation (the sum of calcium, magnesium, potassium and sodium contents), nitrogen and phosphorus contents increased, but only small and inconsistent changes were found in swede and potato leaves. In general the manganese content fell on liming, whereas little change was found in either iron or copper levels. An attempt was made to interpret these changes in composition in the light of differences in the cation-exchange properties of the roots of the various crops.

33. Root cation-exchange capacity and organic acid content of tops as indices of varietal yield. By W. M. Crooke and A. H. Knight. (*J. Sci. Fd Agric.*, **22**, 389-392, 1971.)

The average yields of leek varieties at maturity in field trials have been found to be positively related to differences in their root cation-exchange capacity and their organic acid content, both measured at an early stage of growth. Similar trends were found with artichoke and celery and the results suggest that the root cation-exchange capacity of young plants, and to a lesser extent the organic acid content of their tops, may be useful indices of varietal yield potential.

34. The invasion of pea roots (*Pisum sativum* L.) by soil micro-organisms *Acanthamoeba palestinensis* (Reich) and *Pseudomonas* sp. By J. F. Darbyshire and M. P. Greaves. (*Soil Biol. Biochem.*, **3**, 151-155, 1971.)

The microbiological equilibrium in the rhizosphere is due to microbial and plant activity, with environmental factors influencing both. Using axenic techniques developed in this Institute, the relationships between *Pseudomonas* sp and *Acanthamoeba palestinensis* on pea root have been studied. In monoxenic culture the normal saprophytic bacterium invaded the epidermal and outer cortical cells of the root. The presence of the amoebae did not prevent this invasion, although many bacteria embedded in the mucigel covering the root surface were eaten. The amoebae were also found inside the epidermal and cortical cells, which has been invaded by the *Pseudomonas* sp.

35. Biological transformation of microbial residues in soil. By D. M. Webley and D. Jones. (pp. 446-485 of *Soil Biochemistry*, Vol. II. Edited by A. D. Maclaren and J. J. Skujins. New York: Dekker.) *No reprints.*

Micro-organisms are the main agents for the decomposition of dead plant and animal matter in soils. When these organisms become non-viable they and their components decompose. This chapter reviews the literature of the sources, origin and nature, and biological transformation of microbial residues. The evidence presented suggests that biological transformations may contribute to the soil polysaccharide, organic nitrogen, nucleic acid and humic fractions of soil. It is concluded that when considering the decomposition of organic matter added to soil it is necessary to elucidate the transformation of the successions of micro-populations which colonize this material.

36. Residual effects of phosphate and the relative effectiveness of annual and rotational dressings. By E. G. Williams and J. W. S. Reith. (*Tech. Bull. Minist. Agric. Fish. Fd*, **20**, 16-33, 1971.)

The efficiencies of phosphate residues and dressings applied at different times have been evaluated from yields of roots and oats in 27 field experiments in north-east Scotland. The positional availability and effectiveness of spring dressings can be markedly enhanced by correct timing, to benefit from the concentrating action of ridging and avoid dispersing effects of cultivations. With increasing period of contact with the soil, however, there is an exponential decrease in efficiency, which for roots fell to about 33 per cent after five months, 25 per cent after one year, and 3 per cent after seven years. The superiority of annual applications compared with single rotational dressings depends on the responsiveness of the soils and crops. The best ways to build up the soil phosphate status, however, is by applying correctly time dressings to individual crops according to the particular needs.

37. A phosphate sorption index for soils. By B. W. Bache and E. G. Williams. (*J. Soil Sci.*, **22**, 289-301, 1971.)

The most useful index for the general characterization of phosphate relationships of soils is some measure of their phosphate sorption properties. Detailed phosphate sorption curves are tedious to determine and cumbersome to present. The addition of a single relatively large amount of phosphate (150 mg P/100 g soil) swamps the incidental effects of the initial phosphate contents of the soils; the quotient (phosphate sorbed)/(log. phosphate concentration in solution) calculated from the resulting sorption reaction, correlates very highly with the slope of the sorption curves. This index is therefore considered a simple yet adequate measure of phosphate sorption by soils.

38. Determination of ammonium in Kjeldahl digests of crops by an automated procedure. By W. M. Crooke and W. E. Simpson. (*J. Sci. Fd Agric.*, **22**, 9-10, 1971.)

    An automated colorimetric technique for the nitrogen analysis of crops has been developed. This offers a considerable saving in time, while giving results in agreement with the conventional manual method.

(B) *Awaiting Publication at 30th September, 1971*

39. The classification of soil silicates and oxides. By R. C. Mackenzie. (To appear in *Inorganic Soil Components.* Edited by J. E. Gieseking. Berlin: Springer.)

40. Heavy minerals. By the late W. A. Mitchell. (To appear in *Inorganic Soil Components.* Edited by J. E. Gieseking. Berlin: Springer.)

41. Oxides and hydrous oxides of silica. By B. D. Mitchell. (To appear in *Inorganic Soil Components.* Edited by J. E. Gieseking. Berlin: Springer.)

42. The thermal characteristics of soil minerals and the use of these characteristics in the qualitative and quantitative determination of clay minerals in soils. By R. C. Mackenzie and S. Caillère (Paris, France). (To appear in *Inorganic Soil Components.* Edited by J. E. Gieseking. Berlin: Springer.)

43. Instrumentation for thermogravimetry and differential thermal analysis. By R. C. Mackenzie. (To appear in a monograph on *Thermal Analysis* to be issued by the Society for Analytical Chemistry.)

44. Soils. By R. C. Mackenzie and B. D. Mitchell. (To appear in *Differential Thermal Analysis.* Vol. 2. Edited by R. C. Mackenzie. London: Academic Press.)

45. Peak areas and heats of transition of DTA temperature standards. By R. C. Mackenzie and P. F. S. Ritchie. (To appear in *Thermal Analysis, 1971.* Edited by H. G. Wiedemann. Basel: Birkhäuser Verlag.)

46. Clay mineral studies on some Carboniferous sediments in Scotland. By M. J. Wilson, D. C. Bain, W. J. McHardy and M. L. Berrow. (Submitted to *Sedimentology.*)

47. Clay mineral formation in a deeply weathered boulder conglomerate in north-east Scotland. By M. J. Wilson, D. C. Bain and W. J. McHardy. (*Clays Clay Miner.*, **19**, 345-352, 1971.)

48. The clay mineralogy of the Old Red Sandstones of Scotland. By M. J. Wilson. (Submitted to *J. sediment. Petrol.*)

49. Effects of soil micro-organisms on montmorillonite adenine complexes. By M. P. Greaves and M. J. Wilson. (Submitted to *Soil Biol. Biochem.*)

50. Characterization of soils by pyrolysis combined with mass spectrometry. By J. M. Bracewell. (*Geoderma*, **6**, 163-168, 1971.)

51. A comparison of the ultrastructure and chemical components of cell walls of certain pathogenic fungi. By D. Jones, V. C. Farmer, J. S. D. Bacon and M. J. Wilson. (Submitted to *Trans. Br. mycol. Soc.*)

52. Nature and extent of Scottish peat resources. By R. A. Robertson. (*Suom. maatal. Seur. Julk.*, **123**, 233-241, 1971.)

53. Effect of water-table height on growth of *Pinus contorta* on deep peat. By R. Boggie and H. G. Miller. (Submitted to *Proc. NERC Symp. Peatland Forestry, Edinburgh, 1968.*)

54. Evaluation of peatland sites according to their physical and chemical characteristics. By H. G. Miller, R. A. Robertson and B. L. Williams. (Submitted to *Proc. NERC Symp. Peatland Forestry, Edinburgh, 1968.*)

55. Kilphedir—hut circle excavation site: the soils of the site. By J. C. C. Romans and S. E. Durno. (To appear as appendix to paper by Fairhurst and Taylor in *Proc. Soc. Antiq. Scotl.*)

56. Physical and chemical factors influencing the cation-exchange capacity of peat under field conditions. By B. L. Williams. (Submitted to *Proc. NERC Symp. Peatland Forestry, Edinburgh, 1968.*)

57. Assessment of climatic conditions in Scotland. 3. The bioclimatic sub-regions. By E. L. Birse. (Map and explanatory pamphlet to be issued by the Soil Survey of Scotland.)

58. The soils of Carrick and the county round Girvan. (Sheet 8 and part Sheet 7.) By C. J. Bown. (To appear as *Mem. Soil Surv. Gt. Br.*)

59. The soils of Caithness. By D. W. Futty. (To appear in *The Caithness Handbook.*)

60. Gley soils in the Midland Valley of Scotland. By D. Laing. (Submitted to *Trans. Jt. Meet. Comm. V & VI int. Soc. Soil Sci., Stuttgart, 1971.*)

61. Factors in soil formation. By J. M. Ragg. (To appear in *Biogeography of Scotland.* Edited by J. Tivy.)

62. The photography of soils and associated landscapes. By J. M. Ragg. (To appear in *Soil Survey Handbook.*)

63. Soil temperature. By J. M. Ragg. (To appear in *Soil Survey Handbook.*)

64. Soil bulk density measurement in the field by gamma-ray transmission methods. By J. M. Ragg. (To appear in *Soil Survey Handbook.*)

65. The leaf tip of *Ranunculus reptans* L. By P. C. DeKock, Marjorie F. Rutherford and Evelyn M. Birse. (*Ann. Bot.*, **35,** 1191-1195, 1971.)

66. Trace elements in soils. By R. L. Mitchell. (*Tech. Bull. Minist. Agric. Fish. Fd*, **21,** 8-20, 1971.)

67. Trace elements in soils and factors that affect their availability. By R. L. Mitchell. (To appear in vol. of *Symposium on Minor Metals of the Geochemical Environment, Health and Disease, Chicago, 1970.*)

68. Trace elements in sewage sludges. By M. L. Berrow and J. Webber (Agricultural Development and Advisory Service, Leeds.) (Submitted to *J. Sci. Fd Agric.*)

69. Effects of structural order and disorder on the infrared spectra of brittle micas. By V. C. Farmer and B. Velde (Laboratoire de Petrographie, Paris, France). (Submitted to *Miner. Mag.*)

70. The characterization of soil minerals by infrared spectroscopy. By V. C. Farmer and E. Palmieri. (To appear in *Inorganic Soil Components.* Edited by J. E. Gieseking. Berlin: Springer.)

71. Interaction of ammonia with vermiculite. By J. L. Ahlrichs (Purdue University, Indiana, U.S.A.), A. R. Fraser and J. D. Russell. (Submitted to *Clay Miner.*)

72. Fundamental aspects of iron nutrition of plants. By P. C. DeKock. (*Tech. Bull. Minist. Agric. Fish. Fd*, **21,** 41-44, 1971.)

73. Anion absorption by etiolated wheat leaves following vacuum infiltration. By I. R. MacDonald and A. E. S. Macklon. (Submitted to *Pl. Physiol.*)

74. The chemical composition of pollen, with particular reference to cation-exchange capacity and uronic acid content. By A. H. Knight, W. M. Crooke and H. Shepherd. (Submitted to *J. Sci. Fd Agric.*)

75. Cation-exchange capacity and chemical composition of the floral parts of *Antirrhinum* and *Lilium*. By A. H. Knight and W. M. Crooke. (Submitted to *Pl. Soil.*)

76. Nitrogen fixation by *Azotobacter chroococcum* in the presence of *Colpoda steinii*. 1. The influence of temperature. By J. F. Darbyshire. (Submitted to *Soil Biol. Biochem.*)

77. Nitrogen fixation by *Azotobacter chroococcum* in the presence of *Colpoda steinii*. 2. The influence of agitation. By J. F. Darbyshire. (Submitted to *Soil Biol. Biochem.*)

78. *Aecidium* spp. on *Agathis*. By E. Punithalingham (Commonwealth Mycological Institute) and D. Jones. (*Trans. Br. mycol. Soc.*, **57**, 325-331, 1971.)

79. Frozen-etched spores of *Trichoderma viride*. By D. Jones. (*Trans. Br. mycol. Soc.*, **57**, 348-351, 1971.)

80. Other organic phosphorus compounds. By G. Anderson. (To appear in *Organic Soil Components*. Edited by J. E. Gieseking. Berlin: Springer.)

81. Sulphur in soil organic substances. By G. Anderson. (To appear in *Organic Soil Components*. Edited by J. E. Gieseking. Berlin: Springer.)

(C) *Papers by Members of Staff on Leave of Absence. (No reprints.)*

82. Soil survey of part of the Taieri Uplands, Otago, New Zealand. By J. M. Ragg and R. B. Miller. (New Zealand Soil Bureau.) (To appear as *Rep. N.Z. Soil Bur.*)

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 or periodical reports summarizing the research work that is in progress. Full details can be obtained from the secretaries of the institutes concerned.

A.R.C. 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.
Food Research Institute	Colney Lane, Norwich, NOR 7OF.
Meat Research Institute	Langford, Bristol, BS18 7DY.
Poultry Research Centre	King's Buildings, West Mains Road, Edinburgh, EH9 3JS.
Letcombe Laboratory	Letcombe Regis, Wantage, Berks.
Weed Research Organization	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 Dairy Research Institute	Ayr, Scotland.
Hill Farming Research Organisation	29 Lauder Road, Edinburgh, EH9 2JQ.
Macaulay Institute for Soil Research	Craigiebuckler, Aberdeen, AB9 2QJ.
National Institute of Agricultural Engineering (Scottish Station)	Bush Estate, Penicuik, Midlothian.
Rowett Research Institute	Bucksburn, Aberdeen, AB2 9SB.
Scottish Horticultural Research Institute	Invergowrie, Dundee, DD2 5DA.
Scottish Plant Breeding Station	Pentlandfield, Roslin, Midlothian.

State-aided Institutes (England and Wales)

Animal Virus Research Institute	Pirbright, Woking, Surrey.
East Malling Research Station	East Malling, Maidstone, Kent.
Glasshouse Crops Research Institute	Worthing Road, Rustington, Little-hampton, Sussex.
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.
National Institute for Research in Dairying	Shinfield, Reading, Berks, RG2 9AT.
National Vegetable Research Station	Wellesbourne, Warwick.
Plant Breeding Institute	Maris Lane, Trumpington, Cambridge, CB2 2LQ.
Rothamsted Experimental Station	Harpenden, Herts.
Welsh Plant Breeding Station	Plas Gogerddan, Aberystwyth, Cardiganshire, SY23 3EB.
Wye College, Department of Hop Research	Ashford, Kent.