THE MACAULAY INSTITUTE FOR SOIL RESEARCH

FOUNDED 1930

1967-1968 ANNUAL REPORT

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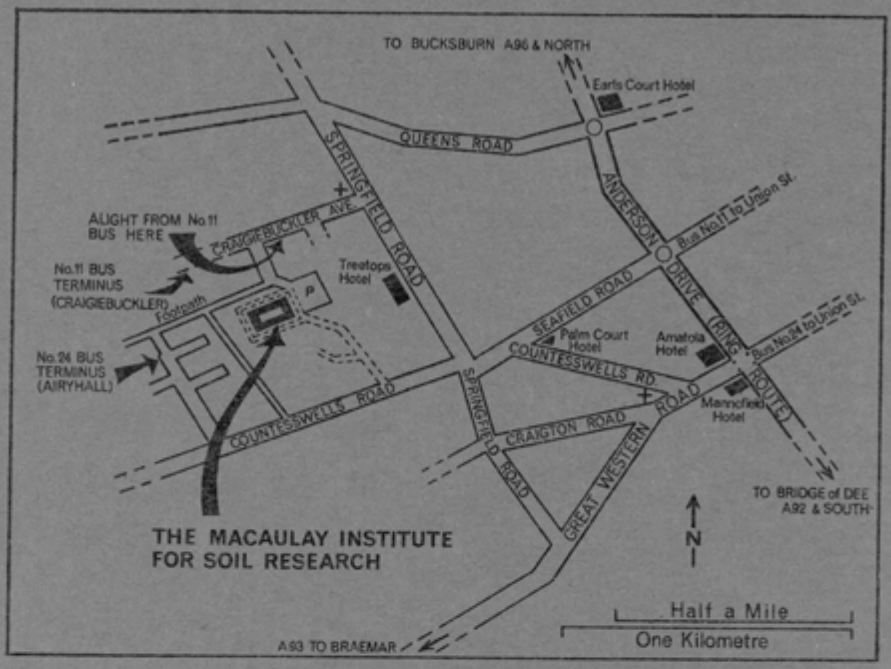

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN AB9 2QJ

(Founded 1930)

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1967-1968

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1967-1968

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R. L. MITCHELL, B.Sc., Ph.D., F.R.I.C., F.R.S.E.—appointed 1/7/68.

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E. G. WILLIAMS, B.Sc., Ph.D.—appointed 1/7/68.

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J. S. ANDERSON.
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MISS J. COWAN—appointed 1/9/68.
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MISS K. A. HADDEN—resigned 12/7/68.
MISS A. LAMB.
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B. SHIRRIFFS.
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W. S. SHIRREFFS.
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MRS J. J. WATT.
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MRS E. R. DONALD.
MRS M. I. DONALD—resigned 31/12/67.
MRS M. DONALD—appointed 1/3/68.
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H. A. ANDERSON, B.Sc., Ph.D.—appointed 1/10/68.
D. J. LINEHAN, B.Sc., Ph.D.—appointed 1/10/68.
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H. SHEPHERD, L.R.I.C.

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MRS J. V. DUNBAR—appointed 2/9/68.

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W. M. Crooke, B.Sc., Ph.D.
G. Anderson, B.Sc., Ph.D.
B. W. Bache, M.A., Ph.D., F.R.I.C.
N. M. Scott, Ph.D., A.R.I.C.
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R. E. Malcolm.
K. S. Caldwell, S.D.A., S.D.D.H.
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G. S. Sharp.
D. M. W. Hutcheson—resigned 30/9/68.
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Miss S. M. Law.
J. Munro.
Miss B. J. Bell.
Miss E. M. Buchan—appointed 1/6/68.
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Miss E. S. Minty—appointed 1/2/68.
Miss P. L. Owens—12/8/68-23/8/68.
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Mrs E. C. Stewart.
Mrs E. B. Still.
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J. S. Wilson.
R. Strachan.
A. G. Gall.
S. A. Duncan.

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Miss J. M. Cooper, B.Sc., Dip. Stat.—appointed 1/8/68.
Miss F. M. Strachan, B.Sc.—appointed 1/8/68.
Miss M. K. Farquharson—resigned 10/10/67.
Mrs K. M. Lobban—resigned 19/4/68.
Mrs C. McIntosh—appointed 22/4/68.
Mrs M. A. Sutherland—appointed 1/11/67.
Miss S. I. D. Walker.

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Mrs R. Noble.

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	M. G. Riddell—appointed 1/12/67.
	R. Riddell.

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	A. W. Gordon—appointed 29/1/68.
	G. A. Reid.
	J. Shaw.
	H. Shaw.
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VISITING RESEARCH WORKERS

B. G. Ellis (Soil Science Department, Michigan State University, East Lansing, Michigan, U.S.A.).

A. S. de Endredy (F.A.O., Rome, Italy).

S. S. Jørgensen (Agrikulturkemisk Laboratorium, Den Kgl. Veterinaer og Landbohøjskole Copenhagen, Denmark).

Mrs Celia Maqueda Porras (Estacion Experimental del Zaidin, Granada, Spain).

J. L. Perez Rodriguez (Centro de Edafologia y Biologia Vegetal, Seville, Spain).

J. A. Horta da Silva (Laboratorio de Engenharia de Angola, Luanda, Angola).

CONTENTS

INTRODUCTION

Dr A. B. Stewart, C.B.E. retired from the Directorship on 30th June 1968, and has been succeeded by Dr R. L. Mitchell, who was Deputy Director from 1958 and Head of the Department of Spectrochemistry from 1937.

The Council have minuted in the following terms their appreciation of the great debt that the Institute owes to the retiring Director: 'When Dr Stewart took over in 1958 developments at Craigiebuckler were at a critical stage. Greatly extended facilities were becoming available in the new building and it was necessary to see that these were fully and appropriately utilized. In achieving this, his natural administrative abilities, his sound judgement, his friendly approach and his fair and generous attitude to his staff were all demonstrated to the full. As a result of his upbringing on an Aberdeenshire farm he started with a sound appreciation not only of the practical realities of land management and crop production but also of the implications of farming practice in relation to the maintenance and improvement of soil fertility.

'In his work as director he displayed a wide knowledge of the varied scientific and technical aspects of soil research and soil-plant relationships. In this he greatly profited from his earlier responsibilities as Head of the Department of Soil Fertility and Deputy Director of the Institute as he did also from his more academic work first at Zurich under Professor Wiegner and later as Strathcona-Fordyce Professor of Agriculture at Aberdeen University from 1954 to 1958. This quite exceptional background of science and practice made him outstandingly well fitted to assess the significance of specialized studies and ensure a fair balance of the varied research activities of the Institute. It enabled him also to plan the proper methods of introduction of the results of the highly specialized research studies into the practical requirements of agriculture through the relevant advisory services. In furthering all these aspects Dr Stewart maintained and developed liaison with the Scottish Agricultural Colleges, the Agricultural Research Institutes and the University of Aberdeen, as well as representing the Institute on scientific, technical and administrative bodies. He was able to present the Institute case effectively and persuasively in his requests to the Department of Agriculture and Fisheries for Scotland and the Agricultural Research Council and was eminently successful in obtaining their support for new projects. The facilities that, as a result, have become available have increased the scientific standing of the Institute at home and overseas during his tenure of the Directorship. It is thus with great pleasure that the Council record their sincere appreciation for all that he did for the Institute and express the hope that he and Mrs Stewart will enjoy a long and happy retirement.'

The Institute received an official visit on 21st August 1968 from Mr Norman Buchan, M.P., Joint Under-Secretary of State for Scotland, who was accompanied by Mr D. C. Dewar, M.P. for Aberdeen (South). In the course of his visit Mr Buchan toured the Institute and discussed the work in progress with numerous members of staff.

It is with deep regret that the death of Dr R. I. Morrison is recorded. Dr Morrison, who joined the Institute staff in 1948 to work with the late Dr G. K. Fraser, made substantial contributions to our knowledge of soil organic matter, as recognized below in the report of the Department of Biochemistry.

During the year various members of staff have been invited to participate in foreign or international proceedings. Dr E. G. Williams accepted an invitation from the Dutch authorities to go to the Netherlands for ten days in October 1967, to discuss arrangements for the meeting to celebrate the fortieth anniversary of the Laboratory for Soil and Crop Testing at Oosterbeek in February 1968, at which he subsequently delivered one of the main lectures. Dr R. Glentworth undertook a lecture tour in the Netherlands in November 1967, visiting Amsterdam, Delft and Wageningen, under British Council auspices. Dr V. C. Farmer was invited to join the Guiding Committee of an O.E.C.D. Project on the Study of Non-Metallic Minerals and attended the first meeting in Paris in January 1968. Dr Farmer was also invited to present one of the Invited Papers to Commission VII of the Ninth International Congress of Soil Science in Adelaide. The Council are greatly indebted to the Agricultural Research Council for meeting half of Dr Farmer's expenses and also enabling Dr J. W. S. Reith to attend this Congress and visit various research stations en route. Mr R. A. Robertson, at the first meeting in Moscow in March 1968 of the Council of the International Peat Society, was honoured by being elected Vice-President of the organization, the first Congress of which he attended in Quebec in August 1968. Mr Robertson had previously received the Gold Insignia of the Technical Institute of the Polish Peoples Republic for his contribution to international collaboration in peat research and development. Dr R. C. Mackenzie was awarded the first Mettler Award in Thermal Analysis at the Second International Conference on Thermal Analysis at Worcester, Mass., in August 1968, for his outstanding pioneering work at the Institute on this subject. The Council are grateful to the Department of Agriculture and Fisheries for Scotland and the Agricultural Research Council for making it possible for the members of staff to participate in these proceedings and, where necessary, making a contribution towards the expenses incurred.

The international connections of the Institute have also been strengthened in another direction: we have had the pleasure of welcoming short-term visitors from some 26 countries during the year. In addition, facilities were provided for five longer-term workers from Angola, Denmark, Spain and United States of America, and also for Dr A. S. de Endredy, in intervals between his FAO assignments. Dr Endredy's wide knowledge and experience have enabled him to make valuable contributions to the work in Pedology.

Dr A. E. S. Macklon returned to the Department of Plant Physiology in November 1967, after leave of absence for one year to work as a Research Associate in the Department of Botany of the State University, Washington, U.S.A.

The Council are pleased to record the promotion to S.P.S.O., on the recommendation of the Panel on Special Merit Promotions, of Dr V. C. Farmer of the Department of Spectrochemistry, where he has made valuable contributions on the application of infrared and ultraviolet absorption methods. They are also pleased to announce that as from 1st November 1968 Dr R. O. Scott will take over the position of Head of Spectrochemistry. Dr Scott came to the Institute in 1939 on a research grant and joined the staff in 1942, specializing in the development of emission spectrochemical techniques.

Members of staff have again served on various technical committees appointed by such official bodies as the Department of Agriculture and Fisheries for Scotland, the Ministry of Agriculture, Fisheries and Food, the Agricultural Research Council and the Forestry Commission, as well as on other scientific panels and groups.

PEDOLOGY

The department continues to emphasize studies leading to a better understanding of the soil system and its components, with particular reference to the manner in which the properties of these contribute to the properties of the soil as a whole.

In general, progress has continued along the lines detailed in previous reports with accompanying gradual development of techniques. During this year, however, the ability of the department to carry out detailed studies has been considerably strengthened, and throughput improved, by the acquisition of several new pieces of equipment. Thus, the X-ray diffractometer installed a year ago has enabled some 2000 samples to be examined mineralogically, about 1500 being examined on the diffractometer itself. The powder camera technique, however, still finds extensive use, the two methods being to some extent complementary. The X-ray fluorescence attachment to the diffractometer is at present being standardized and calibrated: when in full operation it should enable many samples to be rapidly analyzed for various elements. A commercial differential thermal analysis apparatus specifically designed for organic materials is currently being coupled to a mass spectrometer to enable more detailed thermal studies to be undertaken on organic materials and clay-organic complexes. A spectrophotometer, loaned by the Forestry Commission for work on forest soils, has been invaluable in permitting greater accuracy to be obtained in the analysis of wood samples for phosphorus, and a caravan laboratory, also on loan from the Forestry Commission, has proved its worth during the year, not only in whole-tree sampling, but also in weighing fresh peat samples in the field. This laboratory is equipped with balances capable of weighing from 1 mg to 120 kg.

Close collaboration has continued with the Forestry Commission. In addition, contact has been established and maintained with the Highlands and Islands Development Board in connection with peat survey, with the Natural Environment Research Council on the conservation of northern peatlands and with the British Standards Institution on the standardization of peat and peat products. Collaborative studies have been carried out with other departments of the Institute and various samples have been examined for the Forestry Commission, F.A.O., the Universities of Aberdeen, Cairo, Cambridge, Edinburgh, Glasgow, London and Rome, the Weed Research Organization and the Directorate of Overseas Surveys.

The staff of the department have been pleased to welcome a number of post-graduate workers during the year. Mr J. A. Horta da Silva, Laboratorio de Engenharia de Angola, Luanda, Angola, has completed his study of the relationship of mineralogy to swelling and shrinking in tropical soils. Mr S. S. Jørgensen, Department of Soils and Agricultural Chemistry, Royal Veterinary and Agricultural College, Copenhagen, Denmark, has investigated the chemical dissolution of silica and alumina and Mr J. L. Perez Rodriquez, Centro de Edafologia y Biologia Vegetal, Seville, Spain, has examined the effects of separation and pretreatment on the minerals in certain soil clays.

Dr A. S. de Endredy, F.A.O., Rome, has also assisted in the work of the department.

Members of staff have attended, *inter alia*, meetings of the North of England Soil Discussion Group, the Agriculture Group of the Society for Chemical Industry, the Faraday Society, the Mineralogical Society, the Clay Minerals Group of the Mineralogical Society and the Thermal Analysis Group of the Society for Analytical Chemistry as well as a Symposium on Peatland Forestry organized by the Natural Environment Research Council. At these meetings several papers were read.

Mr R. A. Robertson attended the first meeting of the Council of the International Peat Society in Moscow and had the distinction of being elected Vice-President of this recently-formed body. Later in the year he participated in the Third International Congress in Quebec, Canada. As Chairman of the British Standards Institution Panel M/79/2/5 on propagation pots fabricated of peat, Mr Robertson acted as spokesman for the British delegation at a meeting of the International Standards Organization in Paris. Dr R. C. Mackenzie attended the Second International Conference on Thermal Analysis at Worcester, Mass., U.S.A., and was elected Treasurer of the International Confederation for Thermal Analysis; he also visited the Ontario Research Foundation at Toronto and Rutgers University.

Our congratulations go to Mr R. A. Robertson on his being awarded the Gold Insignia of the Technical Institute of the Polish People's Republic for his work in promoting international co-operation in the fields of peat research and development.

Surface Properties of Soils and Soil Clays

Three methods for determining the cation-exchange capacity of vertisols, particularly calcareous types, are currently being assessed, using soils from Kenya, Sudan and Tanzania. Significant correlations have been established between total and specific ion concentration and specific surface area (both total and external).

Study of the cation-exchange capacities of a series of tropical soils from Ghana has shown that the clay mineralogy of these soils can be predicted, with a reasonable degree of success, from the exchange capacity and the organic matter and clay contents. An expanding-lattice mineral in these soils is often inhomogeneous, giving on the diffractometer trace only a step around 14Å which moves to about 18Å on glycerol treatment.

Instrumentation for measurement of specific surface area has been improved by the introduction of a new design of nitrogen-adsorption apparatus enabling determinations to be made in a semi-routine manner, and of a krypton-adsorption apparatus permitting areas of less than 1 m^2/g to be measured. These have contributed considerably to the studies on silica polymorphs (quartz, cristobalite, tridymite and cryptocrystalline silica) and aluminium hydroxides (gibbsite, boehmite and diaspore).

It has been reported previously that hydroxyl groups in inorganic colloidal materials can be replaced by fluoride ions. The kinetics of this process

are not simple, but it has been established that the rate at which hydroxyl ions are released depends largely on the degree of crystallinity of the material and only secondarily on the particle size—that is, on the area of surface exposed to the solution. The ready reaction of gel-like materials has established this as a useful rapid test for inorganic gels in soils[1] and a standard procedure has been developed. With both synthetic and natural silica-alumina gels it has been found that the rate of reaction depends on the composition of the gel, and hence on the nature of the exposed surface.

Soil Mineralogy

Pure minerals examined during the year include samples of biotite, dickite and manganese minerals. In collaboration with Spectrochemistry, a sample of lithiophorite, a common soil manganese mineral, has been characterized by chemical, X-ray, thermal and electronoptical techniques. Electron diffraction studies show that the *b* parameter of the unit cell is three times the value currently accepted: this leads to an alternative siting for the Li^+ in the structure. A review of the properties and mode of occurrence in soils of various forms of silica has been submitted for publication[33]. The history and development of differential thermal analysis[34] has been reviewed and chapters on instrumentation[35], technique[36] and the differential thermal characteristics of oxides and hydroxides of elements of higher valancy than two[37] prepared for a forthcoming volume. Reviews of the techniques used in soil-clay mineralogy[38] and of the thermal characteristics of soil minerals[39] have been compiled for other publications.

The study of the mineralogy of soils and their parent rocks from Angola is now almost complete. In addition to the minerals referred to last year, minerals of the jarosite-alunite group have been detected by X-ray and electron microscope techniques in Miocene sand from the Luanda area and palygorskite has been detected along with montmorillonite in Tertiary calcareous rocks and marls.

A study of iron oxide minerals in soils by chemical, X-ray, thermal and electronoptical techniques has indicated that almost all soil goethites have some Al-for-Fe substitution and that all three unit-cell parameters are thereby affected. There are also indications that in highly ferruginous tropical soils goethite is being converted to hematite with release of aluminium.

Intensification of studies involving chemical analysis of minerals, soils and soil clays has led to the introduction of new equipment and techniques for the rapid size fractionation of soil clays and for improving the accuracy and speed of chemical analysis.

Mineralogy of Scottish Sedimentary and Metamorphic Rocks. The study of the clay mineralogy of the Scottish Dalradian Limestones has been extended to samples from other localities. The clay minerals found include saponite, regularly interstratified saponite-chlorite, kaolinite, illite and chlorite. There appears to be a relationship between metamorphic grade and clay mineralogy. A paper on this subject was read at a meeting of the Clay Minerals Group of the Mineralogical Society and another on the occurrence of saponite in meta-limestones has been published[2].

The clay mineralogy of various Old Red Sandstone and Carboniferous sediments is now being investigated.

Rock Weathering Studies. Two sedentary soil profiles on deeply weathered rock in Inverness-shire show somewhat different trends. In one, on appinite consisting largely of hornblende and biotite, the hornblende alters directly to an interstratified chlorite-smectite (which is unstable and disappears towards the top of the profile) whereas the biotite alters through hydrobiotite to an interstratified chlorite-vermiculite and then to vermiculite. In the other, on granitic gneiss containing quartz, felspar, biotite and muscovite, the biotite appears to be stable: thin sections show that both micas contain intercalated kaolinite formed apparently by decomposition of the felspar. Supporting infrared data were supplied by Spectrochemistry.

A deeply weathered Old Red Sandstone conglomerate, near Clunas, Inverness-shire, contained a variety of rock types. Study of the weathered material showed that plagioclase felspar has altered to montmorillonite, whereas microcline remains stable. In a soil on ultrabasic rock from Rhum, anorthitic plagioclase has changed directly to gibbsite. In Alpine podzols of the Ben Lawers massif chlorite is unstable in the A horizon and weathers to kaolinite and crystalline iron oxides which accumulate in the B horizon[43].

Fine Sand Fraction. The heavy and light fractions of fine sand separates from soils sampled by Soil Survey in the Perth-Arbroath (Sheets 48/49) and Stirling (Sheet 39) areas have been examined optically. In the Perth-Arbroath area, the parent rocks are Highland schists and Old Red Sandstone andesites. The distribution in the soils of the garnet and hornblende from the former and the augite, hypersthene and iron oxides from the latter indicates both the parent rock and the direction of transport of the glacial till.

Clay Fraction. Systematic examination of soil clays from the Perth-Arbroath (Sheets 48/49) and Stirling (Sheet 39) areas has been completed. Differential thermal curves for clay fractions from a number of highly leached soils in these areas show a sudden transition from well-ordered kaolinite and gibbsite (up to 10 per cent) in the lower B and C horizons to alumino-silicate gels in the upper horizons. Some of these soil clays, together with others from north-east Scotland showing similar trends, are currently being examined in greater detail by chemical and physicochemical techniques.

Clay fractions, separated by normal methods, from New Zealand and Japanese soils with high contents of inorganic gels, have been examined by differential thermal analysis. Particle size, pH of the separating medium and organic matter all affect the curves[44].

Further investigation of the non-crystalline components of soil clays has continued using chemical, X-ray, thermal and electronoptical techniques. Silica in flints and materials associated therewith has been found to exhibit varying degrees of crystallinity. The examination of soil gibbsites of varying degrees of crystallinity has been extended to the oxyhydroxides diaspore and boehmite. These are rather more stable to sodium carbonate solution than gibbsite, although poorly ordered boehmite dissolves appreciably.

A number of soils from overseas countries, including the U.A.R., India, Turkey, Ghana, Madagascar and Angola, have been examined to determine the manner in which their properties depend on their clay mineralogy. A detailed clay mineralogical study of a soil used to test the behaviour of the herbicide paraquat has also been made at the request of the Weed Research Organization.

The clay fractions of a number of brown podzolic soils and peaty podzols developed on epidorite, or till derived from epidorite, in the Loch Awe region consist predominently of chlorite. These and other highly chloritic soil clays are being examined in detail.

A paper detailing the clay mineralogy of soils derived from biotite-rich quartz gabbro has now been published[3].

Clay-Organic Complexes. In collaboration with Microbiology a detailed study has been carried out on the complexing of montmorillonite with nucleic acid: montmorillonite-enzyme complexes have also been examined. The surface horizon of a gley soil from Gartly, Aberdeenshire, contains a mineral with interlayer material extractable by hydrogen peroxide and sodium oxychloride. The fact that such interlayers may affect the expansion of the mineral emphasizes the necessity of avoiding pretreatment if the component minerals of soil clays are to be accurately characterized.

Organic and Biological Materials

Differential thermal investigation of organic materials has been greatly aided by introduction of an automatic integrator for peak-area measurement and use of a bomb calorimeter. These are proving particularly useful in a study now under way on the relationships between the degree of humification, particle size and calorific value of peat. Fresh plant materials have also been examined. A combined differential thermal analysis–mass spectrometer system, to enable analysis of evolved gases, is at present being assembled and calibrated.

Papers have appeared during the year on the thermal determination of calcium oxalate in lichens[4] and on the effect of diluent on complete-combustion differential thermal curves for organic materials[5].

Soil Analysis

Standard analytical determinations have been completed on soils collected by the Soil Survey during 1966; examination of those collected during 1967 is almost complete. The possibility of introducing a wider range of physical and chemical tests is presently being investigated. Clay separates from 195 soils have been analyzed for silica, iron and aluminium and about 50 soil samples have been examined on behalf of other departments of the Institute and for outside bodies. In collaboration with Soil Survey, separation and identification of the polyphenolic constituents of the neutral fraction of aqueous extracts of pine needles, which can complex with sesquioxides, is proceeding. The statistical evaluation, in collaboration with Soil Survey and Statistics, of field and laboratory information for a number of Scottish soil series is as yet insufficiently advanced to assess its eventual value.

Peat and Highly Organic Soils

Surveys of selected peat deposits in the Stirling area (Sheet 39) have been completed and examination of deposits in the Nairn district (Sheet 84) is now in progress. A chapter on the peat deposits of Wigtownshire and South Ayrshire (Sheets 7/8) has been contributed to a Soil Survey memoir. Several special surveys related to regional and other developments have also been undertaken. A report on the Kentra and Claish Mosses (2500 acres) in Ardnamurchan has been compiled for the Highlands and Islands Development Board: a similar report on Glenbellart Bog in the Isle of Mull is almost complete. The possibility of using Whin Moss, Midlothian, as a source of peat for horticultural purposes has been investigated and a reconnaissance survey of peat deposits in the Island of Arran has been carried out for the local Council of Social Services.

Standard physical and chemical determinations on peat and herbage samples have been carried out as in previous years. At the request of the Directorate of Overseas Surveys a number of shallow peat profiles from the Falkland Islands are currently being examined to determine their botanical and chemical characteristics. Various methods of testing propagation pots made of peat are being studied in relation to the establishment of a suitable standard: this is in collaboration with the British Standards Institution.

Two papers were presented at the Third International Peat Congress in Quebec, Canada; one of these dealt with British peat resources and their development[45] and the other with the chemical characterization of peat strata. A brief review of the distribution and utilization of peat[46] has been submitted for publication, and an English edition of the Transactions of the Second International Peat Congress has been prepared and edited and is now in press[47].

Root and Moisture Studies. The effect of the oxygen contents of culture solutions on the growth and root development of *Pinus contorta* is being examined. The range zero to 21 per cent oxygen has been employed. Between 10 per cent and 3 per cent, root growth was noticeably less although still appreciable, below 3 per cent it was greatly reduced, and in the absence of oxygen it was almost entirely inhibited. Shoot development did not follow the same pattern, growth being maintained even at low oxygen levels. Further studies are in progress.

In collaboration with Plant Physiology, Section of Radioactivity, the downward movement of water in a peat profile is being studied using tritium and radioactive iodine as tracers. Water movement in peat is slow compared with that in mineral soils, but the rate and amount of travel is related to the height of the water table.

A paper on the effect of different cultural treatments on root development in a grass sward growing on deep peat has been accepted for publication[48].

Pollen Analysis and Quaternary Research. In assessing the history of Quaternary vegetation more emphasis is now being placed on pollen analysis

of selected mineral rather than organic soils. Interpretation of results is somewhat different from that for organic soils, but useful information can be obtained. An example of this technique is provided by work carried out on certain marshland samples submitted by the Department of Geography, University of Cambridge. The results have contributed to the understanding of marshland development in several river estuaries in the county of Suffolk. Some investigations of microscopic and macroscopic remains from archaeological sites have also been carried out, in collaboration with Soil Survey. These are exemplified by studies on archaeological sites in the Island of Jura and at Kilphedir in the Strath of Kildonan, Sutherlandshire. An evaluation of the pollen analytical evidence is being made in collaboration with the archaeologists concerned.

Samples of peat and organic soils from sites in Ireland and the Cairngorms, submitted by the Department of Geography, University of Aberdeen, are probably of glacial age. Papers on structural variations in peat[49] and on climatic variations in Scotland and northern England since the Boreal period[50] have been submitted for publication.

Studies on Forest Soils

Experimental work at Lon Mor, Inverness-shire, on the response of *Pinus contorta* to water-table height has continued along the lines reported last year and preliminary results have been presented at a symposium on Peatland Forestry arranged by the Natural Environment Research Council. The artificially maintained water levels in the perimeter ditches have resulted in water tables ranging from zero to 33 cm below the surface. The average height of trees in the waterlogged plot after six years' growth is 0·8 m as against 3·6 m in the plot with the water table at 33 cm.

Tree Nutrition. The experiments on the nutrition of coniferous trees, carried out in collaboration with the Forestry Commission, have continued. The effect of applications of nitrogen fertilizer on Corsican pine at Culbin Forest, Morayshire, has been investigated, with respect both to tree growth and uptake of nitrogen[51]. Basal-area growth showed a significant linear response over three years of application, during which time the fertilizer treatments totalled 252, 504, 1007 and 1510 kg nitrogen per hectare. Height growth, on the other hand, was depressed at the higher rates of application and, as a result of this, volume increment took a quadratic form, with response at the highest application rate being less than that at the middle two rates. Whole trees were sampled from this experiment, both before and after the three-year period of fertilizer application. The results obtained have revealed that the increase in weight of the trees showed a similar pattern to that of volume growth, with maximum dry-weight increment occurring in those plots that had received 1007 kg nitrogen per hectare.

Analysis of the sample trees enabled calculation of the nitrogen content of the crop for each treatment. At the second sampling, after three years of fertilizer application, the nitrogen content of the tree (including roots) varied from 185 kg in the control plots to 660 kg per hectare in those plots

receiving the heaviest treatment. The fertilizer also caused an increase in the amount of nitrogen within the organic layers on the forest floor, ranging from 120 kg in the plots receiving the lowest dressing to 200 kg nitrogen per hectare in those receiving the heaviest fertilizer dressing. The nitrogen content of the mineral soil, on the other hand, was unaltered by the fertilizer treatments (this soil consisted of wind-blown sand containing virtually no clay and very little organic matter). The total increase in the nitrogen content of the ecosystem over the three years of fertilizer application was equivalent to approximately 100 per cent of the applied fertilizer nitrogen at the lowest rate, as against only 45 per cent in those plots that had received 1510 kg of nitrogen per hectare.

The release of nitrogen by these trees in litter-fall varied with treatment, averaging about 11 kg nitrogen per hectare per annum in the control plots, but rising to an average of 25 kg per hectare per annum in the most heavily fertilized plots. Litter-fall was found to represent the main process of nitrogen loss from the trees, loss into rainwater being insignificant. Indeed, the results obtained suggest that the foliage of unfertilized trees actually absorbed nitrogen from rainwater to the extent of about 0.5 kg per hectare per annum. However, it was found that for mineral nutrients, loss into rainwater ("recretion") can be a far more significant process than litter-fall. For instance, recretion of potassium averaged 15 kg per hectare per annum as against a release in litter of less than 5 kg per hectare per annum. Similarly, greater quantities of magnesium and sodium were lost into rainwater than in litter, but with calcium the two pathways of release are of approximately equal importance and with phosphorus very much less is lost into rainwater than is released *via* litter-fall.

Other fertilizer experiments, including those with boron and copper, have continued with little change in the pattern of response. In addition, the advisory service continues, providing recommended fertilizer rates for forest nurseries, based on soil analyses carried out by Soil Fertility.

Physical Chemistry of Forest Soils. Investigations into the physicochemical factors that influence absorption and retention of nutrient elements by peat, in particular the absorption of inorganic cations by cation exchange, have continued. All experiments have been conducted with raw, moist peat and the results have shown the marked extent to which the exchange capacity is dependent on the pH of the soil solution. For example, a sample of basin sphagnum peat absorbed 120 me NH_4^+ per 100 g of oven-dry material at pH 6·0 but only 30 me per 100 g at pH 3·0. Furthermore, if exchange capacities are expressed on a volume basis (me per litre wet peat) the concentration of exchange sites varies inversely with the moisture content. Thus for peat under field conditions, where it is characterized by a low pH and high moisture content, the concentration of exchange sites participating in the exchange reaction is very low.

Classification of Peatland Sites for Afforestation. A preliminary study has been undertaken to ascertain whether the methods at present used in the north of Scotland to sub-divide blanket peat into various site types prior

to afforestation reflect variations in either the nutrient content or the physico-chemical nature of the peat. Samples were taken, on a volume basis, from a blanket bog in Sutherlandshire according to site types that had been identified by local Forestry Commission field staff. These site types, which had been selected on the basis of vegetation and topography, were found, with certain exceptions, to be fairly closely related to nutrient contents.

Two trends could be detected, these apparently being related to flushing with mineral-rich water, on the one hand, and to erosion, on the other. Both processes resulted in an increased weight of dry peat material per unit volume and this was the predominant factor controlling nutrient content. In addition, the flushing types exhibited high concentrations of nitrogen, phosphorus and potassium, whereas the eroded types were high in calcium and magnesium. The differences between sites were apparent both in the top 15 cm of peat and over the entire depth of profile sampled (25 cm), and could be related to variations in the proportions of certain key species in the vegetation cover.

The influence of topography, and hence flushing, on the concentration of exchangeable cations in the peat was quite marked. Concentrations of exchangeable cations were high in all the flushed types, reaching a maximum in those with the lowest moisture content, whereas the unflushed types were all low in exchangeable cations irrespective of their moisture content.

Values for the degree of base saturation, based on the concentration of exchangeable hydrogen ions in acid washed peat at pH 7, also reflected the supply of inorganic cations received by the peat. The highest values were observed in the flushed types (30-40 per cent) and the lowest in the eroded, unflushed blanket bog type (10-20 per cent), whereas intermediate values (20-30 per cent) were exhibited by unflushed blanket bog that had not been subjected to erosion.

SOIL SURVEY

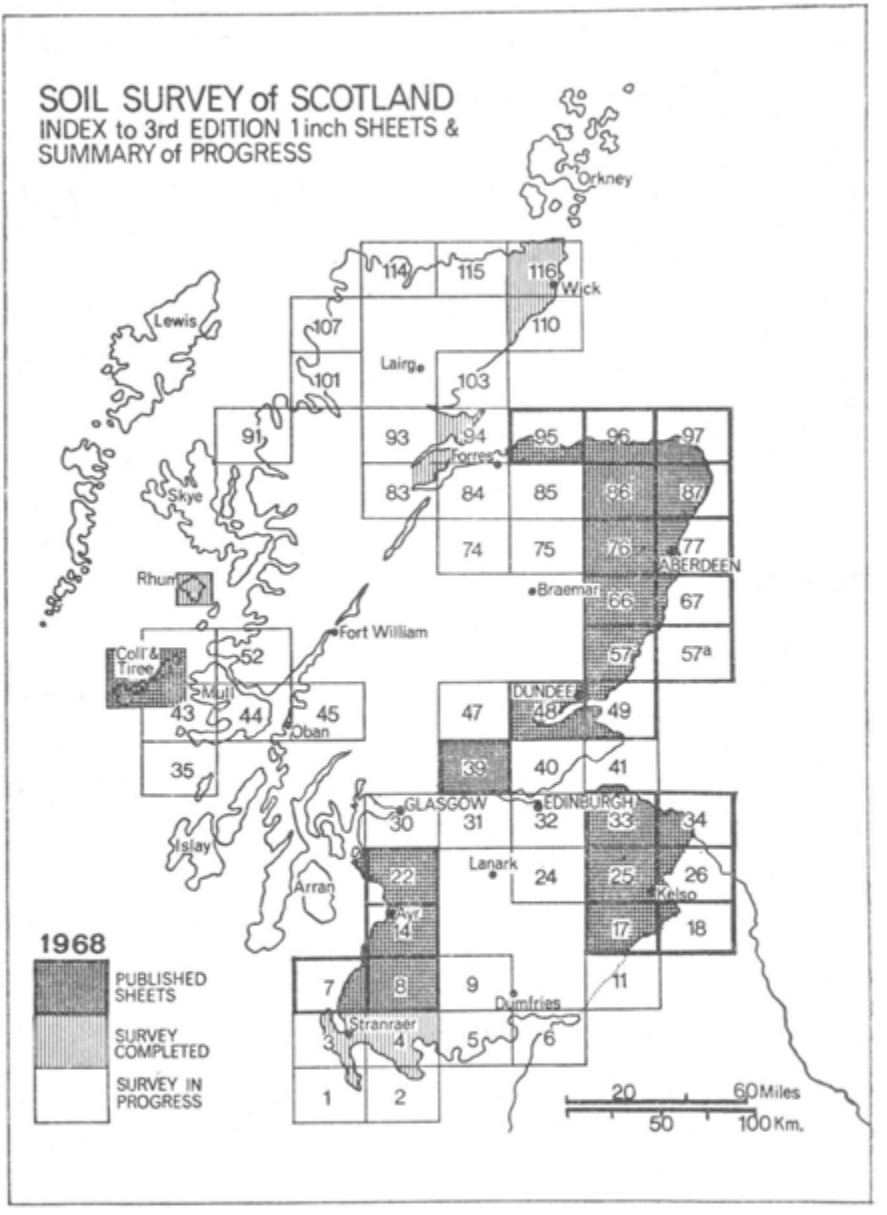
The primary aim of the Soil Survey of Scotland is to identify soils and record their limits and distribution on a map. Soils are identified in the field by their appearance, that is, by a study of the morphological character of the soil profile. They are examined in small pits dug at intervals, the frequency depending upon the complexity of the soils and the scale of mapping. Observations on the geological nature of the parent material, the environment and land use are also made. Soils with similar kind and arrangement of horizons and developed on similar parent material are placed in a category called the soil series, which is the primary unit distinguished. Soil series can be grouped into a larger unit, the soil association, which is a group of soil series developed on similar parent material. A phase is a subdivision of a series. Divisions between series or other mapping units are not always sharp and the permitted range of variation in a series must be established so that it can be distinguished from other series. Laboratory analyses are used to confirm and give precision to field observations as well as for the study of soil forming processes. The soil associations and soil series shown on maps are described in accompanying memoirs or bulletins which contain accounts of the geology, climate, vegetation, agriculture and forestry of the district surveyed.

An outline map included in this report indicates the location and extent of soil survey coverage to date. Approximately one third of Scotland, mainly in the more productive low ground regions, has now been surveyed on a scale of 2·5 inches to 1 mile (1:25,000), with parts on the 6 inches to 1 mile scale (1:10,000). During the current year systematic survey on the scale of 2·5 inches to 1 mile has been continued in eleven areas and a total of 480 square miles completed; 243 profiles have been described and sampled.

There has been a marked increase in requests for Survey information and assistance, more particularly about the physical condition of the soils. These have included requests for soil maps ranging from individual farms to properties of 70 square miles in extent and for information about soil morphological conditions in relation to drainage problems. Collaboration with the Colleges of Agriculture, the Department of Agriculture and Fisheries for Scotland, the Forestry Commission, Planning Authorities, the Highland and Islands Development Board, the Nature Conservancy, the Hill Farming Research Organization, departments of the Macaulay Institute, estate owners and farmers has been maintained.

An envisaged development of the work of the Survey is the production of land use capability maps, involving interpretation of soil survey information made in collaboration with the College Advisory Officers and others. Experimental maps are being prepared and a joint paper with the Soil Survey of England and Wales describing the proposed classification has been prepared.

In connection with a soil map of the world on a scale of 1:5 million to be produced by FAO/UNESCO, Rome, an outline copy of the section covering Scotland has been received, together with definitions of the soil units. These soil units have been adjusted where necessary.


SOIL SURVEY of SCOTLAND
INDEX to 3rd EDITION 1 inch SHEETS &
SUMMARY of PROGRESS
Orkney
Wick
Lewis
Lairg
Forres
Skye
Rhum
Braemar
ABERDEEN
Fort William
Coll & Tiree
Mull
Oban
DUNDEE
GLASGOW
EDINBURGH
Islay
Arran
Lanark
Kelso
Ayr
Stranraer
Dumfries
1968
PUBLISHED SHEETS
SURVEY COMPLETED
SURVEY IN PROGRESS
20 60 Miles
50 100 Km.

The departmental ecologists attended a week's course on phytosociology, supervised by Professor Tuxen, Rinteln, West Germany and Father Moore of University College, Dublin, at the Preston Montford Field Centre, Shropshire. Mr E. L. Birse visited the Department of Botany, University College, Dublin.

Mr J. S. Bibby spent three weeks with Mr A. Thomasson, Soil Survey of England and Wales, at Shardlow, Derbyshire. Information on soil moisture trials was gathered and a study made of experimental work being carried out by the National Agricultural Advisory Service on Land Use Capability Units. The joint Soil Survey Field Meeting scheduled for May 1968 at Church Stretton, Salop, had to be postponed until October because of the outbreak of foot and mouth disease.

The Survey continues to be represented on the Agricultural Research Council Technical Committee on Soil Fertility. Members of staff attended the spring and autumn meetings of the British Society of Soil Science, the meeting of the British Association for the Advancement of Science in Dundee, the symposium on soil ecosystems at the School of Agriculture, Sutton Bonington, Leics., the symposium on the ecological aspects of the mineral nutrition of plants held by the British Ecological Society in Sheffield, the conference on cartography in education sponsored by the Cartographic Section of the British Society of Cartographers, and the annual Technical Symposium of the British Society of Cartographers.

Dr R. Glentworth was invited by the British Council to give lectures at the Department of Geography, University of Amsterdam on Landscape and Soil Formation in Scotland, at the International Training Centre, Delft, on Soil Survey Methods and Map Legends in Scotland, and at the Agricultural University, Wageningen, on Soil Survey and Classification in Scotland.

Systematic soil surveys, with the aid of air photographs, at an approximate scale of 6 inches to 1 mile and compiled on 2.5 inches to 1 mile base maps have been continued in the following areas:

Sheets 116 and 110 (*Wick and Latheron*)

Fifty square miles of mostly arable land have been surveyed in the Thurso-Halkirk and Stemster-North Watten-Lyth districts. All the soils belong to the Reiss Association, comprising soils developed on drifts derived from rocks of Caithness Flagstone Series. The dominant soils are poorly drained non-calcareous gleys. Associated soils are freely and imperfectly drained brown forest soils, podzols with indurated subsoil and shallow soils on rock. The Burn of Acharole district is mainly hill ground. The common soils are peaty gleys of the Reiss Association, with associated non-calcareous gleys. Some peaty podzols are developed on coarse-textured morainic and fluvioglacial material derived from granite and flagstone.

Sheet 84 (*Nairn*)

Systematic survey covering 20 square miles has been carried out in the areas Loch Bunnachton-Farr, Cantraydoune-Nairnside and along the boundary between Sheets 84 and 74. Associations mapped include Countesswells,

Foudland, Strichen, Ardvanie, Millbuie, Corby and Cromarty. The dominant series are iron humus podzols, peaty podzols with iron pan, imperfectly drained peaty podzols, peaty gleys on induration and, to a lesser extent, peaty gleys and low humic gleys. No new associations have been identified. Extensive hill peat occurs above 1500 feet.

Sheet 85 (*Rothes*)

Approximately 30 square miles of hill land near Grantown-on-Spey have been surveyed. The underlying rocks are acid schists which often approach quartzite in composition. Hill features which rise to over 2000 feet are for the most part covered by a thin mantle of drift in which erratics, most commonly of granite, are generally present. The valley side till is thicker, and dumps of stony moraine are found locally along the larger valley bottoms. The greater part of the soils of the area are podzols, peaty podzols, subalpine podzols, or peaty gleys, belonging to the Strichen Association.

Sheet 47 (*Crieff*)

A further 35 square miles have been mapped in two predominantly highland districts, south of Aberfeldy and east of Killin on south Loch Tayside. In the former, north of Strath Braan, rugged moorland occurs rising to altitudes of more than 1500 feet at several points. Peat, peaty gleys, peaty podzols, podzols and rankers all occur in a relatively complex soil pattern at altitudes above 1000 feet. Below this level acid brown earth and gley soils form equally complex patterns. The soil parent material is principally a stony drift derived from Highland Schist rocks and the soils have been included in the Strichen Association. The area recently mapped extends to 15 square miles and lies mainly to the east of the Aberfeldy to Amulree road. To the south of Loch Tay the country includes some dissected and almost precipitous mountainous terrain with deep valleys and associated steep slopes with relatively rounded, almost flat, summits at several elevations. The soil pattern forms an altitudinal sequence of major soil groups from acid brown soils and gleys at the lowest altitudes, below 1000 feet, through podzolic brown soils and podzols about 1250 feet, through peaty podzols and peaty gley soils into peat deposits between 1500 and 2500 feet, succeeded by montane soils on the flatter sites above these levels. The rocky hill slopes and tops support rankers and skeletal soils. Most of the soils are included in the Strichen Association, although some are modified in morphology by the presence of felsitic contamination in the drift, principally derived from the underlying Highland Schist rocks.

Sheets 40 and 41 (*Kinross and Elie/North Berwick*)

Approximately 50 square miles have been mapped in three main areas—the Howe of Fife, the Lomond Hills and the Cleish and Saline Hills. The Howe of Fife is mainly overlain by fluvioglacial sands and gravels derived largely from Old Red Sandstone sediments and lavas, forming the parent material of the Gleneagles Association. Throughout the Howe, occurrences of glacial till derived from Upper Old Red Sandstone sediments give rise to soils of the Kippen Association. The Lomond Hills are composed mainly

of quartz-dolerite with bands of Carboniferous rock occurring on middle slopes. The soils on upper slopes, derived mainly from quartz-dolerite, have affinities with the Darleith series but are considered sufficiently different to warrant separation as the Drumlain series, while a peaty podzol with iron pan occurring under *Nardus* vegetation has been provisionally named the Munduff series, but may eventually be included in the Baidland series. On the Cleish and Saline Hills, soils of the Darleith Association occur on upper slopes. Till derived from Carboniferous sediments covers the lower slopes forming the parent material of imperfectly and poorly drained soils of the Rowanhill Association.

Sheets 32 and 24 (Edinburgh and Peebles)

Apart from an area of about 2 square miles near South Queensferry almost all the systematic survey work this season has been north and east of Biggar where some 20 square miles have been completed. Soils of the Eckford, Bemersyde and Hobkirk Associations have been identified, but considerable difficulty has been encountered in classifying the soils of the Lower Old Red Sandstone lavas and drifts derived from them. These rocks are shown on the geological map as andesites and basalts but have been found to contain sandstones, ashes, and acid igneous rocks which give rise to a wide variety of soils. It is likely that large areas will have to be designated as soil complexes within the Sourhope Association.

Island of Mull

At the close of the 1967 field season attention was focussed on two complexes on the Island of Mull, a moraine complex (provisional name Knockantivore complex) and a complex composed dominantly of peat on granite on the Ross of Mull (unnamed at present). Forty profile descriptions were collected from random sites in each of these complexes for analysis of variation both within a soil type and within the complex.

This season survey has been confined to the area north of a line from Loch na Keal to Salen, where approximately 80 square miles have been mapped. Detailed profile descriptions have been taken from each kilometre grid intersection (wartime grid), supplemented by occasional descriptions between stations where this was warranted. When the survey of the northern part of the island is complete, detailed investigation of randomly selected sample areas within the mapped complexes for variation purposes will be undertaken. Co-operation has continued with the Department of Botany, British Museum, on their botanical survey of Mull.

Sheet 5 and 9 (Kirkcudbright and Maxwelltown)

Survey has been commenced in the area covered by Sheets 5 (Kirkcudbright) and 9 (Maxwelltown). Mapping has been concentrated in four localities: the parishes of Holywood, Castle Douglas, Borgue, and Moniaive, and about 60 square miles in all have been surveyed. At Holywood, the area lies between the River Nith and its tributary the Cluden Water. The soils have developed on the following parent materials: modified till derived from Permian sand-

stone, frost-shattered rock debris derived from these rocks, fluvioglacial gravels and recent alluvium. Most of the soils belong to the freely drained class, apart from those formed on recent alluvium. The Castle Douglas area is underlain by greywackes and shales of the Silurian system and the soil parent materials derived from these rocks are a loam to clay-loam till occurring in thick deposits as isolated drumlins and shallow frost-shattered rock debris directly overlying the solid rock. The soils are mainly freely drained brown forest soils of the Ettrick Association. The soils mapped to the west of Borgue are formed on materials of a similar nature to those of the Castle Douglas area, but shallow soils with frequent rock outcrops predominate over soils developed on till. In the Moniaive district the soils also belong to the Ettrick Association and their pattern of occurrence is similar to that reported for the Girvan and Carrick areas.

Special Surveys

Glen Feshie (*part of Sheet 64*). At the request of the Nature Conservancy about 50 square miles of the 70 square mile Glen Feshie Estate, Inverness-shire, were surveyed with the help of air photographs at the scale of 6 inches to 1 mile. The survey is to be completed next year, and a report with soil maps on the scale of 2·5 inches to the mile will be prepared. Most of the area is underlain by acid Moine schists, and the soils belong to the Strichen Association, but granite outcrops in the north-east corner of the estate and three mapping units belonging to the Countesswells Association have been distinguished.

Scatwell Estates (*parts of Sheets 82, 83 and 91*). A soil survey of the Scatwell Estates in Ross-shire was carried out on some of the ground below about 1500 feet to aid decisions on land use. In the Strathconon area (Sheets 82 and 83) most of the soils belong to the Strichen Association, while around Poolewe (Sheet 91) the parent materials are derived from Lewisian gneiss or Torridonian sandstone. About 25 square miles were surveyed with the help of air photographs purchased by the estate; a brief report will be prepared, accompanied by soil maps on the scale of 6 inches to 1 mile. Twelve profiles were collected for analysis.

Novar Estate (*part of Sheet 93*). The soil survey of the 40 square mile Novar Estate, Ross-shire, which was begun last year has now been completed; profiles have been collected for analysis. Most of the parent materials are moderately coarse-textured drifts derived from acid Moine schists or from pebbly sandstones and conglomerates of Old Red Sandstone age, but a fine-textured reddish brown till derived from Old Red Sandstone strata is sometimes found on the lower ground. A brief report will be prepared, accompanied by soil maps on the scale of 2·5 inches to 1 mile.

Abernethy Forest (*part of Sheet 74*). The soils of Abernethy Forest (Seafield Estate), Inverness-shire, were surveyed. Humus podzols, iron-humus podzols and peaty podzols within the Corby and Strichen Associations have been identified. There is an apparent correlation between degree of develop-

ment of L and F layers, degree of humification and development of an iron pan. A map on the scale of 6 inches to 1 mile has been produced and a report is being prepared.

Maps, Memoirs and Cartographic Work

Soil maps on a scale of 1 inch to 1 mile (1:63,360) for Sheet 39 (Stirling) and Sheets 48/49 (Perth/Arbroath) and a memoir[6] entitled *The soils of the country round Haddington and Eyemouth*, together with accompanying map, have been published. The memoir covering Sheet 7/8 (Girvan/Carrick) is in final draft, apart from one chapter, and that for the Black Isle has been written.

Several maps have reached the colour-proof stage with the Ordnance Survey: the soil and experimental land use capability maps of Sheets 7/8 (Girvan/Carrick) and parts of Sheets 83, 84, 93 and 94 (The Black Isle); the soil maps (2·5 inches to 1 mile) of the Island of Rhum and Candacraig/Glenbuchat, Strathdon, Aberdeenshire; and the experimental land use capability maps (1 inch to 1 mile) of Sheet 39 (Stirling) and Sheets 48/49 (Perth/Arbroath) Two maps for which the bulk of the process work has been done in the Cartographic section are in preparation and will be printed locally: a soil map of north-east Scotland on a scale of a quarter of an inch to the mile (1:250,000) and a land use capability map of Candacraig/Glenbuchat (2·5 inches to 1 mile). A vegetation map comprising two 2·5 inches to the mile sheets forming a transect of Sheet 84 (Nairn) has been lodged with the Ordnance Survey for comment.

An economical method has been evolved for the short-run reproduction of the 2·5 inches to the mile field sheets which, it is proposed, will be made available to College Advisory Officers, officials of the Department of Agriculture and Fisheries for Scotland and other interested parties.

Vegetation Surveys

The vegetation of Sheets 116/110 (Wick/Latheron) has been recorded by plant sociological methods. An account of the vegetation of Sheets 48/49 (Perth/Arbroath) is being prepared.

A map of the climatic regions of Scotland has been prepared for use in soil and vegetation survey work. It is based on potential water deficit and annual accumulated temperature.

Tables of the plant communities of lowland Scotland have been drawn up, according to the methods used by M. E. D. Poore. They are being modified to fall into line with the methods of the Zurich-Montpellier school of plant sociologists so that Scottish plant communities can be more readily placed in the scheme of classification for European vegetation.

Micromorphological Studies

Approximately 370 impregnated soil blocks have been produced during the year; 300 have been sectioned. The GH3 cutting and grinding machine is proving very satisfactory and the previously standard one inch square sections have been superseded by a 3×2 inch size of which some 200 have been made.

Other Work

An account of the soils was prepared for a meeting of the Hill-land Use—Ecology Group at Tomintoul, Banffshire, that was attended by three surveyors.

Thirty talks and lectures on subjects related to the work of the Survey were given in different parts of the country to audiences ranging from students of geography, soil science and forestry of several Universities to visiting parties from the Department of Agriculture and Fisheries for Scotland and the Forestry Commission. Excursions were led in ten counties to demonstrate various aspects of soils to University and College staff and students, officers of the Department of Agriculture and Fisheries for Scotland, Forestry Commission officers and others.

A four-day tour was arranged and conducted for a party of 32 students and five members of staff from the Agricultural University, Wageningen, to examine the soils, landscape and land use of central and south Scotland. A joint excursion was made in north-east Scotland with members of the Department of Agriculture and Fisheries for Scotland Inspectorate and Advisory Officers of the North of Scotland College of Agriculture to examine a number of drainage schemes in relation to soils, following a meeting to discuss the use of soil maps. Collaboration with the three Colleges of Agriculture, the Department of Agriculture and Fisheries for Scotland Inspectorate and the department of Soil Fertility of the Macaulay Institute has been maintained and advice and assistance given on drainage experiments, improvement schemes and the selection of sites for field trials in Stirlingshire, Argyllshire, Perthshire, the Lothians, Angus, Ayrshire, Aberdeenshire, Banffshire, Morayshire and Caithness.

Advice was given to the National Institute of Agricultural Engineering (Scottish Station) on suitable sites for sampling soils with a range of textures and help was given in the collection of samples. Joint field trials were carried out with staff of the National Institute of Agricultural Engineering (Scottish Station) of a prototype gamma-ray probe for determining bulk density. A report entitled *Comparison of soil bulk density measurements in the field by gamma-ray transmission and core sampling methods* has been prepared for submission to the Soil Survey Research Board.

A paper on the variation in the altitudinal zonation of climate in Scotland and northern England since the Boreal Period has been submitted for publication[50].

A paper on the hill-land vegetation of Scotland was read at the symposium of the European Grassland Federation in Aberdeen in July, and information on soils provided for their excursion. An account of the soils of the Dundee area[7] was prepared for the Handbook of the British Association for the Advancement of Science.

The Black Isle (parts of Sheets 83, 84, 93 and 94)

Survey of this area has now been completed and in conformity with previous practice a preliminary summary of the findings is being presented.

The Black Isle is a narrow peninsula in Easter Ross about 20 miles long lying between the Cromarty Firth and the Moray Firth. Its western boundary

is taken to be the A9 road between the Inverness-shire county boundary and Conon Bridge. It has an area of about 108 square miles, with a width of 7 or 8 miles in the broadest part, narrowing to 4 miles near Rosemarkie, and to less than 2 miles near Cromarty. Agriculture is the dominant factor in the economy of the district, with forestry, fishing and tourism as important subsidiaries. Industry is at present limited to servicing these major occupations, and to a large contracting business based on Muir of Ord.

When viewed from the hills on the north side of the Cromarty Firth the Black Isle stands out long, low and smooth in outline, with a broad central spine rising to over 800 feet at the summit of Mount Eagle. At the west end the ground falls away from this axial ridge towards the Cromarty Firth in a succession of gently sloping steps. Between St. Martins and Balblair a broad valley separates the central ridge from a lower coastal rise, 300 to 400 feet high. East of Udale the central ridge narrows and falls to about 400 feet near Cromarty. The coastal edge of the north facing slope between Jemimaville and Cromarty is dissected by many gullies which are deeply incised into the low cliff-line.

The south facing aspect is quite different, with steep rocky cliffs, often 200 to 300 feet high, from Cromarty to Rosemarkie, and a tree clad outline of hills and ridges from Rosemarkie westwards. Even the wide inlet of Munlochy Bay is a remarkably inconspicuous feature when viewed from the Inverness side of the Moray Firth.

The climate of the Black Isle is relatively mild and the agricultural cropping pattern of the lower ground is more comparable with the coastal parts of eastern Strathmore than with Aberdeenshire. Rainfall at coastal stations averages about 25 inches per annum, while 30 inches may be expected on the central ridge. There are two relatively dry periods in the year, the first from April to June, and the second in September, but it is unusual for the rainfall to be below half an inch in any month.

Beneath a discontinuous mantle of superficial deposits the solid rocks of the Isle consist mainly of sandstone and conglomerates of Middle Old Red Sandstone age, with two small blocks of Moine gneiss faulted in on the south facing coast between Cromarty and Rosemarkie. The Middle Old Red Sandstone strata also include subordinate calcareous shales, and "fish beds" containing limestone nodules; in addition, some of the sandstones are slightly calcareous, and have contributed appreciable amounts of calcium carbonate to the derived glacial tills which overlie them.

During the last major glaciation the Black Isle was covered by an ice sheet which left behind erratics of Inchbae gneiss and a slight overstep of sandstone-derived till on the Moine gneiss outcrops, as indicators of its direction of passage from slightly south of west to slightly north of east.

When the main ice sheet melted it left behind on the lower ground a stiff reddish brown basal till overlain by coarser textured stony supraglacial moraine. At the west end of the peninsula the thickness of the supraglacial material may locally be 4 feet or more, but it thins out to 2 feet in the central part and becomes negligible east of Grey Cairn Wood. Both the supra-

glacial moraine and the basal till are derived from the local Middle Old Red Sandstone strata with very little admixture of external material other than erratic stones: they are the most important soil parent materials in the Black Isle, covering about 75 per cent of the total area. The higher ground on Mount Eagle and the south facing coastal ridges between Kessock and Cromarty is generally covered by thin semi-residual drift derived from sandstone, conglomerate or gneiss. These thin drifts account for about 11 per cent of the area. Fluvioglacial sands and gravels occupy less than 2 per cent of the surface and are concentrated at the western end, between Muir of Ord and the Beauly Firth, with intermittent patches of gravelly moraine fringing the coast as far east as Kessock.

A very narrow and not quite continuous strip of low raised beach encircles the Black Isle. The high raised beach is slightly more extensive but is very intermittently developed. These beach deposits occupy only 3 per cent of the area. The remaining part of the mantle of superficial deposits consists of alluvium, solifluction deposits and peat.

Over 85 per cent of the soils of the Black Isle are podzols, podzols with gleyed B horizons, podzols with thin iron pan, or cultivated podzols, while not more than 10 per cent are gleys. Brown earths and brown forest soils have not been distinguished on the 1 inch to 1 mile scale map, but they may occur very locally either in the vicinity of calcareous seepages or on the low raised beach where shell sand, seaweed, and sea birds have enhanced the base status of the soil parent material. Calcareous gleys are sometimes encountered in alluvial areas in the vicinity of small deposits of calcareous marl.

Seven soil associations have been distinguished, and these have been subdivided into twenty named soil series and one complex.

Association	*Parent Material*
Millbuie	Morainic till derived from arenaceous strata of Middle Old Red Sandstone age.
Cromarty	Compact till derived from Middle Old Red Sandstone strata.
Mount Eagle	Shallow drift derived from Middle Old Red Sandstone rock.
Ethie	Shallow drift derived from Middle Old Red Sandstone rock and Moine gneiss.
Kessock	Shallow drift derived from Middle Old Red Sandstone conglomerates.
Corby	Fluvioglacial and morainic gravels.
Boyndie	Fluvioglacial sands.

In addition, the following miscellaneous soils have been mapped:

Low Raised Beach
High Raised Beach
Undifferentiated Solifluction Deposits
Alluvium
Saltings
Basin Peat
Skeletal Soils
Mixed Bottom Land

The Millbuie Association is the most extensive within the Black Isle, and the only one to be represented in all the civil parishes. It occupies just under 72 square miles extending eastwards from the Muir of Ord gravel flats to Udale Bay on the north side, and to Rosemarkie on the south side. The altitudinal range extends from the landward edges of the raised beaches to about 400 feet around the Kessock ridges, and 600 feet on the south-west and north-east sides of Mount Eagle. The greater part of the cultivated land lies below 500 feet, with the higher lying moorland now for the most part under planted woodland.

The parent material upon which the soils have developed is a stony coarse-textured supraglacial moraine with a clay content between 2 and 12 per cent, which may vary irregularly throughout the solum. The colour may vary from brown or yellowish brown (Munsell Colour 10YR5/3 or 10YR5/6) to reddish brown (5YR5/4)—changes which generally reflect the variations in colour of the underlying Middle Old Red Sandstone strata.

Three soil series of the Millbuie Association and one complex have been distinguished on the soil map. Freely drained podzolic soils have been included within the Allangrange series, imperfectly drained podzolic soils within the Millbuie series, and poorly drained non-calcareous gleys within the Roskill series. The "Kettlehole complex" is a patch of knob and kettle dead ice terrain, including soils of all three series together with wet sandy alluvium and peat.

The Allangrange series covers about 24 square miles, and is best developed on the rising ground at the west end of the peninsula between Muir of Ord and the Monadh Moor, where the supraglacial moraine is generally deepest. The semi-natural soil has a surface layer of 2 or 3 inches of litter and fibrous dark brown to black raw humus, overlying a leached A_2 horizon composed of dark grey humose loamy sand, which may be 2 to 4 inches thick. The underlying friable yellow-brown stony sandy loam B_2 horizon is usually between 2 and 10 inches thick and may sometimes show very slight evidence of mottling and impedence of drainage at the base, just above the strongly indurated stony B_3 horizon. The indurated layer may vary from a few to over 18 inches thick; the cementation is toughest in the upper 3 to 4 inches and fades out gradually with depth. The C horizon consists of stony coarse sandy loam, which may be underlain by the compact reddish brown till which forms the parent material of the Cromarty Association further east. A large percentage of the soils of this series are cultivated and have the indurated B_3 horizon within 10 to 15 inches of the surface. Where the indurated layer

lies at 24 inches or more, deep surface horizons, sometimes 18 inches or more in depth, are found, probably indicating selective improvement of infield land.

The Millbuie series covers 43 square miles and is the most extensive in the Black Isle; it is widely distributed over the lower ground west of a line from Rosemarkie to Udale Bay. The series is large enough to reflect the whole range of parent material variation within this association, though the general development of some degree of drainage impedence is in itself an indication that shallower supraglacial moraine underlain by compact till at less than 3 feet is most often encountered. The soils of the Millbuie series include imperfectly drained podzolic soils with either strongly or weakly developed indurated layers, and some imperfectly drained podzolic gleys. The semi-natural podzolic profile generally has a surface layer of about 3 inches of litter and very dark brown fibrous humus, with a trace of well decomposed black greasy humus seldom more than half an inch thick at the base. This is underlain by an A_2 horizon about one inch thick of dark grey humose sandy loam with prominent bleached sand grains. The indurated B_3 horizon is frequently encountered within 12 inches of the mineral ground surface, and not often below 15 inches. On the high central moor the moderately friable yellow-brown sandy loam B_2 horizon with ochreous mottling, which is normally found between the A_2 and the indurated layer, is often replaced by a patchy coloured humose horizon in which shades of grey, grey brown and black predominate. This mixed horizon is interpreted as probably representing a long term churning up of the A and B horizons by the natural windblow of mature trees before extensive settlement and deforestation of the Black Isle took place. Compact reddish brown till generally forms the C horizon of the profile, but in soils transitional to the Cromarty Association (as in the Grey Cairn Wood area) it may be present at the level of the indurated B_3 horizon.

The Roskill series includes only about 3 per cent of the soils of the Millbuie Association. It is best developed in the western half of the Black Isle between the B9162 road and Mount Eagle, particularly on the broad central part of the Millbuie ridge where lateral drainage is difficult. The soils are non-calcareous gleys.

The Cromarty Association is approximately 10 square miles in extent and the second largest in the district. The greater part is located within the parish of Cromarty, though nearly 2 square miles have been mapped in Resolis, Avoch and Rosemarkie, on both sides of the central ridge, and there are small additional patches still further west in Knockbain and Killearnan. The altitudinal range of the association is from below 75 feet near Cromarty to nearly 600 feet in Grey Cairn Wood. A high proportion of the soils have been cultivated, and they include what have long been reputed to be the best arable lands of the Black Isle. The parent material is a compact reddish brown till containing 14 to 21 per cent of clay with a surface veneer of coarser textured supraglacial material most of which becomes incorporated into the plough layer of the arable soil. The clay content of this surface horizon usually exceeds 12 per cent.

The dominant Cromarty series, an imperfectly drained podzolic soil, is over 9 square miles in extent. The combined extent of the Brucefield and Navity series is rather over half a square mile. The Brucefield series includes freely drained podzolic soils, while the soils of the Navity series are non-calcareous gleys. A profile of the Cromarty series from Cromarty Mains at about 225 feet had a dark brown sandy loam cultivated surface horizon, with sub-angular blocky structure and friable consistency, about 12 inches deep. This rather deep plough layer had incorporated the entire A and $B_2(g)$ horizons of the semi-natural soil, and overlay a brown to reddish brown compact weakly indurated sandy loam B_3 horizon, which merged gradually into compact reddish brown sandy clay loam till forming the C horizon. The cultivated surface horizon of this profile had a pH value over 6 and a total phosphate content over 180 mg per g. Comparable C horizon values for soils of this series range from pH 5 to 5·5 and from 70 to 100 mg per g. This illustrates the overwhelming importance of the management factor in the improvement of these soils. Soils of the Cromarty Association are decalcified to a depth considerably below that to which the profile pits are normally dug (3 to 4 feet), but the value of 6 per cent free carbonate obtained from a sample taken about 18 feet below the surface from the side of a deep gully, a mile from Cromarty Mains, may give some indication both of the free carbonate originally present in this soil parent material and of the amount of leaching that has taken place.

The Mount Eagle, Ethie and Kessock Associations cover nearly 12 square miles on the highest parts of the central sandstone ridge around Mount Eagle, on the coast ridges of gneiss between Cromarty and Rosemarkie, and on the conglomerate ridges between Munlochy and Kessock. The soil parent materials are all thin semi-residual drifts, and more than 98 per cent of the soils are freely or imperfectly drained. Most are podzols with thin iron pan, podzols, or podzols with gleyed B horizons, though some of the imperfectly drained soils of the Gallow series of the Ethie Association are gleys. A very large proportion of the soils of all three Associations are now under planted woodland.

The Mount Eagle series of the Mount Eagle Association, with an extent of over 4 square miles, is the largest series within this group of hill soils. The soils are freely drained podzols with or without a thin iron pan. When the iron pan is present there is, of course, some gleying of the $A_2(g)$ horizon overlying the pan, but below the pan the morphology is that of a freely drained profile. A profile of this series from a site at Wester Brae, at about 560 feet, 2 miles from the summit of Mount Eagle has a three inch thick surface layer of pine litter and very dark brown surface humus overlying a three inch grey to dark grey sandy loam A_2 horizon. Below the A_2 a five inch olive-grey sandy loam $A_2(g)$ horizon with darker patches of colloidal humus accumulation near the base overlies a hard thin iron pan with a root mat on its upper surface. Below the thin iron pan there is a pale brown to yellowish brown stony indurated sandy loam B_3 horizon about 9 inches thick, which merges gradually into softer reddish brown sandy loam. Shattered sandstone rock is encountered at 17 to 20 inches below mineral ground surface.

Though the Corby and Boyndie Associations are not extensive, the greater part of their soils, which are developed on morainic and fluvioglacial gravel and sand, are freely drained humus podzols or podzols, and lie below the 200 foot contour around the west and south-west margins of the Black Isle. The soils were formerly extensively cultivated whenever the ground was sufficiently level. A profile sited on the gravel flat about half a mile south-east of Muir of Ord has been cultivated, but still retains the dark coloured

TABLE I

Distribution of land between different Land Use Capability Classes in the Black Isle

Class	*Description*	*Percentage of total area*
1	Land with minor physical or climatic limitations which do not interfere with the sustained production of cultivated field crops.	<0·01
2	Land with some physical or climatic limitations but, under good management, capable of sustained production of field crops.	20
3	Land with moderately severe limitations which restrict the choice of crops or require special cultivation practices.	51
4	Land with severe limitations which restrict the choice of crops and/or require special cultivation practices.	13
5	Land with very severe limitations which restrict its use to permanent pasture or forestry but on which mechanized improvement practices may be possible.	2
6	Land with very severe limitations which restrict agricultural use to rough grazing. Mechanized improvement is impracticable.	12
7	Land with extremely severe limitations, such as built-up areas, industrial waste tips, steep mixed bottom land, bare rock outcrops and high ground above the plantable limit.	2

cemented B horizon of the humus podzol. The surface layer consists of about ten inches of dark reddish brown stony sandy loam overlying a cemented stony loamy coarse sand B horizon about 15 inches thick, which is dark brown to very dark grey brown in the upper part, and dark brown to yellowish brown below. Below the B horizon there was a merging change into brown coarse sandy gravel.

Within the group of miscellaneous soils undifferentiated solifluction soils and alluvium account for about 7 square miles of predominantly gleyed

soils with rather variable parent material. The raised beaches include over 3 square miles of generally free draining sandy and gravelly soils. On the high beach the soils have generally been humus podzols before cultivation, while on the low beach the profile is generally immature, but can develop a dark "brown earth like" profile locally. Mixed bottom land with some peat, and skeletal soils cover just over 3 square miles. This group can include many stages of soil development from the incipient vegetation of gully side slip scars to podzolic soils on thin stony debris overlying sandstone conglomerate or gneissic rock.

In addition to the soil map, a derived map showing land use capability has been prepared on the 1 inch to 1 mile scale, differentiating the seven land classes defined in Table 1 (see previous page). This shows that roughly a fifth of the area is arable land of good quality, a slightly smaller fraction is virtually uncultivable, and the remaining three fifths is cultivable but of indifferent quality.

SPECTROCHEMISTRY

The installation of a multichannel direct reading spectrometer has necessitated a review of the techniques previously employed in the course of the spectrographic determination of trace elements either in concentrates from soil or plant extracts or directly in plant ash, soils or rocks. This is required because the optical characteristics of the direct reader differ appreciably from those of the large quartz spectrographs for which the methods were developed. For instance, because of different relative dispersions, different slit widths and the possibility of inter-order interferences, new analysis or internal standard lines may be necessary. Since the direct reader came into operation, considerable time has been devoted to the study of these factors, and it will shortly be possible to transfer a proportion of the analytical work to it with considerable saving in the time required for the computation of results, particularly as much of this will be carried out on the IBM 1130 computer at the Rowett Research Institute. Facilities for punched tape output from the direct reader, shortly to be added, will reduce the manual operation required still further.

The analytical work carried out for other departments has been very considerably assisted by the appointment of an Experimental Officer to organize and supervise it; in consequence, two of the Scientific Officers have been relieved of this duty and enabled to devote much more time to their research programmes.

In June 1968 Professor Boyd E. Ellis of the Department of Soil Science of Michigan State University, East Lansing, completed a ten-month stay in the department, having studied such problems as the influence of equilibrium pH on the amounts of major and trace element cations extracted by EDTA and the determination of stability constants by the use of ion-exchange resins. During the year, Mrs Celia Maqueda Porras, Estacion Experimental del Zaidin, Granada, Spain, spent eight months studying spectrochemical techniques, particularly atomic absorption methods. Numerous workers from Britain and overseas have visited the department for shorter periods.

Dr V. C. Farmer, on the invitation of the Organizing Committee, presented a paper at the Ninth International Congress of Soil Science in Adelaide, South Australia, and en route visited a number of research laboratories in Malaysia, New Zealand, Australia, Canada and U.S.A. Other members of staff took part in various scientific and technical meetings in the course of the year, and presented several papers to such meetings.

Trace Elements in Soils, Plants and Biological Materials

The study of trace element distribution in plants at different stages of growth, and of soil:plant relationships, has been continued. The findings of some earlier work on cocksfoot at the flowering stage, extended to include additional elements, have now been published[9]. The discussion of trace element behaviour in soils, presented to a National Agricultural Advisory Service Open Conference of Advisory Soil Chemists almost three years ago, is still awaiting publication[54].

Soils and Soil Parent Materials. The examination of nine profiles of podzols with iron pans on different parent materials has been continued. Determinations of total, acetic-acid-soluble and EDTA-extractable trace elements have been made and the assessment of the results is in progress. Preliminary findings indicate that apart from iron the only element whose total content is consistently higher in the pan than in the adjoining horizons is molybdenum, while barium, strontium, gallium, titanium and zirconium appear to be lower in this horizon in most soils. Only in certain instances do acetic-acid-soluble cobalt and nickel behave like iron in showing a higher level in the iron pan. This is also generally relatively higher in EDTA-extractable copper and manganese. Highest values for EDTA-extractable aluminium, chromium, titanium and vanadium usually occur in the horizon above the pan. Upper horizons rich in organic matter generally show a high total lead content and there is a tendency for copper to behave similarly. In these horizons both elements are highly soluble in 0·05M EDTA.

A study has been made of the manganese-rich minerals cryptomelane and lithiophorite, obtained from the Lecht mine near Tomintoul, because of their reported ability to accumulate cobalt. The cryptomelane was found to contain over 100 ppm thallium and the lithiophorite over 2 per cent zinc, but the cobalt content was relatively low. A number of analyses of sewage sludges used in National Agricultural Advisory Service pot and field experiments have been carried out. Determinations of trace element contents of soil profiles obtained in the course of Soil Survey investigations have been continued as in previous years.

Soil Status and Plant Uptake. Analyses, on behalf of Soil Fertility, of samples from their field experimental investigations, and of samples for diagnostic interpretation from areas where trace element disorders are suspected, have continued at a level similar to previous years. The former have been concerned largely with the long-term effects of addition of copper and molybdenum and of the effect of pH on trace element uptake. In one experiment the effect on crop composition of copper and molybdenum application to the soil is still very marked after ten years.

The investigations into the behaviour of lead in plants and the effect of lead contamination of soils on plant uptake have been continued. Preliminary results indicate that lead contamination of soils adjoining roads carrying high density motor traffic does not significantly affect the lead uptake of plants and that the main effect is direct surface contamination of plants by exhaust fumes. The cause of the increases that occur in winter in the lead content of vegetation has been the subject of further study. Cloche-protected herbage has been found to show a smaller increase than unprotected herbage, suggesting that contamination, rather than transfer from the roots, may be involved, but further work on root content is required before the effect can be fully explained.

In collaboration with the National Agricultural Advisory Service, analyses have been carried out on plants grown on soils treated with various sewage sludges, and some correlation obtained for copper, nickel and zinc, but not

for chromium, between above-ground plant content and amount present in the sewage sludge with which the soil was treated.

In an investigation by the Rowett Research Institute on the effect on stock of different forms of grazing, a number of interdental bones have been examined for trace elements: this followed earlier work on other animal organs from the same experiment. Other collaborative work has included the examination of sugar cane samples from South Africa and cotton leaf samples from Northern Nigeria.

Spectrochemical Methods of Analysis

Several important changes have been introduced during the year.

Arc Emission Spectrography. The cathode ray display microphotometer[10] designed in the department is now being used for the evaluation of several elements, such as cobalt and molybdenum, when they are present in concentrates at contents lower than can be measured by non-recording microphotometry. It is also in use for the determination of the total contents of trace elements in soils and rocks.

In the course of work on sewage sludges with abnormally high nickel contents (above 1 per cent) an enhancement of the apparent intensity of the iron internal standard line at 3196·93 A has been found, due to the presence of a coincident weak nickel line, and it has been found necessary either to apply a correction or to use another iron internal standard line for determinations of elements for which the line in question was used.

Flame Emission. A historical review[55] of the development of flame techniques since the first known experiment leading to their introduction was made by a Glasgow scientist in 1752 has been prepared. The introduction of novel gas mixtures, associated with new designs of burners, has opened the door to possible advances in flame emission techniques. Considerable promise has been shown by the excess fuel nitrous-oxide:butane flame, using 5 cm or 10 cm Techtron slot- or Meker-type burners for the determination of calcium, particularly in respect of freedom from phosphate interference. The use of separated-flames employing air:acetylene or nitrous-oxide:acetylene for the determination of molybdenum in soil extracts is being investigated.

Atomic Absorption and Fluorescence. The instrument under construction at the time of the preceding report and designed principally for atomic absorption and atomic fluorescence analyses, but also capable of being employed for flame emission work, is now in operation. A preliminary survey of its capabilities indicates atomic fluorescence detection limits of about 0·02 ppm for zinc and cadmium, using Phillips Spectrum Lamps as irradiating line sources and 10 cm slot-type or Meker-type burners. Detection limits obtained with an AEG XBO 450 xenon-mercury arc lamp as a continuous irradiating source include magnesium 0·3 ppm, copper 2 ppm, chromium 10 ppm, thallium 10 ppm and manganese 1 ppm. Slight modifications to the instrumental design should enable these levels to be improved, but at their present level they might well prove useful for some applications. Considerable improvement should be obtainable by the use of microwave-excited electrodeless

discharge lamps as irradiating source, a modification that is at present being introduced. The use of the xenon arc for multi-element analysis will inevitably be restricted by its low emission at wavelengths below 2500 A. A report on this instrument has been given to a joint meeting of the Atomic Absorption Spectroscopy Group and the Scottish Section of the Society for Analytical Chemistry. It has been used for the development of a variety of burners, including a 10 cm multihole air:butane burner for atomic absorption and fluorescence as well as separated-flame burners for air:acetylene and nitrous-oxide:acetylene flames.

A Techtron AA4 Atomic Absorption Spectrophotometer, with flame emission attachment, has recently been installed and, initially, its application to the routine determination of zinc and copper in EDTA extracts of soils is being studied. Full details of the atomic absorption method developed for the determination of cobalt in soil extracts, without the use of chemical concentration, and covering the range of 0·05 to 2·5 ppm acetic-acid-extractable cobalt in soils have now been published[11]. In this technique precautions are taken to eliminate interference effects due to the presence of calcium and aluminium in the soil extracts.

Direct Photometry. During the latter part of the year considerable effort has gone into the introduction into analytical service of the Hilger and Watts E 789 3-metre grating Polychromator, which is to be used for arc emission work, as distinct from the porous-cup solution-spark and triggered alternating-current arc modes of excitation employed with the small and medium direct readers whose application has been described in earlier reports. These continue to be used, as they serve different purposes to those envisaged for the new and much larger direct reader. The latter is a 49 analysis-channel instrument, four of the channels being reserved for background monitoring and the others for analysis or internal standard elements. Provision has been included to enable the integration of some of the channels to be stopped at a pre-selected time during the burn. This facility can be used with the more volatile elements to prevent background levels building up after the emission of the lines of such elements has been completed. Because of the high intensities available by arc excitation, it has been found necessary to reduce the photomultiplier outputs from a number of channels by the use of appropriate optical filters or by the introduction of additional resistors into the high voltage supplies. For some elements it has proved necessary to incorporate filters excluding either first or second order interferences. The instrument incorporates 63 measuring channels, so that, for selected elements, measurements are available at extended concentration ranges, so avoiding the necessity for re-arcing at a different sensitivity setting.

A further modification has been the incorporation of a double exit slit for the potassium channel at 7665 A. This is the only sensitive potassium line but it suffers seriously from self-reversal. This has been overcome by measuring the intensity on the wings of the rather broad line by means of two slits spaced at equal distances from the line centre. This arrangement reduces the effect of slight instrumental drift, which would be serious if a

single exit slit were employed on one side of the line. Details of this modification will shortly be published[56].

Absorption Spectrometry of Soil Constituents

Infrared studies play a significant role in many fields of clay science. Such studies, however, are widely scattered in the scientific literature, often in specialist journals, and are not easily accessible to research workers with other specialist interests. To make these results more widely available, a review of the contributions of infrared spectroscopy to clay minerals studies has been prepared[57]; a brief assessment of these contributions appears also in a general review of techniques used in soil-clay mineralogy[38]. To assist those who may wish to apply infrared techniques in their own field of study, the methods in use at the Institute, with illustrations of their application, were described at the Ninth International Congress of Soil Science[12]. A more comprehensive treatment of the use of infrared spectroscopy in characterizing soil minerals, covering both theoretical and practical aspects, still awaits publication[58]. Work described in last year's report on the correlation of lattice hydroxyl vibrational frequencies with the octahedral occupancy of layer silicates, and on the application of these results to the study of oxidative weathering of biotites, has now been published[13].

Infrared studies on the interactions of montmorillonite with several herbicides, including 3-aminotriazole and s-triazine derivatives, were made by a member of the department on study leave in U.S.A. The published results[78, 79, 80] show that, in addition to the protonated cation formation generally observed when weak bases are adsorbed on montmorillonite, a hydrolytic reaction which normally requires strongly acid conditions occurs when the triazine derivatives are adsorbed on air-dry base-saturated clays.

A study, in collaboration with Pedology, of the adsorption of benzoic acid on silica, alumina, and calcined kaolinite has led to the recognition of purified diatomite as a preferred inert diluent for differential thermal investigation of organic materials[5]. Work is continuing on amorphous materials in soils, and on the surface reactions of vermiculite. A collaborative study with Pedology of imogolite, a constituent of volcanic ash soils which is often classed with the amorphous allophanes, has shown it to have a more ordered structure with a distinctive infrared pattern.

Inorganic pyrophosphate has been identified in an alkaline extract of soil[59] in the course of a co-operative investigation with Soil Fertility aimed at characterizing the organic phosphorus constituents of soil. Collaborations with Microbiology and Biochemistry on the lysis of fungal cell walls have continued. Infrared spectra have been instrumental in the identification of an $\alpha(1\rightarrow3)$ glucan as a component of certain soil yeasts[14, 60], and in the identification of a condensed polyphosphate anion which is linked to chitosan in the cell wall of *Mucor* species[15].

A new Grubb Parsons Spectromaster infrared spectrometer, giving improved resolution and an extended frequency coverage, has come into service during the year. The demands are such that the older instrument, which has been in service for fourteen years, continues to handle the majority of organic samples. The new spectrometer is used principally for mineral samples, as they require the additional facilities which this instrument provides.

BIOCHEMISTRY

The death of Dr R. I. Morrison on 23rd November 1967 marked the end of an important stage in the study of soil organic matter at the Institute. After the war he and the late R. B. Duff, both talented organic chemists already experienced in research, were persuaded to enter this field, and using the improved analytical techniques then being developed were able to show that the nature of humus substances presented legitimate problems for the organic chemist. As a result of their efforts, and those of equally small groups of pioneers elsewhere, this attitude is now taken for granted, and research on soils goes on within the walls of University Chemistry Departments where the old prejudices against protoplasm and other unmanageable materials may not have died, but are certainly fading away.

Robert Ian Morrison was born in 1915 at Kirn in Argyllshire and educated at Inverness Royal Academy. He went to St Andrew's University in 1934 with a Harkness Exhibition and obtained his B.Sc. with first-class honours in Chemistry in 1938. As subsidiary subjects he took physiology and biochemistry and was placed first in both examinations, showing already a bias towards the biological side which persisted throughout his career. With a Carnegie Research Scholarship he worked under Professor John Read for his Ph.D. (received in 1943) on the effect of stereochemistry on some reaction velocities. He was at this time a keen amateur ornithologist, and also found time to be President of the Students' Representative Council.

From 1941 to 1948 he was employed by I.C.I. (Explosives) Ltd., in Ayrshire, studying cellulose ethers, polyvinyl esters, and the use of micro-organisms to produce various substances, including solvents and antibiotics. Some of the results are incorporated in seven papers published between 1946 and 1949.

Joining the Department of Soil Organic Matter in 1948, he began an investigation of the organic nitrogen of soils. Amino acids constitute about a third of this nitrogen, and he found that acid hydrolysates of soils contained all the amino acids commonly found in proteins, with the addition of one, diaminopimelic acid, peculiar to bacteria. No important differences were found between soils of different types. His results duplicated those of J. M. Bremner at Rothamsted and were never published, but the application of the techniques developed for soil to fresh plant material led to the first demonstration that pipecolinic acid is a normal constituent of plants[84], and was the basis for collaborative work on the free amino acids of chlorotic leaves[85].

His notebooks show that he gave much thought to the nature of humic acid, an intractable problem still far from solved. By applying the technique of oxidation with alkaline nitrobenzene, first developed for the study of lignin, he was able to show that humic acids would yield small but significant amounts of breakdown products related to lignin. Further, humic acids from various sources showed differences in these breakdown products that could be correlated with differences between the lignins of the plants which dominated the soils in question. These experiments[86] were the first con-

vincing demonstration of a direct relation between humic acids and lignin, previous studies along the same lines at Rothamsted and in the United States having failed to overcome the considerable technical difficulties. Some improvements in technique[87] raised the yields of identified products to about 5 per cent of the carbon of the humic acids, and to as much as 10 per cent in certain fractions of them.

Further, as yet unpublished, work on the permanganate oxidation of native and methylated humic acids was the subject of invited papers given to the Society of Chemical Industry in 1964[88] and the Phytochemical Group in 1965. This work required the development of methods for separating and identifying organic acids, and these were also applied to living plant material[85], leading to the identification of D-glyceric acid as a major constituent of the broad bean[89].

Gas-liquid chromatography proved particularly useful for the separation of the aromatic oxidation products, and his experience of the technique led to him to use it to investigate the wax fraction of soils. Although an appreciable proportion (5 per cent) of the soil carbon falls into this category, practically nothing had been done to characterize it. The first results[90] indicated that the highly complex mixture of substances present originates mainly in plants. Once again it was possible to report the finding of a group of substances, long chain methylketones, in nature for the first time[91]. Following these publications, Dr Morrison was invited to contribute the chapter on Soil Lipids to a volume on Organic Geochemistry[61].

The usefulness of organic chemical techniques in many aspects of the Institute's work is illustrated by his work with Dr W. Myskow[92] on the products of decomposition of leguminous roots in sand, by his assistance to Microbiology (biological degradation of lignin) and to Soil Survey (mobilization of iron by extracts of pine needles[93]), but a collaboration conferring notable benefit on both sides was that with Spectrochemistry[94, 95, 96], in which humic acids from sphagnum and phragmites peats were examined by a combination of chemical and spectroscopic techniques.

Latterly infrared spectroscopy has provided a valuable means of characterizing degradation products, and at the time of his death he was using the technique of preparative gas chromatography, which yields quantities large enough for spectroscopic examination. The power of these and other modern analytical techniques can be appreciated only in comparison with what was available in 1948. For example, if the work on amino acids from soil were to be repeated now, it would be carried out by a fully automated procedure, much faster and much more accurately. With such powerful analytical tools in their hands organic chemists today can feel that they will soon understand a great deal more about the nature of soil organic matter. In 1948 things were very different and it took considerable courage to risk one's career in such doubtful terrain. It is much to the credit of Dr Morrison and others like him that they were willing to take this step.

As sometimes happens, Dr Morrison's intellectual abilities were coupled with an enjoyment of manual work, and he was more often than not to be

found working at the bench. On the day he died he had been practising golf swings in the Institute grounds after his lunch. Trivial in itself, this added one last touch to the picture he presented of one fully adapted to his chosen environment. Unhurried in manner and quiet spoken, he was one to whom others turned unhesitatingly for help and advice. Undoubtedly he found many aspects of his life at the Macaulay congenial, but we must still count ourselves fortunate that he chose to work here, when he might so easily have made a more spectacular career elsewhere.

Research Developments

During the year under review, work has continued on soil polysaccharides and humic acids. When radioactive glucose or starch is incubated with soil about a fifth of the radioactivity has been shown to be incorporated in the soil organic matter, chiefly in the polysaccharide, but hardly any pentose seems to be formed. Efforts to find an extraction procedure that would selectively remove the newly-formed material have not so far been successful.

Fractionation of humic acid preparations by gel filtration has shown that only material of lower molecular weight stimulates invertase synthesis in disks of root tissue from beet. An examination of infrared spectra did not indicate that any particular functional group in natural and synthetic humic acids was concerned in the stimulatory effect.

The $\alpha(1\rightarrow3)$ glucan found in the walls of two soil yeasts has been shown to be identical with a glucan described by Dutch workers in a number of other fungi[14]. The walls of baker's yeast, long the subject of chemical investigations, have been found to contain a hitherto unsuspected $\beta(1\rightarrow6)$ glucan component. These two observations emphasize the complexity of cell wall structures, even where only a single sugar component is involved; correspondingly complex enzyme systems must have to be elaborated by the soil organisms that decompose them.

Publications

A number of papers, resulting from collaborative work with Microbiology, Spectrochemistry and Plant Physiology, have been submitted for publication. These deal with cell wall lysis by soil micro-organisms[14, 15, 60] and the invertase activity of storage tissue disks[16, 17, 62, 63]. Dr Cheshire was invited to contribute a paper to a Biochemical Society colloquium on soil biochemistry in Bangor in June 1968; contributions to other symposia have been published[18, 64]. More of the research on humic acid chemistry done by Dr Cheshire while seconded to work with Professor Haworth in Sheffield has been published[81].

PLANT PHYSIOLOGY

Research into the mineral nutrition of plants has continued. Many aspects of plant growth are of general interest, for instance, the effect of bacterial contamination on salt absorption by plants, and various aspects of the biochemistry of plants are gaining importance in other fields. Availability of trace elements such as iron and zinc to man and animals places emphasis on the mode of combination of these elements in plants.

Copper Deficiency in Oats

A further series of experiments has been conducted on copper deficiency occurring in oats grown in the glasshouse on peat of low copper content. Provided iron is readily available, copper deficiency results in plants of a high iron content. This iron appears to be mostly bound in the cytoplasm and electron micrographs have shown electron dense material, presumably iron, in the leaves of copper deficient oat plants. This material somewhat resembles haemosiderin in the tissues of the animal. Similar electron micrograph pictures have been obtained from a sphagnum moss of high iron content.

The deleterious effect of nitrogen seems to be closely associated with the increase in the iron content which occurs when nitrogen is added, but there is little evidence that this effect is due to increased protein formation, since copper deficient oat plants have a high protein content. It would appear that under conditions of copper deficiency protein synthesis continues, but that there is an interference in dry matter production. More iron appears to be bound in the cytoplasm when nitrogen is added as the ammonium ion as compared with nitrate. A greater proportion of the iron of the plant can be squeezed from previously frozen material when a copper amendment has been made to the soil.

Little relationship has been found between the phosphorus and iron contents of copper deficient oat plants as opposed to healthy plants, although their copper contents differ greatly. Addition of phosphorus aggravates copper deficiency, but there is no decrease in the availability of copper in peat as measured by EDTA extraction. The effects of nitrogen and phosphorus are therefore physiological effects within the plant. Evidence has been obtained that the microbial effect on copper availability is negligible, as measurements of microbial populations showed very small numbers and little variation with treatment.

There is evidence that iron exists as phytate in the aleurone layer of the wheat grain, and supporting evidence for this has been obtained from autoradiographs. A study of phytic acid in the potato tuber has shown a polar distribution from stem end to rose end similar to that of potassium. On sprouting of the tuber, the phytic acid concentration is reduced, but none of the inositol phosphate intermediates which appear when maize germinates have been found. An account of the above work was given at the Welsh Soils Discussion Group at Aberystwyth in March[64].

Ion Uptake and Related Studies with Storage Tissue Cells

Direct measurement of electrical potential in single cells of potato tuber confirmed the validity of a straightforward electrochemical theory used to explain the absorption isotherms for chloride in the presence of both constant and varying concentrations of potassium. This study has now been extended to an examination of influx and efflux of chloride in circumstances where ion transport is under the influence of metabolic factors in addition to the electrochemical ones operating in fresh cut tissue and in aged tissue at low temperature. First results indicate that chloride efflux remains small in disks aged in KCl solutions, and that chloride absorption is an active process. Analysis of the efflux data, to provide evidence of the site of this active uptake within the cell, along the lines followed in the earlier study of K^+ fluxes in pea epicotyls, is at present in hand. An account of work on pea epicotyls, carried out in the Department of Botany, Washington State University, during the previous year, has now been published[82].

The anomaly whereby disks of potato tuber show evidence of oxygen deficiency although the whole tuber is never deficient, has been further investigated[19]. Various possible explanations of this effect have been examined and the evidence obtained indicates that the diffusion coefficient of oxygen in the disks is much less than that in the tuber as a result of water injection of the intercellular spaces caused by slicing. This study emphasizes the necessity, when working with storage tissue slices, of selecting conditions such that oxygen tension is not a rate-limiting factor.

The cell-free protein synthesizing system from beet disks reported last year has now been further characterized[69]. In particular, it has been shown that the low phenylalanine incorporating activity of microsomes isolated from freshly cut disks can be increased ninefold by the addition of polyuridylic acid, suggesting that the low activity of these microsomes may be due to a lack of messenger RNA. The results obtained from this work (carried out jointly with the Department of Botany, University of Aberdeen) support the concept that slicing storage tissue initiates a massive gene activation leading to the synthesis of new enzymes. The best documented example of this is the development of invertase activity in beet disks and collaborative work on this aspect continues with Biochemistry. Two papers referred to in last year's report have been published[16, 17]. A new study on the ion uptake properties of germinating pea roots in relation to growth is being carried out jointly with Biochemistry.

Radioactivity

Tritiated water has been used in collaboration with Pedology (Peat and Forest Soils) to trace water movement in a peat experiment drained to different levels. This use of tritiated water is showing encouraging results and should be a useful method for the future. Work using radioactive tracers in other branches of the work of the Institute is being continued. Wheat grain labelled with radioiron and ryegrass labelled with radiozinc have been produced in considerable quantities at the request of other organizations for nutrition studies.

MICROBIOLOGY

In general, the work of the department continues to be concerned with (a) the inter-relationships between soil micro-organisms and the roots of higher plants, and (b) the role of soil micro-organisms in the decomposition of organic matter in soils. Whenever possible, emphasis is placed on physiological aspects, and consequently collaborative work with other departments within the Institute is an important feature of many of the investigations.

During the year members of staff attended a conference on the soil ecosystem at the School of Agriculture of Nottingham University, the annual meeting of the British section of the Society of Protozoologists at Bristol, and the symposium on root growth held in Nottingham.

Rhizosphere Studies

Further trials with the apparatus for growing axenic (micro-organism free) plants have resulted in several improvements. It is now possible to grow some plants to the fruiting stage with the shoots and leaves exposed to the atmosphere, while retaining controlled microbiological conditions in the medium surrounding the roots. Four soil amoebae and four rhizosphere bacteria are being used in the initial studies of the interrelationships of agricultural crop plants and rhizosphere micro-organisms. The bacteria, which were selected for edibility by the protozoa and for their morphology, include *Arthrobacter* spp., *Bacillus* sp., and an unidentified short gram-negative fluorescent rod.

A comparison of population estimates of mixed cultures of a bacterium (*Aerobacter aerogenes*) and a common soil amoeba (*Naegleria* sp.) obtained with a borrowed Coulter counter and by microscopic counting methods, showed that large population changes of amoebae and bacteria are more rapidly detected with a Coulter counter than by existing microscopical methods. The percentage coefficients of variation were lower for individual Coulter counts than for microscopic counts.

Microbial Decomposition of Organic Phosphates

An account of work on the microbial decomposition of myo-inositol hexaphosphate in sand and soil, and the effects of clay minerals and various cations on the process, has been accepted for publication[70].

The study of nucleic acid degradation by soil micro-organisms has continued. It has been shown that nucleic acids are rapidly broken down both in sand inoculated with a suspension of soil micro-organisms and in soil itself. Inorganic orthophosphate accumulates and the microbial population rapidly multiplies. The addition of montmorillonite to the sand cultures increased the amount of inorganic orthophosphate released, but caused the development of a smaller population of micro-organisms. A detailed study of the adsorption of nucleic acids by montmorillonite has been started in collaboration with Pedology. Preliminary results indicate that the adsorption of nucleic acids is similar in many respects to that of proteins.

Lignin Decomposition

The fine structure of an unusual soil fungus, *Acremoniella* sp., isolated during studies on decomposition of lignin-related substances, has been examined with the aid of the transmission electron microscope[20]. This fungus proved to be a new species (*A. velata*) and a note[21] recording it has been published in association with Dr A. H. S. Onions of the Commonwealth Mycological Institute, Kew.

Ultrastructure of Fungi

The importance of the scanning electron microscope for examining directly and in great detail the fine structure of fungal spore surfaces has been described[22, 23]. A selection of these Stereoscan electron micrographs was exhibited in June at an International Conference on Microscopy, organized by the McCrone Research Institute, in Chicago. All the specimens were examined by the Cambridge Instrument Company in their microscope at Chesterton, Cambridge.

Lytic Soil Micro-organisms

Growth experiments with the non-fruiting myxobacterium *Cytophaga johnsonii* have been carried out on the walls of a variety of fungi. It was found that while the myxobacterium could completely lyse the walls of some fungi and partially lyse those of others, some appeared to be resistant. The myxobacterium, which is also unable to utilize mannan and cellulose, was found to attack laminarin, lutean, starch and colloidal chitin. No laminarinase activity was found in the culture fluids after growth on the latter two substrates. The myxobacterium could also utilize laminaribiose and gentiobiose as growth substrates. In incubation experiments with culture fluids from growth of the myxobacterium on the walls of *Saccharomyces cerevisae* these dimers appeared as intermediates during the breakdown of laminarin and lutean respectively.

When certain fungal walls, for example, of *Fusarium culmorum*, were digested with acid followed by alkali, the residue, which still retained the shape of the walls, was shown by infrared analysis to give an excellent chitin spectrum. This material was readily attacked by *C. johnsonii* in growth experiments.

A paper[24] describing a new enrichment technique devised to follow some of the biochemical processes of lysis in soil and to isolate lytic micro-organisms has now been published. A report of the collaborative work on the ultrastructure and biochemical changes that occur in cell walls of *Mucor ramannianus* during lysis by a soil *Streptomyces* sp. has also appeared[15]. An account of a similar study on two soil yeasts, *Cryptococcus albidus* and *Cryptococcus terreus*, not previously recorded in British soils, has been submitted for publication[60]. One interesting feature of the walls of these yeasts was the presence of $\alpha(1\rightarrow3)$ glucan. This component was found to fluctuate in amount according to the duration of the growth experiments and to the medium employed. A joint note[14] on the presence of $\alpha(1\rightarrow3)$ glucan in these yeasts (and another yeast, *Schizosaccharomyces pombe*) has been published.

One important aspect of the above work on lytic organisms concerns the feasibility of using such organisms to control plant pathogenic fungi. In preliminary studies on *Sclerotinia sclerotiorum*, a serious pathogen on many agricultural crops, a fungus has been found to attack the sclerotia (overwintering form of *S. sclerotiorum*) and bring about almost complete decay of this structure. It is of interest that the parasitic fungus was found inside the sclerotia collected from the field. A similar fungus was isolated by another research worker, about ten years ago, in sclerotia of *S. trifoliorum* collected from soil in Cambridge. Two other instances of the occurrence of this organism have been recorded, one in the United States in 1947 and the other in Poland in 1960. A survey of its occurrence, and that of other parasitic fungi, in sclerotia recovered from Scottish soils is being made. The manner in which such parasitic fungi bring about lysis of the sclerotial tissue is now under investigation.

Localized Activity of Soil Micro-organisms

A paper[25] describing the pellet and aggregate techniques developed in this department has been published in the Transactions of the Ninth International Congress of Soil Science held in Adelaide, Australia. The authors are indebted to Dr V. C. Farmer for reading the paper at the Congress on their behalf.

SOIL FERTILITY

The overall research approach remains the concurrent development and integration of field, pot and laboratory studies. The field programme, comprising about 55 experiments every year, is based on a selection of contrasting soil series mapped in the Soil Survey of Scotland. This is made possible by the much valued co-operation of farmers. The chief purpose is to characterize quantitatively the performance of the various series and individual sites in terms of the yields, mineral composition and fertilizer requirements of the main agricultural crops, to provide the basis for inorganic-, organic- and physico-chemical laboratory studies on soil-nutrient-plant relationships. These in turn are designed to clarify the critical soil properties, processes and conditions which regulate nutrient supply and underlie the influences of pedological factors, especially parent material and drainage. In these respects the pot experiments, with their more controlled growth conditions, are an essential supplement to the field investigations. The latter, however, also provide information of more direct practical application on liming and manuring, and form the basis for calibrating and improving laboratory methods for evaluating nutrient status.

The soil advisory work, carried out in collaboration with the North of Scotland College of Agriculture, has the reciprocal advantages of providing a channel for translating research findings into practice and drawing attention to problems requiring investigation. Practical applications of experimental findings are also furthered by contributions to the agricultural press and talks to various agricultural and horticultural organizations.

Representation has been maintained on the Technical Committee on Soil Fertility of the Agricultural Research Council, on the Grassland Committee of the Scottish Agricultural Improvement Council, and on the Scottish Subcommittee of the Sugar Beet Research and Education Committee. Similarly, normal contacts and collaboration have been continued with the Rowett Institute, the Hill Farming Research Organization, and other research and advisory bodies.

At the invitation of the organizing committee, Dr E. G. Williams gave a lecture on the principles and prospects of chemical soil testing at a meeting in Arnhem, Netherlands, to celebrate the fortieth anniversary of the foundation of the Laboratory for Soil and Crop Testing at Oosterbeek. The opportunity was taken to visit the Centre of Agricultural Science at Wageningen and the Institute of Soil Fertility at Groningen. Dr J. W. S. Reith attended the Ninth International Congress of Soil Science in Adelaide from 6th to 16th August 1968, and participated in associated tours from Canberra to Adelaide and Adelaide to Darwin. On the way to Australia visits were made to several experimental stations and University departments of agronomy and soil science in U.S.A., Canada and New Zealand, and the tour as a whole provided extensive and valuable information on research and advisory activities in relation to contrasting agricultural conditions and problems. Various members of staff have participated in meetings, conferences and

committees. These include an open conference on the residual value of applied nutrients, organized by the soil scientists of the National Agricultural Advisory Service, a meeting on soil analyses and fertilizer recommendations held by the Agriculture Group of the Society of Chemical Industry on March 19th, and the symposium on ecological aspects of the mineral nutrition of plants held by the British Ecological Society at the University of Sheffield from 2nd to 5th April 1968. Joint papers on the residual effects of phosphate[71] and the prediction of phosphate requirements of swedes[72], respectively, were presented at the first two conferences. Dr Williams and Dr Reith were invited to serve on the organizing committee of the symposium on hill-land productivity held in Aberdeen from 30th June to 4th July 1968. A review of physicochemical aspects of soil research has been contributed to the 1967 *Reports on the Progress of Applied Chemistry*[73].

Advisory activities together with field and pot experiments entail every year analyses on about 15,000 soil samples and 5,000 crop samples. To improve the efficiency of the nitrogen and phosphorus estimations involved two trains of Technicon Autoanalyser equipment have been acquired and are being brought into operation. A Hewlett Packard, Model 185, CHN Analyser which requires only 1 to 10 mg sample, has also been obtained. This is suitable for determining C and N in soils and N in plant material, but its main value is in analysing small quantities of soil components isolated by chromatographic methods.

Effects of Fertilizers on Crop Yields and Composition. Field work and laboratory analyses of soil and crop samples have been continued to measure the effects of N, P and K dressings on the yield and mineral composition of potatoes, roots and cereals, and on soil nutrient levels. The field experiments use a central composite design, and the sites are chosen in consultation with Soil Survey to ensure that they are representative of the selected soil series. Attention continues to be given also to methods of applying fertilizers, and the effects of broadcast and combine drill applications of phosphate on cereals are being tested at row widths of 3·5 and 7 inches.

A paper on the effects of magnesium dressings on soils and crops, presented in 1964 at the Eighth International Congress of Soil Science in Bucharest, has now appeared[27]. Long term studies are being continued on the effects of various magnesium supplements, with particular reference to the influences of other nutrients, especially K, on the magnesium content of crops and herbage and on the ratio of Mg to other cations.

Trace Elements. The paper on copper deficiency summarized in last year's report has now been published[28]. Other investigations have been continued in collaboration with Spectrochemistry, including further pot work on the uptake of added lead by cocksfoot and examination of the trace element contents of mixed herbage and its constituent species from a field experiment.

Laboratory Evaluation of Nutrient Status. A general interpretation of the main principles and factors which underlie laboratory methods for evaluat-

ing the nutrient status of soils has been outlined in the text of a lecture, mentioned earlier, on the principles and prospects of chemical soil testing[26]. The treatment is based on consideration of (1) the quantity, intensity, buffer and rate aspects of nutrient status, especially the first two, (2) the forms of occurrence and properties of individual nutrients, including effects of soil conditions and climatic factors on solubility and availability, (3) some general crop characteristics, especially responsiveness, placement effects, growth period and root development, and (4) the reagent properties and experimental factors which determine the extracting power of laboratory methods and hence the intensity/quantity bias of the nutrient values. The varying implications of these factors in terms of laboratory requirements are discussed for N, P, S and K. In this way much can be done to rationalize the selection of methods not only for individual nutrients but also for different soil, crop and climatic conditions, and to define specific adjustments and corrections for disruptive variations in critical soil properties. The practical usefulness of laboratory values, however, is determined by their correlation with crop performance in the field, and a joint paper[72] with Statistics on the effectiveness of a selection of conventional methods in predicting phosphate requirements of swedes has been submitted for publication.

Yields from 199 field experiments extending over 15 seasons and covering six soil groups in north-east Scotland were used to calculate correlation coefficients between the response of swedes to 120 lb P_2O_5 per acre and readily soluble phosphate values for the soils determined by the following six methods: 2·5 per cent acetic acid, calcium lactate + HCl (Egner), ammonium fluoride + HCl (Bray), 0·002N H_2SO_4 (Truog), 0·5M $NaHCO_3$ (Olsen) and acetic acid + sodium acetate (Morgan). There are marked effects of soil parent material and drainage on the correlations, which range from $-0{\cdot}05$ to $-0{\cdot}74$. The Morgan and $NaHCO_3$ methods are inferior to the others, with the lactate method generally the best. When the yields are averaged for appropriately selected ranges of soil phosphate values there are clear relationships, showing increasing yield in the absence of applied phosphate, and decreasing response, as the soil status rises. Even so, there is no indication of any convincing advantage from using dressings adjusted according to the soil values compared with a standard rate of 120 lb P_2O_5 per acre, despite the fact that this gave about 30/– per acre less profit than from optimal dressings calculated for individual centres. The latter were obtained by fitting a Mitscherlich equation to the yields. Neither use of the logarithms of the soil phosphate values nor inclusion of other soil properties in multiple regressions gave any appreciable improvement in response predictions. Apart from the fact that the optimal dressings are not well defined, the main reason for the generally rather poor relationships appears to be variation in site characteristics and agricultural factors, rather than soil chemical and textural properties. It seems that the main practical usefulness of the soil phosphate values is not in precise prediction of most profitable dressings but in guiding rotational manuring and ensuring adequate dressings for sensitive crops by occasional monitoring of the phosphate status.

In completion of a study started in the Faculty of Agriculture of Ahmadu Bello University, laboratory work has also been done on the phosphate status of some Nigerian soils, including determinations of exchangeable P (E values), resin-extractable P, P in saturated water extracts, and total, inorganic and organic P. For these poorly buffered soils of low P content, the yield and P uptake of Rhodes grass in pot cultures are determined more by the quantity than the intensity of the phosphate supply, but the resin-extractable P, a composite parameter, was the best single criterion of their P status. An account of this work is being prepared for publication.

Inorganic Phosphate. In addition to the studies on the evaluation of phosphate status, mentioned above, work has continued on other aspects of the inorganic phosphate relationships of different soil series. Various laboratory determinations and concepts, such as retention capacity, degree of saturation and solvent fractionations, which have been found valuable in characterizing agricultural topsoils, are being applied to a comprehensive selection of profiles provided by Soil Survey, to examine chemical relationships and assess the potential contributions of subsoils to crops. Major attention in the field and pot experiments, especially the latter, has again been concentrated on the effects of extremely fine grinding, down to less than 1μ, with and without sulphur, on the availability of rock phosphates.

As indicated earlier, a paper on the residual effects of phosphate and the relative effectiveness of annual and rotational dressings has been accepted for publication.[71] Yields of oats and roots from 27 field experiments have been used to evaluate the efficiency of residues and of dressings applied at different times. For swedes and turnips, superphosphate broadcast on ploughed land in spring, so that it became mixed with several inches of soil by the subsequent cultivations, was only about 50 per cent as effective as dressings applied in the normal way after cultivating, which are not dispersed and become concentrated when the land is ridged prior to seeding. This emphasizes the importance of correct timing of fresh dressings in relation to ploughing and cultivations, to avoid dispersion and ensure optimal positional availability. The drastic effects of chemical fixation, as distinct from positional factors, however, are strikingly demonstrated by the fact that with increasing period of contact between the phosphate and the soil the relative efficiency on roots decreased exponentially to about 33 per cent for autumn dressings, about 25 per cent for one year old residues of dressings applied to the preceding oat crop, and only about 3 per cent for seven-year old residues. It made no difference whether the autumn dressings, or those to the previous crop, were applied before or after ploughing. Even over-winter contact was sufficient to make the inherent solubility sufficiently low to become the dominant factor, so that the effectiveness was no longer appreciably affected by positional differences. Over-winter contact also reduced the efficiency on oats, by 30-40 per cent.

Under very sensitive conditions in pots the residual effect after one year was clearly better for placed phosphate than for dressings distributed through-

out the pots, even when the placement layer was dispersed by emptying and mixing the contents before the second cropping. This demonstrates the importance of degree of saturation, both locally and in the soil as a whole, as a major factor governing phosphate solubility and availability.

On responsive soils, single heavy rotational dressings applied to oats preceding roots were usually inferior to much smaller annual applications supplying the same cumulative total phosphate. The heavy single dressings had advantages in the first year on the oats, but the fresh phosphate of the annual dressings gave them marked superiority not only on root crops in the second year but also on the following oats in the third year. The residues, however, adequately met the requirements of the more quantity-dependent hay in the fourth year. In accordance with a traditional practice, the most effective utilization of a single dressing in this rotation would be to apply it to the root crops, thereby avoiding the main loss and minimizing disadvantages on the other crops.

The results, however, emphasize that the best way to build up the soil phosphate status is by applying correctly timed dressings to individual crops according to their particular needs, with appropriate use of placement methods and full exploitation of cultivation and ploughing operations to obtain maximum concentration and optimal position.

Organic Phosphorus. As mentioned in recent reports chapters on soil organic phosphorus[74] and organic sulphur[75] have been prepared for an *Encyclopedia of Soil Science*. Three papers mentioned in last year's report have now appeared, covering the determination of inositol hexaphosphate in soils[29], the measurement of total organic phosphorus in a number of Canadian soil profiles[30], and the amounts of inositol hexa- and penta-phosphate in the latter soils[31].

An account has also been published of the nature of the inositol penta- and hexa-phosphates in a number of contrasting Canadian and Scottish soils[32]. Esters of *myo-* and *scyllo*-inositol together make up more than 90 per cent of the total, the remainder consisting of esters of *dl-* and *neo*-inositol. The ratio of hexaphosphates to pentaphosphates ranges from 0·9 to 2·4 in the Canadian soils, compared with 3·0 to 4·3 in the Scottish soils. No consistent relationship has been noted between the constitution of this inositol phosphate fraction and any other soil property.

Estimations of inositol penta- plus hexa-phosphates have also been made on a selection of Australian soils. The amounts vary widely, ranging from 1 to 356 ppm P and accounting for 0·4 to 38 per cent of the total organic phosphorus. In undisturbed soil profiles the esters tend to be concentrated near the surface, and increase when organic matter accumulates under leguminous pasture. They decrease when organic matter is lost from the soils as a result of cultivation, but the relative decrease is much smaller than that of the total soil organic phosphorus, showing that inositol phosphates are more stable than the other phosphate esters. This work was carried out in the Soil Fertility Section of the Division of Plant Industry, C.S.I.R.O., Canberra, Australia, and an account has been published[83].

During the isolation of organic phosphorus compounds by ion-exchange chromatography a fraction has been obtained with chromatographic properties matching those of inorganic pyrophosphate. It was purified and precipitated as a barium salt which was shown to be barium pyrophosphate by infrared spectrophotometry. Pyrophosphate does not seem to have been previously detected in soil. It was found in an alkali extract and may have been present in the soil in either inorganic or organic form. A joint paper with Spectrochemistry has been accepted for publication[59].

Soil Acidity. A comprehensive investigation into the chemistry of acidity and buffering mechanisms in Scottish soils has been started. Methods for extracting exchangeable aluminium from acid soils have been compared, and a centrifuge procedure using normal ammonium chloride as extractant seems to be the most efficient and convenient. A number of methods for the colorimetric estimation of aluminium have also been examined; that using solochrome cyanine seems the most reliable, and is sufficiently sensitive for most purposes.

The effects of experimental variables on the measurement of soil pH and the acidity indices that can be derived from it, have been studied. The most troublesome effect is the rise in pH of calcium chloride extracts of some soils. This is most evident with moderately acidic topsoils, and appears to be due to the hydrolysis of a component displaced from the soil during the extraction procedure. For reproducible measurements, pH values in dilute salt suspensions of these soils should be read soon after one hour's gentle shaking. Provided this is done, the concentration of salt in the extract and the ratio of soil to solution do not affect values of the lime potential ($pH - \frac{1}{2}\ pCa$) for neutral and moderately acidic soils, and this function is therefore a unique index of the intensity of acidity of these soils. In the case of strongly acidic soils, where the exchange complex is dominated by aluminium, the aluminium hydroxide potential ($pH - \frac{1}{3}\ pAl$) remains constant, while the lime potential varies due to exchange between calcium and aluminium. An equilibrium value for the lime potential can be interpolated from the adsorption isotherm for the point when the calcium exchange is zero. This interpolated lime potential is probably the preferable acidity index for these soils as it allows a simple comparison between soils of all groups. An account of this work is being prepared for publication.

Cation-exchange Properties and Mineral Composition of Plants. Comprehensive data for a wide range of plant materials gathered over several seasons are being statistically evaluated. The main questions are differential distribution of cations between roots and leaves, and comparisons between monocot and dicot plants, within genera as well as tribes, but several other possible relationships are also being examined.

A further series of small field experiments, covering oats, barley, potatoes and beans, has been carried out to provide material for examining forms of occurrence of nutrients, especially cations and nitrogen, in plants. Beans have proved more suitable than peas for sampling and ease of recovery of roots.

Advisory Work. Over 11,000 soil samples were examined during the year, mainly to assess lime, phosphate and potassium requirements. As in the past, these were taken mostly from agricultural and horticultural land by the staff of the North of Scotland College of Agriculture, but they included also a substantial number from forest nurseries, which are dealt with in collaboration with Pedology. Trace element problems, concerning animal health as well as crop growth, and involving several hundred soil and crop samples, continue to be examined in collaboration with Spectrochemistry.

Attention has often been drawn to the importance of adequate phosphate manuring in the North of Scotland. During the past ten years the proportion of advisory soils with reasonably satisfactory phosphate contents has increased from 16 to 25 per cent, while the relatively low category has decreased from 34 to 23 per cent, leaving approximately 50 per cent in the slightly low group. There is clearly still a widespread need for generous dressings of phosphate, particularly for swedes and potatoes.

The position regarding potassium has always been relatively better than for phosphate. This still holds, only about 1 per cent of the current samples being in the low category, with just over 50 per cent satisfactory, and the remainder only slightly low.

STATISTICS

The main work of the section arises from the need to provide a statistical advisory service to the various departments of the Institute. The aim is to maintain the closest collaboration from the first planning stages to the interpretation and report of statistical analysis of the data.

Three types of task have contributed to greater use of computer facilities available at Rothamsted Experimental Station, the University of Aberdeen and the Rowett Research Institute: (1) the arithmetical processing of data from larger projects involving numerous field and/or laboratory measurements on each sample or plot unit; (2) the repetition of the same type of statistical or mathematical analysis on a large number of sets of data from the same experiment and/or similar experiments in a series: and (3) complex statistical or mathematical analysis which could not be done otherwise by existing staff and facilities in the Institute. Grateful acknowledgment is made to these bodies for the provision of computer facilities.

Meetings and exhibitions concerned with computers and their associated peripheral equipment were attended, as was a symposium on data logging held at Wrest Park, Silsoe. At a meeting of the Agriculture Group of the Society of Chemical Industry, a joint paper[72] on the phosphate requirements of swedes was presented. A paper reviewing some of the statistical methods in use in soil research at the Institute[76] was given at the first ordinary meeting of the Royal Statistical Society to be held in Scotland.

The designs currently in use in field, greenhouse and laboratory experiments range from randomized blocks and latin squares to complex factorial arrangements, lattice squares and central composite designs. This latter design is being used in place of the complete factorial where the interest is in estimating the economic optimal combination of nutrients and a general quadratic equation of the second degree adequately represents the response surface.

The main conclusions from the investigation into the phosphate requirements of swedes[72], referred to above, are summarized under Soil Fertility. Use was made of the results from 199 field experiments extending over 15 years. The response to phosphate dressings was represented by both quadratic and Mitscherlich equations. In each experiment, the two equations were used to predict optimal economic phosphate dressings for a number of combinations of crop prices and fertilizer costs. The results, in terms of financial return, were also compared for fertilizer dressings based on the soil phosphate values obtained by various extraction methods. Multiple regression analysis tested the significance of including a number of soil properties, along with a phosphate value or its logarithm, in equations for predicting the response to phosphate dressings. Properties which did not make a significant contribution to the regression were omitted. The computer programmes for the various stages of this study were written in Elliott autocode or ALGOL.

A number of Plant Physiology greenhouse experiments of randomized block and factorial designs have been concerned with physical measure-

ments of sugar beet and oat plants[68], and with their chemical composition. The data processing and statistical analyses were carried out by computer on account of the large number of properties observed and derived.

Collaborative studies with Pedology (Peat and Forest Soils) have been mainly concerned with the detailed investigation of the nitrogen nutrition of coniferous trees. Randomized block and split-plot analyses of variance have been carried out on physical and chemical observations on trees, their root system, litter, ground vegetation and the sand in which they grow. In elucidating the effect of applied nitrogen on the amount, nature and pattern of tree growth, and on the cycling of nitrogen within the forest ecosystem, a method of "whole tree sampling" was used. This involved the extensive sub-sampling of 27 tree components, for example, various categories of foliage, twigs, branches, etc. The weights of tree parts and the uptake of nutrients in them are related to basal area on a logarithmic scale. Using this information together with the frequency distribution of tree size, according to basal area for each of five levels of applied nitrogen, it was possible to predict, with confidence limits, the total weights of the various tree components and the amounts of the nutrients taken up by them on an area or forest basis. The FORTRAN computer programme required for this work was developed from an ALGOL version used on earlier results from the same experiment.

FORTRAN programmes have been written for other Peat and Forest Soils investigations involving data processing, regression analysis and prediction. Correlation and multiple regression analyses have been used in crystal diffraction and other Pedology studies.

The section has co-operated with the North of Scotland College of Agriculture in the design of a potato trial and in the analysis by computer of the results. A programme in ALGOL was written to fit quadratic response curves to yield data from oat and barley experiments, and to estimate yields and responses for certain levels of applied nitrogen. Collaboration with the Crop Husbandry Department of the West of Scotland Agricultural College continues. Data from NPK factorial experiments on swedes, potatoes, rape and barley have been examined and a further series on the first three of these crops has been planned.

LIBRARY

The library holds an extensive collection of literature on 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.

One hundred and forty-three books were purchased during the year and 41 presented. Only one new journal could be taken, the difficulties arising from increased subscription rates being aggravated by the additional costs imposed by devaluation.

This year the library dealt with 241 loan applications from other libraries. Borrowing from outside sources, mainly the National Lending Library for Science and Technology, continues to be heavy, and 855 requests were made.

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 periodically sent out. No charge is made for reprints and anyone interested in receiving the lists should apply to the librarian. This year 3828 reprints were distributed.

Volume VIII of *Collected Papers*, covering the years 1964 to 1966, has now been published.

PUBLICATIONS

(A) *Published—*

1. Mineralogical and chemical characteristics of a gley soil from north-east Scotland. By B. D. Mitchell, J. M. Bracewell, A. S. de Endredy, W. J. McHardy and B. F. L. Smith. (*Trans. IX int. Congr. Soil Sci., Adelaide, Australia 1968*, **3**, 67-77, 1968.)

   Certain morphological features of a surface-water non-calcareous gley soil have been studied in relation to mineralogical and chemical composition. Chemical dissolution techniques were employed and the effects of these on pedologically unweathered material and on completely gleyed material have been followed by differential thermal analysis, X-ray diffraction, infrared absorption and electronmicroscopic examination. Measurements have also been made of specific surface area, cation-exchange capacity and replaceable hydroxyl ion. The results indicate that although the gley process has induced only minor changes in the bulk mineralogy it has produced significant changes in the surface properties of the two materials.

2. Saponite from the Dalradian meta-limestones of north-east Scotland. By M. J. Wilson, D. C. Bain and W. A. Mitchell. (*Clay Miner.*, **7**, 343-349, 1968.)

   The Dalradian meta-limestones of the Banffshire coast have been investigated as part of a study of the mineralogy of Scottish sedimentary and metamorphic rocks, the main purpose of which is to assess the extent to which soil minerals are inherited from such parent rocks. Saponite was found to be a common constituent of the non-carbonate fraction. Thin sections of the limestones were examined microscopically and the textural relationship between the saponite and the other minerals, particularly those of undoubted metamorphic origin, suggest that the saponite was formed during the metamorphism. Recent reports of the hydro-thermal synthesis of saponite at elevated temperatures and pressures support this hypothesis.

3. The clay mineralogy of some soils derived from a biotite-rich quartz gabbro in the Strathdon area, Aberdeenshire. By M. J. Wilson. (*Clay Miner.*, **7**, 91-100, 1967.)

   Three soils of the Strathdon area, Aberdeenshire, derived from a biotite-rich quartz gabbro and representing well drained, imperfectly drained and poorly drained types, were selected for study. The 50-200μ fractions contained mainly plagioclase felspar, amphibole (tremolite and hornblende), biotite and quartz and the following order of relative stability was established: quartz>amphibole>plagioclase felspar>biotite. In all soils biotite was found to weather to a 14Å aluminous vermiculite-chlorite with zones of kaolinite. The clay mineral composition of the three soils was identical, consisting of trioctahedral vermiculite-chlorite, trioctahedral illite, kaolinite and gibbsite. These minerals originated in various ways through the decomposition of biotite which thus plays a key role in the origin of the clay fraction. It is suggested that the clay-mineral constituents of the soils were formed in a regolith predating the last glacial period, and that post-glacial soil-forming processes have modified them only slightly.

4. The calcium oxalate content of some lichens growing on limestones. By J. K. Syers (Lincoln College, Canterbury, New Zealand), A. C. Birnie and B. D. Mitchell. (*The Lichenologist*, **3**, 409-414, 1967.)

   The calcium oxalate content of several lichen species was determined by differential thermal and thermogravimetric analysis and the results correlated with the calcium in the substratum and potassium in the thalli. The production of large amounts of calcium oxalate appears to be a feature of obligate calcicolous lichens rather than of all lichen species growing on limestone. There is an inverse relationship between the calcium oxalate and potassium contents.

5. Interactions between organic substances and inorganic diluents in differential thermal analysis. By S. Yariv, A. C. Birnie, V. C. Farmer and B. D. Mitchell. (*Chemy Ind.*, 1744-1745, 1967.)

   During the thermal analysis of peat and organic matter aromatic acids are likely decomposition products. From an examination of pure organic materials it has been shown that these or their decomposition products may interact with the inorganic diluent. Of the diluents tested in an earlier investigation calcined diatomaceous earth was found to be the most satisfactory.

6. The soils of the country round Haddington and Eyemouth. (Sheets 33, 34 and part 41). By J. M. Ragg and D. W. Futty. (Memoirs of the Soil Survey of Great Britain: Scotland. 1967. 310 pp. With soil maps. H.M.S.O., £3 15/–.)

   The soils of the county of East Lothian, together with parts of Midlothian and Berwickshire, are described and classified. Chemical data are quoted for 95 soil profiles and further chemical, spectrochemical and mineralogical analyses are given for selected soils. The distribution and characters of the main soil series are related to natural phenomena and land use, which are discussed in the ancillary chapters on the general description of the area, climate, geology, vegetation, agriculture, forestry and soil fertility. The memoir includes a coloured soil map on the scale of 1 inch to 1 mile.

7. Soils. By D. Laing. (pp. 94-106 of *Dundee and District*. Handbook of the British Association for the Advancement of Science. 1968.)

   The soils of Tayside, the greater part of Strathmore and a portion of the Grampian foothills are described with reference to the geological and glaciological history of their parent materials. A map is given showing the distribution of the soil associations and their main characteristics are described. A provisional Land Use Capability Classification for the soils of Britain has been prepared by the staff of the Soil Survey and a note is included on the capability classification of the soils of the district.

8. Land use capability survey. By J. S. Bibby. (pp. 30-32 of *Reclamation in the Seventies*. Scottish Peat and Land Development Association. 1967.)

   The basis of a land use capability classification is discussed, with particular reference to soil conditions in the hinterland of Livingston New Town.

9. The distribution of trace elements in cocksfoot (*Dactylis glomerata*) at flowering. By B. G. Davey and R. L. Mitchell. (*J. Sci. Fd Agric.*, **19**, 425-431, 1968.)

   The contents of 24 major and trace constituents (silicon, phosphorus, nitrogen, sulphur, potassium, sodium, magnesium, calcium, strontium, barium, cobalt, nickel, iron, aluminium, zinc, molybdenum, copper, manganese, boron, lead, selenium, chromium, vanadium, titanium) in cocksfoot at the flowering stage are reported for leaf, sheath and stem of different nodes, as well as for spikelets and whole above-ground plant. Very considerable differences in distribution occur for different elements. This information is relevant to the sampling of plants for diagnostic purposes and may be of significance in animal nutrition.

10. A display microphotometer for use in the analysis of soils and related materials. By R. L. Mitchell, R. O. Scott and A. M. Ure. (*XIII Colloq. Spectrosc. intern., Ottawa*, 1967, 324-338, 1968.)

    A versatile microphotometer designed and built in the Institute and incorporating four methods of measurement is described. In addition to non-recording and pen-recording microphotometry it provides a cathode-ray display of an electronic scan of a portion of a spectrogram, effected by means of an image converter. Results similar to those obtained by recording microphotometry can be produced much more quickly. The applications of the display technique to the assessment of low trace element levels, and to the determination of total trace element contents in rocks and soils are illustrated.

11. The determination of cobalt in soil extracts by atomic absorption: a study of interference effects. By A. M. Ure and R. L. Mitchell. (*Spectrochim. Acta*, **23B**, 79-96, 1967.)

The determination of cobalt in soil extracts by arc excitation following chemical concentration is relatively time-consuming when no other elements are required in the same soil extract. A much more rapid atomic absorption method applicable to the determination of 1-50μg cobalt in soil extracts, covering the range from 0·05 to 2·5 ppm acetic-acid-soluble cobalt, has been developed. At 0·3 ppm Co, the critical level in the diagnostic examination of soils likely to give rise to cobalt deficiency in grazing animals, the coefficient of variation is $\pm$3-4 per cent. Interference effects due to the presence of calcium and aluminium can be reduced to an insignificant level. The equipment includes a high intensity hollow cathode lamp, the behaviour of which has been studied under various operating conditions.

12. Characterization of clay minerals by infrared spectroscopy. By V. C. Farmer, J. D. Russell and J. L. Ahlrichs. (*Trans. IX int. Congr. Soil Sci., Adelaide, Australia, 1968*, **3**, 101-110, 1968.)

The potential contribution of infrared spectroscopy to the characterization of clay minerals is often limited by technical considerations. Recent advances in techniques of sample preparation and handling are described which permit the study of clay mineral spectra under vacuum or controlled-atmosphere conditions after heat treatment at temperatures up to 1000°C. The use of pressed disks to follow the thermal behaviour of a single small sample in the range 100 to 700°C is illustrated Examples of the application of these techniques are given; these include studies of the accessibility and reactivity of ammonium ions and hydroxyl groups in clay minerals, and evidence for the development of octahedral vacancies in biotite and vermiculite consequent upon the oxidation of octahedral ferrous to ferric ions.

13. Vibrations du groupe hydroxyle dans les silicates en couches. By V. C. Farmer, J. D. Russell, J. L. Ahlrichs and B. Velde (Laboratoire de la Petrographie, Sorbonne, Paris). (*Bull. Grpe fr. Argiles*, **19**, (2), 5-10, 1967.)

Infrared studies of soil clays at the Macaulay Institute have, over the past ten years, made a valuable contribution to characterizing their nature and properties. This paper reviews one aspect of this work, concerning the information on structure and composition which can be derived from study of hydroxyl vibrations in crystalline clay minerals. New information is also presented on the assignment of hydroxyl absorption bands in celadonites, biotites, phengites, montmorillonites and beidellites.

14. The occurrence of α (1$\rightarrow$3) glucan in *Cryptococcus, Schizosaccharomyces* and *Polyporus* species, and its hydrolysis by a *Streptomyces* culture filtrate lysing cell walls of *Cryptococcus*. By J. S. D. Bacon, D. Jones, V. C. Farmer and D. M. Webley. (*Biochim. biophys. Acta*, **158**, 313-315, 1968.)

Fungi participate in the decomposition of organic material in the soil, and eventually are themselves degraded. Understanding of these processes is still limited by imperfect knowledge of the chemical composition of the parts of fungi more resistant to degradation, especially the cell walls. A polysaccharide first described from this Institute in 1952 as a constituent of the bracket fungus of birch has now been shown to occur in many other fungi. Soil micro-organisms able to break this material down have now been found.

15. Lysis of cell walls of *Mucor ramannianus* Möller by a soil *Streptomyces* sp. By D. Jones, J. S. D. Bacon, V. C. Farmer and D. M. Webley. (*Antonie van Leeuwenhoek*, **34**, 173-182, 1968.)

Fungi are an important group of micro-organisms which play an active role in the decay of plant debris in soil. Ultimately the fungi themselves are subjected to the lytic enzymes of other soil micro-organisms and consequently contribute to the soil

organic matter complex. This paper describes some chemical and ultrastructural changes that occur in the cell walls of a common soil fungus *Mucor ramannianus*, an active soil saprophyte, during their degradation (lysis) by a soil streptomycete. An important feature of the cell walls of the fungus was the very high phosphate content, most of which has been shown by infrared analysis to be inorganic polyphosphate. The lytic organism was shown to release a polymer from the walls which on chemical hydrolysis gave glucosamine.

16. The effect of inhibitors on the increase in invertase activity and RNA content of beet disks during ageing. By D. Vaughan and I. R. MacDonald. (*J. exp. Bot.*, **18**, 587-593, 1967.)

The importance of changes of invertase activity in relation to growth has already been stressed. This investigation shows that in storage tissue slices of beetroot washed under aseptic conditions the increase in protein content, as measured in terms of cell wall protein and invertase activity, is accompanied by a synchronous increase in the ribose nucleic acid (RNA) content. By using specific inhibitors of RNA and protein synthesis it was shown that there is an interdependence between the increase in RNA and protein contents. A possible mechanism is suggested for the initiation of development of invertase activity, during the early stages of washing, linking RNA and protein synthesis.

17. Invertase development in storage tissue disks of *Beta vulgaris*: its nature, extent and location. By D. Vaughan and I. R. MacDonald. (*J. exp. Bot.*, **18**, 578-586, 1967.)

In continuation of work on the development of invertase activity in disks of beetroot washed under aseptic conditions, it is shown that in thick disks (3·0 mm) invertase develops initially throughout the disk but later only in the outer regions. At the cellular level invertase develops first in the cell wall and later in the cytoplasm. Pretreatment of aged disks with ethyl acetate results in a higher invertase activity as a result of the ester facilitating sugar penetration into the disks from the assay medium as well as allowing the intracellular invertase to be assayed.

18. The chemical environment of soil bacteria. By J. S. D. Bacon. (pp. 25-43 of *The Ecology of Soil Bacteria*. Edited by T. R. G. Gray. Liverpool University Press. 1967.)

This paper was one of a group of reviews intended to provide a background for the main subject of the symposium. It considers soil as a potential growth medium for bacteria, and discusses possible reasons why most of the organic matter is not immediately available as a source of nutrients. All the data presented have been published in detail elsewhere, before or after the date of the symposium (September, 1965.)

19. Further evidence of oxygen diffusion as the determining factor in the relation between disk thickness and respiration of potato tissue. By I. R. MacDonald. (*Pl. Physiol., Lancaster*, **43**, 274-280, 1968.)

A whole potato tuber is a well ventilated organ which under normal conditions never suffers from oxygen deficiency. However when a tuber is sliced to give pieces of tissue for physiological experiments, oxygen deficiency becomes evident in slices above 1·0 mm thick. The cause of this paradox has been investigated and it appears that on slicing water-injection of the intercellular spaces greatly reduces the diffusion coefficient of oxygen from that obtaining in the whole tuber.

20. An electron microscope study of the fine structure of *Acremoniella* sp. By D. Jones. (*Trans. Br. mycol. Soc.*, **51**, 515-518, 1968.)

The detailed structure of the conidia (spores) and mycelium of a little known soil fungus, *Acremoniella* sp., has been studied by examining thin sections in an electron

microscope. The present study forms part of a programme of research into the ultra-structure and chemical components of fungal cell walls; this material is an important, and too often overlooked, fraction of the soil organic matter complex. The conidal wall was particularly interesting since it was found to consist of an inner fibrous layer and an outer thin, single-layered membrane; these layers were connected at certain points by means of loose strands of fibrous material.

21. *Acremoniella velata*. sp. nov. By Agnes H. S. Onions (Commonwealth Mycological Institute) and D. Jones. (Trans. Br. mycol. Soc., **51**, 151-152, 1968.) *No reprints available.*

22. Examination of mycological specimens in the scanning electron microscope. By D. Jones. (*Trans. Br. mycol. Soc.*, **50**, 690-691, 1967.)

    A scanning electron microscope has been used to reveal the ultra-structure of surface features of mycelium and spores of soil fungi. A comparison of the results with those from optical and transmission electron microscopic techniques indicates that the scanning microscope may well prove of value in studies where the ultra-structure of fungal walls during degradation by other soil organisms is being determined.

23. Surface features of fungal spores as revealed in a scanning electron microscope. By D. Jones. (*Trans. Br. mycol. Soc.*, **51**, 608-610, 1968.)

    The identification and consequent classification of many important fungal species is very often based on the surface ornamentation of their spores, for example, spines, papillae, etc. The recent introduction of scanning electron microscope techniques has enabled specimens to be examined directly at very high magnifications and with excellent resolution. A previous paper from this Institute has described for the first time the ultra-structure of the spore surface of a very unusual soil fungus and hyphae of another fungus. The present paper describes observations on a further range of fungi, including species which attack economically important plants such as wheat and oats.

24. A new enrichment technique for studying lysis of fungal cell walls in soil. By D. Jones and D. M. Webley. (*Pl. Soil*, **28**, 147-157, 1968.)

    Fungi play an important role in the degradation of plant debris in soil. Ultimately the fungal tissue itself is subjected to the degradation processes. An enrichment technique has been developed which allows for detailed analysis of this second stage in the organic matter cycle. Aggregates (2 mm diameter) were moulded from a mixture of kaolin (an inert binding material) and fungal wall preparations and incubated on soil. The microbial population colonizing the aggregates was studied in detail and in addition it was possible to extract the enzymes from these aggregates which were capable of dissolving the fungal walls. Electron microscopic techniques were employed to follow the extent to which the walls were attacked and in addition to reveal the ultra-structure of the walls.

25. Techniques for the study of localized microbial activity in soil. By D. M. Webley and D. Jones. (*Trans. IX int. Congr. Soil Sci., Adelaide, Australia, 1968*, **3**, 657-664, 1968.)

    Micro-organisms are not very evenly distributed throughout the soil but often develop rapidly in microhabitats where conditions, for example, the presence of organic substrates, are most favourable. This paper describes techniques developed at the Institute using pellets and aggregates made of a mixture of the organic substance and kaolin, as an inert base, which can be incubated in or on soil and subsequently investigated by a wide range of techniques. A number of ways are described for studying microbiological and biochemical changes which occur, with both soluble and insoluble organic substrates, in the localized soil environment.

26. Principles and prospects of chemical soil testing. By E. G. Williams. (pp. 17-31 of a special publication issued in connection with the 40th anniversary celebrations of the Bedrijfslaboratorium voor Grond en Gewasonderzoek, Oosterbeek, Netherlands. 1968.)

A general interpretation is presented of the principles and factors which underlie laboratory methods for evaluating soil nutrient status, based on consideration of the Intensity, Quantity, Buffer and Rate aspects of nutrient supply, together with nutrient and crop characteristics, and the chemical and experimental factors which determine the magnitude and significance of extraction values. Individual requirements are summarized for N, P, S and K, with particular reference to effects of soil, crop and climatic factors.

27. Effects of magnesium dressings on soils and crops. By J. W. S. Reith. (*Trans. VIII int. Congr. Soil Sci., Bucharest, Rumania, 1964*, **4**, 337-345, 1967.)

Field experiments have shown that in northern Scotland the yields of crops and grass are very seldom limited by a shortage of magnesium. The main purpose of applying magnesium is to increase its content in crops and herbage grown for feeding stock, with the object of reducing the incidence of the animal disorder hypomagnesaemia. Applying about 300 to 1000 lb magnesium per acre increased the content in herbage by over 50 per cent throughout the growing season. Such treatment produced only small to moderate increases in the magnesium content in swede roots and cereal straw, and had very little effect on the content in cereal grain. One dressing of 30 lb magnesium per acre had very little effect on crop contents, but if applied annually gradually raised the levels in both soils and crops. At equivalent rates no outstanding differences have been found between the effects on magnesium levels of magnesium sulphate, kieserite, magnesite, calcined magnesite and magnesian limestone.

28. Copper deficiency in crops in north-east Scotland. By J. W. S. Reith. (*J. agric. Sci.*, **70**, 39-45, 1968.)

This reports the main results from field and pot experiments, carried out during 1951 to 1966, on the effects of copper deficiency on crop and herbage growth. Spring-sown oats and barley are more susceptible to this deficiency than grass. It can be corrected by applying 10 to 20 lb copper sulphate per acre to the soil and this treatment is usually effective for at least eight years. The EDTA method for estimating the extractable copper content of soils has been found to give a good prediction of the need for applying copper to spring-sown cereals.

29. Investigations on the analysis of inositol hexaphosphate in soils. By G. Anderson. (*Trans. VIII int. Congr. Soil Sci., Bucharest, Rumania, 1964*, **4**, 563-572, 1967.)

Inositol hexaphosphate, the most abundant organic phosphorous compound in soils, can occur in a bound form, associated with other components of the soil organic matter. As a result, existing methods of measurement can give low values, and modified procedures have been developed. Two contrasting methods are described and their merits or disadvantages discussed. It was found that inositol hexaphosphate accounted for 24 to 58 per cent of the total soil organic phosphate, and constituted up to 0·2 per cent of the weight of the soil.

30. Observations on the accuracy of an ignition and an extraction method for measuring organic phosphate in some Canadian soils. By R. B. McKercher and G. Anderson. (*Soil Sci.*, **105**, 198-200, 1968.)

The phosphorus which occurs in organic forms in soil is usually measured by ignition or alkali extraction methods, which differ very much in principle. With many soils the two types of method give similar values, but where they differ it has proved difficult to assess which gives the more valid results. Examination of a number of Canadian soil profiles has provided some new evidence on this problem.

31. Content of inositol penta- and hexa-phosphate in some Canadian soils. By R. B. McKercher and G. Anderson. (*J. Soil Sci.*, **19**, 47-55, 1968.)

    It has previously been shown that up to one quarter of the phosphate in British soils occurs in the form of inositol penta- and hexa-phosphates, organic substances derived from plants and micro-organisms. Investigation of these substances has been extended to cover a number of Canadian soils of varying origin. The amounts found are much lower than in British soils, both in absolute terms and relative to the total soil phosphate. Forest soils contain larger quantities than soils developed under grass.

32. Characterization of the inositol penta- and hexa-phosphate fractions of a number of Canadian and Scottish soils. By R. B. McKercher and G. Anderson. (*J. Soil Sci.*, **19**, 302-310, 1968.)

    A comparison of the organic phosphate in Scottish soils with that in soils from Saskatchewan and Quebec has earlier shown that in the former a much higher proportion occurs as inositol polyphosphates. A detailed examination of the nature of the isomeric inositol penta- and hexa-phosphates has been carried out on four soils from Scotland and Canada. The Scottish soils were all similar in constitution, with about three to four times as much of the hexa-phosphates as penta-phosphates. In the Canadian soils, which were more variable in composition, the ratio of hexa- to penta-phosphates ranged from 0·9 to 2·4. Esters of *myo-*, *scyllo-*, *dl* - and *neo*-inositol were detected in most cases, and the most abundant single component was *myo*inositol hexa-phosphate, the phytic acid found in plants and micro-organisms, followed usually by *scyllo*inositol hexa-phosphate. The proportion of the latter was particularly high in two Canadian soils of high pH, but a very acid Scottish soil also contained a relatively large amount, and no consistent relationship was noted between the constitution of the inositol polyphosphate fraction and any other soil property.

(B) *Awaiting Publication at 30th September, 1968—*

33. Oxides and hydrous oxides of silica. By B. D. Mitchell. (To appear in *Encyclopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2, Section D. Berlin: Springer.)

34. Basic principles and historic development. By R. C. Mackenzie. (To appear as Chapter 1 of *Differential Thermal Analysis*. Edited by R. C. Mackenzie. London: Academic Press.)

35. Instrumentation. By R. C. Mackenzie and B. D. Mitchell. (To appear as Chapter 3 of *Differential Thermal Analysis*. Edited by R. C. Mackenzie. London: Academic Press.)

36. Technique. By R. C. Mackenzie and B. D. Mitchell. (To appear as Chapter 4 of *Differential Thermal Analysis*. Edited by R. C. Mackenzie. London: Academic Press.)

37. Oxides and hydroxides of higher-valency elements. By R. C. Mackenzie. (To appear as Chapter 9 of *Differential Thermal Analysis*. Edited by R. C. Mackenzie. London: Academic Press.)

38. Techniques in soil-clay mineralogy. By R. C. Mackenzie and V. C. Farmer. (Submitted to *Rep. Progr. appl. Chem.*)

39. 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. Caillière (Paris, France). (To appear in *Encyclopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2, Section D. Berlin: Springer.)

40. Heavy minerals. By W. A. Mitchell. (To appear in *Encyclopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2, Section D. Berlin: Springer.)

41. The classification of soil silicates and oxides. By R. C. Mackenzie. (To appear in *Encyclopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2, Section D. Berlin: Springer.)

42. The oxides of iron, aluminium and manganese. By R. C. Mackenzie, E. A. C. Follett and R. Meldau (Gütersloh, Germany). (To appear in *The Electronoptical Investigation of Clays*. Edited by J. A. Gard. London: Mineralogical Society.)

43. Alpine podzol soils on the Ben Lawers massif, Perthshire. By J. H. Stevens and M. J. Wilson. (Submitted to *J. Soil Sci.*)

44. Effects of particle size, pH and organic matter on the thermal analysis of allophane. By A. S. Campbell (Lincoln College, Canterbury, New Zealand), B. D. Mitchell and J. M. Bracewell. (Submitted to *Clay Miner.*)

45. Peat resources and development in the U.K. By R. A. Robertson and P. C. Jowsey. (Submitted to *Trans. III int. Peat Congr.*)

46. Peat resources and their development. By R. A. Robertson. (Submitted to *Proc. N. Engl. Soils Disc. Grp.*)

47. Transactions of the Second International Peat Congress, Leningrad, 1963. Edited by R. A. Robertson. 2 vol. 1968. H.M.S.O., £12.

48. Effect of different cultural treatments on root development in a grass sward growing on deep peat. By R. Boggie. (*J. Br. Grassl. Soc.*, **23**, 280-284, 1968.)

49. Structural variations in peat. By J. M. Stewart (McMaster University, Hamilton, Ontario, Canada) and S. E. Durno. (Submitted to *New Phytol.*)

50. Variations in the altitudinal zonation of climate in Scotland and northern England since the Boreal Period. By S. E. Durno and J. C. C. Romans. (Submitted to *Scott. geogr. Mag.*)

51. Research into nitrogen nutrition on the sands of Culbin Forest, Morayshire. By H. G. Miller. (Submitted to *J. Sci. Fd Agric.*)

52. A natural system of classification. By J. W. Muir. (Submitted to *J. Soil Sci.*)

53. Hill-land vegetation in Scotland. By E. L. Birse. (Submitted to *Symposium on Hill-land Productivity, Scotland, 1968.*)

54. Trace elements in soils. By R. L. Mitchell. (Submitted to *Proc. N.A.A.S. Conf. on Trace Elements in Soils and Crops, London, 1966.*)

55. Flame methods: their development and application. By R. L. Mitchell. (To appear as Chapter I of *A Handbook of Flame Emission and Absorption Methods*. Edited by J. A. Dean and T. C. Rains. New York: Dekker.)

56. Direct photometry of self-reversed lines using a double exit slit. By J. C. Burridge and R. O. Scott. (Submitted to *Spectrosc. Lett.*)

57. Infrared spectroscopy in clay mineral studies. By V. C. Farmer. (Submitted to *Clay Miner.*)

58. The characterization of soil minerals by infrared spectroscopy. By V. C. Farmer and F. Palmieri. (To appear in *Encyclopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2, Section D. Berlin: Springer.)

59. Indentification of inorganic pyrophosphate in alkaline extracts of soil. By G. Anderson and J. D. Russell. (Submitted to *J. Sci. Fd Agric.*)

60. A study of the microbial lysis of the cell walls of soil yeasts (*Cryptococcus* sp.). By D. Jones, J. S. D. Bacon, V. C. Farmer and D. Webley. (Submitted to *Soil Biology and Biochemistry.*)

61. Soil lipids. By R. I. Morrison. (To appear as Chapter 19 of *Organic Geochemistry: Methods and Results*. Edited by G. Eglinton and Mary T. J. Murphy. Berlin: Springer.)

62. Effect of humic acid on the development of invertase activity in slices of beetroot tissue washed under aseptic conditions. By D. Vaughan. (Submitted to *Proc. Symp. Humus et Planta, IV, Prague, 1967.*)

63. The stimulation of invertase development in aseptic storage tissue slices by humic acids. By D. Vaughan. (Submitted to *Soil Biology and Biochemistry.*)

64. The relationship between trace elements in soils and plants. By P. C. DeKock and M. V. Cheshire. (*Rep. Welsh Soils Discuss. Grp., No.* 9, 98-108, 1968.)

65. The metabolism of nitrogen in plants. By P. C. DeKock. (To appear in *Tech. Bull. Min. Agric. Fish. Fd, No. 15.*)

66. Uptake of nitrogen by plants. By P. C. DeKock and E. A. Kirkby. (To appear in *Tech. Bull. Min. Agric. Fish. Fd, No. 15.*)

67. Fundamental aspects of iron nutrition of plants. By P. C. DeKock. (Submitted to *Proc. N.A.A.S. Conf. on Trace Elements in Soils and Crops, London, 1966.*)

68. An investigation into the effect of varied phosphorus and iron concentrations in the nutrient medium on the cation and anion content of oats. By Linna Bentley (University of London), P. C. DeKock and R. H. E. Inkson. (Submitted to *Pl. Soil.*)

69. Further characterization of amino acid incorporation by subcellular fractions from sterile beet disks. By R. J. Ellis (University of Aberdeen) and I. R. MacDonald. (*Planta*, **83,** 248-256, 1968.)

70. The hydrolysis of *myo*inositol hexa-phosphate by soil micro-organisms. By M. P. Greaves and D. M. Webley. (Submitted to *Soil Biology and Biochemistry.*)

71. Residual effects of phosphate and the relative effectiveness of annual and rotational dressings. By E. G. Williams and J. W. S. Reith. (Submitted to *Proc. N.A.A.S. Conf. on Residual Value of Applied Nutrients, London, 1968.*)

72. Prediction of phosphate requirements of swedes from soil phosphate values. By J. W. S. Reith, R. H. E. Inkson and E. G. Williams. (Submitted to *J. Sci. Fd Agric.*)

73. Soils: some physico-chemical aspects. By B. W. Bache. (Submitted to *Rep. Progr. appl. Chem.*)

74. Other organic phosphorus compounds. By G. Anderson. (To appear in *Encyclopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2, Section C. Berlin: Springer.)

75. Sulphur in soil organic substances. By G. Anderson. (To appear in *Encyclopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2, Section C. Berlin: Springer.)

76. Statistics in soil research. By R. H. E. Inkson. (Submitted to *Appl. Statist.*)

(C) *Papers by Members of Staff on Leave of Absence: Published or Accepted for Publication—(No reprints.)*

77. 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.*)

78. Montmorillonite—S-triazine interactions. By M. I. Cruz and J. L. White (Purdue University, Indiana, U.S.A.) and J. D. Russell. (*Israel J. Chem.*, **6,** 315-323, 1968.)

79. The absorption of 3-aminotriazole by montmorillonite. By J. D. Russell, and M. I. Cruz and J. L. White (Purdue University, Indiana, U.S.A.). (*J. agric. Fd Chem.*, **16,** 21-24, 1968.)

80. Mode of chemical degradation of S-triazines by montmorillonite. By J. D. Russell and M. I. Cruz and J. L. White (Purdue University, Indiana, U.S.A.). (*Science, N.Y.*, **160,** 1340-1342, 1968.)

81. Humic acid-III. By M. V. Cheshire and P. A. Cranwell and R. D. Haworth (University of Sheffield). (*Tetrahedron*, **24,** 5155-5167, 1968.)

82. Potassium and nitrate uptake and cell transmembrane electropotential in excised pea epicotyls. By A. E. S. Macklon and N. Higinbotham (Washington State University, U.S.A.). (*Pl. Physiol., Lancaster*, **43,** 888-892, 1968.)

83. Inositol phosphates in some Australian soils. By C. H. Williams (Division of Plant Industry, C.S.I.R.O., Canberra City) and G. Anderson. (*Aust. J. Soil Res.*, **6,** 121-130, 1968.)

(D) *Publications of Dr R. I. Morrison—*

84. The isolation of L-pipecolinic acid from *Trifolium repens*. By R. I. Morrison. (*Biochem. J.*, **53,** 474-478, 1953.)

85. The metabolism of chlorotic leaves. I. Amino acids. II. Organic acids. By P. C. DeKock and R. I. Morrison. (*Biochem. J.*, **70,** 266-272, 272-277, 1958.)

86. The alkaline nitrobenzene oxidation of soil organic matter. By R. I. Morrison. (*J. Soil Sci.*, **9,** 130-140, 1958.)

87. Products of the alkaline nitrobenzene oxidation of soil organic matter. By R. I. Morrison. (*J. Soil Sci.*, **14,** 201-216, 1963.)

88. Products of the oxidative degradation of humic acid. By R. I. Morrison. (*Chemy Ind.*, 1883, 1964.)

89. Glyceric acid in broad bean. By R. I. Morrison and P. C. DeKock. (*Nature*, **184,** 819, 1959.)

90. The wax fraction of soils: separation and determination of some components. By R. I. Morrison and W. Bick. (*J. Sci. Fd Agric.*, **18,** 351-355, 1967.)

91. Long-chain methyl ketones in soils. By R. I. Morrison and W. Bick. (*Chemy Ind.*, 596-597, 1966.)

92. Decomposition of leguminous plant roots in sand. I. Transformation of nitrogen. II. Humus formation. By W. Myskow and R. I. Morrison, (*J. Sci. Fd Agric.*, **14,** 813-821, 1963; **15,** 162-168, 1964.)

93. The mobilization of iron by aqueous extracts of plants. I. Composition of the amino-acid and organic-acid fractions of an aqueous extract of pine needles. By J. W. Muir, R. I. Morrison, C. J. Bown and J. Logan. (*J. Soil Sci.*, **15,** 220-225, 1964.)

94. The formation of anisic acid by oxidation of methylated *Sphagnum*. By V. C. Farmer, and R. I. Morrison. (*Chemy Ind.*, 231, 1955.)

95. Chemical and infrared studies on *Phragmites* peat and its humic acid. By V. C. Farmer and R. I. Morrison. (*Sci. Proc. roy. Dublin Soc., Ser. A*, **1,** 85-104, 1960.)

96. Lignin in *Sphagnum* and *Phragmites* and in peats derived from these plants. By V. C. Farmer and R. I. Morrison. (*Geochim. cosmochim. Acta*, **28,** 1537-1546, 1964.)