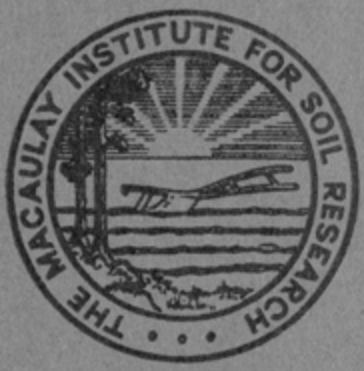
THE MACAULAY INSTITUTE FOR SOIL RESEARCH



FOUNDED 1930

1964-1965 ANNUAL REPORT

No. 35

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

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SINTJE de BOER (Centrum voor Plantenphysiologisch Onderzoek, Wageningen, Netherlands).

G. P. BRINER (Department of Agricultural Chemistry, University of Melbourne, Australia).

M. EEROLA (Department of Soil Geology, University of Helsinki, Finland).

C. de S. F. GOMES (Museu e Laboratorio Mineralogico e Geologico, Universidade do Coimbra, Portugal).

R. L. HALSTEAD (Soil Research Institute, Ottawa, Canada).

MRS ALISON INNES (University of Aberdeen Research Scholar).

T. A. JACKSON (Department of Microbiology, Yale University, Connecticut, U.S.A.).

J. D. MCFARLANE (School of Wool Technology, University of New South Wales, Kensington, N.S.W., Australia).

R. B. MCKERCHER (Soil Science Department, University of Saskatchewan, Saskatoon, Canada).

G. ORBELL, (D.S.I.R. Soil Survey, Alexandra, Central Otago, New Zealand).

J. B. PASSIOURA (School of Agriculture, University of Melbourne, Australia).

J. M. STEWART (Department of Biology, McMaster University, Hamilton, Ontario, Canada).

S. YARIV (Department of Inorganic and Analytical Chemistry, The Hebrew University, Jerusalem, Israel).

CONTENTS

INTRODUCTION

Research on soils and soil-plant relationships has continued steadily with the overall objective of obtaining information of value in maintaining and improving soil fertility. To this end, field, pot, glasshouse and laboratory studies of soils and plants have been extended. Useful co-operation with other research organizations and with the agricultural advisory services has been maintained. As in previous years, considerable scientific benefit has resulted from Institute representation at Conferences and meetings bearing on its research activities, from secondment of staff to work at centres abroad, from providing facilities for visiting research workers and from an increasing exchange of publications..

An event of some importance, which stemmed from the work of the Institute, was the holding in Aberdeen in September, 1965, of the First International Conference on Thermal Analysis. This Conference, which was under the Chairmanship of Dr R. C. Mackenzie, was attended by 294 scientists from 28 countries. In the presidential address to the Agriculture Section of the British Association for the Advancement of Science at its meeting in Cambridge in 1965, the Director reviewed the subject of soil, plant and animal relationships with particular reference to trace elements in plant growth and animal health[1]. His presidential address given in 1964 to the British Society of Soil Science and dealing with investigational approaches to soil as a medium for plant growth has recently been published[2]. Dr R. L. Mitchell was enabled by the Agricultural Research Council to accept an invitation from the Organizing Committee to attend and present a paper at the Fifth Australian Spectroscopy Conference. This Conference, which was arranged under the auspices of the Australian Academy of Science, was of high scientific value and proved most rewarding. Thanks to the generosity of the authorities in Australia and New Zealand, Dr Mitchell was also able to pay fruitful visits to various soil, plant and veterinary laboratories in Australia and New Zealand, where a considerable amount of spectrochemical work of relevance to investigations at the Macaulay Institute has been carried out in recent years. Other visits abroad made by members of staff and financed by the Agricultural Research Council covered attendance at meetings of an O.E.C.D. Co-operative Research Group in Paris, the International Peat Committee in Sweden, and a study of peat survey methods in Holland.

Dr P. C. DeKock, head of the department of Plant Physiology, was granted leave of absence for 11 months from February, 1965, to permit him to accept an invitation from the University of California, Los Angeles, to spend nine months as an Associate Professor undertaking research on problems of chlorosis in plants, and to spend two months as a Visiting Lecturer at various Canadian universities under the auspices of the National Research Council of Canada and the Nuffield Foundation. Following an invitation from the University of Purdue, U.S.A., Mr J. D. Russell, department of Spectrochemistry, was granted leave of absence for one year from February, 1965, to

enable him to undertake, as an Instructor (Research) in the Department of Agronomy, an investigation by infrared spectroscopy of the adsorption of organic compounds on soil colloids. This topic is closely allied to collaborative studies on the organic and inorganic components of soils by infrared spectroscopy and other methods meantime in progress between the department of Spectrochemistry and other departments of the Institute. A useful arrangement involving an exchange between one of the soil surveyors on the staff of the Institute and a soil surveyor on the staff of the Soil Bureau in New Zealand has been entered into. Mr G. Orbell arrived in May,1965, from New Zealand and spent the first four months of the year which he is to spend in Scotland on soil survey work with Mr J. M. Ragg, who left at the end of September to undertake a year's work in New Zealand.

In addition to receiving a very large number of short term visitors from 28 countries, the Institute has provided facilities for longer term work for visiting scientists from Australia, Canada, Finland, Netherlands, Israel, New Zealand, Portugal and the U.S.A., as well as from centres in Great Britain.

Members of staff have again served on various technical committees appointed by such 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 main lines of work during the year follow those described in previous reports, but the appointment of a surveyor has enabled the commencement of a systematic peat survey. The techniques to be employed in such a survey are receiving detailed attention—in particular the use of air-photo techniques in conjunction with limited ground traverse for the mapping of large areas of hill peat.

Collaboration and co-operation with the Forestry Commission and the Hill Farming Research Organization have continued and many joint projects are being pursued with other departments of the Institute. Samples have also been examined at the request of various outside bodies including the Forestry Commission, Hunting Technical Services, and the Universities of Aberdeen, Cambridge and Newcastle.

Mr C. de S. F. Gomes, Department of Mineralogy and Geology, University of Coimbra, Portugal, Dr G. P. Briner, Department of Agricultural Chemistry, University of Melbourne, Australia, and Mr M. Eerola, Department of Soil Geology, University of Helsinki, Finland, have spent extended periods in the department during the year. Dr J. M. Stewart, Department of Biology, McMaster University, Hamilton, Ontario, Canada, has now completed his studies on the stratigraphy of peat deposits in north-east Scotland, and the thesis of Mr J. H. Kirkman, a Ministry of Agriculture, Fisheries and Food research scholar, on *Characteristics and Distribution of Amorphous Inorganic Material in some Scottish Soils* has been accepted for the degree of Ph.D. by the University of Aberdeen.

Members of the department have attended *inter alia* meetings of the Clay Minerals Group of the Mineralogical Society and of the Microchemical and Thermal Analysis Groups of the Society for Analytical Chemistry as well as the First International Conference on Thermal Analysis in Aberdeen. During this conference it was a pleasure to welcome many overseas visitors to the Institute. Dr R. C. Mackenzie was President of the Conference and has now been appointed Treasurer of the Executive Committee set up to maintain liaison between countries in the interval between conferences. By invitation Dr Mackenzie also gave an address on the origin of clays[37] at a meeting of the Ussher Society in St Austell, Cornwall.

During the year Mr P. C. Jowsey visited the Agriculture Research Centre at Wageningen and the International Training Centre for Aerial Survey at Delft to study survey methods in use in Holland. Mr R. A. Robertson attended a meeting of the International Peat Committee in Malmö, Sweden, and also, by invitation, paid a visit to peat research centres in Bavaria.

Methods

Despite the value of differential thermal analysis in soil-clay mineralogy[3] cumulative evidence has made it increasingly clear that thermogravimetry is a necessary adjunct in the investigation of naturally occurring inorganic and organic materials. However, as the capacity of the thermobalance is con-

siderably less than that of the differential thermal apparatuses only a selected number of samples can be handled by the former. Furthermore, to enhance the diagnostic value of differential thermal analysis it is now apparent that identification of the evolved gases is essential and, since the existing equipment could not be adapted readily or successfully to accommodate gas detection units, a miniature block of different design has had to be constructed. Preliminary results show considerable promise. These aspects and others dealing specifically with the application of thermal methods to the investigation of soils and plant materials were the subject of papers read before the Microchemical Group of the Society for Analytical Chemistry and at the inaugural meeting of the Thermal Analysis Group of the same Society.

The techniques employed in the department[4,38] for, and the value of chemical analysis[5] in, mineralogical studies have recently been described.

Pretreatment of Samples. The removal of organic matter from soil clays using a combination of centrifuging techniques with either hydrogen peroxide or sodium hypochlorite treatments has continued and it is now apparent that the aluminium and iron associated with the complex oxalates formed during treatment with peroxide are derived from the organic fraction and do not, as was earlier considered possible (Ann. Rep., 1961-62), indicate attack on the mineral fraction. Synthetic clay-organic complexes, in particular montmorillonite-benzoic acid, are being studied by thermal methods, and special attention is being paid to the effect of the thermally inert material used as diluent on the stability of this complex.

Soil Mineralogy

In continuance of the policy of collecting fundamental information on minerals likely to occur in soils, the X-ray diffraction, electronoptical and thermal characteristics of a number of minerals have been determined. These minerals included datolite, synthetic iron oxides, bauxites from Dutch Guiana, the core material of a Warsaw geode, and serpentines from several localities. Portuguese kaolinites have also been studied by these techniques, and in addition the surface morphology of some of these kaolinites has been investigated in further detail by replica methods and attempts made to relate the degree of order to the electron diffraction pattern. A review of clay mineralogy with a critical appraisal of the present position and future trends has been submitted for publication[39].

Differential thermal analysis and differential thermogravimetry have been employed to study the relative ability of cations to compete for exchange sites in vermiculite and a study of the ammoniation of montmorillonite using X-ray diffraction and infrared spectroscopy is in progress in collaboration with the department of Spectrochemistry. Papers dealing with hydration of sorbed ions on montmorillonite[6] and the sorption of ferric oxide gel on kaolinite surfaces[7] have now been published.

Fine Sand Fraction. The systematic optical examination of the fine sand fraction of Scottish soils has continued. A more detailed study has been made of the fine sand fractions of various soils from Turkey and the Sudan.

Silt Fraction. The most striking feature of soils developed on andesite and granitic rocks in north-west Turkey is their high silt content. This can probably be attributed to frost action but may also involve loess accumulation. Silt-sized cristobalite in parent-rock andesites persists in the soil, indicating a high stability.

Clay Fraction. The systematic examination by X-ray diffraction and thermal methods of soil clays from the Girvan and Carrick areas (Sheets 7/8) will be completed shortly. These clays show the usual mineral suites[4]. However, recent improvements to the sensitivity of recording of the differential thermal trace have revealed that small amounts of gibbsite (< 5 per cent.) are much more common in Scottish soil clays than was hitherto thought.

Soil clays from overseas territories have also been examined, including those from a selection of soil types from Japan and Australia obtained primarily to compare the nature of their poolry ordered aluminosilicate component with that in Scottish soil clays. All the principal clay minerals have been established in soil clays from the Sudan.

Non-crystalline Inorganic Components. The investigation of poorly ordered inorganic material in soil clays has continued, using, as suggested in a recent publication[8], chemical dissolution in conjunction with instrumental techniques—thermal analysis, X-ray diffraction, infrared absorption spectroscopy, electron microscopy and specific surface-area measurements. This procedure has shown that poorly ordered material can in certain Scottish soils constitute a large part of the clay fraction. The X-ray amorphous material is not, however, present as a separate phase and in all samples examined iron oxide is an essential component[9,10]. These observations have led to a more intensive investigation of the action of dithionite on iron oxides in a number of well-defined soil types from various parts of the world.

Scottish soil clays frequently contain gibbsite which appears from X-ray diffraction and infrared absorption evidence to be poorly crystalline. A possible means of characterization of this material using extraction with dilute solutions of sodium carbonate is being investigated.

Rock Weathering. As part of a programme on the pedological weathering of micas[11], a biotite-quartz-gabbro from Strathdon, Aberdeenshire, is being investigated; in the fine sand fraction, zones of kaolinite and gibbsite within the flakes of weathered mica were detected by X-ray diffraction and confirmed optically and by differential thermal analysis. It is significant that the kaolinite has been shown by single crystal diffraction to have derived its orientation from the parent biotite indicating epitaxial or possiblet opotactic origin[40].

Organic and Biological Materials

Thermal methods have been used to characterize the morphologically distinct zones of a hill peat profile. The interaction of degree of humification, ratio of fibre to amorphous material, mineral matter and botanical com-

position are all reflected to some extent on the differential thermal and differential thermogravimetric curves[12]. A paper dealing with the application of differential thermal analysis to fresh plant material and the interpretation of the thermal peak patterns in relation to botanical composition and classification has been published[13]. The series of well-defined energy changes occurring on heating calcium oxalate in an inert atmosphere have been found to provide a convenient and rapid means of monitoring both large and trace amounts of calcium oxalate in lichens.

In collaboration with the department of Microbiology an electron microscope study of the cell surface of *Cytophaga johnsonii*, a non-fruiting myxobacterium, and related organisms has been carried out[41].

Soil Analysis

Standard analytical determinations have been completed on the soils collected by the department of Soil Survey during the 1963 field season and on about a sixth of those collected during 1964. Total carbon, nitrogen, exchangeable hydrogen and pH determinations have been carried out on the remainder of the 1964 samples and other determinations are in hand. Clay samples separated from 87 soils have been analysed for total silica, iron and aluminium, and about 150 miscellaneous samples of soil, water, etc., have been analysed on behalf of other departments of the Institute and outside establishments.

Two papers giving an account of the collaborative work with the department of Soil Survey on the ability of aqueous extracts of pine needles to complex with sesquioxides[14,15] have appeared. This work is being continued.

Peat and Highly Organic Soils

Detailed surveys of selected peat deposits have been carried out in Kincardineshire (Sheets 40/42/43) and in areas of Wigtownshire and south Ayrshire (Sheets 7/8). In the Kincardineshire area the majority of the raised basin bogs have been extensively cut over and an indication of their former conformation can be obtained only from isolated remnants which have remained relatively undisturbed. Many upland areas in this region are covered by extensive tracts of shallow to moderately deep hill peat and an exploratory transect was made across a typical example in an attempt to establish a satisfactory survey procedure. It has been concluded that a routine ground survey of such peat land would generally be impracticable and that air-photo interpretation supplemented by a limited ground check offers a more promising approach.

In south-west Scotland a detailed survey of the area between Loch Doon and Loch Dee has been completed. The southern end of this area is characterized by a series of small well developed raised bogs which comprise the Silverflowe Nature Reserve. The nature and conformation of the peat over the remainder of the area, where afforestation is in progress, will be determined after interpretation of the survey data. A special detailed topographic survey has been made of the experimental peat catchment at Blacklaw Moss, Lanarkshire.

A paper[16] on the nature, extent and utilization of Scottish peat resources has been published and another[42] describing an improved peat sampler has been submitted for publication.

At Moss Maud, Aberdeenshire, a study of the main meteorological factors of the bog environment has been concluded. Work is now in progress to define and assess the main factors which retard the colonization of cut-over peat areas. Different methods of sampling peat for moisture determinations are being compared on a statistical basis in order to establish a generally acceptable standard procedure.

Collaboration has been maintained with the Hill Farming Research Organization, the Nature Conservancy and various University departments particularly with regard to investigations on heather burning, hill land-use and hill ground productivity[17]. A survey of vegetation on a Forest Reserve at Scare Hill, Aberdeenshire, has been carried out in collaboration with the department of Soil Survey. Permanent quadrats established 16 years ago have been re-mapped. The performance of the trees is being assessed on the basis of girth and total height measurements.

The effects of preservation in peat on the surface features of leaves from four common bog plants have been investigated by means of electron microscopy[43]. Other laboratory investigations have continued along the lines previously reported, including microscopic studies related to peat classification and chemical and physical determinations for the purpose of characterization and assessment.

Hydrological Studies. In collaboration with the Agronomy Department of the Hill Farming Research Organization, investigations on the hydrology and nutrient balance of deep peat catchments have continued at Blacklaw Moss, Lanarkshire. In a study of the general relationships between monthly precipitation, run-off, potential evapotranspiration and water-table height in the main catchment during the three-year pre-drainage period (1959-61) no consistent relationship between rainfall and run-off was apparent without reference to the season of the year[18]. Processing of field records for the four-year period 1962-65 is nearing completion and the results obtained will be used to study the effects of additional drainage on the relationship between the various parameters. Pretreatment calibration of the seven "micro-catchments" is still in an early phase of development. The systematic sampling of rain and run-off water for chemical analysis has continued.

Pollen Analysis and Quaternary Research. The detailed palynological and stratigraphical investigations on Cruden Moss, Aberdeenshire, have been concluded. Radiocarbon dating, being carried out by the National Physical Laboratory on peat samples from several selected sites in north-east Scotland, should increase the accuracy of pollen zonation and the correlation of pollen analytical data within this area and beyond. Pollen analysis of peats from sites in the northern and western isles has continued and work on buried peats from various sources is still in progress. Data from peats and organic deposits submitted from an archaeological investigation at Kilphedir, Suther-

land, are being assessed. Palynological evidence of prehistoric agriculture (Landnam) forms the basis of a paper[44] submitted for publication.

Studies on Forest Soils

The aeration-drainage experiment on peat at Lon Mor, Inverness-shire, has continued. An assessment made by the Forestry Commission staff in November, 1964, showed that with increase in depth of drains, tree height, shoot length and percentage survival generally increased and the colour of the foliage changed from yellow-green to green. Significant differences in tree height and shoot length were found between the 0 cm and the 10 cm drainage treatments and also between the 30 cm and the 50 cm drainage treatments. Automatic recording equipment has been installed to compare the fluctuations in water levels with rainfall. A botanical analysis has been made of the experimental area.

In conjunction with the section of Statistics a comparative study has been made of peat sampling on a volume and a weight basis using different types of samplers. Samples were taken from a *Scirpus/Eriophorum* blanket peat in Inverness-shire, a *Calluna* hill peat in Kincardineshire, and a raised bog in Aberdeenshire. At each site the top 12 inches were sampled at 2 inch intervals. No significant difference in moisture content was found between the samples on a weight basis from the three types of peat, but a significant difference in moisture content and wet bulk density was found between the samples obtained on a volume basis from the hill and blanket peats. A botanical analysis is at present being made of these different peats.

Although each is consistent in itself, the moisture content results on the weight and volume basis give different impressions of the moisture profile. For example, on the raised bog, the moisture content per unit volume was the same at the top and bottom of the profile but because of difference in pore space there was a smaller volume of peat at the bottom than at the top of the profile. As a result, the moisture content by weight, that is the ratio of the weight of water to the weight of water plus peat, was considerably larger than that on a volume basis and varied considerably up the profile. It appears that a better picture is obtained of the moisture regime of a peat site by sampling on a volume basis.

A paper on quantity potential relationship in nutrient studies on forest soils[19] has now been published.

Tree Nutrition. The experiments already laid down to investigate the nitrogen nutrition of coniferous trees have continued and no further experiments have been commenced during the past year. Intensive investigations to elucidate the effect of applied nitrogen on the amount, nature, and pattern of tree growth, and on the cycling of nitrogen within the forest ecosystem, have been initiated in the experiment laid down in 1964 on a 38-year-old Corsican pine crop on wind-blown sand dunes at Culbin, Morayshire. In this experiment monthly collection of litter fall has shown that, over the period June 1964 to May 1965, 2,800 kg. of tree litter per hectare fell in the untreated control plots, as against approximately 2,000 kg. per hectare in those

plots receiving nitrogen; the difference is almost entirely accounted for by variation in needle fall. This litter is returning some 11 kg. of nitrogen per hectare per annum to the forest floor in the untreated control plots, whereas in the treated plots the amount is 8 kg. nitrogen per hectare for the lightest treatment (75 lb. nitrogen per acre per annum) increasing to 9·5 kg. for the heaviest treatment (450 lb. nitrogen per acre per annum). Measurements from litter fall are now being supplemented by collection and analysis of nutrients returned to the forest floor *via* rain water passing through the canopy and by studies on the rate of litter decomposition. Foliage samples are being collected monthly and tree growth is being followed by weekly measurements of the basal area of 75 trees by means of vernier girth bands.

During the year a considerable number of samples of plant material and peat have been analysed in the laboratory. A large number of these originated from an intensive sampling of the trees, ground vegetation, litter, humus and soil at the Culbin experiment prior to the application of fertilizer. This involved the subsampling of whole trees for analysis and necessitated the development of new and improved means of subsampling from large quantities of material.

The advisory service providing recommended fertilizer rates for forest nurseries based on soil analyses carried out by the department of Soil Fertility continues. The year has seen a marked increase in the number of privately-owned nurseries taking advantage of this service.

SOIL SURVEY

The systematic survey of the soils of Scotland on a scale of 2·5 inches to 1 mile has continued in the areas under survey in the previous year. A start has been made in the north-west Highlands on Sheets 101 (Ullapool) and 107 (Lochinver). The distribution of the sheet areas and coverage of the survey is shown on the map, from which it will be seen that the policy is to cover first the low ground regions which are the more valuable agriculturally. An area of approximately 500 square miles has been surveyed, 60 on Sheet 47 (Crieff); 40 on Sheet 85 (Rothes); 100 on Sheets 110 and 116 (Latheron and Wick); 45 on Sheet 101 (Ullapool); 5 on Sheet 107 (Lochinver); 115 on Sheets 3 and 4 (Stranraer and Wigtown); 60 on Sheet 84 (Nairn); 80 on Sheets 31 and 32 (Airdrie and Edinburgh). A detailed survey on a scale of 6 inches to 1 mile was made of the 6 square mile Cambusmore Estate, Callander, Perthshire.

Mr I. C. Baillie, a trainee student with the Ministry of Overseas Development, spent seven months on field work in the Wick-Latheron area.

Mr I. D. Hill, on the completion of his assignment in Antigua, West Indies, has transferred from the Pool of Soil Scientists to the Directorate of Overseas Surveys. Mr D. M. Lang continues his assignment in Nigeria within the Pool of Soil Scientists.

Two papers [14, 15] on collaborative work with the departments of Pedology and Biochemistry on the mobilization of iron by aqueous extracts of plants have now been published. A paper on frost weathering and solifluction products in southern Scotland[45] and a historical review of the soils and agricultural regions of Scotland[46] have been accepted for publication. A brief account of the soil survey of East Lothian has been published[21].

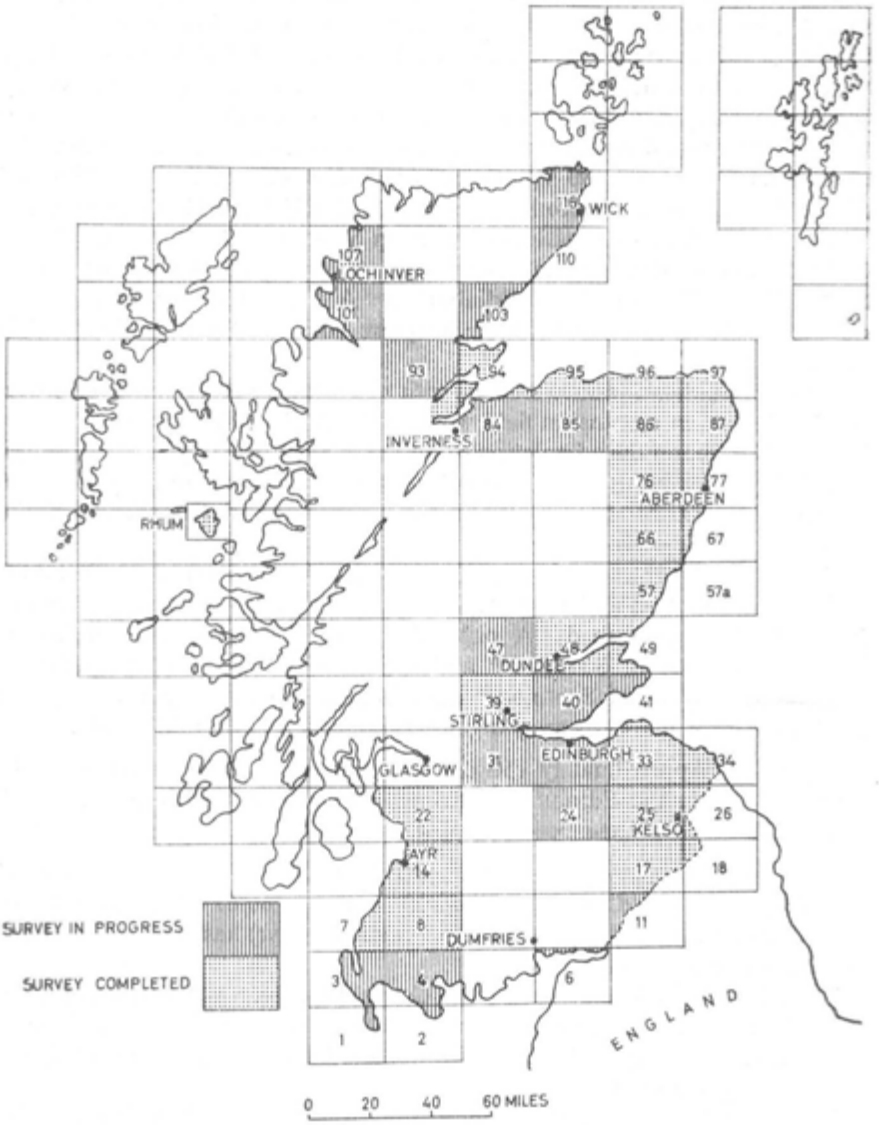
Sampling. Approximately 150 cores, 3 feet deep, were extracted by the Proline Corer in the Edinburgh, Stirling, Girvan and Forres areas; in addition 250 profiles have been sampled.

Maps and Memoirs. The colour proofs of Sheets 33, 34 and part 41 (Haddington/Eyemouth/North Berwick) and of 66/67 (Banchory/Stonehaven) are awaited. A colour proof of Sheet 14 (Ayr) has been received and certain corrections made.

The fair copy of Sheets 7/8 (Girvan/Carrick) has been submitted and a line proof is awaited. A fair copy of Sheet 39 (Stirling) has been submitted to the Ordnance Survey. Work has commenced on the fair copy of Sheets 48/49 (Perth/Arbroath).

The memoir covering the Haddington, Eyemouth and North Berwick sheets[47] was submitted to H.M.S.O. in January, 1965, and work is well advanced on the memoir to cover Sheets 66/67/57 (Banchory, Stonehaven, Forfar). Memoirs for Sheets 39 (Stirling), 48/49 (Perth/Arbroath) and 7/8 (Girvan/Carrick) are in preparation.

Correlation and Related Work. A reappraisal was made of certain soil associations on Sheets 48/49 (Perth/Arbroath), in particular of the soils


WICK
LOCHINVER
INVERNESS
ABERDEEN
RHUM
DUNDEE
STIRLING
GLASGOW
EDINBURGH
KELSO
AYR
DUMFRIES
ENGLAND
SURVEY IN PROGRESS
SURVEY COMPLETED
0 20 40 60 MILES

developed on raised beach, estuarine and fluvioglacial deposits, and certain mapping problems were resolved.

The Ayr, Girvan and Carrick areas were visited for purposes of correlation, and to make preparations for the joint Soil Survey field meeting to be held in that district in 1966.

Assistance has been given in the arrangements for the post-conference tour of the Aberdeen meeting of Commission II and IV of the International Soil Science Society in September, 1966.

Micro-morphological Work and Soil Monolith Preparation. The thin section laboratory has produced some 250 impregnated soil blocks for future sectioning and prepared 100 thin sections.

Thirty-one soil monoliths mounted in wooden boxes have been prepared for inclusion in the soil library. The entire collection of some 240 monoliths has now been individually labelled and fully listed and catalogued.

Vegetation Surveys. The vegetation of Sheet 84 (Nairn) has been recorded by plant sociological methods. A representative transect of vegetation, 10 kilometres in width, extending from the coast to the uplands has been mapped. Aerial photographs were used as base maps in the field and the detail has been transferred to 2½ inches to 1 mile maps.

Work on the study of variation within plant communities has continued. It is hoped to show, by means of transects and by analysis of already existing quadrat data, possible degrees of association or dissociation of the vascular plant and bryophytic communities, and to explain these links in terms of environmental factors. Ten such transects have so far been sited in locations between Nairn and Fife.

Ad Hoc Projects. A field excursion to the Island of Rhum, arranged on behalf of the British Society of Soil Science by Mr D. F. Ball of the Nature Conservancy and Mr J. M. Ragg, was held in May. Four members of the Scottish Survey attended.

On behalf of the Nature Convervancy a survey on a scale of 2·5 inches to 1 mile was made of the Inverpolly and Inchnadamph Nature Reserves, Sutherland, and at the request of the Department of Architecture Planning Research Unit of the University of Edinburgh a proximate survey of some 60 square miles was made in connection with the Grangemouth-Falkirk Regional Survey and Plan. Following an enquiry from the Scottish Peat and Land Development Association a 200 square mile area surrounding Livingston New Town, West Lothian, was mapped on a scale of 2·5 inches to 1 mile. The region is situated within the confines of Sheets 31 (Airdrie) and 32 (Edinburgh) both of which were under survey at the time of this request. A report will be prepared.

Sheets 66/67 (Banchory/Stonehaven)

The area covered in the above sheets is situated in east Scotland and lies to the west and south of Aberdeen. It comprises some 432 square miles on Sheet 66 (Banchory) and 90 square miles on Sheet 67 (Stonehaven). The region includes the greater part of Kincardineshire in the east, with approxi-

mately 100 square miles of Aberdeenshire in the north-west and about the same area of the county of Angus in the south-west. The part north of the River Dee, with the exception of a small area around Banchory, lies in Aberdeenshire.

The region is predominantly agricultural with only small towns and villages of which the largest is Stonehaven, the County Town of Kincardineshire, with a population of 4,500; Banchory, Aboyne and Laurencekirk have populations of less than 2,000. Industry, which is mainly directly or indirectly related to agriculture, is on a small scale. There is, however, a significant seasonal tourist trade.

The main physiographic feature of the area is the great Highland Boundary Fault which runs south-westwards from Stonehaven, dividing the terrain into two major physical regions of highlands and lowlands. North of the fault, in the Grampian Highlands, the rocks are the folded metamorphic rocks of the Dalradian series of the Highland Schist formation and the large mass of the Kincardine Granite. The schists vary greatly in composition, but in the area under review are mainly quartz-schists, quartz-mica-schists and granitic gneiss, often heavily permeated by sills, veins and stringers of granite. South of the fault, in the lowland region, rocks of the Lower Old Red Sandstone formation underlie the area known as the Howe of the Mearns which forms the northern part of the Vale of Strathmore.

Drainage is dominated by the River Dee in the north and the North Esk in the south, and between these two major systems are the Waters of Cowie, Carron, Bervie and Luther. All have their catchments in the Grampians. Tributaries of the Dee are the Waters of Tanar and Feugh.

Within the two major physical regions eight land form regions can be recognized, each having distinctive surface characteristics.

The landscape pattern is determined by the solid geology, modified in detail by the physical factors concerned in the physiographic history of the region, mainly the effects of glaciation. The units delineated have been distinguished by their surface characteristics; each has a type of relief, or slope-form pattern, which is repeated within that locality. The units are:

North of the Fault

1. The Dee Valley
2. The Strachan basin and the Feugh valley
3. The Netherley and Skene lowlands
4. The Grampian foothills
5. The Grampians

South of the Fault

6. The Howe of the Mearns
7. Strathfinella
8. The Garvock Hills

1. *The Dee valley* traverses Sheet 66 from the Moor of Dinnet (500 ft.) to Peterculter (100 ft.). Between Banchory and Kincardine O'Neil the valley is contained between steeply sloping banks, and from Kincardine O'Neil west

to Dinnet it is about a mile wide with low banks and an extensive alluvial floodplain. East of Banchory the valley is a mile wide and the containing slopes are gentle to moderate.

2. *The Strachan basin and the Feugh valley* lie in an east-westerly direction south of, and parallel to, the Dee valley. They form a broad basin within the Grampian foothills and contain extensive flats of fluvio-glacial gravels and alluvium. At the head of the valley is the Forest of Birse, a steep-sided highland glen.

3. *The Netherley and Skene lowlands* occupy the coastal region south of the Dee, extending from Banchory to Stonehaven. The area is comparable with and an extension of the Skene lowlands on the north side of the river. The altitude is generally below 500 feet and the relief consists of gently rolling slopes interspersed with depressional to flat areas with peat-filled hollows. Granite and granitic gneiss, the underlying rocks, outcrop in places, and the region is characteristically bouldery with fields divided by massive stone walls, called dykes.

4. *The Grampian foothills* occur mainly south of the Dee at an elevation below 2,000 feet. Where underlain by the Highland Schists, in a belt some 2 miles north of the fault, the slopes are moderately steep and smooth. The foothills south and west of Banchory are of granite; they have craggy skeletal summits and irregular convex/concave bouldery slopes. On gentle slopes and flat plateaux blanket peat is extensive.

5. *The Grampians* occur at a higher altitude, the Braid Cairn (2,907 ft.) being the highest point. Other prominent hills are Mount Beattock (2,250 ft.), Hill of Gairney (2,478 ft.), Cock Cairn (2,387 ft.), Black Hill (2,272ft.) and the Hill of Wirren (2,220 ft.). Slopes vary from moderate to steep. Many of the summits are of bare rock or have only skeletal soils.

6. *The Howe of the Mearns* occupies the northern extremity of the Vale of Strathmore and consists of the gently rolling land north of the North Esk Water, generally at an altitude below 400 feet and underlain by red marl of the Old Red Sandstone formation. It is bounded on the east by the Garvock Hills and on the west by Strathfinella Hill and the Grampian foothills.

7. *Strathfinella.* The heather clad summit of Strathfinella Hill, which rises to 1,357 feet, is underlain by Old Red Sandstone. It is separated from the Grampian foothills by Strathfinella, a valley through which passes the Highland Boundary Fault. The foot slopes are of arable land, while the mid slopes are moderately steep and are extensively planted with conifers.

8. *The Garvock Hills*, situated on the eastern side of the Howe of the Mearns, rise to 400-600 feet. They are underlain by Old Red Sandstone conglomerate, sandstone and contemporaneous lava rocks which form the eastern edge of the Strathmore syncline. The undulating relief is caused by the underlying strata which run in ridges with a north-westerly to south-westerly strike, producing short irregular slopes.

The climate of lowland Strathmore from Stonehaven to Forfar is moderately dry with a good proportion of bright days and winds mainly westerly. The Dee valley, however, has a bleaker climate, being open to winds from the north and east. Thirty to thirty-five inches of rain annually is the normal expectation over Strathmore. Over the Dee valley and the Skene and Netherley lowlands, which lie within the rain shadow of the Grampians, rainfall is lower, with the driest locality, the coastal strip between Stonehaven and the Bervie Water, having an annual average of about 27 inches. The annual average rainfall increases to 60 inches or so on the higher hills.

The duration of the growing season when the mean daily temperature exceeds 6°C (42°F) is from 235 to 245 days in Strathmore and lower Deeside but decreases with altitude in the foothills to around 200 days at 1,000 feet. The latest assessment of evapotranspiration from a grass covered surface for Angus and Kincardine is:

Potential Transpiration

April	May	June	July	Aug.	Sept.	Summer	Winter	Year
ins	ins	ins	ins	ins	ins	ins	ins	ins
1·75	2·65	3·10	2·95	2·50	1·25	14·15	2·45	16·60

The values suggest that dry soil conditions do not occur frequently over the foothills or over much of the lowland. The period of greatest risk of drought, particularly on the lighter soils in the coastal regions, is from mid-May to mid-July.

Sixty-five soil series have been distinguished and these have been grouped into seventeen soil associations based on the lithological composition of their parent materials, as follows:

Association	*Parent Material*
Laurencekirk	Till derived from Old Red Sandstone sediments, mainly marls and fine grained sandstones, together with residual marl and water-sorted material overlying the above till.
Mountboy	Till derived from Old Red Sandstone lavas and sediments.
Stonehaven	Till derived from Old Red Sandstone sediments, mainly conglomerate, with some sandstone and lava.
Forfar	Water-sorted material, generally more than 2 ft. deep, overlying till derived from Old Red Sandstone sediments.
Balrownie	Till derived from Old Red Sandstone sediments, mainly sandstone, together with water-sorted material generally less than 2 ft. deep overlying the clay loam till.
Tipperty	Red lacustrine clay and silt derived from Old Red Sandstone rocks.
Collieston	Red water-sorted bands of various textures, generally overlying sand and gravel.
Strathfinella	Till derived from Old Red Sandstone sandstone with acid igneous and metamorphic rocks.
Tarves	Till derived from mixed acid igneous, acid metamorphic and basis igneous rocks.

Deecastle	Till derived mainly from calc-silicate rocks.
Strichen	Till derived from quartz-mica-schist.
Countesswells	Till derived from granite and granitic gneiss.
Dinnet	Till containing gravel and pebbles derived from fluvio-glacial deposits.
Auchinblae	Red fluvio-glacial sand and gravel.
Boyndie	Fluvio-glacial sand.
Corby	Water-sorted and morainic gravel.
Pow	Silty estuarine alluvium.

In addition the following miscellaneous soils have been mapped:
Hill Peat
Basin Peat
Peat Skeletal Complex
Alluvium
Links
Dune Sand
Raised Beach Shelly Gravel

During the Pleistocene Period the region of north-east and east Scotland experienced three cycles of glaciation. The first left little evidence of its passage in the area discussed; the second was the most intensive and the glacial till deposits were laid down very largely in this period. The third was of relatively low intensity. At the glacial maximum the British ice sheets and the Scandinavian ice sheet which filled the North Sea were locked edge to edge along the line of the present sea coast from Yorkshire to the Moray Firth.

In the Dee valley the direction of ice movement was largely from west to east, but in the Vale of Strathmore ice dispersing from the Central Highlands into the vale was partially deflected to the north-east, in the general direction of Stonehaven, by the Sidlaw Hills.

The retreat of the final phase of glaciation is marked by moraines, gravel kames and outwash plains of sands and gravels derived mainly from rocks of the Highland Schists and granite. In the Dee valley the readvance of the third ice sheet appears to have incorporated water-worked gravels into a till which now forms the parent material of the Dinnet Association. In Strathmore, as has been previously observed in the Stirling and Perth/Arbroath sheets, the surface of almost all the boulder clay below an altitude of 250 ft. has been modified by periglacial and fluvio-glacial streams flowing along the complex system of glacial meltwater channels which occur in the area. The soils on till, or on only slightly modified till, occurring mainly south of the North Esk, belong to the Balrownie Association and form gently undulating land of high productive capacity. Soils on the modified till which have over 2 feet of sandy loam surface overlying clay loam till at some depth belong to the Forfar Association. The dominant series in the above two associations is a brown podzolic soil with some gleying in the B horizon. Where the surface horizons are deep, the land imposes few restrictions on the production

of a wide range of crops. Appropriate applications of lime and fertilizers, based on soil analyses and fertilizer trials, soon overcome any nutrient problems. The freely and imperfectly drained series of these two associations can withstand the use of heavy machinery, they are easily cultivated, allow early growth in the spring and are capable of carrying large stocks of cattle and sheep over a long period of the year without physical damage. The above remarks are equally applicable to similar soils of the Laurencekirk Association, some 20 square miles in extent. These three associations, Laurencekirk, Balrownie and Forfar are representative of the high-quality land in Strathmore.

The clay content of the Laurencekirk till is from 25 to 33 per cent., with silt (50-2μ) around 33 to 38 per cent. The cation exchange capacity of the imperfectly drained Laurencekirk series is about 15 m.e./100 g. throughout the profile. Percentage saturation is about 80 per cent. in the surface horizon, 70 in the B and 50 in the C horizon. In the uncultivated soils, which are rare, the profile is a freely drained iron podzol on a sandier till. The exchange capacity of the highly organic L/H horizons is very high, with values of 80-110 m.e./100 g., but values drop to 6 to 12 in the B and C horizons. The pH value of 4·0 in the litter layers rises to 5·5 in the C horizon. In the long-cultivated Laurencekirk series the pH is 6·7 in the S horizon but drops to 5·5 in the C horizon. In the Drumforber series of this association, where the parent material is residual weathered marl or mudstone, the pH of the soft rock is 6·7 and the soil is 100 per cent. saturated. No free lime has been observed within the profiles of this association but calcareous marl of high purity has been found in the depressional areas associated with soils of poor drainage, at depths generally below 4 feet. Marl leached from the Old Red Sandstone till composing the parent material of the Balrownie Association was at one time extracted from the Restenneth, Roscobie and Forfar Lochs.

Total phosphate values for these associations derived from Old Red Sandstone are generally in the low to medium range, with the lowest values for any horizon around 70 mg. P_2O_5/100 g. and the highest around 300. Acetic acid-soluble phosphorus in the cultivated soils is now, as a result of fertilizer application, generally at a satisfactory level (10 mg. P_2O_5/100 g.) in the surface horizons. Soluble phosphorus is not infrequently very high in the B_2 and C horizons.

In the Mountboy Association, in which basic lava rock in addition to sandstone is a major component of the parent material, the total phosphorus content is in the medium to high category, varying from 230 to 460 mg. P_2O_5/100 g. within profiles, and it is apparent that for the association as a whole the amount of phosphate inherent in the lava rock is higher than in the sedimentary rocks of the Old Red Sandstone Formation.

From Stonehaven southwards to the North Esk, and including the Garvock Hills, the soils are developed on till derived from Old Red Sandstone conglomerate with some sandstone and lava. The soils are distinguished as the Stonehaven Association and cover 60 square miles; the dominant Stonehaven series, a brown forest soil with imperfect drainage developed on a

stony clay loam till, covers 33 square miles. The freely drained Shields series, an iron podzol developed on stony sandy loam till and occupying 20 square miles, is next in extent, followed by soils with poor drainage distinguished as the Balhagarty series, a non-calcareous gley occupying 6 square miles. From the analytical results the Stonehaven series would appear to be comparable with the Laurencekirk and Balrownie series, but proximity to the coast, a generally higher altitude, and stoniness are factors which adversely affect plant growth. In consequence the system of farming is that of the six or seven course rotation, with a three years grass ley, rather than the more intensive cropping of the Laurencekirk, Balrownie and Forfar associations.

Over the hill ground of the Grampians, the Grampian foothills, the Netherley and Skene lowlands, the Strachan basin and the Feugh valley, and the Dee valley, soils of the Countesswells Association, developed on till derived from granite and granitic gneiss, cover some 140 square miles. The parent material is mainly of a stony, coarse sandy loam texture, and the rock is intrinsically lower in nutrients than rocks of the Old Red Sandstone Formation. Bordering the Highland Boundary Fault, the Grampian foothills are underlain by Highland Schist rocks which give rise to soils of the Strichen Association, developed on till derived from quartz-mica-schist and occupying some 130 square miles. The soils have textures in the sandy loam to fine sandy loam classes. These two associations range in altitude from over 2,500 feet to 100 feet and each contains a sequence of soil series including brown podzolic soils, peaty podzols with iron pan, poorly drained gley soils and very poorly drained peaty gleys. Both associations occur extensively in the north-east and east of Scotland and have been fully described in earlier reports. Most of the heather moor and peaty moorland, excluding the hill peat which covers 60 square miles, is contained within these associations. Iron podzol soils of the Strichen series cover 46 square miles, while iron podzols of the Countesswells Association are of approximately the same extent. The peaty podzol soils with iron pan of the Countesswells Association are distinguished as the Charr series, and profiles can be admirably seen in cuttings over the Cairn o' Mounth road which passes through this association on most of the northern side of the summit. A similar profile of the Strichen Association, distinguished as the Gaerlie series, occurs south of the summit on the Cairn o' Mounth road.

The soils of the Charr series have a pH of 3·4 in the organic surface horizon, which rises to 4·5 in the C horizon. Iron podzol soils of the Countesswells series in the semi-natural state are somewhat less acid, ranging from pH 3·9 in the organic surface horizons to 5·1 in the C. In the uncultivated brown podzolic soil of the Raemoir series the range in pH is from 5·0 to 5·5 in the A horizon to 5·5 to 6·0 in the C. Owing to the coarse texture, which is generally stony coarse sandy loam, the exchange capacity of the Countesswells soils is low, except where horizons of organic accumulation occur. Indurated B_3 horizons are invariably present in the freely drained series of this association and this limits the effective rooting depth of trees and cultivated crops.

Within the Dee valley, extending from the vicinity of Loch Kinord to east of Banchory, the flanks of the valley over a distance of two miles from the river are covered by glacial deposits giving rise to soils which have been grouped into four associations, Corby, Tarves, Strichen and Dinnet. The predominant soil is a freely drained brown forest soil in which the mull surface and absence of the podzolized A_2 horizon appear to be largely due to a cover of birch woodland. The fluvio-glacial gravel terraces of the Corby Association carry both the Corby series, an iron podzol, and the Kinord series, a brown forest soil. West of Banchory and extending to near Aboyne a till derived from a mixture of rocks, including acid igneous, acid and basic metamorphic and basic igneous rocks, occurs on the valley sides. This has been separated as giving rise to soils of the Tarves Association in which the Tarves series, a brown forest soil, is the most widespread. The texture in this area of the association is coarser than in the type area of Tarves, Aberdeenshire. Soils on till of Highland Schist origin, to which quartz-mica-schist rock is the main contributor, have been distinguished as the Strichen Association in which the Fungarth series, a brown forest soil, is dominant.

The parent material of the Dinnet Association, which can be viewed in cuttings on the Moor of Dinnet, is a till containing water-worn cobbles, gravel and coarse sand and is apparently composed of fluvio-glacial gravels picked up in the re-advance of the Dee glacier. A brown forest soil with a mull surface and containing earthworms is the dominant soil, occurring even under heath vegetation. Bronze-age man is known to have had extensive settlements around Loch Davan and Loch Kinord and it is possible that both primitive agriculture and the persistence of birch forest have contributed to the mull surface. The parent materials of the Corby, Strichen and Dinnet associations are sufficiently acidic to give rise to markedly podzolized soils; the clay content is generally < 10 per cent. and surface pH values are from 4 to 4·5. The presence of calc-silicate rock, although widely shown on the geological map, is not readily apparent and it has been recorded in only five localized patches shown as the Deecastle Association; in these, however, pH values of 7 occur in the C horizon and the presence of wild strawberry and cowslip indicate the higher base status.

There is a marked contrast in agriculture between the Howe of the Mearns and the rest of the area. Some of the most productive land in Scotland is contained within the Laurencekirk Association where farm units are large, farms of over 600 acres being not uncommon. With a high level of fertility, the traditional rotation for this area, which was oats, potatoes, wheat, turnips, barley, hay and grass for grazing, has now been adjusted to include a high proportion of cash crops such as seed potatoes, sugar beet, barley, winter wheat, peas for canning and soft fruits. The most important cash crop is the potato which has consistently produced the highest financial returns per acre over a period of years. Yields in excess of 12 tons are common. Potato seed is mainly for English growers but is also exported to South Africa and Spain.

In North Kincardine and the remainder of the area the cropping potential is much lower and livestock farming is universal, crops being grown for feeding to livestock rather than for sale. In the glens and upland areas sheep farming is extensively carried on, mainly with Blackface sheep on *Calluna* heath. There are, however, a number of pedigree flocks of Border Leicester and Suffolks on the low ground farms.

Afforestation has been extensive over the past 30 years: the Commission forests at Drumtochty, Fetteresso and Durris now cover some 20,000 acres. Much of this planting has been done on land which formerly carried *Calluna* heath or moorland on podzol or peaty podzol soils. Private woodlands occupy some 5,000 acres at Glentanar and 4,000 on the Glendye and Fask estates, while many smaller estates, for instance at Finzean, Ballogie and Thornton, have extensive plantations. The private owners have tended to plant areas where trees have persisted for a very long time—remnants of the Caledonian forest occur at Glentanar—but the Forestry Commission has successfully undertaken planting on land which has been devoid of trees for several centuries. Exposure to westerly winds is one check to tree growth and much information as to planting techniques and the best choice or strain of species suitable for the area has been gained. Scots pine, for instance, does not grow well near the east coast even if the soils appear suitable and *P. contorta* is now used.

When viewed from the Howe of the Mearns, Strathfinella Hill, with its upland grazing, forested slopes and arable lowland, provides a good example of the effective use of the land. This pattern of land use is found generally throughout the region.

SPECTROCHEMISTRY

During the past few years, the utilization of spectrochemical and related physical methods for the determination of major and trace constituents in plants, soils and rocks has increased considerably in numerous laboratories throughout the world. This can be related to the availability of reliable direct reading instruments capable of carrying out the required determinations, provided always that the difficulties which may arise with different types of materials are appreciated. In general, in soil and plant work, an emission spectrochemical approach appears most appropriate, but for the analysis of rocks and minerals and for total contents in soils, X-ray fluorescence spectrometry is finding favour. For certain trace element determinations, a spark-source mass spectrograph can give sensitivities unobtainable by the other techniques mentioned, and could have applications in the search for further biologically important elements.

Most of the trace element studies in the department have still to be made by spectrographic techniques with photographic recording and microphotometry, involving appreciable delays in the examination of samples from comprehensive long-term experiments, because of the continued demands for service analyses. The advantages of direct reading with electronic print-out, coupled with the facilities of a versatile computer, would include more accurate determinations, as corrections for matrix and inter-element effects could be applied more rigorously.

Such developments were prominent at the two meetings attended by Dr R. L. Mitchell during the year, namely the fifth Australian Spectroscopy Conference in Perth, Western Australia, and the twelfth International Spectroscopy Colloquim in Exeter, England. The latter was also attended by several other members of staff. At both conferences, striking advances in atomic of high intensity hollow cathode lamps, are being adopted as soon as possible. of high intensity hollow cathode lamps are being adopted as soon as possible. In the course of his journey to Australia, Dr Mitchell visited a number of institutions where spectrochemical and trace element work is being carried out. These included laboratories in Honolulu in Hawaii, Hamilton, Palmerstown North, Wellington and Christchurch in New Zealand, Sydney, Canberra, Melbourne, Adelaide and Perth in Australia, and Kuala Lumpur in Malaysia. Soils in the areas in which several of the classical trace element deficiencies occur were examined on a number of field excursions.

Mr Shmuel Yariv of the Department of Inorganic and Analytical Chemistry of the Hebrew University of Jerusalem is spending a period of 12 months in the department, and is engaged in infrared studies of the adsorption of organic acids by clay minerals.

Various members of staff have attended meetings of scientific and official organizations in Great Britain. Dr R. L. Mitchell served on the technical organizing committee of the twelfth International Spectroscopy Colloquium. Dr A. M. Ure described the technique developed for the determination of

cobalt to the Atomic Absorption Spectroscopy Group of the Society for Analytical Chemistry. An abridged version[50] of a lecture on soil research in Scotland, mentioned in last year's report, still awaits publication.

Trace Elements in Soils, Plants and Biological Materials

The methods now available in the department enable some 23 elements to be determined in plant materials. The elements are potassium, sodium, calcium, magnesium, cobalt, nickel, molybdenum, iron, lead, tin, zinc, titanium, vanadium, chromium, silver, copper, manganese, barium, strontium, boron, silicon, aluminium and phosphorus. This involves the use of several techniques, including excitation by flame, porous cup solution spark, direct current arc and rotating disk alternating current arc. In soil extracts it is still difficult to determine certain of these elements conveniently, and more use is made of porous cup solution spark excitation.

Soils and Soil Parent Materials. From the area of Ayrshire covered by Sheet 14 of the Soil Survey of Scotland, soils of the Glenalmond, Rowanhill, Hindsward, Drongan, Blair and Knockskae associations have been examined for trace element contents. The parent materials in this area are generally an admixture of Carboniferous and Old Red Sandstone sediments with basic lavas, and there are consequently variations in trace element contents within one association depending on the proportions of igneous rocks and arenaceous and argillaceous sediments. Generally, however, the trace element contents lie within the anticipated ranges. Once again the mobilization of a number of elements in the gleyed lower horizons of poorly drained profiles has been observed. Both profiles from the Knockskae Association on felsite were uncultivated, but deficiencies of cobalt and copper might be expected should soils of this association be improved.

Soil Status and Plant Uptake. The correlation between the content of trace elements in the soil and their uptake by the plant involves a number of factors which tend to be ignored in many considerations of the subject. The most difficult point to decide is what should be understood by plant uptake. Different species, and even different varieties, growing side by side on the same soil can have different contents of trace elements—higher for some elements and lower for others. This relationship can be quite different at different soil pH-values, and is probably affected by other soil characteristics such as the nature of the organic fraction. Within the plant itself the distribution of the different trace elements varies, and the nature of the sample examined can affect the finding appreciably. All these effects operate for samples taken at a pre-determined stage of growth. Changes in distribution within the growing plant occur at different stages of growth, with the development of seedhead and aging of the foliage. These effects are of quite different magnitudes for grasses, root crops or deciduous trees, but certain trends can be observed. For instance, the lead content of foliage appears always to increase when senescence occurs. In deciduous trees [51, 52] the effect can result in a 5-10 fold increase before the leaf is shed; in pasture herbage, which persists over the winter, the increase may approach 50 fold.

A considerable proportion of the trace element investigations in the department are concerned with the establishment of these effects, in particular with their significance in diagnosis of plant disorders and with the assessment of animal intake.

In collaboration with the department of Soil Fertility, a study of the trace element uptake of different herbage species grown on soils which had received incremental levels of various phosphatic fertilizers is in progress. An investigation of the effects of the addition of cobalt to the soil on various herbage species at different soil pH-values over a 4-year period is approaching completion. Cobalt was applied as sulphate in superphosphate and in chelated form: differences in initial effectiveness and in persistence occur. Preliminary indications are that application as sulphate is to be preferred, even on neutral or alkaline soils.

Analyses of plants grown in National Agricultural Advisory Service pot experiments on various sewage sludges have been carried out in order to assess the availability and uptake of possibly toxic trace elements, to supplement the information available on the contents of the sludges themselves. A number of analyses of composts from town refuse have been made on behalf of the Forestry Commission. Such materials often contain appreciable amounts of total and extractable zinc, lead, copper and nickel. As a result of these findings and their own nursery experience, the Forestry Commission have abandoned the use of such composts in their forest nurseries, because of the known susceptibility of conifers to zinc toxicity and the impracticability of mitigating the effects by liming—a practice that may be feasible in other circumstances.

A number of enquiries have been received regarding the utility of fertilizers containing a mixture of added trace elements. Commercially available products unfortunately seldom reveal the actual contents of the trace elements which are claimed to be present in beneficial amounts, and it is difficult to assess the consequences of their use. In general, only trace elements present in the soil near or below deficiency levels should be added, at a rate specified by an advisory officer with knowledge of local conditions. A policy involving the addition of trace elements already present in abundance can only have deleterious effects in the long run, and could in some instances be harmful within a short time. One element persistently included in such mixtures is molybdenum, despite the fact that areas of molybdenum excess are well recognized in England and Scotland, and, in Scotland at least, quite large areas are on the brink of molybdenum excess. There is no evidence that in most soils the level of available essential trace elements is not satisfactorily maintained by normal agricultural practices and by the weathering of constituent minerals which contain them in a less readily available form. Only for soils where recognized deficiencies are liable to occur, with, for instance, boron, copper or cobalt, should remedial action be taken. Even if a soil is deficient in all three, the requirement is seldom for these elements simultaneously: boron should properly be applied before the root crop, copper before

the cereal and cobalt before the pasture herbage, so that the optimum benefits can be obtained from each element.

A collaborative experiment with the Rowett Research Institute involving the determination of cobalt, copper, zinc, molybdenum, manganese and iron in various organs of cattle fed on herbage managed in different ways is at present in progress. Analyses of 45 samples each of kidneys and livers have been completed, and other organs are being examined. This should help to provide a link between soil:plant relationships in herbage investigations and animal utilization.

Spectrochemical Methods of Analysis

No major changes in the methods employed have been introduced during the year, but several modifications in techniques and equipment have been introduced with the aim of facilitating serial analysis and reproducibility.

Pretreatment and Concentration. The concentration technique involving precipitation by 8-hydroxyquinoline, tannic acid and thionalide has not been substantially modified since its introduction some 20 years ago. It has proved to be widely applicable, and only occasionally are samples encountered which necessitate slight variation of the technique. Two such instances may be mentioned.

In the presence of a high level of phosphate, considerably above that normally present in plant materials, an appreciable amount may be coprecipitated if the tannic acid and thionalide reagents are added immediately after the addition of 8-hydroxyquinoline, but not if the initial oxine precipitate is allowed to age for a few hours before addition of the other reagents. The presence of phosphate in the concentrate is of little significance except for molybdenum, for which a depression of 10-20 per cent. may occur with 50 per cent. phosphate in the concentrate. For other elements only the concentration ratio, and therefore the limit of determination, is affected.

With extracts of certain organic soils, sufficient oxalate may remain after the normal treatment with nitric acid to precipitate appreciable amounts of calcium at pH 5·2. The presence of calcium in the concentrate is readily detected by the colour of the arc discharge, and by the presence of strong calcium lines. If necessary, for instance because of calcium interference with the determination of zinc, oxalate can be decomposed by ignition before concentration.

Arc Emission. The use of recording microphotometry for the determination of a number of trace elements present in concentrates near the limit of determination by non-recording microphotometer is now standard practice. The elements most frequently concerned are cobalt, molybdenum and lead, at the levels reported in the 1963-64 Annual Report; in addition, zinc, tin and silver have occasionally been assessed down to 300, 10 and 1 p.p.m., respectively, an improvement in sensitivity of some 5-10 fold.

The display microphotometer constructed in the department has shown that it could be successfully applied to this type of work, and modifications to enable the measurement of line peak-height to be made electronically on

a double beam cathode ray tube are being carried out. With visual measurement from a scale on the cathode ray tube it has proved possible to obtain results in agreement with those given by the Leeds-Northrup recording microphotometer with a very considerable saving in time.

Preliminary studies with a gas-sheathed arc unit designed in the department confirm that a nitrogen-free environment in which no CN-bands are emitted can be obtained without working in an enclosed chamber. An argon-oxygen mixture is much more efficient than commercial carbon dioxide, which apparently is not adequately nitrogen-free.

Flame Emission. One of the three-channel flame photometers used for the serial determination of potassium, sodium and calcium has been fitted with a modified EEL atomizer in place of the Lundegårdh-type atomizer previously employed. The changes in the EEL atomizer involved modification of the air-pressure and solution flow-rate to suit the requirements of the Lundegårdh-type burner. The speed and convenience of analysis has been considerably improved by fitting an extended suction tube to the atomizer, so enabling a set of samples to be sprayed in turn into the flame without removal from their tray.

Some cylinders of acetylene received during the year have given rise to difficulties in the determination of potassium because of the presence of phosphine as an impurity. This produces a band at the potassium wavelength in addition to a stronger band in the 5500-6300A region. The effect is most pronounced when a cylinder is new, and decreases after some of the contents have been used. The flame displays a marked milky-white coloration if the phosphine content is high. The identification of the cause of this effect is an illustration of the value of a spectrographic instrument when difficulties arise or when new techniques are being developed. The flame spectrograph unit has been brought into operation again for elements such as manganese and strontium, not conveniently covered by flame photometry.

Direct Photometry. The small direct reader used for the determination of magnesium in soil and plant extracts has been fitted with an enclosed spark stand similar to that used with the medium direct reader. This is a considerably modified version of the Hilger and Watts FS32 stand. Apart from the increased safety to the operator, this stand reduces both the noise level and the possibility of corrosion of equipment by acid fumes, as an extraction system to deal with fumes and droplets has been incorporated.

Atomic Absorption. The modified atomic absorption equipment incorporating a recorder, described in the 1963-64 Annual Report, has now been in full operation for 18 months and is providing satisfactory determinations of cobalt in acetic acid extracts of soils for advisory purposes. The saving of time, compared with analyses by the concentration technique previously employed, is considerable, particularly at periods of peak demand for soil cobalt determinations in winter and early spring.

Absorption Spectrometry of Soil Constituents

Information about the properties and reactivity of clays can be obtained by studying the infrared spectra of molecules adsorbed on their surface. This technique is now attracting wide interest, as it yields information which could be obtained in no other way, and which is directly relevant to soil properties. The work of the department has yielded important information in this field. Investigations of the adsorption of water[22], ammonia[53], ethylamine[23] and pyridine[54] by montmorillonite-type clays have now either been published or await publication. Work on pyridine was begun by one member of the department while on leave of absence at Michigan State University, and work on ethylamine was completed there. Water is a universal adsorbant on soil clays and ammonia is in commercial use as a fertilizer. Ethylamine and pyridine are appropriate model compounds for certain basic organic molecules which occur naturally in, or are added to, soils. A general feature of these investigations is the importance of the exchangeable cations on the clays in determining the nature and strength of adsorption. The reactions observed are often those which might be anticipated in aqueous solution, although in several instances comparable information on aqueous systems is not available. The nature of the clay surface can, however, play a dominant role. Pyridinium ion is strongly adsorbed in montmorillonite, but not in saponite. There is evidence, too, that chemical reactions which perhaps involve the formation of free radicles and which do not occur in aqueous solution can be induced on the clay surface.

The infrared spectrum of a mineral can be used simply as a characteristic feature to distinguish the different mineral species and their varieties. In this field, infrared spectroscopy is proving a useful ancillary to the facilities for X-ray and thermal studies available in the department of Pedology. Its application in characterizing amorphous components in soils has been reviewed[8]. With increasing understanding of the details of the spectrum, structural features of minerals, which could not readily be obtained by other techniques, can be deduced. This has been illustrated in a study of tobermorite now awaiting publication[55]. This calcium silicate, whose importance in cement chemistry has long been recognized, is now known to occur in some soils. There are still many features of mineral spectra, however, which are not well understood. New factors which are not important in the more fully investigated field of organic chemicals arise in silicates. One of these is the strong electric field associated with silicate vibrations, whose effect is dependent on particle size and shape. This and other effects are discussed in a paper awaiting publication[56].

Collaborative work with the departments of Biochemistry and Microbiology, now published, includes a study of polysaccharides synthesized by root organisms[24] and the characterization of some plant glycosides[25]. Studies of soil waxes, and of lignin decomposition by soil organisms, are in progress. Many *ad hoc* samples arising from work in these and other departments have been examined. A satisfactory report on the nature of these samples is

facilitated by an intimate knowledge of the work out of which they have arisen, and has usually involved a thorough search of the literature for information on related compounds.

In the infrared study of both inorganic and organic substances it is important to distinguish between absorption arising from constitutional hydroxyl groups and that from water adsorbed on the surface or incorporated in the crystal structure of the samples. This distinction can often be conveniently made by following dehydration reactions in alkali-halide pressed disks[57].

BIOCHEMISTRY

Research in the department has for some years been directed towards obtaining a better understanding of the carbohydrates present in soils. The chief obstacle to progress is the difficulty of separating them from the other constituents. The use of 72 per cent. sulphuric acid at room temperature, a rather desperate expedient because it simultaneously degrades the material that is being extracted, has until recently been the only way by which a substantial proportion could be isolated and analysed.

The sulphuric acid extract is diluted and heated, thus completing the degradation of polysaccharide to its constituent sugars, which may then be separated and measured by chromatography. The yields of sugar obtained by this method exceed those obtainable by any other procedure and are believed to represent the greater part of that present; they usually account for 10 to 20 per cent. of the soil carbon. The only method of extraction that gives yields approaching this is one developed recently in the department of Soil Fertility (*see* p. 00) using aqueous acetylacetone at pH 8 with ultrasonic disintegration. Relatively mild conditions such as these are obviously to be preferred for studies of the nature of the carbohydrate fraction.

The sulphuric acid method, which was described at the Biochemical Society meeting in Dundee in June, 1965, and has now been submitted for publication,[58] is being used to follow the fate of radioactive starch in soil. The rate of disappearance of radioactive glucose (which is the main constituent of starch) and of the appearance of radioactive carbon in other soil sugars is being measured. Early results show that under the conditions chosen half the starch is oxidized to carbon dioxide within a few weeks, but even after three months the soil glucose is still more radioactive than the other sugars: among these the other soil hexoses, galactose and mannose, are most quickly labelled with radioactive carbon from the glucose. By continuing these studies with radioactive starch and later using other plant polysaccharides it should be possible to judge how much of the soil polysaccharide at any particular time consists of the products of primary microbial action on plant residues, and how much is plant polysaccharide resistant to microbial action or protected by association with soil minerals.

Effects of Humic Acids on Plant Tissue. The development in collaboration with the department of Plant Physiology of a method for preparing disks of beet tissue under aseptic conditions[26] has made it possible to examine the effect of humic acids on this tissue without the complicating activities of microorganisms. It was discovered that humic acid from a mineral soil considerably enhanced the synthesis of the enzyme invertase that occurs when the disks are kept in aerated water and leads to a rapid breakdown of the sugar contained in them.

This effect is being investigated from two points of view. Although it seems to have a connection with the growth of plant cells[27], the appearance of

invertase in this test system is still insufficiently explained and a better understanding of its biological significance is being sought.

On the other hand humic acid preparations have been subjected to various chemical manipulations to see which features are essential to their action. For example, the removal of more than nine-tenths of the associated mineral constituents does not abolish the effect, and the ash itself has no stimulatory action. This suggests that organic constituents are responsible, but synthetic " humic acids " made by oxidation of catechol, with or without the presence of nitrogenous substances, were found to be inactive.

So much of the chemical structure of humic acids is still a matter of controversy or conjecture that any means of focusing attention on a particular aspect, as by this biological test, is welcome. The investigation is being helped considerably by the experience gained previously in the department by studies of the chemistry of humic substances. It is hoped that eventually some light will be thrown upon the way in which soil organic matter influences the growth of root systems.

Publications. These observations on a biological effect of humic acid were briefly reported to the Biochemical Society meeting at Dundee, and Dr Morrison gave an account of his recent work on the chemistry of humic acids to the Phytochemical Group at their meeting in Aberdeen. Publications during the year include four posthumous papers by Dr R. B. Duff[24,25, 28, 29] and various collaborators, a communication on the action of a rhizosphere organism on yeast cell walls[30], and an account of some constituents of leaf extracts[14].

Dr Bacon contributed a review of the chemical environment of soil bacteria to a Symposium on their ecology, held by the University of Liverpool in September, 1965; the proceedings are to be published in due course.

PLANT PHYSIOLOGY

The main topics on which research has been concentrated during the year are mineral nutrition of plants with respect to iron metabolism, cation exchange capacity of plant tissues, ion absorption and electrical potential measurements in plant cells.

Iron Metabolism in Plants. Studies have continued on the interaction of iron, nitrogen and copper in the nutrition of oats grown in copper deficient peat, in collaboration with the department of Biochemistry.

The herbicide amitrole (3-amino 1, 2, 4-triazole) induces chlorosis in plants and its mode of action may be by a disturbance of the iron metabolism in the leaf. This theory is being investigated by a comparison of healthy, iron-deficient and amitrole-induced chlorotic plants. *Lemna minor* has proved to be a most suitable test plant for these comparative studies of biochemical changes, fine structure of cells by electron microscopy, and by autoradiography which employs radioactive isotopes and shows distribution of iron and other elements.

Ion Absorption. The relationship between ion absorption and metabolism in storage disks continues to provide numerous research problems. Protein synthesis inhibitors have been shown to exert differing effects on the development of an ion absorption capacity in disks and the actual absorption of ions consequent to this development. Thus it is possible to distinguish the synthesis of the machinery implementing ion absorption from the mechanism of absorption itself.

Further attention has been paid to the effect of different incubation conditions of the disks, especially sterile as compared with non-sterile conditions, during the early stage of the development of an ion uptake capacity. It appears that sterility, or the lack of it, may result in pronounced differences in the rate of this development.

Ion Transport and Electrical Potentials in Plant Cells. The measurement of transmembrane electrical potentials in single cells of storage tissue has continued, with the emphasis on measurements at temperatures between 0° and 2·5°C. The results of this work have confirmed the validity of theoretically derived values used in earlier low temperature ion transport studies to describe the passive uptake of chloride from potassium chloride solutions by potato tuber tissue. Membrane potentials have also been measured in solutions of calcium, magnesium and sodium chlorides as part of a study of the effect of other counter-ions on the passive uptake of chloride by disks.

Continued collaborative work with the Department of Botany, University of Aberdeen, on the measurement of electrical potentials across detopped roots, has led to firm conclusions about the nature of the uptake of the major nutrient ions by whole root systems. An account of this work[61] has been submitted for publication.

Cation Exchange Capacity of Plant Materials. Work has continued with the department of Soil Fertility on the measurement of the cation exchange capacities of roots of different species and varieties within a single species. A relationship between cation exchange capacity and mineral composition of the plants has already been established for different species. However, the small range of cation exchange capacities covered by varieties has made the relationship with mineral composition difficult to demonstrate. The most satisfactory results were found with varieties of leeks in which the exchange capacity of the roots could be related to the total cation content of the tops and other factors. Subsequent work has been undertaken to confirm these findings with leeks and investigate other members of the genus *Allium* and genera of the same family having a number of varieties within a species.

Radioactivity

Radioactive tracer techniques continue to be used extensively, particularly in plant physiological and biochemical studies.

MICROBIOLOGY

The main lines of work in the department outlined in last year's report have been continued and details of the progress made are given below. Collaboration with other departments in the Institute in many of the investigations has been maintained.

During the year Dr S. de Boer of the Plant Physiological Research Centre, Wageningen, Holland, spent about two months studying the pellet and other techniques used in the department. Mr T. A. Jackson, Yale University, U.S.A., spent a similar period studying the methods for the investigation of the role of micro-organisms in the weathering of rocks and minerals.

Dr J. F. Darbyshire attended the second International Congress of Protozoology held in London in July, and Mr M. P. Greaves attended the Symposium on the Ecology of Soil Bacteria which took place in Liverpool in September.

Rhizosphere Studies

In the study of the breakdown of organic phosphates by micro-organisms from the root region of Ryegrass S23, Timothy S50 and Cocksfoot S143 it was found that the total numbers of micro-organisms decomposing phenolphthalein diphosphate, sodium glycerophosphate, sodium phytate, lecithin, ribonucleic and deoxyribonucleic acids were higher on the root surfaces and in the rhizosphere soils than in the non-rhizosphere soil. Occasionally preferential stimulation of organisms hydrolysing some of these compounds was observed in the root regions. A paper[52] containing full details of this work has been accepted for publication.

In collaboration with the department of Soil Fertility, the study of the breakdown of phytic acid (inositol hexaphosphoric acid) in buffered solution by certain soil bacteria has continued. It was found that the commercial samples of sodium phytate used were contaminated with inorganic orthophosphate and lower esters of inositol, such as the penta-, tetra-, tri- and diphosphates. Difficulties were encountered in the purification of this commercial phytate, especially in the removal of the pentaphosphate ester. These were overcome by the use of ion-exchange resin chromatographic methods and a salt of pure inositol hexaphosphoric acid has now been obtained. Further evidence has been obtained that a stepwise removal of inorganic phosphate from the hexaphosphate occurs during its breakdown by the micro-organisms.

The effect of clay minerals, such as montmorillonite, on the hydrolysis of phytic acid by the organisms has been studied. It was shown that in the adsorbed state phytic acid is not so readily available for hydrolysis. Similarly insoluble phytates, such as iron and aluminium salts, are resistant to hydrolysis by the organisms tested.

A paper[24] on the incidence of polysaccharide producing bacteria in the root region of the above mentioned pasture grasses has been published. The results of a detailed electron microscopic study of the structure of the cell surface of the non-fruiting myxobacterium, which was found to be present

among the predominant organisms on the root surface of the grasses at certain stages of growth, has been accepted for publication[41]. Further work in collaboration with the department of Biochemistry has shown that the myxobacterium has the ability to attack the walls of yeasts and certain filamentous fungi. A short communication on some features of the yeast cell wall as revealed by using cultures of the myxobacterium has been published[30].

The study of protozoan and bacterial populations in the rhizosphere of the perennial ryegrass (S23) was continued under more controlled conditions in the greenhouse. Similar experiments are in progress with cereals and other crop plants. Further improvements to the method of estimating the numbers of soil protozoa outlined in last year's annual report have been developed. The small soil suspension aliquots from the dilution series are now incubated on soil extract agar and the use of the bacterium (*Aerobacter aerogenes*) as a food source is omitted. These modifications allow a greater variety of flagellates to develop; the numbers of amoebae and ciliates are unaffected. Other methods tested were the soil staining technique of Bunt and Tchan (*Proc. Linn. Soc. NSW.*, **80**, 148, 1955) and the galvanotaxic technique of Hairston and Kellerman (*Ecology*, **45**, 373, 1964). The chief limitation of the former method is that it is difficult to identify the stained protozoa beyond their class. In the latter method only the larger ciliates were stimulated to migrate by the weak electrical current (D.C.) employed.

The paper describing the "most probable number" method for enumerating bacteria which produce 2-ketogluconic acid in soils and other habitats[29] has been published.

Lignin Decomposition

Results from previous work in the department have shown that certain species of soil fungi are able to metabolize lignin-related compounds such as syringic, vanillic and p-hydroxybenzoic acids, and their corresponding aldehydes. The pellet technique developed in the department was employed in the latter studies. By using a completely different method for isolating the fungal population colonizing pellets, in which vanillic acid and α-conidendrol (also a lignin-related substance) were incorporated, the range of soil fungi capable of metabolizing these substances in pure culture has been extended. The method involved the direct transfer of spores and mycelial strands developing on the pellets to suitable agar media. Pure culture studies employing ultraviolet absorption spectrometry and paper chromatography showed that with the exception of *Acremoniella* sp. all fungi isolated metabolized vanillic acid when supplied as sole carbon source. In the case of *Volutella* sp. growth-promoting substances supplied as yeast extract were required before the vanillic acid was metabolized. It is of interest to note that one isolate, *Stilbum* sp. did not match any previously recorded species of this genus and in addition produced an antifungal substance which inhibited spore germination of many of the soil fungi.

Progress has also been made in isolating soil micro-fungi capable of utilizing lignin when supplied as sole carbon source in culture media. The pellet technique was again employed but with the dilution plate method to isolate

the fungi. The lignin substrate incorporated in the pellets was extracted from Phragmites reed and barley straw. Ultraviolet and infrared absorption spectrometry have both been employed for estimating the qualitative and quantitative changes in the lignin in pure culture studies. Results so far obtained indicate that species of fungi such as *Humicola* and *Cephalosporium*, although not generally associated with lignin decomposition, utilize 41 per cent. and 31 per cent. respectively of the lignin supplied as sole carbon source in a mineral salts medium. In addition it has been shown by infrared studies that the residual lignin in the culture media had been altered.

The above projects are being carried out in collaboration with the departments of Spectrochemistry and Biochemistry.

Continuous Culture Apparatus

With the help of the instrument workshop a one stage continuous culture apparatus has been built in the department. Preliminary experiments on the growth of micro-organisms required for physiological studies, etc., have been started. The production of 2-ketogluconic acid under controlled conditions of temperature, aeration, pH and rate of agitation is also being investigated.

SOIL FERTILITY

The main research topics are briefly outlined below. The programme as a whole continues to be directed towards improvement of manurial practice and crop production through better understanding of (a) the capabilities and nutrient relationships of different soil types, (b) the significance of pedological factors, soil properties and environmental conditions, (c) the fertilizer requirements and mineral composition of different crops, and (d) the effectiveness of different types of fertilizers, including the importance of time, frequency and method of application. The overall experimental approach, therefore, remains the concurrent development and integration of field, pot and laboratory studies covering the various plant nutrients, the main agricultural crops, and selected soil types mapped in the Soil Survey of Scotland.

Importance continues to be attached to translation of research findings into practice through the medium of advisory soil testing in collaboration with the North of Scotland College of Agriculture, contributions to the agricultural press, and talks and demonstrations to visiting groups and agricultural and horticultural bodies.

The department continues to be represented on relevant committees and working parties set up by the Agricultural Research Council, including the new Technical Committee on Soil Classification and Soil Fertility, on the Grassland Committee of the Scottish Agricultural Improvement Council, and on the Scottish Sub-committee of the Sugar Beet Research and Education Committee. Collaboration has also been maintained with the Agricultural Research Council Unit of Statistics in the preparation of reports on the Survey of Fertilizer Practice carried out by the Scottish Colleges of Agriculture, and with several other research organizations, especially the Hill Farming Research Organization and the Rowett Research Institute.

Considerable efforts are being devoted to various aspects of the preparations for the joint meeting of Commissions II (Chemistry) and IV (Fertility) of the International Society of Soil Science in Aberdeen in 1966. Dr E. G. Williams has been elected to the Council of the British Society of Soil Science.

Dr J. W. S. Reith attended a meeting in Paris, convened by the Organization for Economic Co-operation and Development, on the use of black peat in the production of slow-acting nitrogenous fertilizers.

Dr W. M. Crooke read a paper on differences in the chemical composition of plant varieties at the meeting of the Society for Experimental Biology in Aberdeen in April, 1965.

Dr J. B. Passioura, School of Agriculture, University of Melbourne, completed a year's visit to the department in November, 1964, during which he studied the use of anion exchange resin to extract inorganic soil phosphate and to study phosphate mobility. Dr R. L. Halstead, Soil Research Institute, Ottawa, Canada, left in August after a similar visit, during which he collaborated in an investigation on the use of acetylacetone to extract organic phosphate and other organic constituents from soils. Mr J. D. McFarlane, Lecturer in Agronomy, School of Wool Technology, University of New South

Wales, Australia, also came during the year, for two months, to gain an insight into soil phosphate investigations, methods for evaluating the phosphate status of soils, and advisory soil testing in general.

A review article[64] was prepared for the 1964 Reports on the Progress of Applied Chemistry, covering Pedology and Soil Fertility, Biological Weathering, Trace Elements, Major Cations, Inorganic Phosphate, Organic Phosphate, Sulphur and Chemical Soil Testing. In the treatment of all these topics particular attention has been given to illustrating the ramifying influences and implications of soil parent material and drainage conditions.

Effects of Fertilizers on Crop Yield and Composition. Two papers summarized in last year's report have now appeared. One[32] deals with the main effects of N, P and K on the botanical and chemical composition of herbage cut five times per annum for conservation, and the other[33] with the influence of nutrient applications, especially K, on the mineral composition of crops grown in Scotland. A review[34] has also been published of the main factors, including soil acidity, drainage conditions, moisture regime and temperature, which affect the mineral composition of crops. The fact that there are so many factors involved makes it difficult to interpret the significance of results and limits the usefulness of plant analyses. Even so, provided the limitations are realized, crop analyses can be a valuable supplement to soil data in the diagnosis of mineral deficiencies or excesses. They can also provide useful information on the mineral content of fodder for stock, and a basis for adjusting applications of major and trace elements to ensure appropriate crop contents for both plant growth and animal health.

Field experiments to measure the effects of different rates of N, P and K on the yield and composition of the main agricultural crops on different soil types have been continued. In the past a 4^3 factorial design involving all combinations of four rates of N, P and K has been used in these experiments, but a central composite type of design has been introduced this year, in collaboration with the section of Statistics. This design reduces to a minimum the treatments with no N, no P and no K, and concentrates on providing information on the response surface in the region of the optimal nutrient rates.

Different forms of N and K are also being tested. Both nutrients, especially at higher rates of application, usually depress the dry matter content of potato tubers.

Methods of Applying Fertilizers. Field experiments on barley, oats and swedes to compare the effectiveness of broadcast and band applications of ortho- and meta-phosphates have been continued, in conjunction with a wider pot investigation, mentioned below under inorganic phosphorus, on the effectiveness of various non-ortho phosphates.

Calcium and Magnesium. Two papers [65], [66] summarized in last year's report are due to appear and experimental work has been continued on the long-term effects of various Mg supplements and other nutrient applications, especially K, on the Mg content of crops.

Trace Elements. Investigations have been continued in collaboration with the department of Spectrochemistry on the need for trace element applications, on methods and amounts required to correct deficiencies, and on the effects of other nutrients on the trace element content of crops, especially grassland herbage. The joint paper[35] on the effects of additions of lime, fertilizers and some trace elements on the contents in plants, mentioned in recent reports, has now appeared.

Inorganic Phosphorus. Improvement of the efficiency of applied phosphate remains an objective of outstanding practical importance. In addition to amelioration of soil conditions, the use of efficient methods of application, especially suitable placement, and appropriate adjustments of the timing, frequency and amounts of dressings, the main approach to this problem is modification of the physical and chemical form in which the phosphate is applied. Detailed testing of the normal range of orthophosphates on different crops and soils continues to yield valuable practical information, but seems unlikely to lead to any major further increase of the level of efficiency. Accordingly it was decided three years ago to undertake a comprehensive programme of pot experiments, to examine the effectiveness of non-orthophosphates of various structures, including condensed forms of different chain length and ring sizes, and selections of more novel compounds of various other types. The main effort has again been devoted to this programme, which has been made possible by the expert and much appreciated co-operation of the Research and Development Department of Scottish Agricultural Industries, Ltd., Edinburgh, in synthesizing and characterizing the materials. In several instances, placement effects have also been examined, including some field tests, as indicated above under methods of applying fertilizers.

Long-term field experiments on the residual effects of superphosphate and ground mineral phosphate have been continued, and data are being gathered for a major reassessment of the usefulness of various conventional extraction methods for evaluating the phosphate status of soils. Interest has also been maintained in the fractionation and solubility of inorganic phosphorus compounds in soils, and the experimental approaches to these questions have been reviewed[64].

Organic Phosphorus. Investigations on the distribution of the principal organic phosphates which occur in soils, the hexa- and penta-phosphates of inositol have continued, and co-operative studies are being carried out with the department of Microbiology on the mineralization of these esters by soil micro-organisms. The esters of several isomers of inositol have been identified in a range of British and Canadian soils. The most abundant in several of the soils so far examined is *myo*-inositol hexa-phosphate, but the distribution pattern is being further investigated.

Alkaline solvents such as sodium hydroxide are among the most effective extractants so far used for soil organic phosphate. But they can cause marked changes in the nature of organic constituents during extraction, and the use of milder reagents is being studied. An account[67] of an investigation on the

use of acetylacetone as extracting agent has been submitted for publication. It has been found that repeated extraction of acid-leached soil with aqueous acetylacetone at pH 7-8 removes about two-thirds of the organic phosphate. In several soils so far examined the use of ultrasonics to aid dispersion has resulted in a virtually quantitative extraction at pH 8, and this aspect is being further investigated. As further illustrated below under sulphur, a high proportion of the whole soil organic matter is dissolved under these very mild conditions, and the procedure has the added advantage that the acetylacetone can be readily removed by ether extraction.

A paper[68] on the analysis of inositol hexaphosphate in soils, mentioned in last year's report, is due to appear, and chapters dealing with the nature and properties of the organic phosphorus and sulphur compounds in soil have been contributed to a forthcoming Encyclopedia of Soil Science[69, 70]. Both the latter topics are also briefly covered in the review article in the 1964 Reports on the Progress of Applied Chemistry[64]. In addition, a chapter on the isolation and characterization of the organic phosphorus compounds in soil, with particular emphasis on nucleic acids and their derivatives, has been prepared for a work on Soil Biochemistry[71].

Sulphur. Detailed laboratory studies have been continued on the sulphur relationships of ranges of surface soils and selected profile samples, with particular reference to the implications of parent material, drainage conditions, cropping and manuring. These investigations cover mainly (a) the nature, distribution, interrelationships and significance of various categories of soil S, including total S, total organic S, total and readily-soluble inorganic S, C-bonded S, reducible SO_4, etc., and (b) the significance of soil properties and constituents in relation to sulphate sorption and retention. The results have already provided much valuable information, hitherto lacking, about the sulphur contents and relationships of Scottish soils, and in some respects are complementary to, and link up with, studies on organic and inorganic phosphorus. For example, the acetylacetone extraction procedure[67] mentioned above under organic phosphorus is also very highly effective in extracting sulphur, accounting for 80-100 per cent. of the total S in the eight soils examined.

The ultimate objective is to obtain a better understanding of the sulphur status of Scottish soils in relation to cropping and manuring, and the long-term experiment commenced four years ago to examine the consequences of using sulphur-free fertilizers is being continued.

Cation-exchange Properties and Mineral Composition of Plants. Further work has been carried out to relate variation in the major and trace element content of varieties of crop-plants to varietal differences in the cation-exchange capacity (C.E.C.) of the roots. For plants grown in soil the pattern is not always consistent. In studies so far completed, root C.E.C. of leek varieties relates well to the total cation (Ca + Mg + K + Na) content of the tops, and the individual contents of iron, copper and titanium. With ryegrass, however, although the range of C.E.C. found is as wide, the variation in composition is not so clearly related. Similar examination of a range of varieties of

dicotyledonous plants including tomato, pea and various *Cucurbitaceae* is in progress, and it is useful at this juncture to comment briefly on the implications of studies on the C.E.C. of plant roots.

Since it was first shown that plant roots carry a net negative charge and possess cation-exchange sites associated with the free carboxyl groups of pectin in the cell wall, many workers have studied the phenomenon. Plant roots in general exhibit quite a wide range of cation-exchange capacities, so that Donnan distribution principles can be applied, and an increase in adsorption of divalent cations (relative to monovalent ones) is found to accompany increase in root C.E.C. This parallels the observed lower Ca:K ratio in the tops of cereals and grasses (low C.E.C.) as compared to clovers and other dicot plants (high C.E.C.).

Current theories of ion uptake postulate the existence of carriers which combine with cations and so effect their entry into the root. After absorption the carrier is released and passes out of the root where it can again become operative. So far no carriers have been isolated, nor have the areas or zones in the root acting as absorption sites for the various cations been defined. In this scheme cation exchange has no direct part to play, beyond that of replacing H^+ at the root surface by cations of the bathing liquid.

It can well be argued, however, that this picture ignores a possible effect imposed on the soil-plant system by the roots themselves in that, depending on the species of plant concerned, the proportions of divalent and monovalent cations held in the immediate vicinity of the plant root will be governed largely by its C.E.C. For plants growing in soil, and particularly in soil low in nutrients, the interaction between soil and root colloids may, therefore, exert a considerable influence on cation uptake.

In attempting to rationalize about the cation content of plants, it is clearly relevant to bear in mind the existence of this reproducible and characteristic property of the plant root which can influence the composition of the cation suite at the root surface and probably affect the final cation make-up of the plant. It is in fact useful in explaining differences between different plants, or between species of the same plant, grown on the same soil.

Other fields where this fundamental root characteristic may prove useful are plant-breeding, ecology and possibly chemical taxonomy In hill-land improvement schemes, for example, selection of a grass strain of high C E.C. will tend to favour its establishment under conditions where strains of the same species, but of lower C.E.C., might fail to compete with encroaching native species for the low amounts of calcium normally present in such habitats. Welsh work has shown that strains of ryegrass tolerant of high concentrations of aluminium and manganese in the soil have a lower C.E.C. than susceptible strains, and this may well be a significant factor accounting for their ability to thrive under acid soil conditions. In viticulture, German growers find the iron nutrition of vines growing on calcareous soils is much improved if a rootstock of high C.E.C. is selected. Successful competition among plants in nature appears to depend on a combination of root C.E.C. and prolific rooting characteristics. Thus grasses, with a low C.E.C. but strong root

development, may outgrow dicot plants of high C.E.C. but poorer rooting ability.

In general members of the same genus will show similar C.E.C. values. This is well shown amongst conifer species in a recent publication[20]. Within families, however, agreement may be less good, and where the family is particularly large and diverse its members may cover quite a wide range of C.E.C. This is true of a family such as the *Compositae*, but here again some rationalization is possible through recourse to C.E.C. values, and recent German work has shown that within this family members of the *Tubuliflorae* are clearly distinguishable from those of *Liguliflorae* because of higher C.E.C.

Advisory Work. About 14,000 soil samples were analysed during the year to assess lime and nutrient requirements. As usual, most of these represented agricultural and horticultural land and were sent in by the staff of the North of Scotland College of Agriculture, but there were also a number of samples from forest nurseries which were examined in collaboration with the department of Pedology. Soil and crop samples from areas with suspected deficiencies or excesses of trace elements, involving animal health problems as well as crop growth, continue to be examined in collaboration with the department of Spectrochemistry. A number of instances have occurred in recent years where high molybdenum contents in crops, especially herbages, grown on poorly-drained acid soils seem to induce copper deficiency symptoms in stock.

The main aims, basis and limitations of chemical methods of soil testing are briefly discussed in the review article[64] mentioned earlier.

STATISTICS

The section provides a service for the Institute. Thus, much of the work is based on the research programmes of other departments and results derived from analyses carried out in the section will be recorded in the reports of these departments.

Advice on experimental design is most frequently required by the department of Soil Fertility. Experimental designs currently in use include randomized blocks, with and without split plots, latin squares, triple lattices, lattice squares, and factorial designs, some of which have confounding, fractional replication or split-plots.

In a series of experiments where the main object is to determine the optimum amounts of the nutrients N, P and K, a composite design has been used. These designs are basically augmented 2^m factorials developed specifically for fitting second degree response surfaces of the type $Y = b_0 + b_1n + b_2p + b_3k + b_{11}n^2 + b_{22}p^2 + b_{33}k^2 + b_{12}np + b_{13}nk + b_{23}pk$ where Y is the predicted yield and n, p and k denote the levels of the nutrients N, P and K as measured from the centres of their ranges of values. Taking into account the cost of the nutrients and the value of the crop, one can readily obtain from this equation, by maximizing the profit with respect to all three variates n, p and k, the economic optimum levels for the nutrients. A brief review of the complete factorial design and its disadvantages for this purpose are included, with a comparison between two variations of a composite design, in an account[72] which has been accepted for publication. The results showed that there can be a certain flexibility in the choice and arrangement of such designs to suit particular conditions.

Solutions of the Mitscherlich response equation,

$$Y = A[1 - 10^{-C(x+B)}],$$

have been derived for a number of cases with equally and unequally spaced levels of the independent variable, x. Polynomials which play an important part in the solution have been tabulated for four sets of unequally spaced levels. The precision of the estimates of B, representing the soil content of P_2O_5, was examined using yield results from experiments with swedes and phosphate fertilizer. The results have now been published[36] and show that, among the six cases considered, estimates of B with the greatest precision are provided by three unequally spaced nutrient levels, the second increment being between two and three times the first.

In collaboration with the department of Soil Fertility an account[32] of the effects of N, P and K on the botanical and chemical composition of herbage from a series of grassland regional manurial experiments of factorial design has been published. The experiments were co-ordinated by the Grassland Committee of the Scottish Agricultural Improvement Council.

Collaborative studies with the department of Plant Physiology are concerned with the effects of a number of factors on the chemical composition

and the relationship between phosphorus-iron and potassium-calcium ratios in plant leaves. An examination of the variability in copper content and or uptake, indicating that the square roots of the observations should be used or uptake, indicating that the quare root· of the ob·ervations should be used to make the variance independent of the mean. In another experiment the standard deviation was found to be proportional to the mean for copper uptake, indicating that the logarithmic transformation should be used. In a number of experiments a highly significant linear relationship between calcium and malic acid in plants was found. There were differences in the slopes of the regression lines but only one case of a significant curvature in the relationship was found.

In collaboration with the department of Pedology (Peat and Forest Soils) an examination was carried out on foliage analysis results and height and girth increments for a number of years from an experiment with slow-acting nitrogen. In addition to assessing the effects of the treatments on the individual variates, the correlations of the various increments in height and girth with the percentage of nitrogen in the needles for the same and for the previous year were obtained. Randomized block designs were used at three centres in a comparison of different samplers for peat. The results examined were moisture content, by weight and volume, and wet bulk density. Other collaborative studies included the relationship between solids and the acreage of bogs, the effect of water level on tree height and shoot length, and laboratory experiments on the measurement of the pH of water and water/peat mixtures. A further set of results in terms of head of water from the catchment area at Blacklaw Moss, Lanarkshire, has been processed by computer to give daily and weekly run-off in cubic feet per acre and equivalent weekly inches of rainfall.

Co-operation with the North of Scotland College of Agriculture has continued on a series of winter wheat trials, testing the influence of variations in sowing date, seed rate and nitrogenous fertilizer applications in randomized blocks with split-plots. A report has been made on the statistical analysis of further sets of data. A confounded factorial design was used in an NPK potato manuring trial and corrections for block differences were made to the estimates of the effect of the treatments.

The Crop Husbandry Department of the West of Scotland Agricultural College has extended the series of joint NPK experiments to include barley and rape crops. For barley a 4^3 design, with three degrees of freedom of the three-factor interaction confounded with blocks, has been used, while the rape trials are based on the 3^3 design with three blocks of nine plots. The potato and swede trials continue.

Grateful acknowledgement is made to the Agricultural Research Council Unit of Statistics and to the University of Aberdeen for providing teleprinting and computing facilities.

LIBRARY

The library stock of books and periodicals on soil science and related subjects is primarily for the use of the Institute staff, but loans are made to individuals and institutions both on direct application and through the inter-library services with which full co-operation is maintained. This year 178 items were lent to other libraries and 764 requests were made to the loans schemes on behalf of members of staff.

Ten journals and 128 books were added to stock during the year. A list of periodical holdings is available on request.

Lists of available reprints of staff papers are distributed from time to time and can be supplied as issued to anyone interested. No charge is made for reprints. Requests for papers this year involved the dispatch of 6209 reprints from the library, while 814 reprints were supplied automatically to individuals and institutions known to be interested in specific branches of the research work.

The seventh volume of *Collected Papers* (1961-1963) was issued during the year.

PUBLICATIONS

(A) *Published—*

1. Aspects of soil plant and animal relationships. By A. B. Stewart. (*Advmt. Sci., Lond.*, **22**, 429-438, 1965.)

   Presidential address delivered to Section M (Agriculture) at the Cambridge meeting of the British Association for the Advancement of Science, September, 1965.

2. Soil in the field and in the laboratory. By A. B. Stewart. (*J. Soil Sci.*, **16**, 171-182, 1965.)

   Presidential address. Meeting of the British Society of Soil Science at Leeds, September, 1964.

3. The thermal investigation of soil clays. By R. C. Mackenzie. (pp. 200-244 of *Soil Clay Mineralogy*. Edited by C. I. Rich and G. W. Kunze. Chapel Hill: University of North Carolina Press.) *No reprints.*

   The principles and theory of differential thermal analysis and thermogravimetry are outlined and apparatus and technique considered in detail with particular emphasis on those aspects important in application to soil clays. The fact that both techniques have considerable qualitative and quantitative value in soil clay mineralogy is illustrated by a discussion of the characteristics of selected curves for pure minerals and for soil clays.

4. Glinistye mineraly shotlandskikh pochv. (The clay minerals in Scottish soils). By R. C. Mackenzie. (Pochvovedenie, No. 4, 75-87, 1965.) *No reprints.*

   After a brief description of the techniques used for clay mineralogical investigations at the Macaulay Institute, an assessment of the applicability of these methods is given. Results obtained over the past number of years show that for the limited range of Great Soil Groups found in Scotland there is a definite correlation of clay mineralogy with the type of rock from which the parent material was derived.

5. Chemical analysis in the quantitative mineralogical examination of clays. By M. L. Jackson (University of Wisconsin) and R. C. Mackenzie. (pp. 313-325 of *Soil Clay Mineralogy*. Edited by C. I. Rich and G. W. Kunze. Chapel Hill: University of North Carolina Press.) *No reprints.*

   Despite some differences in approach in the application of chemical methods to soil-clay mineralogical problems in the laboratories of the two authors, there is general agreement about their value. Not only can selective methods be used for specific components but total chemical analyses can be employed to refine a mineralogical analysis based on instrumental results.

6. Hydratationseigenschaften von Montmorillonit. By R. C. Mackenzie. (*Ber. dt keram. Ges.*, **41**, 696-708, 1964.)

   The hydration of clays is of agricultural importance because this process at low water contents determines largely the tension with which water is retained by the soil and hence its availability to plants. Theories concerning the hydration of clays, particularly of montmorillonite, are considered and the present rather unsatisfactory position regarding the uncertainty of the nature of the primary process of hydration described. A theoretical treatment is developed whereby the amounts of water associated with the montmorillonite surface and with the exchangeable cations can be derived from loss-in-weight curves, and these values are related to theoretically calculated "hydration energies." At a fixed water vapour pressure it is shown that for certain ions, particularly divalent ions, the ion has a greater influence then the layer surface, whereas for other ions, particularly monovalent ions, the influence of the layer surface is predominant. Change of saturating ion can thus influence greatly both the amount of water present in a montmorillonitic soil at a given water vapour pressure and its availability.

7. The retention of amorphous, colloidal ferric hydroxide by kaolinites. By E. A. C. Follett. (*J. Soil Sci.*, **16**, 334-341, 1965.)

Amorphous iron oxides have been recognized in the clay fraction of a wide variety of soil types. The retention of one form of amorphous iron oxide, colloidal ferric hydroxide, by kaolinite has been studied by electron microscopy. The colloid particles were found to be sorbed on only the basal planes surfaces of the kaolinite flakes and the sorption reaction was unaffected by the presence of excess NH_4^+, Ca^{2+} or Al^{3+}. Cationic surface-active agents prevented the reaction. Differences observed in colloid distribution and density on the introduction of a competing surface indicated that only one surface of a flake attracted colloid particles and similar experiments with quartz and gibbsite suggested the silicatetrahedra surface of kaolinites as the probable site of colloid fixation. Neither pH variations, saturation with ammonium acetate, prolonged washing, nor ultrasonic vibrations affected the distribution of colloid which was removed only by extraction with sodium dithionite.

8. Amorphous inorganic materials in soils. By B. D. Mitchell, V. C. Farmer and W. J. McHardy. (*Adv. Agron.*, **16**, 327-383, 1964.) *No reprints.*

Recent developments in the study of amorphous inorganic material in the clay fraction of soil are considered in relation to its nature and occurrence. The physical and chemical methods employed for the detection and estimation of amorphous material are discussed. The possible modes of formation of amorphous constituents and their effect on soil properties are tentatively assessed.

9. Chemical dissolution techniques in the study of soil clays. Part I. By E. A. C. Follett, W. J. McHardy, B. D. Mitchell and B. F. L. Smith. (*Clay Miner.*, **6**, 23-34, 1965).

For purposes of characterization, clays are frequently divided into fractions; they may be divided, for instance, according to particle size. In this investigation, however, clays from two soil profiles developed on glacial till derived from basic lavas were divided according to their solubility in dilute sodium carbonate solution. The effects of this treatment were studied by X-ray diffraction, differential thermal, infrared absorption, electronopitcal and specific surface area measurements. Results led to the conclusion that the clays consisted of completely disordered, poorly ordered and highly crystalline material with no clear line of demarcation between the components.

10. Chemical dissolution techniques in the study of soil clays. Part II. By E. A. C. Follett, W. J. McHardy, B. D. Mitchell and B. F. L. Smith. (*Clay Miner.*, 6, 35-43, 1965.)

The type and distribution of ferric compounds in the clay fraction has a most important bearing on the physico-chemical properties of the soil, and some knowledge of this is essential in interpreting problems of soil genesis and of mineral weathering. The removal of the alkali-soluble fraction from the soil clays has been found to influence markedly the efficiency with which iron oxides can be extracted. In soil clays pretreated with 5 per cent. sodium carbonate up to 40 per cent. more iron was extracted by $Na_2S_2O_4$ than from soil clays treated with this reagent alone. Evidence, particularly electron-microscopic, indicates that the fraction soluble in $Na_2S_2O_4$ consists largely of poorly ordered ferruginous complexes containing some silica and alumina.

11. An occurrence of phlogopite and its transformation to vermiculite by weathering. By Wilma W. Smith Aitken. (*Mineralog. Mag.*, **35**, 151-164, 1965.)

A sample of soil from Caithness, containing large particles of vermiculite, provided an excellent source of material for a study of the weathering of phlogopite. By using X-rays, the orientation relationship between the fresh mica and its weathering product, vermiculite, was established. Identification of inclusions within these minerals was made possible by use of infrared, electron microscope and chemical methods in addition to the X-ray technique.

12. Thermal analysis of a Scottish hill peat. By J. M. Stewart, A. C. Birnie and B. D. Mitchell. (*Proc. I Int. Conf. Thermal Anal., Aberdeen*, 1965, 64-65, 1965.) *No reprints.*

The recognition of differences in morphology from the surface to the base of a peat profile and determination of the physical and chemical significance of these can have an important bearing upon the efficient utilization of the peat deposit. The investigation has shown that thermal techniques can be used for the characterization of the morphologically distinct zones of a peat profile. The interactions of such factors as humification, ratio of fibre to amorphous material, mineral matter and botanical composition are all reflected to some extent in the differential thermal and thermogravimetric curves.

13. The application of differential thermal analysis to plant materials. By B. D. Mitchell and A. H. Knight. (*J. exp. Bot.*, **16**, 1-15, 1965.)

This paper gives preliminary information on the application of differential thermal analysis to the investigation of plant material. Differential thermal analysis curves are shown for the leaves of higher plants, pollen, lower plants, including ferns, mosses, algae, fungi, lichens and yeasts, and a range of reference organic chemical compounds. Tentative interpretations of the curves are made in terms of peak patterns and botanical classifications.

14. 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.)

As part of a general approach to rock weathering and soil formation, an investigation was carried out into certain aspects of the mobilization of iron in podzols. The three agents normally considered responsible for this are (a) humic acid fractions, (b) micro-organisms and (c) water-soluble compounds from fresh leaf litter. This paper is concerned only with water-soluble compounds from fresh Scots pine needles. An aqueous extract of pine needles was divided into three fractions, one consisting principally of amino-acids, one of organic acids and one of neutral compounds. The principal constituents of the amino-acid and organic-acid fractions were identified and their contents in the needles determined by means of paper and column chromatography.

15. The mobilization of iron by aqueous extracts of plants. II. Capacities of the amino-acid and organic-acid fractions of a pine needle extract to maintain iron in solution. By J. W. Muir, J. Logan and C. J. Bown. (*J. Soil Sci.*, **15**, 226-237, 1964.)

Scots pine trees normally grow on soils which are depleted of iron in the upper horizons and enriched in the lower horizons. Various workers have shown that water-soluble material extracted from pine needles is responsible for mobilizing part of this iron. There is, however, considerable uncertainty about the identity of the active compound or compounds. The present investigation was undertaken to provide some information on this. The capacity of each constituent of the amino-acid and organic-acid fractions of a pine needle extract (*see* No. 14 above) to maintain iron in solution was measured over a wide range of pH. None of the amino-acids hand any effect, but all the α-hydrocarboxylic acids present in the acid fraction were active. These findings are related to soil processes and to morphological character of the soils on which pine trees normally grow.

16. Scottish peat resources. By R. A. Robertson. (*Int. Peat Congr., Leningrad*, 1963. Section I.)

The nature and extent of Scottish peat resources and the survey techniques in current use are discussed. Results are given of investigations on harvesting and de-watering peat and its utilization for industrial and other purposes. In the immediate future it is likely that research and development will be directed more towards the use of peat land for agriculture and forestry.

17. Quantities of plant nutrients in heather ecosystems. By R. A. Robertson and G. E. Davies (Hill Farming Research Organization). (*J. appl., Ecol.*, **2**, 211-219, 1965.)

Data are presented on the magnitude and distribution of the nutrient fund in several stands of Callunetum. The significance of nutrient input by precipitation and removal by livestock is considered in relation to potential nutrient loss following heather burning.

18. Run-off studies on a peat catchment. By R. A. Robertson and I. A. Nicholson and R. Hughes (Hill Farming Research Organization). (*Int. Peat Congr., Leningrad*, 1963. Section II.)

This paper presents some hydrological data from the initial phase of a long-term study on the water and nutrient balance in deep peat catchments. Relationships between monthly rainfall, run-off, evapotranspiration and water-table height for a three year period are discussed. There is no consistent relationship between rainfall and run-off without reference to the season of the year.

19. Quantity potential relationships in nutrient studies. By J. B. Craig. (*Scott. For.*, **18**, 318-319, 1964.)

The nutrient buffering capacity of a forest soil and the minimum and optimum potentials of each nutrient for each tree species are likely to be of more value in tree nutrient studies than either qualtity or potential measurements alone.

20. Mineral composition, cation-exchange properties and uronic acid content of various tissues of conifers. By W. M. Crooke, A. H. Knight and J. Keay. (*Forest Sci.*, **10**, 415-427, 1964.)

As part of a larger investigation into the possible influence of the cation-exchange properties of roots on the mineral composition of the plant, an examination of 26 species of conifer seedlings from a granitic soil has been made. The data failed to show the expected relationship between root cation-exchange capacity (C.E.C.) and total cation content of the tops which had been found for higher plants. The C.E.C. of conifer roots covers a relatively narrow range (20-30 m.e./100 g.) and is higher than values for stems, needles, pollen and seed (11-15 m.e./100 g.). The mineral composition of the various tissues of the seedlings shows little variation as far as major cations, P or S is concerned but interesting differences in Cl content were noted, the levels in needles of *Sequoia* and *Metasequoia* being particularly high. Nitrogen was highest in pollen and seeds and lowest in roots and stems. Analysis of needles from *Pinus contorta* grown in Scotland from seed from different locations in western Canada and U.S.A. showed the C.E.C. to range from 8·6 to 9·7 m.e./100 g. and to correlate with their N content. Needle weight and length and N content are related and all increase with distance from the coast of the seed source. Little variation is found in other chemical constituents.

21. The soil survey of East Lothian. By J. M. Ragg. (*El Jacaro* (East Lothian Junior Agricultural Club J.), No. 7, 15-18,1965.) *No reprints.*

A brief outline of some of the findings of the soil survey of East Lothian and related agricultural problems.

22. An infrared spectroscopic study of the dehydration of montmorillonite and saponite. By J. D. Russell and V. C. Farmer. (*Clay Miner. Bull.*, **5**, 443-464, 1964.)

The nature of amorphous inorganic constituents in soils is not yet fully understood. This study was carried out in order to provide background information which might assist the characterization by infrared spectroscopy of amorphous materials frequently found in admixture with montmorillonite and saponite in the clay fraction of soils. Dehydration processes in montmorillonite and saponite are outlined and a precise explanation of the role of the exchangeable cations is given.

23. An infrared study of complexes of ethylamine with ethylammonium and copper ions in montmorillonite. By V. C. Farmer and M. M. Mortland (University of Michigan). (*J. phys. Chem.*, **69**, 683-686, 1965.)

The adsorption of ethylamine on montmorillonite has been studied as part of an investigation on the nature of the interactions between nitrogenous compounds and soil clays. Ethylamine is converted to ethylammonium ions when adsorbed on hydrogen and calcium montmorillonite, but forms a co-ordination complex with copper ions. Excess ethylamine forms strong hydrogen bonds with ethylammonium ions.

24. A study of polysaccharide-producing organisms occurring in the root region of certain pasture grasses. By D. M. Webley, R. B. Duff, J. S. D. Bacon and V. C. Farmer. (*J. Soil Sci.*, **16**, 149-157, 1965.)

It is well known that soil structure is improved under pasture grasses. The contribution of micro-organisms and their products, e.g. polysaccharides, to the stability of soil aggregates is also well recognized, but there is little information about the root region of grasses in this connection. In this paper a study has been made of the incidence of polysaccharide-producing bacteria in the root region of three common pasture grasses. It has been shown that there is a high percentage of bacteria in this region capable of synthesizing both capsular and slime material. Infrared and chromatograph analyses of these extracellular substances have shown that the ability to produce fructosans is commoner in isolates from the root surface than from rhizosphere and non-rhizosphere soil. These results are discussed in relation to the soil carbohydrate fraction.

25. Catalpol and methylcatalpol: naturally occurring glycosides in *Plantago* and *Buddleia* species. By R. B. Duff, J. S. D. Bacon, C. M. Mundie, V. C. Farmer, J. D. Russell and A. R. Forrester (University of Aberdeen). (*Biochem. J.*, **96**, 1-5, 1965.)

Knowledge of the processes by which soil organic matter is formed is closely linked to knowledge of the composition of the plant residues which contribute to it. During an examination of the sugars in a variety of plants it was noticed the plantain leaves contained a substance which decomposed readily to give black insoluble material. Further investigations showed that it was present also in *Buddleia* leaves, and it was eventually found to be identical with a known constituent of the fruit of the catalpa tree. A second substance not hitherto noticed in *Buddleia* is a simple derivative of the first. These identifications were made with the minimum of chemical manipulations, by the use of various physical methods, in particular infrared and nuclear magnetic resonance spectroscopy.

26. The development of invertase activity in slices of the root of *Beta vulgaris* L. washed under aseptic conditions. By J. S. D. Bacon, I. R. MacDonald and A. H. Knight. (*Biochem. J.*, **94**, 175-182, 1965.)

The root tissue of sugar beet or red beet (*Beta vulgaris* L.) is rich in sucrose but hexose (glucose, frustose) is virtually absent. However, when slices are prepared from a root and aged for 2-3 days in aerated tap water the sucrose is almost entirely converted to hexose and it is shown that this change is associated with the development of invertase activity in the tissue. The possibility that the appearance of this hydrolytic enzyme might be due to bacterial invasion of the cut slices has been eliminated by preparing and aging the slices under aseptic conditions. Invertase activity is now believed to be associated with growth changes in plant tissues but the possibility that physical damage or wounding of roots could lead to invertase development with consequent loss of sucrose before and during processing is considered. With the development of a technique for maintaining root slices under sterile conditions it will now be possible to undertake experiments on the effect of organic substances, including fractions from soil, on uptake of nutrients by this tissue.

27. Quelques speculations sur le rôle de l'invertase dans les tissues végétaux. By J. S. D. Bacon. (*Bull. Soc. fr. Physiol. vég.*, **10**, 136-144, 1964.)

The possession of the enzyme invertase by animals and micro-organisms enables them to digest sucrose, which is exclusively a plant product. The presence of a similar enzyme in plants is more difficult to explain. Earlier ideas that it was concerned in the synthesis of sucrose are no longer accepted, but it may be involved in the transport and utilization of the sugar, particularly in growing tissues.

28. The occurrence of apiose in *Lemna* (duckweed) and other angiosperms. By R. B. Duff. (*Biochem. J.*, **94**, 768-772, 1965.)

Apiose, a branched chain five-carbon sugar, hitherto known only as a constituent of yellow glycosides in parsley, other Umbellifers, and a few other families, or of the polysaccharide of an Australian marine flowering plant (*Posidonia australis*), has now been shown to be very widely distributed in higher plants. *Lemna* and *Wolffia*, duckweeds which occur in the British Isles and are well suited to physiological and biochemical studies, have been found to be among the richest sources. An examination of *Lemna* has shown that much of the apiose is present in the polysaccharide fraction. It has been suggested that the resistance of the fibre of *Posidonia* to microbial decomposition, which leads to its accumulation in vast quantities on South Australian beaches, is due to the presence of apiose. The sugar may similarly retard the decomposition of other plant residues in soil.

29. The incidence, in soils and other habitats, of micro-organisms producing 2-keto-gluconic acid. By D. M. Webley and R. B. Duff. (*Pl. Soil*, **22**, 307-313, 1965.)

Previous studies from the Institute have shown that bacteria which produce 2-keto-gluconic acid are very effective dissolvers of difficultly soluble phosphates and silicates. In this paper a new method is described for enumerating this group of bacteria in soils and other habitats. It has been shown that the highest numbers of bacteria which produce 2-ketogluconic acid are found in manured soils, in organic debris from rock crevices, in the rhizosphere of plants and around pellets containing carbohydrates which have been buried in soil. There is therefore a close association of this group of organisms with habitats rich in organic matter.

30. Features of the cell-wall structure of yeast revealed by the action of enzymes from a non-fruiting myxobacterium (*Cytophaga johnsonii*). By J. S. D. Bacon, Beatrice D. Milne, Irene F. Taylor and D. M. Webley. (*Biochem. J.*, **95**, 28C-30C, 1965.)

During active decomposition of plant residues in soil there is a considerable multiplication of the micro-organisms responsible. This new microbial cell material is subsequently broken down by further microbial activity, so beginning another cycle of organic matter decomposition in the soil. Organisms which carry out this second process must possess enzyme systems capable of attacking for example the cell walls of fungi, the composition of which is very different from that of plant residues. This paper is concerned with a non-fruiting soil myxobacterium (*Cytophaga johnsonii*) which is shown to attack the walls of the yeast cell. It also demonstrates how the wall of the yeast cell can be modified to accentuate the action of the myxobacterial enzymes, and casts new light upon the structure of the yeast cell wall.

31. A comparative study of the influence of salt type and concentration on $^{14}CO_2$ fixation in potato slices at 25°C and 0°C. By I. R. MacDonald and G. G. Laties (University of California). (*J. exp. Bot.*, **15**, 530-537, 1964.)

Ion absorption is the initial stage in plant nutrition and disks of storage tissue provide convenient material for investigating the mechanism of ion absorption in plant tissue. In this paper the relationship between ion absorption and organic acid synthesis in potato disks at 0°C and 25°C has been studied using radioactive carbon dioxide. It is shown that at 25°C ionic balance within the tissue is achieved by adjustment in the concentration of organic acid anions. Attention is drawn to the

difficulties encountered in interpreting results obtained by the use of radioactive carbon dioxide.

32. The effects of fertilizers on herbage production. II. The effect of nitrogen, phosphorus and potassium on botanical and chemical composition. By J. W. S. Reith and R. H. E. Inkson, *and collaborators*. (*J. agric. Sci.*, **63**, 209-219, 1964.)

Six factorial experiments, each lasting three years, were undertaken to determine the effects of nitrogen, phosphorus and potassium on herbage cut five times each year. This paper reports the botanical data and the results for the chemical composition of the herbage. Clover practically disappeared with the nitrogen treatments while potash increased its growth only in the absence of nitrogen. All nitrogen dressings markedly increased the yield of crude protein, but only the highest rate of 348 lb. N per acre raised its percentage. The phosphorus percentage showed very little influence of treatment. Potassium dressings increased substantially potassium content but reduced sodium. There were considerable seasonal increases in calcium and magnesium both of which showed variations with the nitrogen and potassium treatments. In one experiment the effect of selected treatments on a range of trace elements was determined and was found to be relatively small. Attention is drawn to the large removal of nutrients in herbage frequently cut for conservation.

33. Effect of fertilizer applications on the mineral composition of crops in Scotland. By J. W. S. Reith. (pp. 55-62 of *Das Kalium und die Qualitat landwirtschaftlicher Produkte. Proc. II Reg. Conf. Potash Inst., 1965.* 1965.)

The paper presents mean results for the effects of N, P and K fertilizers on the mineral composition of swedes, oats, barley and mixed herbage, and summarizes the main findings from numerous experiments carried out in north-east Scotland. The mineral content of grain usually shows negligible effects of fertilizer applications whereas some of the constituents in swede roots, oat and barley straw, and mixed herbage may be increased or decreased. Except for Na which may show large variations, normal fertilizer dressings are unlikely to increase or decrease the N, P, K, Ca and Mg contents by more than 25 per cent. The effects of fertilizers are much smaller than the the two- to three-fold variations in the mineral composition found in crops and herbage grown on different soils and in different seasons.

34. Mineral composition of crops. By J. W. S. Reith. (*N.A.A.S. q. Rev.*, No. 68, 150-156, 1965.)

The paper outlines some of the factors influencing the mineral composition of crops. In addition to the available nutrient content in soil, the effects of type of soil, acidity, drainage conditions, temperature, moisture supply, crop species or variety, seasonal variation and nutrient applications are considered. Attention is drawn to the large variation in the mineral composition of crops, including herbage, grown on different soils in different years. The importance is stressed of collecting samples at the stage of growth when their analyses can be expected to reveal any deficiencies and excesses, or the effects of nutrient applications.

35. The effect of soil treatment on trace element uptake by plants. By J. W. S. Reith and R. L. Mitchell. (*Proc. IV Int. Colloq. Plant Anal. Fert. Problems (1962)*, 241-254, 1964.)

A study of the effect of various fertilizers on the trace element content of pasture herbage and cereals. The treatments considered include NPK fertilizers, liming materials and trace element additions. The crop contents reported, which were determined by spectrochemical methods, cover samples taken at different seasons during a number of years following treatment. The effects of trace element applications and of liming are shown to be of considerably more importance than the effects of NPK fertilizers.

36. The precision of estimates of the soil content of phosphate using the Mitscherlich response equation. By R. H. E. Inkson. (*Biometrics*, **20**, 873-882, 1964.)

By using the Mitscherlich response equation, the amount of available phosphate in soils can be estimated from the yield data in field experiments. A statistical evaluation was made of the effects, on the precision of these estimates, of variations in the number and spacing of the levels of phosphate treatments used in experiments. Two cases of equal spacing and four cases of unequal spacing were considered and it was found that experiments with levels of 0, 1, 3 and 0, 1, 4 (e.g. 0, 40, 120 and 0, 30, 120 lb. P_2O_5 per acre) provide estimates of the soil content of P_2O_5 with the greatest precision.

(B) *Awaiting Publication at 30th September, 1965—*

37. Origin of clay minerals in soils. By R. C. Mackenzie. (Submitted to *Proc. Ussher Soc.*)

38. Methods of mineralogical analysis of soils. By W. A. Mitchell. (Submitted to *Proc. N.A.T.O. Int. Study Group on Soils, Cambridge, 1964.*)

39. Clay mineralogy. By R. C. Mackenzie and B. D. Mitchell. (*Earth Sci. Rev.*, **2** (1), 1966.)

40. Weathered biotite from Aberdeenshire, Scotland. By M. J. Wilson. (Submitted to *Nature, Lond.*)

41. An electron microscope study of the cell surface of *Cytophaga johnsonii* and some observations on related organisms. By E. A. C. Follett and D. M. Webley. (*Antonie van Leeuwenhoek*, **31**, 361-382, 1965.)

42. An improved peat sampler. By P. C. Jowsey. (Submitted to *New Phytologist.*)

43. The election microscopy of leaf surfaces preserved in peat. By J. M. Stewart and E. A. C. Follett. (Submitted to *Can. J. Bot.*)

44. Pollen analytical evidence of "Landnam" from two Scottish sites. By S. E. Durno. (Submitted to *Trans. Proc. bot. Soc. Edinb.*)

45. Frost weathering and solifluction products in southern Scotland. By J. M. Ragg and J. S. Bibby. (Submitted to *Geogr. Annbr.*)

46. The soils and agricultural regions of Scotland: an historical review. By R. Glentworth. (Submitted to *Scot. Agric.*)

47. Soils of the country round Haddington and Eyemouth (Sheets 33, 34 and part 41). By J. M. Ragg and D. W. Futty. (To appear as *Mem. Soil Surv. Gt. Brit.: Scot.*)

48. Soil survey of Great Britain: application to problems of engineering. By R. Glentworth. (Submitted to *Proc. N.A.T.O. Int. Study Group on Soils, Cambridge, 1964.*)

49. A method for measuring the iron-mobilizing capacity of aqueous extracts of plants. By J. W. Muir. (Submitted to *Trans. VIII Int. Congr. Soil Sci., Bucharest*, 1964.)

50. Soil Research in Scotland. By R. L. Mitchell. (*Mitt. natur*). *Res. Bern.*, n.f., **22**, 49-62, 1965.)

51. The trace and major element composition of the leaves of some deciduous trees. I. Sampling technique. By M. M. Guha and R. L. Mitchell. (Submitted to *Pl. Soil.*)

52. The trace and major element composition of the leaves of some deciduous trees. II. Seasonal changes. By M. M. Guha and R. L. Mitchell. (Submitted to *Pl. Soil.*)

53. Infra-red study of the reactions of ammonia with montmorillonite and saponite. By J. D. Russell. (Submitted to *Trans. Faraday Soc.*)

54. An infrared study of the co-ordination of pyridine and water to exchangeable cations in montmorillonite and saponite. By V. C. Farmer and M. M. Mortland (University of Michigan). (Submitted to *J. Chem. Soc.*)

55. Thermal decomposition of 14Å tobermorite from Crestmore. By V. C. Farmer and J. Jeeveratnam, K. S. Speakman and H. F. W. Taylor (University of Aberdeen). (Submitted to *Proc. Ann. Conf. Highways Res. Board, U.S.A.*)

56. Effects of particle size and structure on the vibrational frequencies of layer silicates. By V. C. Farmer and J. D. Russell. (Submitted to *Spectrochim. Acta.*)

57. Dehydration reactions in alkali halide disks. By V. C. Farmer. (Submitted to *Spectrochim. Acta.*)

58. The extraction of carbohydrates from soil by sulphuric acid. By M. V. Cheshire and C. M. Mundie. (Submitted to *J. Soil Sci.*)

59. Uptake of nitrogen by plants. By P. C. DeKock and E. A. Kirkby. (Submitted to *Proc. N.A.A.S. Con). on Nitrogen and Soil Organic Matter, London,* 1964.)

60. The metabolism of nitrogen in plants. By P. C. DeKock. (Submitted to *Proc. N.A.A.S. Conf. on Nitrogen and Soil Organic Matter, London. 1964.*)

61. Active and passive transport of the major nutrient ions across the root of *Ricinus communis.* By D. J. F. Bowling (University of Aberdeen), A. E. S. Macklon and R. M. Spanswick (Botany School, Cambridge). (Submitted to *J. exp. Bot.*)

62. A study of the breakdown of organic phosphates by micro-organisms from the root region of certain pasture grasses. By M. P. Greaves and D. M. Webley. (Submitted to *J. appl. Bact.*)

63. Enrichment in soil of fungi which utilize aromatic compounds. By Moira E. K. Henderson. (Submitted to *Pl. Soil.*)

64. Soils. By E. G. Williams, W. M. Crooke and G. Anderson. (*Rpts. on Progr. appl. Chem.*, **49**, 307-319, 1964.)

65. Effects of soil magnesium levels and of magnesium dressings on crop yield and composition. By J. W. S. Reith. (Submitted to *Proc. N.A.A.S. Conf. on Availability of Soil Potassium and Magnesium, London, 1963.*)

66. Effect of magnesium dressings on soils and crops. By J. W. S. Reith. (Submitted to *Trans. VIII Int. Congr. Soil Sci. Bucharest, 1964.*)

67. The extraction of organic matter from soils by means of ultrasonic dispersion in aqueous acetylacetone. By R. L. Halstead, G. Anderson and N. M. Scott. (Submitted to *Nature, Lond.*)

68. Investigations on the analysis of inositol hexaphosphate in soils. By G. Anderson. (Submitted to *Trans. VIII Int. Congr. Soil Sci., Bucharest, 1964.*)

69. Other organic phosphorus compounds. By G. Anderson. (To appear as Chap. 4 of *Encyclopedia of Soil Science.* Vol. 2, Berlin: Springer.)

70. Sulphur in soil organic substances. By G. Anderson. (To appear as Chap. 5 of *Encyclopedia of Soil Science.* Vol. 2, Berlin: Springer.)

71. Nucleic acids, derivatives and organic phosphates. By G. Anderson. (To appear as Chap. 3 of *Soil Biochemistry.* Edited by A. D. McLaren and G. H. Peterson. U.S.A.: Dekker.)

72. Field experiments to estimate optimum fertilizer levels. By R. H. E. Inkson. (Submitted to *Pl. Soil.*)

(C) *Thesis*—

The following thesis has been accepted for the degree of Ph.D. by the University of Aberdeen:

Characteristics and distribution of amorphous inorganic material in some Scottish soils. By J. H. Kirkman.