THE MACAULAY INSTITUTE FOR SOIL RESEARCH

FOUNDED 1930

1965-1966 ANNUAL REPORT

No. 36

The Macaulay Institute is situated on the western outskirts of Aberdeen, about three miles from the centre of the city. The main entrance is on Countesswells Road, but visitors using public transport should take the Corporation Bus (Route 18) to Craigiebuckler Terminus, from which the Institute is reached in a few minutes by Craigiebuckler Drive.

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

(Founded 1930)

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POST-GRADUATE RESEARCH WORKERS

J. L. Ahlrichs (Department of Agronomy, Purdue University, Lafayette, Indiana, U.S.A.).

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

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

Mrs Alison Innes (University of Aberdeen Research Scholar).

G. Lombardi (Istituto di Petrografia, Citta Universitaria, Rome, Italy).

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

F. Megusar (Department of Biotechnical Science, University of Ljubljana, Yugoslavia).

B. O. Njoku (Department of Agricultural Research, Moor Plantation, Ibadan, Nigeria).

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

F. Palmieri (Istituto di Chimica Agraria, Universite di Napoli, Portici, Italy).

C. Péaud-Lenoel (Laboratoire de Photosynthèse, Centre National de la Recherche Scientifique, Gif-sur-Yvette, Nr. Paris).

A. Ramos (Estacion Experimental del Zaidin, Granada, Spain).

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

CONTENTS

INTRODUCTION

The overall objective of the work of the Institute is to obtain by means of field, pot, glasshouse and laboratory studies of soils and plants information of value in the maintenance and improvement of soil productivity. With this in view, fundamental and applied research on soil, soil-plant and, as appropriate, soil-plant-animal relationships has been further developed. Collaboration with the Agricultural Advisory Services continues to be of very great value in the two directions of drawing attention to practical problems requiring investigation and of having research findings applied in practice. Useful collaboration with other research and educational organizations has been maintained and further valuable scientific contacts have been established through Institute representation at conferences bearing on its research activities, by the provision of facilities for visiting research workers from both home and abroad, and from a steadily increasing exchange of scientific publications.

In September the British Society of Soil Science was host to a joint meeting in Aberdeen of Commissions II and IV (Soil Chemistry and Soil Fertility) of the International Society of Soil Science. This conference was organized by a committee composed of members of staff of the Soil Science Department of the University of Aberdeen and of the Institute and was attended by 258 soil scientists and some 50 guests from 38 countries. At the inaugural meeting participants had the honour of being addressed by the Rt. Hon. William Ross, M.B.E., M.P., Secretary of State for Scotland. The main topics discussed at the conference were: Soil Organic Matter and Fertility; Nitrogen, Phosphorus and Sulphur in Soils and Plant Nutrition; Principles of Experimentation in Soil-Crop Relationships; Major Cations in Soil and Plant Nutrition; Trace Element Availability and Uptake by Plants; Nutrient Diffusion and Flow in Soils. It is planned to publish the Proceedings of the conference early in 1967. Following the meeting in Aberdeen, 66 of the delegates participated in a week's tour of Scotland.

With the aid of grants kindly provided by the Agricultural Research Council, the Institute was represented as follows at various conferences abroad: by Dr J. S. D. Bacon at a meeting of the Federation of European Biochemical Societies in Warsaw; by Dr R. C. Mackenzie and Dr V. C. Farmer at an International Clay Conference in Jerusalem; by Mr M. P. Greaves at the ninth International Congress for Microbiology in Moscow. In addition, the Department of Agriculture and Fisheries for Scotland made it possible for Mr R. A. Robertson to attend a meeting of the International Peat Committee in Helsinki.

Dr P. C. DeKock, Head of Plant Physiology, who was on leave of absence from the Institute from February, 1965, to January, 1966, completed his term as Visiting Professor at the University of California, Los Angeles, and thereafter spent three months as visiting lecturer at various Canadian universities under the auspices of the National Research Council of Canada and the Nuffield Foundation. In May, 1966, Dr DeKock spent two weeks in

Poland under the auspices of the Polish Botanical Society as a guest lecturer at the Universities of Wroclaw, Krakow and Warsaw. Mr J. D. Russell, Spectrochemistry, returned to the Institute after spending a year in the U.S.A. as Instructor (Research) in the Department of Agronomy, University of Purdue, working on an investigation by infrared spectroscopy of the adsorption of organic compounds on soil colloids. Mr G. Orbell of the Soil Bureau, New Zealand, and Mr J. M. Ragg of the Soil Survey of Scotland, who were on exchange visits, returned to their respective stations after having spent a most useful year on soil survey work in each other's countries.

Following an invitation from Dr J. E. Falk, Chief of the Division of Plant Industry, C.S.I.R.O., Australia, Dr G. Anderson, Soil Fertility, was granted leave of absence for six months to enable him to work in the laboratories of the Soil Fertility Section, C.S.I.R.O., in Canberra, collaborating in studies on the nature and significance of organically bound phosphate in soils.

Dr R. C. Mackenzie accepted an invitation from Professor O. E. Radczewski, Chairman of the Ausschuss Staubmorphologie of the Verein Deutscher Ingenieur, to present a paper at a scientific meeting in Vienna. The paper which he gave dealt with the morphology of the oxides of iron, aluminium and manganese as revealed by the electron microscope. The Verein Deutscher Ingenieur kindly defrayed the cost of this visit.

Dr M. V. Cheshire, Biochemistry, was seconded in January to the University of Sheffield to work for one year in the Department of Chemistry with Professor Haworth on research on humic acid.

In addition to receiving a very large number of short-term visitors from twenty-six countries, the Institute has provided facilities for longer-term work for visiting scientists from Canada, Israel, Italy, New Zealand, Portugal, Spain and Yugoslavia, as well as from centres in Great Britain. Mr R. B. McKercher, who spent three years at the Institute as an Overseas Post-graduate Scholar of The Agricultural Institute of Canada, has been awarded the degree of Ph.D. of the University of Aberdeen for his thesis entitled *The distribution and significance of various categories of organic and inorganic phosphorus in soils*. Thanks to the Agricultural Research Council who provided a grant from the Underwood Fund, it was possible to have Dr C. Péaud-Lenoël of the Laboratoire de Photosynthèse, Centre National de la Recherche Scientifique, Gif-sur-Yvette, Paris, spend a period of three months at the Institute working with Dr J. S. D. Bacon, in the department of Biochemistry, on problems of mutual interest, including investigational work on the use of radioactive isotopes with small quantities of root tissue—a field in which Dr Péaud-Lenoël is an acknowledged authority.

An Agricultural Research Council Visiting Group came to the Institute in September, 1966, and this opportunity is taken to express to members of the group the Institute's warm thanks for the careful thought given to the programme of work and for the helpful suggestions made in the course of the visit.

Members of the 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.

It is with deep regret that the death on 17th June, 1966, of Professor A. C. O'Dell is recorded. Although he had been a member of the Council of Management for only a short period, Professor O'Dell had for many years been keenly interested in many aspects of research work, and the Institute shares with many other organizations the sad loss of one who contributed so much to the educational and cultural life of a wide community.

PEDOLOGY

The main aim of the department remains to obtain a better fundamental understanding of the complex soil system and to this end the programme of work has proceeded along essentially the same lines as those detailed previously.

During the year much emphasis has been placed on the occurrence of a mixed inorganic gel system in Scottish soils, since this material can occur in considerable amounts associated with the surfaces of crystalline particles and hence can influence the properties of the soil disproportionately to the amount present. The application of thermal methods to organic materials has also been extended and the acquisition of a commercial differential thermal analysis apparatus is enabling the output of a greater volume of results, although the necessity for an apparatus specially designed for organic materials is becoming more pressing.

Close collaboration with the Forestry Commission and the Hill Farming Research Organization has continued, and joint investigations with other departments of the Institute are, as formerly, being pursued. Samples have also been examined for the Forestry Commission, Hunting Technical Services, F.A.O., and the Universities of Aberdeen, Cambridge, Cairo (Egypt) and Lincoln College (New Zealand).

Mr C. de S. F. Gomes, Department of Mineralogy and Geology, University of Coimbra, Portugal, completed his studies on Portuguese clays during the year, and Dr G. Lombardi, Institute of Petrography, University of Rome, Italy, carried out an extended study on alunitic clays with particular reference to the accuracy of differential thermal estimation. Dr A. S. de Endredy, F.A.O., Rome, has also assisted in the work of the department during his leave.

Members of the department have attended *inter alia* meetings of the Clay Minerals Group of the Mineralogical Society, the Society of Foresters of Great Britain, the Thermal Analysis Group of the Society for Analytical Chemistry, the conference of Commissions II and IV of the International Society of Soil Science, and an International Symposium on Reaction Mechanisms in Inorganic Solids, as well as serving on committees under the auspices of the British Standards Institution and the Natural Environment Research Council. In connection with the conference of the International Society of Soil Science, an exhibition illustrating the survey, classification and use (including afforestation) of peat was prepared.

Mr R. A. Robertson attended, as British representative, a meeting of the International Peat Committee at Helsinki in connection with the establishment of an International Peat Society, and Dr R. C. Mackenzie attended the 1966 International Clay Conference in Israel, at which he was elected a member of the Council of the new Association Internationale pour l'Etude des Argiles and re-elected Chairman of the Nomenclature Committee. In addition, Dr Mackenzie delivered a lecture by invitation at a colloquium on

Fine Mineral Particles, held in Vienna and arranged under the auspices of the Ausschuss Staubmorphologie of the Verein Deutscher Ingenieur.

Methods

Apparatus. The flexibility and efficiency of existing equipment for differential thermal analysis has been improved by the introduction into the microvolt recorder circuit of a scale-expanding unit and a commercial apparatus has now been acquired.

Pretreatment of Samples. The dispersion of soils and rocks by ultrasonic waves is being intensively studied: so far there is no evidence that such treatment causes the destruction of clay minerals. Application of differential thermal and thermogravimetric techniques to complexes of benzoic acid and benzoic acid salts with montmorillonite has demonstrated that, above its melting point, benzoic acid can react with certain diluents usually regarded as inert. Furthermore, the combustion characteristics of the retained benzoate are affected by the metallic ion present and catalytic effects have been observed. It is clear that such factors must be considered when interpreting thermal curves.

Soil Mineralogy

Several pure minerals were investigated during the year: alunite, in particular, was intensively studied by X-ray, electronoptical and thermal methods. Considerable amounts of tubular material (identified by electron diffraction as halloysite) were detected in samples of alunite from Italy and replicas of fractured surfaces examined under the electron microscope showed the halloysite tubes to be interspersed randomly among the alunite crystals. Furthermore, replicas showed the Italian alunite crystals to have a different morphology from those of a sample from South Africa. Thermal methods were shown to be particularly valuable in the rapid and accurate estimation of alunite in natural samples.

The mineralogy of vertisols and entisols from the White Nile region of the Sudan is being determined with a view to assessing the cause of differences in the cracking behaviour of these soils. Initial results suggest that cracking phenomena are more closely related to specific surface area and to the nature of the saturating cation than to mineralogy.

Chapters dealing with classification of silicates and oxides found in soils[30] and with electronoptical investigation of the oxides of iron, aluminium and manganese[31] have been prepared for forthcoming publications.

Fine Sand Fraction. Both light and heavy mineral separates from the fine sand fractions of soils supplied by Soil Survey from Perthshire and Angus (Sheets 48 and 49) have been examined optically. Most of these soils have been formed on mixed glacial deposits derived from various rock types and their mineral suites show a marked similarity. However, the plagioclase content of the light mineral separates, and the augite content of the heavy, vary considerably and this variation can be related to the dominant parent rock type. A chapter on heavy minerals in soils has been written for a forthcoming work[32].

Clay Fraction. The systematic examination by X-ray diffraction and thermal methods of soil clays from the Girvan and Carrick areas (Sheets 7/8) has been completed and typical mineral suites for the various series established. In many of these soils gibbsite is a common accessory mineral *(see* Ann. Rep. 1964/65). Examination of soil clays from the Banchory, Stonehaven and Forfar areas (Sheets 66/67/57) is in progress.

The clay fractions of a number of immature soils derived from basic rock in Rhum contained considerable amounts of X-ray amorphous material, consisting in one instance of almost pure gibbsite. A feature of the A horizons of some alpine podzolic soils developed on chlorite-muscovite schists in the Ben Lawers area was the decrease in chlorite concentration and increase in kaolinite compared with the lower horizons; in the B horizons goethite, lepidocrocite and hematite were all identified.

In continuance of the study of the non-crystalline components of soil clays a series of soils from Japan have been investigated as well as samples from British Guiana, Ghana and Uganda and a number of specially selected Scottish soils. Particular attention is being paid to the nature of the iron oxide and aluminous components of the gel system using sodium dithionite and sodium carbonate reagents. Preliminary results of treatments in a strong ultrasonic field indicate that this increases the rate at which silica, alumina and ferric oxide are removed without increasing the total amount extracted. A paper dealing with the amount and distribution of non-crystalline silica, alumina and ferric oxide in selected soils from north-east Scotland has now been accepted for publication[36], and one considering the origin of clay minerals in soils[1] has appeared. A comprehensive review of clay mineralogy[2] has been published.

In collaboration with the department of Plant Physiology (Radioactivity), a method for determining the cation-exchange capacity of clays using ^{45}Ca is being investigated: in this connection a micro titration method for the determination of calcium has been developed.

Rock Weathering. A more detailed account[37] of weathered biotite flakes containing zones of kaolinite and gibbsite[3] has now been submitted for publication. A study of the clay mineralogy of soil profiles derived from the same biotitic rock[38] shows the presence of aluminous vermiculite-chlorite, trioctahedral illite, kaolinite and gibbsite in soils of all drainage categories. Since all these minerals can be formed from biotite, this mica may play an important part in the formation of the clay fractions of these soils. It is considered that the formation of these minerals occurred in the regolith before the last glaciation and that subsequent pedogenic processes have caused only slight modification.

Aluminium Hydroxides. In connection with the above study, the conditions of formation of the various polymorphs of aluminium hydroxide are being studied by X-ray diffraction, electronoptical and thermal methods. Whether formed by the neutralization of acid aluminium salt solutions or by hydrolysis of aluminium amalgam, the initial precipitate consists of pseudo-

boehmite (i.e. a poorly crystalline gel with a weak diffuse X-ray pattern similar to that of boehmite). The recrystallization of this material to bayerite or gibbsite can be controlled by the nature of the other cations and anions present. This sensitivity to conditions of formation has been confirmed by electron microscopy and diffraction.

Mineralogy of Scottish Sedimentary and Metamorphic Rocks. In order to establish which soil-clay minerals have been inherited and which have been formed or altered during pedogenesis, a systematic survey of the mineralogy of the clay fraction of Scottish sedimentary and metamorphic rocks has commenced. The heavy separate of the fine sand fraction is also being examined to assess which mineral species can be used as indicators of the provenance of the glacial deposits which form the parent material of most of our soils. In a number of samples supplied by the Geological Survey from the Passage Group of the Carboniferous rocks of Stirlingshire, underclays were invariably dominated by disordered kaolinite, whereas highly crystalline kaolinite was found in sandstones and shales. Limestone rocks of Dalradian age from Banffshire were found to contain montmorillonite as the principal clay mineral.

Organic and Biological Materials

In assessing the application of thermal methods to the characterization of a Scottish peat profile[39], the effects of such factors as particle size, degree of humification, fibre content, mineral matter content and botanical composition have been considered. These methods are currently being applied to a wide range of fresh plant materials, including pollen and pine needles. Thermoanalytical methods have also been used to determine the calcium oxalate content of several species of lichens[40] and results have been correlated with the amounts of calcium in the substratum and of potassium in the thalli[41].

Papers dealing with an electron microscope study of the cell surface of *Cytophaga johnsonii*[4] and the electron microscopy of leaf surfaces preserved in peat[5] have now been published. Further studies in collaboration with the department of Microbiology have led to the development of a technique for locating specimens set in Araldite resin for thin sectioning; this was described in a brief paper presented to a joint meeting of the Physical Society, the Institute of Physics and the Royal Microscopical Society.

Soil Analysis

Standard analytical determinations have been completed on the soils collected by Soil Survey during the 1964 field season, on over a third of those collected during 1965 and on a limited number of those collected during 1966. Total nitrogen, mechanical analysis and pH determinations have been completed on the remainder of the 1965 samples and other determinations are in hand. Clay separates from 20 samples have been analysed for silica, iron and aluminium, and about 100 miscellaneous samples of soil, water, etc., have been analysed on behalf of other departments of the Institute and various outside establishments. Collaborative work with Soil

Survey on the ability of aqueous extracts of pine needles to complex with sesquioxides is continuing.

Peat and Highly Organic Soils

Surveys of selected peat deposits in Kincardineshire (Sheets 40/42/43) and in the Wigtownshire and South Ayrshire areas (Sheets 7/8) have now been completed. Work is currently in progress in the Stirling area (Sheet 29), which includes the extensive raised bogs of the upper valley of the River Forth and considerable tracts of hill peat on the Campsie and Ochil Hills and in South Perthshire. The acquisition of basic optical equipment for the study and interpretation of air photographs will considerably increase the utility of these as an adjunct to ground surveys.

At the request of the Planning Research Unit, University of Edinburgh, a special peat survey has been carried out in the Slamannan area as part of the Grangemouth Falkirk Regional Survey and Plan. In addition, a series of maps (4 miles to 1 inch) showing the distribution of deep peat in Scotland has been prepared for the Peat Sub-Committee of the Natural Environment Research Council's Commitee on Hydrological Research. These maps together with information about the depth and other characteristics of peat in selected areas, including river catchments, are being studied in order to obtain some indication of the possible hydrological significance of climatic peat.

A paper describing the construction and use of an improved peat sampler[6] has been published.

A detailed study is being made of the moisture retention characteristics of peat over the range pF 0-4·2. A sand box has been constructed to study these characteristics at the lower end of the pF scale; above pF 2·7 a conventional pressure-membrane apparatus is being used. These investigations are being related to field experiments, such as that in progress at Lon Mor, Inverness-shire, and to the retention of moisture in peat produced for horticultural purposes.

A large number of physical and chemical determinations have been carried out on a wide variety of horticultural peats. The results have been submitted to the British Standards Institution and are being used in the preparation of a British Standard Specification for peat for horticultural and landscape purposes. Work is now in progress to determine the significance of other physical and chemical factors and to develop suitable methods of analysis.

Systematic laboratory investigations on peat, herbage and water samples have continued along the lines previously reported and reports on various aspects of peat utilization have been prepared for restricted circulation.

Hydrological Studies. Investigations on the hydrology and nutrient balance of deep peat catchments have continued at Blacklaw Moss, Lanarkshire, in collaboration with the Agronomy Department of the Hill Farming Research Organization. Pretreatment calibration of the "micro-catchments" is nearing completion and preparations are in hand to burn selected catchments in

order to investigate the effects of this treatment on run-off characteristics and nutrient loss.

Pollen Analysis and Quaternary Research. Peat samples from various types of deposits have been taken from sites in ten counties ranging from Shetland to Roxburgh. Pollen analyses on these will advance the understanding of peat development and site classification and will add evidence to that already produced about the vegetational history of Scotland. Collaborative work with Soil Survey has continued with the sampling at sites in the counties of Inverness, Nairn and Banff. The pollen diagram for Letham Moss, Stirlingshire, has been completed and material from sites in north Fife has been examined as part of a collaborative study with the Geological Survey. A paper describing palynological evidence of prehistoric agriculture (landnam) in Scotland[7] has been published.

Studies on Forest Soils

Assessments of tree growth on the aeration-drainage experiment on peat at Lon Mor, Inverness-shire, have continued. With increasing depth of drains, both the height growth and the survival of trees directly notched into the peat surface has generally increased. All the drained plots showed significant increases in the length of leading shoots produced in 1965 over those produced in 1964, whereas in the undrained plot only a few very stunted trees now survive.

Tree Nutrition. The experiments already laid down to investigate the nitrogen nutrition of coniferous trees have continued in collaboration with the Forestry Commission. The application of urea, in 1963, to 80-year-old Scots pine at Alltcailleach forest, Aberdeenshire, resulted in increases of up to 50 per cent in the diameter growth, both at breast height and at 25 feet up the stem, during the years 1964 and 1965, there being little difference in the relative diameter growths at the two heights. In experiments on young Corsican pine on wind-blown sand dunes at Culbin, Morayshire, repeated applications of 100-200 lb nitrogen per acre per annum resulted in an initial increase in height growth of around 300 per cent. After a number of years, however, these heavily fertilized trees have started to exhibit an increasing incidence of necrosis of the leading bud, with a consequent marked reduction in height increment—though girth increment remains relatively unchanged. The nature of this damage suggests a deficiency of copper, boron or zinc, and an experiment has now been laid out to test this hypothesis. In the same forest an investigation is being conducted into the effect of applied nitrogen on both tree growth and the distribution and movement of nutrients within a crop of 38-year-old Corsican pine. Prior to the application of fertilizers the nutrient content of the entire ecosystem was determined[8]. The relative abundance of the major nutrients was found to be Na > K > Mg > N > P > Ca whereas incorporation of the nutrients by the trees has been in the order N > K > Ca > Mg > P > Na. The amounts of both nitrogen and calcium in the tree crop represented an appreciable proportion of the total amounts within the ecosystem (13 and 18 per cent respectively, with a further 16 and

10 per cent under the forest floor). The results of these determinations have emphasized the importance of including the underground portions of the trees in order to obtain an accurate picture of the nutrient demands of tree crops. The roots were found to have entirely different nutrient concentrations and ratios from the other, more frequently analysed, tissues comprising the aerial portions. Thus, the concentrations of iron, aluminium, mangesium, sodium and sulphur in the roots are particularly high, whereas those of calcium and manganese are relatively very low. The application of 450 lb nitrogen per acre per annum to this crop has resulted in an almost five-fold increase in basal area growth and has more than doubled the foliage nitrogen content. The nitrogen treatments, after initially depressing the rate of litter fall, have now resulted in a much increased rate of fall over that of the control, this difference mainly occurring during the period of peak fall in autumn. The same pattern is accentuated in the case of the return of nitrogen to the forest floor *via* this process, due to a marked increase in the nitrogen content of the litter produced by treated trees. The fertilizer treatments have also increased the amount of inorganic nitrogen lost from the trees into the rain-water passing over the foliage.

Experiments using water and sand culture in the greenhouse have shown the marked preference of coniferous trees for the ammonium rather than the nitrate form of nitrogen in the rooting media. Further studies have been undertaken to relate relative and absolute growth rates to the photosynthetic area developed under different nitrogen regimes.

The advisory service providing recommended fertilizer rates for forest nurseries based on soil analyses carried out by Soil Fertility continues. The success of some of the newer fertilizers, such as magnesium ammonium phosphate, in Forestry Commission nursery experiments has resulted in these being included in the range of fertilizers prescribed. The prescribing of fertilizers containing both nitrogen and potassium rather than nitrogen alone for top-dressing has greatly reduced the incidence of potassium deficiences and considerable success has been obtained with the use of ground sulphur as an acidifying agent, thus avoiding the danger of ammonium toxicity that sometimes occurs with sulphate of ammonia.

SOIL SURVEY

Soil survey work undertaken during the year has continued the systematic coverage of the soils of Scotland on a scale of 2·5 inches to 1 mile. In this inventory, the mapping units distinguished are based on the genetic soil group, parent material and hydrological conditions of the profile. Related series are grouped into a larger unit, the soil association, which occupies an area in which different soils occur in a characteristic pattern, or forms a landscape which has characteristic kinds, proportions and distribution of component soils derived from one rock source or a mixture of several.

An area of some 500 square miles has been surveyed: 55 on Sheets 40, 41 and part 32 (Kinross, Elie/North Berwick, and Edinburgh); 50 on Sheet 84 (Nairn); 70 on Sheets 110 and 116 (Latheron and Wick); 30 on Sheet 103 (Golspie); 120 on Sheets 1, 2, 3 and 4 (Kirkmaiden, Whithorn, Stranraer and Wigtown); 70 on Sheet 47 (Crieff); 37 on Sheet 85 (Rothes); 46 on Sheet 24 (Peebles); 27 on Sheets 43 and 35 (Iona and Colonsay). In addition a map has been prepared and a report is in preparation on a survey, on a scale of 6 inches to 1 mile, of the Inverpolly and Inchnadamph Nature Reserves, 42 and 5 square miles respectively, on Sheets 101 and 107 (Ullapool and Lochinver). A soil map and report on the 25 square mile Candacraig Estate, Aberdeenshire, on a scale of 6 inches to 1 mile has been completed. A similar survey was made of the adjacent Glenbuchat catchment involving an area of about 15 square miles on Sheet 75 (Tomintoul), at the request of the North of Scotland College of Agriculture.

Mr D. M. Lang, formerly a member of the Pool of Soil Scientists, has been transferred to the Land Resources Division of the Directorate of Overseas Surveys. Mr G. Orbell, Soil Survey Officer on the staff of the Soil Bureau, New Zealand, left in March after eight months on Soil Survey work in Scotland. Mr J. M. Ragg returned in late September from a similar assignment in New Zealand. On his way to and from New Zealand he visited research centres in Canada and U.S.A.

The joint Soil Survey Field Meeting attended by the staffs of the Surveys of England and Wales and of Scotland was held in Ayr from 22nd to 27th May; soils of south-west Scotland were demonstrated and discussions held.

The joint meeting of Commissions II and IV of the International Society of Soil Science, held in Aberdeen from 5th to 17th September, involved members of the Survey in the preparations for the excursions and post-conference tour, and also in the staging of a display depicting the soils and agriculture in eight regions of Scotland. One hundred and forty monoliths representative of mapped soil series were displayed, together with appropriate analytical data, and some 150 photographs illustrating the agriculture and scenery of the regions were used.

An historical review of the soils and agricultural regions of Scotland[9] and papers on frost weathering and solifluction products in southern Scotland[10], on semi-fossil lichen fungi in Scottish hill soils[11], on the soils of Scotland[12],

and on alpine soils of north-east Scotland[13] have been published, while a paper on a method for measuring the iron-mobilizing capacity of aqueous extracts of plants is awaiting publication[44].

Maps and Memoirs. Line proof copies of Sheets 7/8 (Girvan/Carrick), Sheet 39 (Stirling) and Sheets 48/49 (Perth/Arbroath) received from Ordnance Survey have been checked and colour models submitted. Publication of Sheets 66/67 (Banchory/Stonehaven) and Sheets 33, 34 and part 41 (Haddington/Eyemouth/North Berwick) is awaited. The page proof of the memoir to accompany the Haddington/Eyemouth map has been received and an index is in preparation. An account of this area is given in this report. Memoirs are in preparation for Sheets 66/67 and 57 (Banchory/Stonehaven and Forfar), Sheets 7/8 (Girvan/Carrick), Sheet 14 (Ayr), Sheets 48/49 (Perth/Arbroath), Sheet 39 (Stirling) and the parts of Sheets 83, 84, 93 and 94 (Inverness, Nairn, Alness and Cromarty) covering the Black Isle.

Vegetation Surveys. An account of the vegetation of Sheets 7/8 (Girvan/Carrick) has been prepared for inclusion in the memoir for that area. A similar report, based on plant sociological units, relates to the Black Isle, Ross-shire.

The mapping of a broad transect of vegetation on Sheets 84 and 94 (Nairn and Cromarty) has been completed. The plant sociological communities set up for describing the vegetation of lowland areas of Scotland were not always found to be satisfactory units for mapping. For example, the moorland communities of dry *Calluna* moor, wet *Calluna* moor, *Calluna-Eriophorum vaginatum-Trichophorum* moor and upland *Calluna-Eriophorum vaginatum* moor were split up into facies and intergrades for mapping purposes. These narrower mapping units often reflect the influence of grazing intensity, burning, slope and soil differences or a combination of these factors. In other cases the topography changes over very short distances with a resulting intense small-scale pattern in the vegetation which cannot be shown on a map of scale 1:25,000. Such areas of vegetation have been mapped as complexes of the plant communities composing them.

Micro-morphological Studies and Soil Monolith Preparation. Over 250 impregnated soil blocks have been sectioned and further information obtained on the processes involved in the evolution of high altitude soils in the north-east of Scotland. It is felt that many of the processes encountered at these altitudes are related to those responsible for soil genesis at lower levels and considerable soil material has been collected from lowland soils, derived mainly from Old Red Sandstone, for micro-morphological examination in the future.

Considerable work has been done in connection with the Soil Library, which totals nearly 300 monoliths and has aroused a great deal of interest. It is hoped to make regular additions to the collection in coming years.

Ad Hoc Projects. Liaison with the Colleges of Agriculture, the Forestry Commission, the Geological Survey and the Land Drainage Division of the Department of Agriculture and Fisheries for Scotland has been maintained. Lectures on the soils of particular regions were given to students, agricultural

advisory officers, forestry officers and other interested groups. Excursions demonstrating the soils of a number of regions to similar organizations were led. Further use was made of the display of soils and peat arranged for the conference of the International Society of Soil Science when, at the request of the Education Department of Aberdeen Corporation, talks were given to senior pupils of the six Senior Secondary Schools in Aberdeen. Collaboration with the Scottish Peat and Land Development Association has been maintained and an excursion to view the soils of Livingston (new town) hinterland was made by members of the association and others. Consultations were held in connection with land drainage projects of an experimental nature in Perthshire and Stirlingshire.

Collaboration with Moray County Council, in particular with the County Surveyor's Department, was concerned with wind erosion of soils of the Boyndie Association, subsoil information in regard to re-alignment of roads projects and the locating of suitable deposits of road fill and gravel. Help was also given to the Seafield Estates in the selection of a farm for a forest nursery, and by making detailed soil surveys in connection with their planting programme. Archaeological sites under excavation by the Universities of Aberdeen and Edinburgh were visited and soils sampled; phosphate values in the vicinity of such sites are often found to be unusually high.

Sheets 33 (Haddington), 34 (Eyemouth) and part 41 (North Berwick)

The area covered by the above maps comprises almost all the county of East Lothian, together with parts of Berwickshire and Midlothian, and has a total area of 493 square miles. It includes Haddington, the county town of East Lothian, Tranent, a coal-mining town, and North Berwick and Dunbar, popular holiday resorts. Farming is the major industry of the area.

The Lammermuir fault, which extends approximately from Dunbar to Tynehead, is part of the more extensive Southern Upland Boundary fault which forms the boundary between two of Scotland's three major structural divisions, the Midland Valley and the Southern Uplands. The Lothian Plain is the part of the area which lies in the Midland Valley, at an elevation between sea level and 800 feet. It is underlain by Carboniferous sedimentary and igneous rocks, with Old Red Sandstone sediments along its southern edge. To the south of the Lothian Plain and forming part of the Southern Uplands are the Lammermuir Hills, an upland plateau rising to 1750 feet, underlain by Ordovician and Silurian greywackes and shales, with a steep scarp along the northern edge and a gentle dip to the lower ground of the Border Lowlands in the south-east. The principal river systems of the area are those of the River Tyne, which rises near Tynehead in the south-west and flows north-easterly across the Lothian Plain to reach the sea near Dunbar, and the Whiteadder Water and its many tributaries which drain the Lammermuir Hills in a south-easterly direction, eventually joining the River Tweed.

The two major divisions, lowland and upland, have been further sub-

divided on a basis of uniform lithology, relief, and physiographic history to give the following seven land form regions:

Lothian Plain	1. Coastal Plain.
	2. Haddington Plain.
	3. Lothian Platform.
Southern Uplands	4. Lammermuir Hills.
	5. Eastern Lammermuirs.
	6. Border Lowlands.
	7. Lamberton Moor.

The area under review lies in a relatively dry part of Scotland. Mean annual rainfall at altitudes below 500 feet is less than 30 inches, and some parts of the coastal plain average less than 25 inches per annum. Above 500 feet there is a steady increase with altitude; at 1000 feet the average rainfall is over 35 inches, while at 1700 feet it is over 40 inches. Peak rainfall occurs in late summer, spring being the driest part of the year. Potential evapo-transpiration data from stations in East Lothian and Berwickshire indicate that there is a water loss of about 3 inches in winter and so the growing season may open in April with a water deficit. From April the monthly rate of loss increases to a maximum of over 3 inches in June and July, a total summer loss of about 14 inches. From the end of June onwards the soil-water deficit may be 2 inches or more until the balance is redressed by the August rain. Average monthly temperatures in the Lothian Plain range from 2·3°C in January to 14·5°C in July, while in the Southern Uplands they are slightly lower, particularly the average monthly minimum temperatures which are well below freezing in January and February. The growing period (defined as that period of the year in which the daily mean temperature is 5·6°C or above) extends in the more favoured parts of the Lothian Plain from the end of March until well into November, a period of 225 to 250 days, but this number falls steadily with increase in altitude and at 1000 feet the period is about 190 days. Average soil temperatures, recorded at 1 foot below the surface at a station in the Lothian Plain, range from just over 3°C in January to 15·4°C in July. Haar, associated with easterly winds, has an important bearing on plant growth as it occurs mainly in spring and thus cuts out the much-needed solar warmth. On the other hand, it does provide condensed moisture for seedlings during the dry spring.

The solid rocks range in age from Ordovician to Carboniferous. The oldest and most extensive are the shales of the Southern Uplands. Lower Old Red Sandstone sandstones, conglomerates and red marls, together with beds of coarse ash and andesitic lavas, occur in the neighbourhood of Reston and Eyemouth. Two acid intrusions, at Priestlaw and Cockburnlaw, are also of this age and show variation in composition. Upper Old Red Sandstone conglomerates, derived mainly from greywackes and grits, occur in a belt of country extending from Sprott to Dirrington Great Law, while red sandstones and marls occur in a narrow zone along the Lammermuir fault and in a broader belt between Preston and Foulden. Carboniferous rocks under-

lie nearly the whole of the Lothian Plain. The sediments consist of shales, sandstones, limestones, and coal, and the igneous rocks are mainly olivine basalt and trachyte lavas with occasional tuffs. Intrusions of Permo-Carboniferous age, mainly basic in composition, occur in the form of sills, dykes, plugs and laccoliths, the most prominent of which form the Bass Rock, North Berwick Law and Traprain Law.

The whole area was heavily glaciated during the Pleistocene Period by an ice sheet which moved from west to east and eventually left behind a widespread cover of till of variable depth over the Lothian Plain and over the lower ground in the Southern Uplands. Deglaciation followed, leading to the deposition of fluvioglacial sands and gravels. Post-glacial changes in sea-level resulted in the formation of the various raised beach deposits of sands, silts and gravels which are now widespread from sea level up to 100 feet.

It is on these various unconsolidated deposits that most of the soils are developed. Fifty-seven soil series have been mapped, and have been grouped together, on the basis of similarity of parent material, into the following 22 associations:

Association	*Parent Material*
Bemersyde	Intrusive rhyolites and trachytes.
Biel	Drifts derived from Lower Carboniferous sediments and Upper Old Red Sandstone conglomerates and sandstones.
Cairncross	Lower Old Red Sandstone grits, ashbeds and sandstones.
Darleith	Carboniferous basaltic and trachytic intrusions and extrusions.
Darvel	Fluvioglacial sands and gravels derived mainly from Lower Carboniferous igneous and sedimentary rocks.
Dreghorn	Raised beach silts, fine sands, sands and gravels.
Eckford	Fluvioglacial sands derived mainly from Upper Old Red Sandstone sediments.
Ettrick	Silurian and Ordovician greywackes and shales.
Fraserburgh	Raised beach and windblown shelly sand.
Hobkirk	Upper Old Red Sandstone sandstones and marls.
Humbie	Till derived from Upper Old Red Sandstone and Lower Carboniferous sediments.
Innerwick	Fluvioglacial sands and gravels derived mainly from Upper Old Red Sandstone conglomerates.
Kilmarnock	Till derived from Lower Carboniferous sediments and igneous rocks.
Lauder	Upper Old Red Sandstone conglomerates.
Minto	Till derived from Upper Old Red Sandstone, Silurian and Ordovician sediments.
Priestlaw	Granodiorite and allied rocks.
Smailholm	Upper Old Red Sandstone sediments and Lower Carboniferous igneous rocks.

Stirling	Raised beach silts and clays.
Tynehead	Drifts derived from Carboniferous sandstone sediments and Ordovician greywackes.
Whitsome	Calcareous till derived from Lower Carboniferous sediments and basic lavas, Upper Old Red Sandstone, Silurian and Ordovician sediments.
Winton	Till derived from Carboniferous sediments.
Yarrow	Fluvioglacial gravels derived mainly from Ordovician and Silurian greywackes.

In addition, the following miscellaneous soils have been mapped:

Hill Peat
Basin Peat
Alluvium
Peat-alluvium Complex
Saltings
Mixed Bottom Lands

The 57 soil series represent eight major soil sub-groups, of which the commonest and most widespread are the brown forest soils, covering 35 per cent of the area, and the brown forest soils with gleyed B and C horizons, covering over 30 per cent of the area. Iron podzols and peaty podzols together account for about 11 per cent, while gleys (calcareous, non-calcareous and peaty) amount to only 5 per cent. Brown calcareous soils are of very limited occurrence and cover only 1·5 per cent of the area. Of the miscellaneous soils, peat covers about 6 per cent of the area.

The most extensive soil association is the Ettrick Association. This covers about 30 per cent of the area and contains the greatest number of soil series. The soils are mainly developed on a stony drift of medium texture derived from the Ordovician and Silurian greywackes, grits and shales, and they occur throughout most of the Lammermuir Hills and on Lamberton Moor. Linhope series is the most extensive series in the association as in fact it is in the area as a whole. It is a freely drained brown forest soil and typically supports an acid grassland vegetation, although occasionally it is used as an arable soil. The main features of profile morphology are an A horizon of dark brown loam with well-developed crumb structure and a moder, or occasionally mull, humus, a B_2 horizon of high chroma and weak structure, and a brown or yellowish brown stony C horizon. The reaction is about pH 4 or less in the A horizon, increasing down the profile to pH 5 in the C horizon, and base saturation is less than 30 per cent, although values tend to be slightly higher under cultivation. Total P_2O_5 values are moderate to low, but the amount of readily-soluble P_2O_5 is generally very low and often less than 1 mg per 100 g. SiO_2/Fe_2O_3 ratios of between 9·7 and 11·6 in the H and about 4·8 in the B_2 indicate that some podzolization has taken place in this series.

Minchmoor series, an iron podzol under a *Calluna* dominant vegetation, and Dod series, a peaty podzol with a *Calluna-Nardus* vegetation, are

developed on parent materials similar to that of Linhope series. A dry, fibrous raw humus, a grey sandy A_2 horizon, and a humus-iron B_2 are the main morphological features of the Minchmoor series profile, while Dod series has a black greasy or peaty humus, a gleyed "cheesy" A_2g horizon and a thin iron pan. The B_2 horizons are usually of high chroma, as in Linhope series, but where the iron pan is absent or only weakly developed, as sometimes occurs in Dod series, gleying may spread into the B_2 horizon. Both podzols show similar chemical features, the main one being the strongly leached and acid nature of the soil, as indicated by a pH of 3·5 in the A horizons, increasing to about 4·8 in the C_1; base saturation is generally less than 5 per cent in both series. The silica-sesquioxide data below are for a profile of Minchmoor series and give an indication of the degree of translocation of iron and aluminium oxides that has taken place.

Horizon	Percentages			Ratios			
	SiO_2	Fe_2O_3	Al_2O_3	SiO_2/R_2O_3	SiO_2/Fe_2O_3	SiO_2/Al_2O_3	Al_2O_3/Fe_2O_3
A_1/H	51·44	14·50	29·90	2·23	9·41	2·92	3·22
A_2	58·28	2·02	31·00	3·06	74·62	3·19	23·38
B_2	34·32	29·40	29·00	1·22	3·10	2·01	1·54
C	34·88	27·10	27·90	1·31	3·41	2·12	1·61

Of minor extent are the Ettrick series, a non-calcareous gley, the Hardlee series, a peaty gley, and the Kedslie series, a brown forest soil with gleyed B and C horizons, all developed on a parent material of clay or silty clay texture.

The clay fractions from soils developed on the medium- and fine-textured parent materials show a predominance of illite (60-70 per cent) with kaolinite 15 per cent, and chlorite and gibbsite each 5 per cent.

Soils of the Lauder Association occur in the eastern part of the Lammermuir Hills. They are developed on reddish brown or red parent materials derived from the Upper Old Red Sandstone conglomerates with occasional sandstones, and have many similarities to the soils of the Ettrick Association. The parent material is either a very stony drift or shattered rock on which Lauder series (brown forest soil), Langtonlees series (iron podzol) and occasionally Ewelairs series (peaty podzol) occur, while a till of fine texture and restricted to depressions and valleys gives rise to the Spott (brown forest soil with gleyed B and C), the Lylestone (non-calcareous gley) and the Wakenway (peaty gley) series. Chemical analyses correspond closely to those for similar series in the Ettrick Association, although readily soluble P_2O_5 in Lauder series appears to be present in greater amounts than is found in the Linhope series. Illite is again the main clay mineral present, although its percentage is somewhat lower than in the Ettrick Association, and there is an increase in the percentages of kaolin and chlorite.

Another group of red soils is the Hobkirk Association, developed on Upper Old Red Sandstone sandstones and derived drifts. These soils occur

mainly around Chirnside, but are found less frequently in patches along the Lammermuir fault. Hobkirk series, a brown forest soil, is the dominant series. It is generally developed on soft rotten sandstone, although it also occurs on a thin drift. Its use is mainly as an arable soil. The S horizon is typically a dark reddish brown sandy loam with weak blocky structure and friable consistence, the B_2 a reddish brown sandy loam with similar structure and consistence to the S, and the C horizon a soft red sandstone. A B_3 horizon with weak induration is often present, and this restricts root penetration. High pH and base saturation are features of this series. The pH values are about 6 in the S horizon and 7 or more in the C, reflecting the calcareous cement of the sandstone; exchangeable calcium in the C horizon of one profile is 11·1 me/100 g soil.

The clay fractions are predominantly illitic, as is typical of soils developed on parent materials of Old Red Sandstone derivation.

The Winton Association, the second largest in the area, is the dominant soil association of the Lothian Plain; these soils, however, are now considered to be separate series of the Rowanhill Association, an association which is widespread throughout the whole of the Midland Valley. The parent material is a till derived from Carboniferous sedimentary rocks with occasional lavas. Typically it is a reddish brown clay, although variations in colour and texture occur, particularly in localities where the till is thin, due to difference in the proportion of contributive parent rocks. The two main series are Winton and Macmerry; the Winton series is developed directly on the till and the Macmerry series occurs where the upper part of the till has been modified to give an overlying layer of coarser texture material above the clay till. The Winton series, a brown forest soil with gleyed B and C horizons, is regarded as a "heavy" soil agriculturally. Its main morphological features are a sandy clay loam S horizon with sub-angular blocky structure, a $B_2(g)$ horizon of clay loam with a coarser structure, many mottles of high chroma and gley streaks, and a $B_3(g)$ horizon of similar texture with a prismatic structure, and mottles of less frequency and lower chroma.

Base saturation is generally 100 per cent below the S horizon and values for exchangeable calcium are high. The pH is also high and increases from about 6·5 in the S horizon to 7·5 or more in the C horizon; the high pH may in some instances give rise to fixed phosphate and trace element troubles in crops. The high lime content is partly due to the presence of limestone, although it also undoubtedly reflects agricultural practice; a profile of identical morphology, but under old woodland, is by contrast much more acid, with a pH of 4·5 in the A horizon increasing to only 4·7 in the C, and is, except in the L/F horizon, low in exchangeable cations and total and readily soluble P_2O_5, while the base saturation varies from 20 to 70 per cent. The Macmerry series, also important agriculturally, is regarded as a "medium" soil. The natural drainage of the soil, although classed as imperfect, is generally better than in the Winton series. A typical example has an S horizon of dark grey-brown sandy loam with sub-angular blocky

structure, a yellowish brown sandy loam B_2(g) horizon which may show induration, and a B_3(g) of reddish brown clay loam with prismatic structure as in the Winton series. The sharp change in texture occurs at variable depths and reflects the change in material from modified to non-modified till. Base exchange capacity and pH are generally lower than in the Winton series. The dominant clay mineral in the Winton series is kaolinite, of which unusually high contents (65-70 per cent) are reported, with illite (10-20 per cent) and vermiculite (10 per cent) also present.

The Kilmarnock Association, although less extensive than the Winton, is another important soil association of the Lothian Plain. The soils are developed on a mixed till derived from Carboniferous igneous and sedimentary rocks. This till has a clay loam texture, with clay content generally between 30 and 38 per cent. The colour varies from yellowish brown to reddish brown, the reddish hues typically occurring in the vicinity of weathered conglomerates. The main series is Kilmarnock series, a brown forest soil with gleyed B and C horizons. The drainage class is imperfect, although as this series occurs under a rainfall of less than 25 inches per annum some of it approaches almost free drainage. Profile morphology is similar to that of the Winton series, although mottling is usually less intense. Chemical features of the soil are high exchangeable calcium, particularly in the C horizon where values may be as high as 17·29 me/100 g, and high values in the C horizon for readily soluble P_2O_5, 32·8 mg/100 g being recorded for one profile. Base saturation is generally 100 per cent below the S horizon and pH values are between 5 and 6 in the S, increasing to almost 8 in the C. A high content of kaolinite is found and barytes has also been detected in the clay fraction.

Although not very extensive, and of very scattered distribution, the soils of Darleith Association are a distinctive feature of the countryside in the Lothian Plain. They are developed on rocky outcrops of the Carboniferous igneous lavas and intrusions and thus are stony shallow soils which are mainly uncultivated. Only one series, the Darleith, and a skeletal soil occur. The Darleith series, a freely drained brown forest soil, has a well-developed crumb or granular structure in the A horizon and a friable consistence in the A and B horizons. The chemical features are high amounts of exchangeable calcium (20-30 me/100 g), full base saturations below the S, and a pH of 6-6·5 in the A horizon increasing to 7 in the C.

Fluvioglacial deposits form the parent material for soils of four associations, Darvel, Eckford, Innerwick and Yarrow, which together cover less than 9 per cent of the area. The soils are mostly freely drained brown forest soils, their main features being extremely coarse texture and very weak structure. The two series of Innerwick Association distinguished show a markedly high base status, mainly due to a high exchangeable calcium content, and a reaction of over pH 6·5 in the S horizon increasing to over 7 in the C; total and readily soluble P_2O_5 amounts are high in the S horizon and in one instance the latter is as high as 93 mg/100 g. It is probable that this reflects agricultural practice and is not an inherent feature of the soils.

Soils of the Dreghorn Association are developed on the raised beach deposits, either sands and gravels (Dreghorn series) or fine sands and silts (Peffer series). High pH values recorded in these series are again probably a result of a long history of liming, as Dreghorn series, under old woodland, has a pH of 3·63 in the A horizon, increasing to only 4·35 in the C.

Soils of the Fraserburgh Association, developed on shelly sand deposits of raised beach or windblown origin, are the only examples of brown calcareous soils in this area. A pH of over 7·5 is usual in the surface, increasing to 8·5 in the C horizon. Calculated $CaCO_3$ percentages for one profile of Fraserburgh series are 6·6 in the A horizon, 9·1 in the B_2, increasing to 10·9 at the base of the profile.

Analysis of selected soils by the department of Spectrochemistry indicates that the distribution of trace elements is that normally expected for soils developed on parent materials derived from mainly argillaceous and arenaceous sediments. The soils of Darleith and Kilmarnock Associations, however, have much less chromium, nickel and cobalt than normally occurs in soils developed on parent materials derived mainly from basic igneous rocks. There appears to be little danger of any trace element toxicities occurring within the area, but copper, cobalt and manganese in the coarse textured soils, such as Lauder, Eckford and Fraserburgh Associations, are at levels at which deficiencies might occur. Copper deficiency, producing "wither tip" in cereals, does occur in some soils of the Eckford series in Berwickshire, while excessive liming on parts of the Eckford and Darvel series has given rise to manganese deficiency in oats and occasionally in barley.

Farming is the major industry over the whole of the area, and three systems can be distinguished—hill sheep farms, upland livestock rearing farms, and low ground arable/livestock farms.

Hill sheep farms, occurring in the Lammermuir Hills, typically have a few enclosed "in-by" fields to provide oats, turnips, hay, etc., for the animals, but most of the ground is under rough grazing. The Scottish Blackface is virtually the only breed of sheep on these farms, and a common rate of stocking is one ewe to 1½-2½ acres of hill ground. A few beef cattle are also kept on the hill, the balance between cattle and sheep depending to a considerable extent on the quality of the rough grazings, cattle preferring a grassy vegetation.

Upland farms occur in the foothills of the Lammermuir Hills and throughout the Eastern Lammermuirs region. Sheep are still an important feature and, unless there is much rough grazing, the breed is the North Country Cheviot. Cattle, however, play a bigger part in the economy than they do on the hill farms. The majority of fields are farmed in rotation, and cash crops of oats and barley may be grown, average yields being oats 26 cwt/acre and barley 28 cwt/acre.

On the low ground farms of the Lothian Plain, natural conditions favour cropping. Crop yields are high, and typical average yields are barley 30 cwt/acre, oats 30 cwt/acre, winter wheat 35 cwt/acre, spring wheat 30 cwt/

acre, maincrop potatoes 220 cwt/acre, sugar beet 220 cwt/acre and swedes 500 cwt/acre. Under favourable circumstances, crop yields in excess of these are common. Cattle and sheep are still part of the farming system, the cattle being store beasts bought for fattening and the sheep mainly half-bred ewes producing cross lambs sold either young or as heavy lambs in the autumn. Store lambs from the upland and hill farms are also fattened on the lowground farms. Horticulture is of importance in East Lothian, much of the produce going to Edinburgh and Glasgow markets.

Forestry is not of great importance economically, and woodland acreage is small and of scattered distribution. The establishment of trees to provide shelter is, however, an important feature, both along the windswept coast where belts of sea-buckthorn have been planted, and in the upland regions where Scots pine predominates, together with beech.

SPECTROCHEMISTRY

In trace element investigations it is not with plant physiological or animal nutritional problems that the department is primarily concerned, but with factors controlling the supply of trace elements from the soil to the plant and so with the amount present in the plant for utilization by the animal. The soil is the natural source of trace elements in both plant and animal, and the practical objective of trace element investigations on soils is the better understanding of the processes affecting uptake by plants, with a view to the development of methods of assessing availability. There is no simple criterion for the measurement of plant uptake or plant response. For some elements in one plant species it can be relatively easy to obtain a correlation with soil content provided secondary factors such as climate do not vary too much from year to year, but different elements behave differently even in the same species, and many independent or inter-dependent factors may be involved. The plant is a complex organism that is continually developing, with concomitant changes in the absolute contents and in the distribution of its constituent trace elements throughout the different plant parts. Even in the relatively simple instance of the leaves of deciduous trees marked seasonal changes in composition occur, and these vary in character as well as magnitude with different elements[14, 15]. Such changes are much more difficult to interpret in agricultural crops such as cereals in which there is development of additional plant parts throughout much of the growing season. The current investigations on agricultural crops are designed to ascertain which plants or indeed which plant parts, at which stage of growth, reflect most accurately the soil trace element status and, on the other hand, which soil extractants can most effectively be employed to measure the availability of a particular element, as reflected by plant response or plant content. The ultimate aim is to be able, by soil analysis, to predict plant behaviour without having to sample a plant at a predetermined stage of growth. The assumption will presumably always have to be made that none of the major nutrients is limiting, as this can affect the whole balance within the plant.

Four visiting research workers have spent periods of 6-12 months in the department. Dr F. Palmieri, Instituto di Chimica Agraria della Università degli Studi di Napoli, Portici, Italy, Dr J. L. Ahlrichs, Department of Agronomy, Purdue University, Lafayette, Indiana, U.S.A., and Dr S. Yariv, Department of Inorganic and Analytical Chemistry, Hebrew University, Jerusalem, have worked on infrared problems, while Mr B. O. Njoku, Department of Agricultural Research, Moor Plantation, Ibadan, Nigeria, has studied methods for the analysis of soils and plants. Numerous other visitors, many of whom were from overseas, have spent periods varying from a few days upwards in the department in order to obtain experience of specific techniques.

Mr J. D. Russell returned in February, 1966, after spending one year on

leave of absence in the Department of Agronomy, Purdue University, Lafayette, Indiana, U.S.A.

Various members of staff have attended meetings of scientific and official organizations concerned with spectrochemical and trace element problems. Dr R. L. Mitchell presented a paper dealing with various aspects of trace element behaviour in soils to a N.A.A.S. Open Conference of Advisory Soil Chemists on *Trace Elements in Soils and Crops.*

Dr R. L. Mitchell was a member of the steering and local organizing committees of the joint meeting of Commissions II and IV of the International Society of Soil Science, held in Aberdeen in September, 1966. Several members of staff attended the conference and assisted with the excursions and tour.

The abridged version of a lecture given in Switzerland on soil research in Scotland has now been published[16], but one paper discussed in last year's report still awaits publication[46] and illustrates the undesirable delays which often occur between submission of papers and their publication. A period of 18 months is not uncommon.

Trace Elements in Soils, Plants and Biological Materials

There have been no significant changes in the techniques employed to investigate soil status or plant distribution. A comparison is being made between the levels of ammonium-acetate-extractable and EDTA-extractable molybdenum in soils which carry herbage with relatively high molybdenum contents, in order to ascertain which reagent gives the better correlation with plant uptake.

Soils and Soil Parent Materials. Some 20 soil profiles typical of Scottish soils were shown to participants at the International Society of Soil Science Conference local excursions and post-conference tour. Comprehensive trace element analyses were carried out on these profiles, which were prepared by Soil Survey. The results illustrated the marked influence of the nature of the parent material on the total contents of most biologically important trace elements, and the over-riding effect of soil drainage conditions on the extractable contents of these elements, particularly in the subsurface horizons. Results for total and appropriate extractable contents of some 20 elements in the various horizons of the different profiles were presented in the guide books prepared for the local excursions and the tour.

The examination of selected soil profiles from areas covered by the Soil Survey of Scotland is being continued; samples from profiles from Sheets 7/8 (Girvan/Carrick) are at present being dealt with.

Soil Status and Plant Uptake. The investigation of the lead content of pasture herbage has been continued, and a report of preliminary findings illustrating the seasonal increase in lead in dry matter from around 1 p.p.m. in summer to around 10 p.p.m. in early winter and as high as 40 p.p.m. in spring before new growth commenced has been accepted for publication[47]. In an attempt to ascertain the source of the increased lead content of the above-ground part of the plant, samples of marram grass grown on

sand dunes have been collected at short intervals from September, 1965, to May, 1966, as the roots of this plant can readily be sampled and analysed. The possibility of surface deposition of lead being responsible for the increase in mixed herbage can be ruled out for various reasons. The increase appears to occur when active growth ceases and may arise from a translocation from root to leaf. It is this effect that is being investigated in marram grass.

The study of seasonal variation in the various types of plant material has continued. Samples of cocksfoot and timothy from a mixed pasture herbage at Craigiebuckler have been taken at regular intervals and separated into their constituent plant parts. Similar material from cereals and other crops grown in 1965 is now being analysed.

In order to clarify the nature of the rapid changes which occur in the trace element composition of deciduous tree leaves when they emerge from the bud, appropriate samples of horse-chestnut leaves have been taken and their analysis is nearing completion. It has at length been possible to complete the analysis of the various parts of a 30-year-old Scots pine and of the soil on which it was grown, and the results are being prepared for publication. This work has involved the determination of some 22 elements fully and others partially in over 300 samples.

In collaboration with Soil Fertility, analysis of plant and soil samples from numerous field experiments has continued. These have included studies of the effects of treatment of soils with various trace elements, particularly cobalt and copper, and with lime and phosphatic fertilizers.

Materials examined in the collaborative experiments with the Rowett Institute on the effect of pasture management on the trace element status of animals have this year included pancreas, heart and bone samples. These have generally required some preliminary investigation in order to find the most suitable method of pretreatment, as their contents of major constituents differ appreciably from those of materials for which the analytical techniques were developed.

Other miscellaneous samples from external sources examined for trace element contents have included clover seeds from the National Agricultural Advisory Service, coconut leaves from Ceylon, and various plants from New Guinea.

Spectrochemical Methods of Analysis

No changes in the basic methods employed have to be reported, although the availability of the display microphotometer described below suggests that a modified method for the determination of the total trace element contents of soils may shortly be introduced.

Pretreatment and Concentration. The lowering of the limit of determination in quantitative analysis by the cathode layer arc method by the use of recording microphotometry has served to show that several of the chemicals used for the preparation of standard mixtures or in the course of the concentration method contained very small traces of elements being determined. It has now proved possible to select or prepare samples of

Fe_2O_3 and $FeCl_3$ with reduced Mo, of SiO_2 with reduced Zr and Li and of TiO_2 with reduced Pb contents. Some improvements in Al_2O_3 and $CaCO_3$ purity has also been effected.

Arc Emission. The cathode-ray display microphotometer designed and developed in the department and built in the Institute Workshop has now been completed and brought into use. This instrument provides a display on a cathode ray tube, covering about 0·6 mm. of a stationary spectrogram, by means of electronic scanning of an image-converter image of the spectrogram over a photomultiplier slit. Background and line peak densities are measured by means of a cursor provided by the second beam of the cathode ray tube. In addition, the microphotometer incorporates selenium cell and photomultiplier non-recording microphotometry and recording microphotometry using a Beckman pen recorder, so that complete facilities for all methods of plate measurement are available on one instrument. Display presentation is very much quicker than pen recording, involving seconds instead of minutes for each line group examined.

Preliminary investigations indicate that the cathode-ray display microphotometer can be employed in the determination by cathode-layer arc emission of the total content of trace elements in soils, using spectrograms obtained with a three-step sector with a step ratio of 1:4, in order to cover the wide range of contents found for some elements. The lower limits of detection are as good as those obtained by the semi-quantitative technique at present employed and the reproducibility is better. Accuracy should be considerably improved as more precise account can now be taken of variations in background density and interference from neighbouring lines.

Flame Emission. The second three-channel flame photometer used for potassium, sodium and calcium determinations has now been fitted with a modified EEL atomizer of the type described in the 1964-65 Annual Report. With these atomizers a sample volume of 25 ml is sufficient for determination of potassium, sodium and calcium by flame photometer and magnesium by porous-cup solution-spark direct reader. For most types of sample these determinations are carried out in the same analysis solution, to which strontium has been added to overcome aluminium and phosphate interference on calcium and to serve as an internal standard for magnesium. The analysis solutions are held in 25 ml hinged-lid polythene sample tubes into which the diluent and strontium solutions are dispensed by automatic pipette and the sample solutions by suction-operated inverted Daffert pipettes similar to those employed at The West of Scotland Agricultural College Spectrographic Unit. The inverted Daffert pipette facilitates rapid rinsing and dispensing of individual sample solutions. In practice several such pipettes giving different volumes are fitted on a turntable so that different aliquot volumes are readily obtainable. Batches of 28 sample tubes are mounted in press-fit holes in holders made of 1 inch thick expanded polythene sheet (Plasazote). As this is a non-absorbent closed cell material the tubes can be washed without removal from the holders.

Direct Photometry. The small and medium direct readers in the department continue to give excellent service. Despite its limitations because of low dispersion, the medium direct reader provides a convenient means for the analysis of a number of elements, notably copper, zinc, manganese, boron, aluminium and silicon, in soil extracts and plant ash, while the small direct reader fits well into the scheme for the serial analysis of soil and plant extracts for potassium, sodium, calcium and magnesium by providing reliable and rapid determinations of magnesium.

Atomic Absorption. An ASL high intensity hollow cathode lamp has now been fitted to the atomic absorption equipment used for the determination of cobalt in soil extracts. This has involved the construction of an additional stabilized power supply. This lamp simplifies the operation of the equipment and should have a longer useful life than conventional hollow cathode lamps, although there has been little gain in performance because the high dispersion monochromator gave resolution adequate for the separation of interfering, non-resonance lines emitted by the simpler lamps.

In the determination of cobalt in soil extracts, samples with high calcium contents give high results because of a particle scattering effect. It has been found possible to correct for this interference by measuring the apparent absorption of a cobalt line which is not absorbed by cobalt present in the flame and thereby deriving a measure of the effect which occurs at the absorbing wavelength. As calcium contents sufficiently high to cause a significant interference are infrequent, it is not necessary to apply this correction process to all soil extracts but only to those whose calcium content, measured by a simple filter flame photometer which continuously monitors the solutions being examined, requires it.

Using the atomic absorption equipment employed for the determination of cobalt, a preliminary investigation of the possibility of using atomic fluorescence for the determination of zinc has been carried out, with a Philips zinc discharge lamp to irradiate the flame. Early results are promising, although zinc contamination in the flame, arising from the brass burner tube when HCl is present in the analysis solution, has delayed further work until a stainless steel burner can be obtained.

Absorption Spectrometry of Soil Constituents

Infrared studies on clays have been directed towards characterizing the structure, surface properties, and reactivity of the types of clay minerals which occur naturally in soils. Studies on the mechanism of adsorption of ammonia[17] and pyridine[18] on montmorillonite and saponite have now been published. The work on ammonia has considerably clarified the processes likely to occur when anhydrous ammonia, used as a fertilizer, is injected into soils, but further studies, now in progress, on the interaction of ammonia with other clay components are necessary to complete the picture. Previous studies on the adsorption of organic compounds on montmorillonite have been concerned principally with organic bases. A study

of the adsorption of nitrobenzene and benzoic acid, which has been accepted for publication[48], now extends our knowledge to neutral and acidic compounds. With these molecules, as with the organic bases previously studied, the exchangeable cations and their directly co-ordinated water molecules have been found to play a predominant role in the adsorption process. The finding that benzoic acid is adsorbed principally as the unionized monomer explains recent observations that fulvic acid is preferentially adsorbed by montmorillonite under acid conditions. Changes in the infrared spectra of benzoic acid and nitro-benzene in the adsorbed state have also led to the identification of the molecular vibrations which give rise to certain of their absorption bands[49]: this information is essential for translating infrared results from adsorption studies into chemical terms.

The clay fraction of soils is generally complex, and overlapping of the absorption bands of different components can cause ambiguities. Differences in the stability of clay minerals on heating, and consequent changes in their spectra, have been found to assist in differentiating the constituents of such complex mixtures. The use of alkali-halide pressed disks in studying dehydration reactions has been discussed[19]. Changes in spectra associated with loss of hydroxyl and ammonia from ammonium rectorite[77] appear to be typical of dioctahedral smectites which derive their layer charge from aluminium-for-silicon substitution, as similar changes are shown by beidellite. These results, together with others which distinguish beidellite from montmorillonite, have been presented in a paper reviewing infrared studies of clays carried out in this department[50]. A general survey of the techniques and theoretical background necessary for the characterization of soil minerals by infrared spectroscopy, together with a bibliography of mineral spectra, has been prepared[51]. An analysis of the effects of crystal dimensions, and of interlayer cations, on layer silicate spectra has now been published[20].

In these clay studies, assistance and facilities provided by Pedology have been essential to the prosecution of the work, and, in turn, infrared studies have contributed to projects in progress in that department. Collaborative work with Biochemistry and Microbiology has been concerned particularly with the characterization of fungal cell walls and of soil fractions by infrared spectroscopy. Both infrared and ultraviolet techniques have contributed to a collaborative study of lignin degradation by soil micro-organisms[52].

BIOCHEMISTRY

During the past three years, at the suggestion of Microbiology, a study has begun of the biochemical aspects of the degradation of fungal cell walls by soil micro-organisms. This process must play an important part in the conversion of higher plant material into soil organic matter, because residues of higher plants are often extensively attacked by fungi before entering the soil.

Fungal cell walls consist for the most part of organic substances insoluble in water, and so present special difficulties to the chemist and biochemist, both of whom prefer to deal with reactions taking place in solution. The agents elaborated by the attacking organism are mainly soluble proteins (enzymes) excreted into the surrounding medium. Often they are produced only when the substances they act upon are present, and are thus described as "induced" enzymes. Once formed they have to be able to penetrate the cell wall, and this is never likely to be easy because all enzyme molecules are relatively large. Each enzyme will usually attack only a single component of the wall, so that complete dissolution will need the combined action of several enzymes.

Our earliest studies were confined to the action of *Cytophaga johnsonii*, a myxobacterium shown previously (*see* Ann. Rep. 1964/65) to be abundant on the roots of grasses, upon yeast cell walls. The latter were chosen because something is known of their chemical composition. When the cytophaga was grown in the presence of living yeast cells or cells killed by mild heat treatment (75 °C) no evidence could be obtained of enzymes attacking the yeast cell walls, but when it was grown upon autoclaved yeast or walls separated from yeast cells it dissolved the walls. The fluid in which the myxobacterium had been growing contained enzymes that would remove carbohydrate from the walls, but would not dissolve them completely. The addition of a thiol to the test system was found to be necessary for this to happen (*see* Ann. Rep. 1964/65).

The question then arose as to which constituents of the yeast cell wall were being attacked. Previous chemical evidence has shown two polysaccharides, mannan and glucan, to be major constituents of the wall; examination of the products of degradation showed clearly that the glucan was being attacked, but not the mannan.

One way of finding out whether this was the only substance being attacked would be to offer the cytophaga various constituents of the wall singly, and see whether any of them would stimulate the production of enzymes capable of completely dissolving the wall. The most obvious substance to test would be the glucan, but this was widely reported to be a very insoluble substance and hence apparently could not be separated from other insoluble constituents of the wall. However, we have now discovered that a relatively mild treatment (heating at 80 °C for 3 hours at pH 5·0) so alters the condition of the glucan that it becomes soluble in dilute aqueous alkali. It should therefore now be possible to purify and test this as an inducer of cytophaga enzymes.

A further result of this discovery is that we have been able to establish the location of another constituent of the yeast cell wall, chitin. In some filamentous fungi (e.g. *Fusarium*) this is an important structural element but in yeast it is a very minor component. After the glucan has been removed by alkali a small residue is left. The electron microscope shows this to consist of numerous small disks, corresponding to the bud scars in the original yeast wall, crater-like structures formed where a daughter cell has been budded off[53]. This residue seems to contain all the chitin of the wall, mixed with a little glucan, and its infrared spectrum resembles closely that of the cell wall of *Fusarium*. When added to cytophaga cultures these structures disappear, but the culture fluid is not capable of dissolving the whole wall.

These results are sufficient to illustrate the complexities revealed even by the cytophaga/yeast system. The investigation is being extended to more complex fungal walls, and to the use of other soil organisms (e.g. fungi and actinomycetes) isolated by reason of their ability to attack them. In some of these cases it has not yet been possible to achieve complete dissolution of the walls, either by growing cultures or by the culture fluid.

Much useful information has been given by electron micrographs taken by Microbiology, which relate the chemical and biochemical findings to the actual degree of transformation of wall structures, and by infrared spectra obtained by Spectrochemistry, which often help considerably in the identification of insoluble materials derived from the walls.

Dr Bacon gave a paper on this subject to the meeting of the Federation of European Biological Societies in Warsaw in April, 1966.

Soil Organic Matter

Investigations of the lipids of soils have included a study of the factors influencing their existence; a note on the occurrence of long-chain methyl ketones in soils[21] has been published, and a full paper on the wax fraction[54] submitted.

Dr M. V. Cheshire has been seconded for a year from January, 1966, to work with Professor R. D. Haworth in the University of Sheffield, where he is gaining very valuable experience of the use of advanced physical techniques, especially mass spectrometry, in the study of humic acid structure. He is participating in a programme of research on humic acid chemistry supported by the Agricultural Research Council; some of the results have already been submitted for publication[78]. The programme of work on soil carbohydrates has continued in a diminished form during his absence; a paper on this subject has appeared[22], and a review on the chemical environment of soil bacteria is in press[55].

Plant Biochemistry

A final paper based on work by the late Dr M. J. Palmer has been accepted for publication[56]. Biochemical changes in disks of storage tissue (*see* Ann. Report 1964/65) studied in collaboration with Plant Physiology are the subject of two further publications[57, 58]. Work on copper-deficient oats mainly done by Dr Cheshire in the department of Plant Physiology (*see*

Ann. Rep. 1964/65) before his appointment to the staff has been completed and accepted for publication[59].

Visiting Workers

Mr F. Megusar, of the University of Ljubljana, came to the department on a six-month I.A.E.A. fellowship in January, 1966, and his stay has been extended for a further six months. He is studying the effect of added ammonia and nitrate on the mineralization of the organic nitrogen of soils under laboratory conditions.

Dr C. Péaud-Lenoël of the Laboratoire de Photosynthèse of the Centre National de la Recherche Scientifique, Gif-sur-Yvette, spent three months in the department with the support of the Underwood fund. He set up facilities for studying the products formed in the earliest stages of uptake of glucose by wheat roots, and so gave us the benefit of his considerable experience of handling small quantities of radioactive compounds. His advice was also freely sought and given on many other aspects of plant biochemistry, and in retrospect his stay seems to have been far too short; it is hoped that he will be able to return soon.

PLANT PHYSIOLOGY

From October to January Dr P. C. DeKock held a lectureship to the Western Canadian Universities under the auspices of the National Research Council of Canada and the Nuffield Foundation. He later lectured at the Polish Universities of Wroclaw, Krakow and Warsaw as well as at several agricultural research stations.

Mineral Nutrition

The distribution of major nutrient elements has been studied along the potato tuber[63]. In immature daughter tubers the constituents were found to be distributed evenly from " heel " to " rose " end, whereas in mature tubers the distribution becomes polar, potassium and phosphorus showing an increasing gradient from heel to rose end, and iron a decreasing gradient. The distribution of potassium shows at all stages a direct relationship with citric acid. During sprouting, potassium concentration in the tuber falls together with the citric acid concentration, but the gradient is maintained until in the exhausted mother tuber only potassium shows any gradient at all.

Since the cells of the potato tuber are large, it has also been possible to measure the potential difference (PD) between the inside concentrations of potassium and a bathing solution of 10mM KCl. The PD was shown to be directly related to the inside concentration of potassium and since during the movement of potassium from the sprouting tuber the gradient is maintained, it is considered that PD is an important factor in the distribution of potassium within the plant. Moreover the discrepancy between the potassium and citric acid concentrations is constant and must relate to other organic acids. Further studies are in progress.

Salt Uptake Studies

Storage tissue disks reflect in microcosm most of the essential metabolic activities of which the whole plant is capable. Ion absorption is one such activity which is especially prominent and disks are therefore useful material with which to investigate the relation between ion uptake and metabolism, the more so since they permit a distinction to be made between the development of a capacity for ion absorption and the subsequent utilization of that capacity. The evidence for the theory that ion transport is directly linked with protein synthesis or turnover was re-examined during the year under review[57]. Results obtained by the use of puromycin, a specific inhibitor of protein synthesis, and two isomers of chloramphenicol indicate that an inhibitory effect of chloramphenicol on ion absorption was previously wrongly attributed to a contemporaneous effect on protein synthesis. It has now been shown that puromycin has very little effect on ion uptake *per se* but is a potent inhibitor of the development of ion uptake capacity. It is therefore the development of the capacity for ion absorption rather than the actual utilization of that capacity that is directly dependent on protein synthesis. Additional evidence was obtained by the use of D-threo-chloramphenicol, an inhibitor of bacterial protein synthesis, and the inactive

L-threo-isomer. The D isomer inhibited the development of ion uptake capacity more effectively than the L isomer which in turn inhibited the absorption *per se* more effectively than the D isomer. To account for these results a model was proposed in which D-threo-chloramphenicol is active both as an uncoupler of oxidative phosphorylation and as an inhibitor of protein synthesis while L-threo-chloramphenicol acts only in the former capacity and puromycin only in the latter. Experimental evidence from other workers has since confirmed the correctness in principle of this model. The conclusion to be drawn is that the inhibition of ion uptake by chloramphenicol or other inhibitors during short-term studies cannot be attributed to a synchronous effect on protein synthesis.

The desirability of using storage tissue disks cut and aged under aseptic conditions has again been stressed in a paper submitted for publication[64] during the year, in which it was shown that the development of an ion uptake capacity in beet disks may be retarded by bacterial contamination. The previous paper[57] drew attention to the possible hazards of using antibiotics to maintain a degree of sterility. Collaboration has continued with Biochemistry in elucidating the development of invertase activity in beet disks aged aseptically and a preliminary report[58] has been submitted for publication. Current projects include a study of the influx and efflux of labelled ions under conditions of passive and active movement and for this purpose an attempt has been made to grow beet labelled with Na^{22}, Cl^{36} and P^{32}. Flux measurements are made in conjunction with measurements of the electrical potential across the cell membrane and a paper on this subject[65] has been accepted for publication. The effect of oxygen tension on respiration and ion absorption is also being investigated.

Aminotriazole

The action of aminotriazole on *Lemna minor* L. is confined to differentiating cells, as the mother frond is unaffected even under conditions of iron deficiency. Addition of iron to the mother frond leads to a synthesis of chlorophyll even in the presence of aminotriazole. The meristem is also not affected as when the aminotriazole is "used up" production of normal tissue by the meristem recommences. In the affected areas the chloroplasts abort. No mitochondria were found and the cell nucleus appeared granular.

A collaborative study of the action of aminotriazole on tobacco plants[79] showed that the ratios of phosphorus to iron, potassium to calcium and citric acid to malic acid were all higher in the affected tissue.

Collaborative Work

Collaborative work on various aspects of mineral metabolism carried out at the University of California, Los Angeles, has now been published[80]. Iron deficiency was shown to increase the level of citric acid in tobacco leaves and to decrease malic acid. Presence of bicarbonate in the medium intensified the chlorotic condition. In various varieties of lemon, it was shown that potassium content and citric acid content were related. Citric

acid is considered to be synthesized in the lemon so that potassium must be absorbed in response to this synthesis. A study was made of phosphorus toxicity in raspberries[81] and the similarity of the metabolic pattern to iron deficiency has been pointed out. Translocation of iron is one of the main factors involved in susceptibility to chlorosis in plants and results indicate that the process of translocation is metabolic[82].

Radioactivity

The use of radioactive isotopes as tracers has continued with various departments in studies of salt absorption, soil phosphate and soil organic matter. A recent application, by Pedology, of an isotopic method has been the use of ^{45}Ca to measure the cation exchange capacity of clays. Collaborative work with Soil Fertility has also continued on the cation exchange capacity of plants.

MICROBIOLOGY

In general the work of the department is concerned with certain major groups of soil micro-organisms (bacteria, fungi, actinomycetes and protozoa) with reference to their relationships with higher plants and their role in the decomposition of organic matter in soils. Whenever possible emphasis is placed on physiological studies in order to obtain a better understanding of the conditions needed for the optimum functioning of soil micro-organisms in plant growth. Progress made during the year in the aspects of the above which are under investigation in the department is outlined below. Collaboration with other departments within the Institute in many of the studies has continued.

During the year Dr Alberto Ramos, Estacion Experimental del Zaidin, Granada, Spain, spent a month in the department studying the methods used for the breakdown of difficultly soluble inorganic and organic phosphates by soil micro-organisms. Dr J. F. Darbyshire attended the joint meeting of the British Society for Parasitology and the British section of the Society for Protozoologists at Cardiff in April, Mr M. P. Greaves attended the ninth International Congress for Microbiology in Moscow in July, and Dr D. Jones attended the International Conference of the Royal Microscopical Society, held in London in July.

Rhizosphere Studies

The paper containing details of the study of the breakdown of organic phosphates by micro-organisms from the root region of certain pasture grasses has now been published[25].

The co-operative study, with the department of Soil Fertility, on the mineralization of inositol phosphates by soil micro-organisms has continued. A summary of some of the results of this work has been published in the Proceedings of the ninth International Congress for Microbiology, Moscow, 1966. It was found, using a strain of *Aerobacter aerogenes*, that the phytase activity was associated with the insoluble debris obtained after ultrasonically disintegrating the bacterial cells. It was also shown that the "cell-free" supernatant contained a trace of activity which was inhibited by the large amounts of inorganic orthophosphate present. The cell debris preparation was used to examine the enzymatic hydrolysis of a range of inositol phosphates and the products of hydrolysis of *myo*-inositol hexaphosphate were separated and identified by ion-exchange resin and paper chromatography. This separation of the products of hydrolysis of inositol hexaphosphate by a microbial enzyme has not previously been reported.

The effects of factors such as temperature, pH and inorganic orthophosphate were also investigated. A paper containing full details of this work has been submitted for publication[66].

Further studies of the mineralization of inositol phosphates are in progress using micro-organisms isolated from the root region of pasture grasses. The hydrolysis of these compounds *in situ* in soil and sand is also being investigated using the pellet technique developed in the department.

The results of the studies of the protozoan rhizosphere population of perennial ryegrass (S23) growing under field conditions are in the press[67]. Large numbers of amoebae and flagellates were found in the rhizosphere soil close to ryegrass roots. Further experiments with oats, white mustard and perennial ryegrass growing in controlled environment chambers also demonstrated large populations of amoebae and flagellates, but in addition they showed that the size of the protozoan rhizosphere population is also related to the physiological age of the plant and the moisture status of the soil. The reasons for these correlations and the interrelationships of protozoa and bacteria in the rhizosphere will be investigated in the future.

Lignin Decomposition

A paper embodying the results of studies on the use of the pellet technique for examining ecological and physiological aspects of the fungal degradation of lignin and related aromatic compounds, referred to in the Annual Report for 1964/65, has been accepted for publication[52]; an abstract summarizing these results has been published in the Proceedings of the ninth International Congress for Microbiology, Moscow, 1966. A paper describing previous work carried out in the department in connection with the above has now been published[26].

Lytic Soil Micro-organisms

The results of the detailed electron microscope study of the structure of the cell surface of the non-fruiting myxobacterium *Cytophaga johnsonii*, which has been shown to attack the walls of the yeast cell, have now been published[4]. Apart from its ability to attack the walls of yeast and certain fungi it has been found that the organism will digest the cell contents of eubacteria under certain conditions. A paper describing this work[42] has been accepted for publication.

A study of the degradation by soil fungi and actinomycetes of fungal cell walls has also been initiated. Two fungi, *Fusarium* sp. and an unidentified sterile fungus (No. 6), have been isolated and their growth on both solid and liquid media containing whole yeast (*Saccharomyces cerevisiae*) or isolated walls of this yeast results in lysis of the cell walls. Ultra-thin sections and shadowed specimens examined in the electron microscope have provided important information on the manner in which the walls are degraded. A paper incorporating results of studies on the two fungi referred to has been accepted for publication[68]. In this connection, also, it has been discovered in the department of Biochemistry that treatment of whole yeast with acetate buffer followed by extraction with dilute alkali gives a residue which on examination in the electron microscope has been shown to be composed largely of bud scars. A joint paper[53] describing this work has been accepted for publication.

A joint note describing a new technique for locating fungal material, which is difficult to see after partial lysis, in Araldite blocks before the preparation of ultra-thin sections was presented at a joint meeting of the Physical Society,

the Institute of Physics and the Royal Microscopical Society on *Advances in Electron Microscopy*.

A modification of the pellet technique has been made to study some of the processes involved in the lysis of hyphal walls of soil fungi. This involves the preparation of aggregates from a paste of kaolin and fungal walls in a similar manner to that used by Griffiths and Jones (*Pl. Soil*, *23*, 17-33, 1965) for moulding artificial soil aggregates. Fungi and actinomycetes developing on these aggregates, during their incubation on soil, have been isolated by direct transfer of spores to suitable agar media and subsequently shown in growth experiments to be very active in degrading fungal walls. Electron microscopy has been used to follow the manner in which the fungal wall is degraded and to throw light on its ultrastructure. In addition it has been possible to extract from these aggregates enzymes which were subsequently also shown to be very active in degrading fungal cell walls. A paper reporting these results[69] has been submitted for publication.

The above projects on lytic micro-organisms and the degradation of aromatic compounds are being carried out with the collaboration of the departments of Biochemistry and Spectrochemistry.

Other Work

A paper reporting the occurrence of the semi-fossil fungal components of a pyrenocarpic lichen, probably a species of *Polyblastia*, in thin sections of hill soils from the north-east of Scotland has been published[11].

SOIL FERTILITY

In addition to the research programme, the departmental activities include major consultative and advisory soil testing responsibilities. These provide an essential channel for translating research findings into practice, draw attention to problems requiring investigation, and naturally merge into the research programme.

The research activities continue to be based on integration of field, pot and laboratory studies covering the various plant nutrients, contrasting soil series mapped in the Soil Survey of Scotland, and the main agriculture crops. This approach serves two purposes. From the more practical point of view it provides essential information on manuring and crop production and establishes objectively and quantitatively the implications of soil type and pedological factors, particularly differences in parent material and drainage conditions, in terms of soil properties, nutrient relationships and fertilizer requirements. From the more fundamental research angle, systematic studies of this kind on carefully selected contrasting soils constitute the best approach to the problem of identifying and measuring the pivotal properties which govern soil-nutrient-plant relationships and underlie the effects of pedological factors and management practices, not only in the particular soils but also, in principle at least, in soils in general. Detailed studies on these lines have been continued and the main topics are briefly indicated below.

Importance continues to be attached to practical application of results through advisory soil testing in collaboration with The North of Scotland College of Agriculture, contributions to the agricultural Press, and talks to various agricultural and horticultural bodies. Similarly, representation has been maintained on a Technical Committee on Soil Fertility of the Agricultural Research Council, the Grassland Committee of the Scottish Agricultural Improvement Council, and 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 other research organizations, especially the Rowett Institute and the Hill Farming Research Organisation.

Much time and effort had to be diverted during the year to the detailed preparations for the joint meeting of Commissions II (Soil Chemistry) and IV (Soil Fertility) of the International Society of Soil Science in Aberdeen in September, 1966. Dr E. G. Williams, Dr J. W. S. Reith and Dr W. M. Crooke served on the Local Organizing Committee and also as the conveners of the Programme, Post-Conference Tour, and Local Excursions Sub-committees, respectively. In addition to the administrative requirements, the arrangements for the tour and excursions entailed prolonged efforts in the selection of appropriate field sites and farms, provision of analytical data, collection of agricultural and manurial information, and assembling of descriptive guide books, to illustrate influences of soil type

and environmental factors in terms of soil properties, manurial practice and crop production.

At the kind invitation of the Chief of the Division of Plant Industry, C.S.I.R.O., Australia, Dr G. Anderson spent six months leave of absence in the Division's Soil Fertility Section in Canberra collaborating in studies on soil organic phosphates, with particular reference to accumulation under pasture and decreases under arable cropping. Grateful acknowledgement is made to the Australian authorities for the financial aid which made this visit possible. The opportunity was also taken to visit some research centres in New Zealand, Hawaii and Canada.

Mr R. B. McKercher, Department of Soil Science, University of Saskatchewan, completed a three-year research study on the distribution of various categories of organic and inorganic phosphate in soils, for which he was awarded the degree of Doctor of Philosophy by the University of Aberdeen, and is now Assistant Professor of Soil Science in his home university.

As mentioned in last year's report, a review article[27] was prepared for the 1964 *Reports on the Progress of Applied Chemistry*.

Effects of Fertilizers on Crop Yield and Composition. Field experiments to measure the effects of N, P and K on the yield and composition of the main agricultural crops have been continued on different soil types, at centres chosen in consultation with the department of Soil Survey. The results from these experiments are being used in collaboration with the section of Statistics to calculate optimal economic levels of N, P and K, and a joint paper[70] on potatoes was presented to the recent joint meeting of Commissions II and IV of the International Society of Soil Science in Aberdeen. The calculations, based on a quadratic response surface, show the large variations in optimal nutrient rates between different fields. For potatoes grown in north-east Scotland, at current prices the average optimal nutrient rates for fresh tubers are 85 lb N, 157 lb P_2O_5 and 194 lb K_2O per acre. If dry matter production is used instead, the optimal N and K_2O rates are reduced to 75 and 156 lb respectively but the P_2O_5 is slightly raised to 165 lb. per acre. These differences are due to the fact that the percentage of dry matter in the tubers is usually reduced by both N and K dressings, but is practically unaffected by P. The calculated profit from using the average optimal rates at all centres is almost £8 per acre less than that obtained by using the optimal rates for individual sites. These individual optimal rates generally produce higher yields than the average dressings. This work underlines the need for and value of developing better methods for predicting optimal nutrient rates, especially for a crop such as potatoes with a high market value.

Methods of Applying Fertilizers. No new field work was undertaken, and attention has been confined to analyses of crop samples from earlier experiments.

Calcium and Magnesium. Two papers[71, 72] mentioned in last year's report are still in press. Field experiments and laboratory analyses of crop and

soil samples have been continued on the long-term effects of various sources and rates of Mg, including the influences of other nutrients, especially K, on the Mg content of crops and herbage.

Trace Elements. Field and laboratory work on various trace element deficiencies and excesses have been continued in collaboration with Spectrochemistry, including a new experiment on a soil of Old Red Sandstone origin, to measure the effects of different rates of N, P and K on the trace element content of mixed herbage and some of the constituent species.

Samples of herbage from various sites have shown a very large rise in the lead content during late autumn and winter months, and a joint paper[47] on this work has been accepted for publication.

Inorganic Phosphorus. Long-term field experiments, with supplementary pot evaluations and laboratory solubility measurements, have been continued to study the residual value of superphosphate and ground mineral phosphate in contrasting soil types. Otherwise, attention has been centred mainly on characterization of the phosphate status of soils from field experiment sites by a range of selected conventional extraction methods, and on the pot and field studies, mentioned in last year's report, on the effectiveness of various phosphate compounds, including rock phosphates in extremely finely ground form.

Organic Phosphorus. A paper dealing with extraction of organic constituents from soil by ultrasonic dispersion in aqueous acetylacetone[28] has now been published. Unlike extraction with sodium hydroxide, this treatment should cause very little chemical change and the nature of the extracted phosphatic components is being studied.

Further information, including results of collaborative studies by Dr Anderson in the Soil Fertility Section of the Division of Plant Industry, C.S.I.R.O., Canberra, Australia, has been obtained on the distribution of inositol penta- and hexaphosphates in British, Canadian and Australian soils, and the reactions and relationships of these esters with other soil constituents are under investigation. A paper on the analysis of inositol hexaphosphate in soils[73] mentioned in last year's report is still in press. Co-operative studies have continued with the department of Microbiology on the mineralization of inositol phosphates by micro-organisms. An account of the hydrolysis of inositol phosphates by *Aerobacter aerogenes* was given at the ninth International Congress for Microbiology in Moscow and a paper[66] has been submitted for publication.

As noted in the Annual Report for 1964/65, a chapter describing the isolation and characterization of nucleic acids, nucleic acid derivatives, and other phosphate esters from soil is due to appear in a book on *Soil Biochemistry*[74]. Other chapters on soil organic phosphorus and sulphur have been prepared for an *Encyclopedia of Soil Science*[75, 76].

Sulphur. A field experiment to examine the long-term effects of using sulphur-free fertilizers is now in its fifth year, and detailed laboratory studies have been continued on a range of contrasting soils, covering sulphate sorption characteristics and the distribution and inter-relationships

of various categories of organic and inorganic sulphur. Data included in the paper mentioned above under organic phosphorus[28] show that ultrasonic dispersion in aqueous acetylacetone can extract 80-100 per cent of the total soil sulphur.

Cation-exchange Properties and Mineral Composition of Plants. Cation-exchange sites exist throughout the plant, and at an earlier stage in these investigations some comparisons were made between tissues. In the majority of cases root and leaf cation-exchange capacities (C.E.C.) are of the same order, but certain plant species have a leaf C.E.C. lower than their root C.E.C., with differences of up to 50 per cent. Even wider differences have now been found between certain varieties of cucurbits, where the leaf C.E.C. can be only 25 per cent of the root C.E.C. In estimating C.E.C., the first step, using 0·01 N HCl, is to replace exchangeable cations by H^+. In general, length of acid wash does not affect the values obtained, but use of an 18-hour wash was found to increase the leaf C.E.C. of cucurbits to a level comparable with that found for the root tissue, which gave the same value with either short (5-minute) or long acid wash.

A further anomaly of these cucurbits is that their leaf tissue contains an excess of cations over the anions ($H_2PO_4^-$, SO_4^{--}, Cl^-, and NO_3^-) normally included in cation-anion balances, and this imbalance is found to be due to an appreciable carbonate content. Moreover, the varieties containing carbonate are those which have a low leaf C.E.C.

The mineral analysis of plant material sampled over the past two seasons continues, and a refinement introduced in leaf nutrient balance studies has been the fractionation of cations and anions using simple extractants. A not unexpected but quite general feature of this approach has been the demonstration of a close connection between insoluble Ca + Mg in leaves and the sum of their contents of oxalic and uronic acids. Lastly, in an endeavour to improve the correlation between uronic acid (pectin) and the root C.E.C., estimations of the esterified groups of pectin have been made and a correction applied. In general, however, these methyl groups do not fully account for the discrepancy and this must imply that the decarboxylation method used to estimate pectin includes CO_2 from non-pectic sources.

Advisory Work. Over 11,500 advisory soil samples were examined during the year. Most of these were sent in from agricultural land by the staff of The North of Scotland College of Agriculture, but they included also a number of samples from forest nurseries which were dealt with in collaboration with Pedology. Soil and crop samples from areas with special problems, which may concern animal health as well as plant growth, continue to be given more detailed coverage, including where appropriate trace element examination in collaboration with Spectrochemistry. As mentioned in last year's report, high molybdenum contents have been found in an appreciable number of soil and crop samples from various districts in northern Scotland, and extraction with neutral ammonium acetate is proving a very useful method for characterizing these soils.

STATISTICS

The section collaborates with the various departments of the Institute in the planning of experimental projects, carries out the statistical analysis of the resulting data and prepares reports on the findings.

Hitherto most of the computing work has been carried out on electric calculating machines, but increasing use is now being made of the Elliott 803 electronic computer at the University of Aberdeen. Mr R. H. E. Inkson and Mr J. B. McDowall have attended programming courses. In addition to using and amending existing programmes, the section has produced computer programmes for data processing and for the analysis of data from experiments of central composite and lattice square designs.

Mr Inkson read a paper on data processing and statistical computations at a symposium on the use of computers in biochemical research, held by the Aberdeen Biochemical Association. Mr Inkson also attended the joint meeting of Commissions II and IV (Soil Chemistry and Soil Fertility) of the International Society of Soil Science in Aberdeen in September, 1966, and presented a paper dealing with a method of estimating the optimal nutrient rates for potatoes[70]. The method was based on a second degree response surface which proved adequate in the series of twenty-one 4^3 factorial experiments. The nutrients were nitrogen, phosphorus and potassium, and a number of different ratios were considered for cost of nutrient/value of crop. The results showed the need for, and the value of developing better methods for estimating optimal nutrient rates. On the basis of this work a central composite design, using only fifteen treatments, has now been adapted for this type of investigation. Some disadvantages of the complete factorial design for this purpose are briefly reviewed, and two variations of a central composite design are compared in a paper[29] which has now been published.

In addition to central composite designs, other 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 number of large experimental projects and series of experiments computer facilities are required for data processing and tabulation. Examples of these are various aspects of soil analysis and crop composition, studies in tree growth, and run-off from catchment areas where the volume of routine computational work would otherwise be prohibitive.

Results from a factorial experiment with oats grown in peat, carried out in collaboration with Plant Physiology and Biochemistry, have been accepted for publication[59]. Copper was a factor in the experiment and the main interest was in the copper content of the oats. Because of the large number of variates observed, the processing and analysis of the data were done by computer. Correlation and regression analyses have been used in investigating the relationship between potassium and citric acid in potato tubers for a number of varieties. An examination of the relationship

between the ratios, P/Fe and K/Ca, and chlorosis in pear leaves was carried out by multiple regression analysis. Further factorial experiments on oats and on potatoes have been designed with iron, phosphorus and potassium as the factors.

Collaborative studies with Pedology (Peat and Forest Soils) give rise to considerable amounts of data for processing and statistical analysis. Further moisture content and wet bulk density results have been examined in a comparison of sampling methods for peat. The angular transformation was used in a vegetation survey dealing with the effect of water level. In a root penetration experiment a logarithmic transformation was used for counts of radioactivity in roots of different grass species at various depths in the soil. In an intensive investigation into the nature of the response of trees to nitrogen more than 700 variates have already been examined. A further annual set of results in terms of head of water from the catchment area at Blacklaw Moss, Lanarkshire, has been processed, and the computer programme modified to give additional information on daily and weekly run-off in cubic feet per acre and equivalent inches of rainfall. In the calibration of a one-quarter 90° V notch for sub-catchment areas, the linear regression of the logarithm of flow on the logarithm of head of water was examined for different ranges of head and confidence limits for predicted values obtained.

The section has co-operated with the Horticulture Department of The North of Scotland College of Agriculture in designing a split-plot factorial experiment in a shrub growth study.

Collaboration with the Crop Husbandry Department of the West of Scotland Agricultural College continues. Data from NPK factorial experiments on swedes, potatoes, rape and barley have been examined and a further series on all four crops has been planned.

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

Eight additional journal subscriptions were taken out this year and 137 new books added to stock. Despite the improvement in journal cover over the past few years, the number of requests which have to be passed to other libraries continues high and full co-operation in the inter-library lending schemes is essential to the provision of a satisfactory library service. This year 691 items were borrowed from other libraries and 147 lent.

Gifts and exchange arrangements produce a steady flow of reports, reprints and pamphlets, and much valuable material is obtained for the library this way. The Institute maintains a mailing list of individual scientists and institutions interested in the various branches of the research work, and lists of available reprints of staff papers are regularly sent out. No charge is made for reprints. This year 6994 reprints were dispatched from the library.

PUBLICATIONS

(A) *Published—*

1. The origin of clay minerals in soils. By R. C. Mackenzie. (*Proc. Ussher Soc.*, **1**, 134-151, 1965).

   Since the properties of any soil are determined largely by the minerals in the clay fraction, the nature and origin of such minerals are necessarily of interest in soil science. Mineralogical studies have shown that three processes determine the nature of the clay minerals in soils—namely, inheritance, alteration and synthesis—and all may operate simultaneously depending upon the conditions of the pedological environment. There are conditions, however, under which one or another predominates and these yield valuable information on the "life-cycle" of clay minerals. The importance of these three modes of formation is discussed with particular reference to Scottish soils.

2. Clay mineralogy. By R. C. Mackenzie and B. D. Mitchell (*Earth Sci. Rev.*, **2**, 47-91, 1966.)

   A comprehensive review with about 400 references.

3. Weathered biotite from Strathdon, Aberdeenshire. By M. J. Wilson. (*Nature, Lond.*, **210**, 1188-1189, 1966.)

   Interlayer spaces in weathered biotite from soils and weathered rock near Strathdon, Aberdeenshire, are partially filled with aluminium. The same biotite also contains zones of kaolinite.

4. 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.)

   In connection with the contribution of micro-organisms and their products to the stability of soil aggregates recent studies at the Institute have shown that of the predominant gram-negative rods isolated which were capable of synthesizing capsules and/or slime material, up to 25 per cent from the root surface of 16-month old grasses are non-fruiting myxobacteria. Those isolates were subsequently identified as *Cytophaga johnsonii*. The present paper gives a detailed account of the surface structure of this extremely interesting organism and in particular its "slime" envelope which unti now had never been conclusively demonstrated. The study also shows that this external envelope has some very unusual features and is totally different in many respects from the capsules of ordinary bacteria.

5. The electron microscopy of leaf surfaces preserved in peat. By J. M. Stewart and E. A. C. Follett. (*Can. J. Bot.*, **44**, 421-427, 1966.)

   The effects of preservation in peat on the surface features of leaves from *Phragmites communis*, *Eriophorum vaginatum*, *Calluna vulgaris* and *Sphagnum palustre* were followed by means of electron microscopy. This preliminary study has pointed to the leaf litter stage as being significant for the alteration of the submicroscopic surface features. The primary agents responsible for the erosion of surface prominences would appear to be micro-organisms in conjunction with the physical and chemical processes of peat formation.

6. An improved peat sampler. By P. C. Jowsey. (*New Phytol.*, **65**, 245-248, 1966.)

   A peat sampler is described which eliminates the more serious faults of the Hiller type. The samples obtained are free from distortion, readily accessible for measurement and examination and may easily be removed intact for transport to the laboratory.

7. Pollen analytical evidence of "landnam" from two Scottish sites. By S. E. Durno. (*Trans. Proc. bot. Soc. Edinb.*, **40**, 13-19, 1965.)

   Pollen analytical evidence of prehistoric agriculture is derived from two sites in Lanarkshire and Perthshire.

8. Current research into the nitrogen nutrition of Corsican pine. By H. G. Miller. (*Forestry, Suppl.*, 1966, 70-77.)

   The value of considering artificially applied fertilizers in relation to the natural movement and distribution of nitrogen within a forest ecosystem is discussed. The fact that the ecosystem must contain a very much greater quantity of nitrogen than is required by the trees if there is to be sufficient in circulation for healthy tree growth is demonstrated with preliminary results from experimental work on the sand dunes of Culbin forest.

9. The soils and agricultural regions of Scotland: an historical review. By R. Glentworth. (*Scott. Agric.*, **45**, 61-67, 1966.)

   For the six agricultural regions of Scotland—the Highlands, the North-eastern region, the East central region, the Midland Valley and the South-west, the Tweed Basin, and the Southern Uplands—descriptions are given of the principal soils and their formation and distribution, the climate, and the types of farming practised. Changes in climate and the effect on vegetational succession from tundra to deciduous forest in post-glacial times are discussed in relation to the settlement of Neolithic man. A brief resume of agricultural improvements which have taken place from the run-rig agriculture of the 16th Century to the present is given.

10. Frost weathering and solifluction products in southern Scotland. By J. M. Ragg and J. S. Bibby. (*Geogr. Annlr.*, **A48**, 12-23, 1966.)

    The extent of detritus present on the summits and higher slopes of the Southern Uplands has been found to be much greater than previously supposed. Studies of the depth, vertical sequence, preferred stone orientation, mechanical and chemical analyses have led to the conclusion that the vertically sorted deposits are the result of a long period of intensive frost weathering under periglacial conditions and that the hills on which they are found probably escaped the last period of glaciation.

11. Semi-fossil lichen fungi in Scottish hill soils. By J. C. C. Romans, J. H. Stevens, L. Robertson and D. Jones. (*Nature, Lond.*, **209**, 96, 1966.)

    The semi-fossil fungal components of a pyrenocarpic lichen, probably a species of *Polyblastia*, have been found in thin sections of hill soils from north-east Scotland. There appears to be no previous record of similar material.

12. Soils of Scotland. By R. Glentworth. (*Progm. a. Summ. Pap. Jt. Meet. Commn. II & IV Int. Soc. Soil Sci., Aberdeen* 1966. 10 pp.; to appear also in *Soil Chemistry and Fertility*, Transactions of the Joint Meeting.)

    Major soil groups distinguished in the systematic soil survey of Scotland are named and briefly described; their relation to European classifications and the American 7th Approximation are given. Background information on the post-glacial history, the geology and the altitudinal zonation of soils in Scotland is summarized.

13. Alpine soils of north-east Scotland. By J. C. C. Romans, J. H. Stevens and L. Robertson. (*J. Soil Sci.*, **17**, 184-199, 1966.)

    The soils of north-east Scotland show considerable zonal variation as altitude ranges from sea level to 4000 feet. This paper deals with the zone of alpine soils which is usually found above 2300 feet, although relationships with the sub-alpine podzol and peaty podzol zones are discussed. Profile morphology reflects the gradual decrease in biological and chemical activity with increasing altitude, though local

variations in microclimate are important. The macromorphological and micromorphological features of the alpine soils are reviewed and it is suggested that their development has been a response to a succession of slow pedogenetic processes which have operated under cool, cold or very cold climatic conditions.

14. The trace and major element composition of the leaves of some deciduous trees. I. Sampling techniques. By M. M. Guha and R. L. Mitchell. (*Pl. Soil*, **23**, 323-338, 1965.)

Problems arising in the sampling of the leaves of deciduous trees for diagnostic purposes are considered. Findings for 21 trace and major inorganic constituents are presented and such factors as analytical precision, surface contamination and differences between petiole and leaf blade contents are discussed.

15. The trace and major element composition of the leaves of some deciduous trees. II. Seasonal changes. By M. M. Guha and R. L. Mitchell. (*Pl. Soil*. **24**, 90-112, 1966.)

Seasonal variations in the contents of trace and major inorganic constituents of the leaves and some other parts of three species of deciduous trees are presented. The elements considered can be divided into three groups, (A) Co, Ni, Fe, V, Ti, Sr, Pb and Al, (B) Mn, B, Si, Ca, Sr, Ba and Mg, and (C) Cu, Mo, Zn, P, K and Na, which show quite different trends of behaviour. The implications of these differences with respect to diagnostic sampling and fertilizer policy are considered.

16. Soil research in Scotland. By R. L. Mitchell. (*Mitt. naturf. Ges. Bern*, n.f., **22**, 49-62, 1965.)

An account of the organization of agricultural research in Scotland and of the work of the Macaulay Institute.

17. Infrared study of the reactions of ammonia with montmorillonite and saponite. By J. D. Russell. (*Trans. Faraday Soc.*, **61**, 2284-2294, 1965.)

As a preliminary investigation into the behaviour of gaseous ammonia added to soils, a study of the reaction of this fertilizer with the soil clay minerals montmorillonite and saponite has been made. Several reactions are differentiated and their role in the fixation of ammonia by the above soil constituents is discussed.

18. 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). (*J. chem. Soc.*, **A**, 344-351, 1966.)

In the interactions which occur between soil components and water, organic matter, and such additives as herbicides, pesticides and soil conditioners, the surface properties of clay minerals play an important role. In this paper pyridine has been taken as a model compound for certain basic organic compounds which occur naturally in, or are added to soils, and an attempt has been made to distinguish the nature of the surface reactions which occur between pyridine and montmorillonite. Changes in infra-red spectra and interlaying spacing show that pyridine enters the interlayer spaces in this mineral, where it can be held by hydrogen bonding with the water of hydration round exchangeable cations, or by direct co-ordination with the cation, or by conversion to pyridinium ions. Direct co-ordination is important with the transition metal cation, copper: formation of pyridinium is important with less basic exchangeable cations, and with the acid form of montmorillonite.

19. Dehydration reactions in alkali halide pressed disks. By V. C. Farmer. (*Spectrochim. Acta*, **22**, 1053-1056, 1966.)

The infrared absorption of adsorbed water on soil clay obscures important parts of the clay spectrum. Alkali halide disks are sufficiently porous to allow water adsorbed on samples dispersed in the disks to escape when the disks are heated. The porosity of the disks is shown to depend on the nature of the alkali halide and the grinding conditions used. These results indicate the optimum conditions for dehydration studies in pressed disks.

20. Effects of particle size and structure on the vibrational frequencies of layer silicates. By V. C. Farmer and J. D. Russell. (*Spectrochim. Acta*, **22**, 389-398, 1966.)

Soil minerals occur in sizes ranging from submicroscopic clays to coarse sands, and in characterizing them by their infrared spectrum it is important to recognize those features of the spectra which are purely a function of particle size, so that these can be distinguished from features which reflect variations in composition and structure. Kaolin minerals show shifts in absorption frequencies with particle size which are ascribed to an effect of the electric fields induced by the vibrating dipoles. Some other field effects in layer silicates are discussed.

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

As part of the programme of research into the chemical nature of soil organic matter, attention has been turned to the hitherto largely neglected wax fraction of soils. This note reports the isolation from both a soil and a peat of aliphatic methyl ketone fractions with carbon length ranging from C_{17} to C_{37} in which the odd-numbered members predominate. The occurrence of these ketones as natural products, now reported for the first time, should be of significance in the understanding of the biological degradation of long-chain alkanes and related substances present in plant materials.

22. The extraction of carbohydrates from soil by sulphuric acid. By M. V. Cheshire and C. M. Mundie. (*J. Soil Sci.*, **17**, 372-381, 1966.)

Polysaccharides constitute the largest recognizable fraction of the organic matter of soils and play an important role as an energy source for microbial growth and in maintaining the structural stability of soils. This paper describes methods of extraction and analysis of the sugar units of which the soil polysaccharides are comprised.

23. 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). (*J. exp. Bot.*, **17**, 410-416, 1966.)

To understand the mineral nutrition of plants it is necessary to assess both the chemical and electrical forces which influence the entry of nutrient ions into the root. Measurements of the electrical potential and chemical concentration gradients between the root surface and the conducting tissues indicate that potassium, sodium, calcium and magnesium enter the root passively, each ion moving down its electrochemical potential gradient. Conversely, the electrochemical forces in the root act against the uptake of nitrate, chloride, sulphate and phosphate and these ions must therefore be accumulated actively, by mechanisms dependent on metabolic processes within the plant.

24. The influence of age on the cation-anion balance in the leaves of Brussels sprouts (*Brassica olerace* var. *gemmifera*). By E. A. Kirkby and P. C. DeKock. (*Z. PfErnähr. Dung. Bodenk.*, **111**, 197-203, 1965.)

The chemical composition of a series of Brussels sprout leaves of varying age from the same plant was investigated. It was shown that the gross cation-anion ratio increased from about 0·2 in the youngest leaves to 1·0 in the oldest. This increase resulted from the increase in calcium and decrease in nitrogen concentration of the older leaves. A close balance was obtained between the amounts of cations (Ca + Mg + K + Na) and anions (NO_3^- + SO_4^{--} + $H_2PO_4^-$ + Cl^- + organic anions) in the leaves and in particular there was a very high correlation between the concentrations of calcium and malate.

25. 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. (*J. appl. Bact.*, **28**, 454-465, 1965.)

In view of the fact that a considerable amount of soil phosphorus is "bound" in

organic forms, a study has been made of micro-organisms from the root region of certain pasture grasses with regard to their ability to break down the following organic phosphates: phenolphthalein diphosphate, glycerophosphate, sodium phytate, lecithin and nucleic acids. The root region contained more organisms capable of attacking the substrates examined than root-free soil. The results are considered in relation to the possible contribution of micro-organisms to the phosphorus nutrition of crop plants.

26. Enrichment in soil fungi which utilize aromatic compounds. By Moira E. K. Henderson. (*Pl. Soil*, **23**, 339-350, 1965.)

Lignin is one of the major components of the plant material which becomes incorporated in soil on the death and decay of plants. Various aromatic compounds, probably derived from lignin, have been isolated from soil but only in very small quantities, which indicates that decomposition of the plant material is taking place. In order to investigate this decomposition representative aromatic substrates related to lignin were buried in soil in the form of pellets, using the pellet technique of Webley and Duff (*Nature, Lond.*, **194**, 364, 1962.) for investigating localized microbial development in soil. Increased numbers of fungi occured on pellets containing α-conidendrin, α-conidendrol, syringic and vanillic acids and in the soil surrounding them. The growth in pure culture on these compounds of a number of the species which were isolated was studied. Some of these species had not been obtained by the techniques used previously in the study of the decomposition of lignin by soil fungi and the range of fungi known to be able to grow on lignin-related aromatic compounds has therefore been extended.

27. Soils. By E. G. Williams, W. M. Crooke and G. Anderson. (*Rep. Prog. appl. Chem.*, **49**, 307-319, 1964.) *No reprints.*

Review article covering pedology and soil fertility, biological weathering, trace elements, major cations, inorganic phosphorus, organic phosphorus, sulphur and chemical soil testing. Recent developments are briefly reviewed from the point of view of the influences of soil parent material and drainage conditions.

28. Extraction of organic matter from soils by means of ultrasonic dispersion in aqueous acetylacetone. By R. L. Halstead, G. Anderson and N. M. Scott. (*Nature, Lond.*, **211**, 1430-1431, 1966.)

Strong alkalies are among the most effective extractants for removing organic phosphates from the soil, but they can cause marked changes in the nature of the extracted material and alternative milder reagents have therefore been tested. It has been shown that four successive extractions of acid-leached soil with aqueous 0·2M acetylacetone at pH 7 to 8 will remove about two-thirds of the organic phosphate. The use of an ultrasonic probe to assist dispersion of the soil in the solvent increases the amount extracted and in eight varied soils from Britain and Canada all the organic phosphate is removed at pH 8. A high proportion of the soil organic matter is dissolved under these mild conditions.

29. Field experiments to estimate optimum fertilizer levels. By R. H. E. Inkson. (*Pl. Soil*, **24**, 447-453, 1966.)

Field experiments provide a basis for fertilizer recommendations. Some defects of an incomplete factorial scheme are commented on in relation to characterizing a problem area. The complete factorial is briefly reviewed. Using the general polynomial of the second degree as the equation of a response surface, composite designs provide a more uniform precision for the coefficients. These designs are basically augmented 2^m factorials. One such design and a variation on it are compared. The economics of the situation are also included to provide a method of computing economic optimal rates for the fertilizers.

(B) *Awaiting Publication at 30th September, 1966—*

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

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

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

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

34. Some granitic and andesitic soils in north-west Turkey. I. General description of the soils. By A. Irmak and F. Gulcur (University of Istanbul) and W. A. Mitchell. (Submitted to *Agrochimica.*)

35. Some granitic and andesitic soils in north-west Turkey. II. Analytical and mineralogical studies. By A. Irmak and F. Gulcur (University of Istanbul) and W. A. Mitchell. (Submitted to *Agrochimica*).

36. Distribution in some Scottish soils of an inorganic gel system related to "allophane." By J. H. Kirkman, B. D. Mitchell and R. C. Mackenzie. (Submitted to *Trans. R. Soc. Edinb.*)

37. The weathering of biotite in some Aberdeenshire soils. By M. J. Wilson. (Submitted to *Mineralog. Mag.*)

38. The clay mineralogy of some soils derived from a biotite-rich quartz gabbro in the Strathdon area, Aberdeenshire. By M. J. Wilson. (Submitted to *Clay Minerals.*)

39. The characterization of a peat profile by thermal methods. By J. M. Stewart, A. C. Birnie and B. D. Mitchell. (*Agrochimica*, **11**, 92-104, 1966.)

40. The thermal analysis of lichens growing on limestones. By B. D. Mitchell, A. C. Birnie and J. K. Syers (Lincoln College, Canterbury, New Zealand). (*Analyst, Lond*, **91**, 783-789, 1966.)

41. The calcium oxalate content of some lichens growing on limestone. By J. K. Syers (Lincoln College, Canterbury, New Zealand) and A. C. Birnie and B. D. Mitchell. (Submitted to *Lichenologist.*)

42. A comparison of the lytic action of *Cytophaga johnsonii* on a eubacterium and on yeast. By D. M. Webley, E. A. C. Follett and Irene F. Taylor. (Submitted to *Antonie van Leeuwenhoek.*)

43. 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.*)

44. 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.*)

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

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

47. The lead content of pasture herbage. By R. L. Mitchell and J. W. S. Reith. (*J. Sci. Fd Agric.*, **17**, 437-440, 1966.)

48. Infrared study of the absorption of benzoic acid and nitrobenzene in montmorillonite. By S. Yariv, J. D. Russell and V. C. Farmer. (Submitted to *Israel J. Chem.*)

49. Vibrational assignments in nitrobenzene, benzoic acid and other mono-substituted benzenes. By V. C. Farmer. (Submitted to *Spectrochim. Acta.*)

50. Infrared absorption spectrometry in clay studies. By V. C. Farmer and J. D. Russell. (Submitted to *Clays Clay Miner.*)

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

52. The ecology and physiology of soil fungi involved in the degradation of lignin and aromatic compounds related to lignin. By D. Jones and V. C. Farmer. (Submitted to *J. Soil Sci.*)

53. The location of chitin in the yeast cell wall. By J. S. D. Bacon, Elizabeth Davidson, D. Jones and Irene F. Taylor. (*Biochem. J.*, **101**, 36-38C, 1966.)

54. The wax fraction of soils: separation and determination of some components. By R. I. Morrison and W. Bick. (Submitted to *J. Sci. Fd Agric.*)

55. The chemical environment of soil bacteria. By J. S. D. Bacon. (To appear in *The Ecology of Soil Bacteria*. Edited by T. R. G. Gray. Liverpool University Press.)

56. The effect of illumination on the malic acid content and anion-cation balance of mustard leaves (*Sinapis alba*). By M. J. Palmer and J. S. D. Bacon. (*Biochem. J.*, **102**, 304-312, 1967.)

57. The relation between ion absorption and protein synthesis in beet disks. By I. R. MacDonald, J. S. D. Bacon, D. Vaughan and R. J. Ellis (University of Aberdeen). (*J. exp. Bot.*, **17**, 822-837, 1966.)

58. The development and location of invertase activity in washed storage tissue slices. By D. Vaughan and I. R. MacDonald. (Submitted to *Pl. Physiol.*)

59. Factors affecting the copper content of oats grown in peat. By M. V. Cheshire, P. C. DeKock and R. H. E. Inkson. (Submitted to *J. Sci. Fd. Agric.*)

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

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

63. Physiological gradients in the potato tuber. By A. E. S. Macklon and P. C. DeKock. (Submitted to *Physiologia Pl.*)

64. Bacterial infection and ion absorption capacity in beet disks. By I. R. MacDonald. (Submitted to *Ann. Bot.*)

65. The role of transmembrane electrical potential in determining the absorption isotherm for chloride in potato. By A. E. S. Macklon and I. R. MacDonald. (*J. exp. Bot.*, **17**, 703-717, 1966.)

66. The hydrolysis of inositol phosphates by *Aerobacter aerogenes*. By M. P. Greaves, G. Anderson and D. M. Webley. (Submitted to *Biochem. biophys. Acta.*)

67. Protozoa in the rhizosphere of *Lolium perenne* L. By J. F. Darbyshire. (*Can. J. Microbiol.*, **12**, 1287-1289, 1966.)

68. Lysis of the cell walls of yeast (*Saccharomyces cerevisiae*) by soil fungi. By D. Jones and D. M. Webley. (Submitted to *Trans. Br. mycol. Soc.*)

69. A new enrichment technique for studying lysis of fungal cell walls in soil. By D. Jones and D. M. Webley. (Submitted to *Pl. Soil.*)

70. Estimating optimal nutrient rates for potatoes. By R. H. E. Inkson and J. W. S. Reith. (Submitted to *Soil Chemistry and Fertility: Trans. Jt. Meet. Comm. II & IV Int. Soc. Soil Sci., Aberdeen, 1966.*)

71. 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.*)

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

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

74. 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. New York: Dekker.)

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

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

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

77. Infrared study of the thermal decomposition of ammonium rectorite. By J. D. Russell and J. L. White (Purdue University, Indiana). (*Clays Clay Miner.*, **14**, 181-191, 1966.)

78. Humic acid. Part II. Structure of humic acid. By M. V. Cheshire and P. A. Cranwell, C. P. Falshaw, A. J. Floyd and R. D. Haworth (University of Sheffield). (Submitted to *Tetrahedron.*)

79. Effect of aminotriazole on composition of tobacco leaves. By P. C. DeKock and H. Hsieh, E. Bogin and A. Wallace (University of California, Los Angeles). *Phyton*, **23**, 49-52, 1966.)

80. Contributions by P. C. DeKock to *Current Topics in Plant Nutrition.* By A. Wallace (University of California, Los Angeles). (pp. 3-9, 18, 32-34, 38-40, 99.)

81. Excess phosphorus and iron chlorosis. By P. C. DeKock and A. Wallace (University of California, Los Angeles). (Calif. Agric., **19**(12), 3-4, 1965.)

82. Translocation of iron to plants. By A. Wallace (University of California, Los Angeles) and P. C. DeKock. (pp. 323-331 of *Isotopes and Radiation in Soil-Plant Nutrition Studies.* Vienna: International Atomic Energy Authority. 1965.)

83. Cation exchange capacity and mineral nutrition of plants. By P. C. DeKock. (pp. 34-39 of *3rd British Columbia Soil Science Workshop Report.* 1965.)

84. Interactions of major and minor elements. By P. C. DeKock. (pp. 59-67 of *Mineral Nutrition of Plants*. Edited by P. C. DeKock. University of British Columbia. 1965.)

(D) *Thesis*—

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

The distribution and significance of various categories of organic and inorganic phosphorus in soils. By R. B. McKercher.