THE MACAULAY INSTITUTE FOR SOIL RESEARCH

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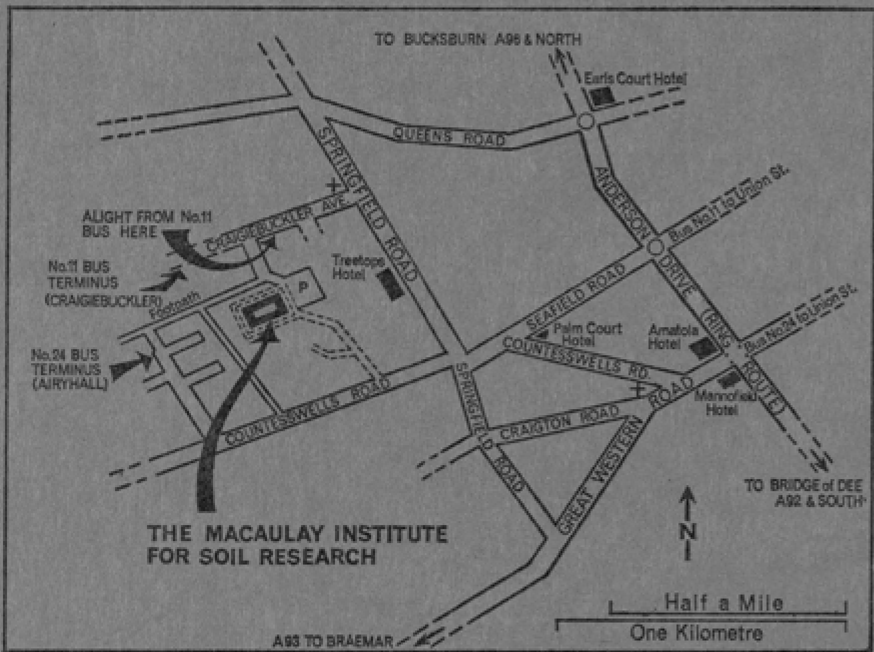
The Macaulay Institute for Soil Research is one of the eight Scottish state-aided agricultural research institutes which are supported by funds from the Department of Agriculture and Fisheries for Scotland and whose research programme is co-ordinated by the Agricultural Research Council.



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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

(Founded 1930)

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1969 - 1970

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1969-1970

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A. D. Moir.
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R. S. Rae—resigned 31/3/70.
P. G. Sutherland—appointed 18/3/70.
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Miss S. A. Bell—appointed 15/6/70.
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Mrs M. Donald—resigned 31/1/70.
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Miss R. H. Greig.
Miss L. A. W. Harvey—appointed 3/11/69.
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Mrs N. S. C. Mackie—resigned 31/3/70.

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Mrs N. Nicol—resigned 30/11/69.
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Miss A. G. Walker—appointed 18/5/70.
Miss V. Walker—appointed 18/5/70.
G. Bruce.
I. M. Still.

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Miss P. Gaskin—appointed 13/10/69.
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Miss L. M. Towler—resigned 10/10/69.

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Mrs N. Smith—resigned 31/8/70.
Miss A. C. Adam.
Mrs M. Angus—appointed 1/3/70.
Miss F. Davies—appointed 20/10/69.
Miss P. Lorimer—resigned 28/2/70.
B. G. Ord.
A. Reid—resigned 30/9/70.
A. Sim.

Radioactivity A. H. Knight, B.Sc., A.R.I.C.
H. Shepherd, L.R.I.C.

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Mrs L. A. Johnston—appointed 24/8/70.
Miss C. A. Jones.

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Mrs J. V. Dunbar.

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J. Munro.
Miss B. J. Bell.
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Mrs J. Douglas—resigned 31/1/70.
Mrs H. M. Duncan—resigned 30/9/70.
Mrs M. H. Hepburn.
Miss H. R. Hutchison.
Miss C. Ireland.
Miss M. A. Legge—resigned 31/7/70.
Miss E. A. Mackay.
Mrs B. B. Mackie.
Miss N. I. MacWilliam—appointed 3/8/70.
Miss E. Pithie.
Miss C. A. Ross—appointed 1/10/70.
Miss M. Sinclair—appointed 16/2/70.
Miss R. Wallace—appointed 14/7/70.
A. R. Douglas.
S. Harris—appointed 3/11/69.
J. S. Wilson—retired 24/10/69.
R. Strachan.
A. G. Gall.
S. A. Duncan.

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Miss F. M. Strachan, B.Sc.
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Miss A. McDonald.
Miss P. L. Parton—appointed 1/7/70.
Miss S. I. D. Walker.

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	M. G. Riddell.
	A. I. A. Wilson.
	R. Riddell.

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	H. Mann—retired 31/3/70.
	A. Mutch.
	A. W. Gordon—resigned 27/3/70.
	J. S. Morrison—appointed 3/8/70.
	G. A. Reid.
	J. Shaw.
	H. Shaw.
Caretakers	Mr and Mrs W. Ryder.

VISITING RESEARCH WORKERS

D. van Dam (Afdeling voor Regionale Bodemkunde, Landbouwhogeschool, Wageningen, Netherlands).

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

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

F. Culçur (Orman Fakultesi, Universitesi, Istanbul, Turkey).

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

A. Odiase (Department of Forestry, University of Ibadan, Nigeria).

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

J. Quakernaat (Nederlandse Organisatie voor Zuiver-Wetenschappelijk Onderzoek, The Hague, Netherlands).

W. K. Robertson (Institute of Food and Agricultural Sciences, University of Florida, U.S.A.).

Volkan Sölen (Orman Fakultesi, Universitesi Istanbul, Turkey).

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

S. St. J. Warne (Department of Geology, University of Newcastle, Newcastle, New South Wales, Australia).

**Sandwich Course student.*

CONTENTS

INTRODUCTION

During the period from October 1969 to September 1970 that is covered by this report there have been a number of changes in the Council of Management. Professor Sir Edmund Hirst, Dr G. H. Mitchell, Professor W. O. Kermack, Mr Maitland Mackie and Professor Sir Stephen J. Watson all retired on completing their terms of office. Mr W. A. Fraser, who served on the Council from November 1969 until June 1970, and Mr W. A. Blackhall withdrew on ceasing to be Governors of The North of Scotland College of Agriculture. The newly appointed members, with the periods for which they have been nominated, are Professor J. I. G. Cadogan, Forbes Professor of Chemistry in the University of Edinburgh (three years), Mr J. A. Robbie, Assistant Director Scotland, Institute of Geological Sciences (three years), Principal E. M. Wright, Principal and Vice-Chancellor, University of Aberdeen (five years), Dr T. B. Miller, Head of Division of Agricultural Chemistry and Biochemistry, School of Agriculture, Aberdeen (three years), Mr W. Anderson Taylor, Kilduthie, Banchory, Kincardineshire (three years) and Professor N. F. Robertson, Principal, East of Scotland College of Agriculture (three years). The Right Honourable the Viscount of Arbuthnott, Arbuthnott House, Laurencekirk, Kincardineshire, has been co-opted for a period of four years. Members of Council who have been re-appointed are Professor J. Monteath Robertson, Gardiner Professor of Chemistry, University of Glasgow (three years), Professor T. C. Phemister, Kilgour Professor of Geology and Mineralogy, University of Aberdeen (five years), Professor P. E. Weatherley, Regius Professor of Botany, University of Aberdeen (five years), Mr J. J. M. Hannah, 3 Baird Road, Alloway, Ayrshire (three years), Professor G. M. Burnett, Professor of Chemistry, University of Aberdeen (three years) Mr G. D. Holmes, Director of Research, Forestry Commission (four years), Professor J. D. Matthews, Professor of Forestry, University of Aberdeen (four years) and Sir William Gammie Ogg, Arnhall, Edzell, Angus (four years). Professor Phemister has been re-elected Chairman of Council and Convener of the Site and Buildings Committee; Professor Monteath Robertson is now Convener of the Staff Committee and Professor Burnett Convener of the Finance Committee.

The Council and members of staff learned with sincere regret of the sudden death of Professor W. O. Kermack on 20 July 1970, only a few months after his retirement from the Council, on which he had served actively since May 1949.

It is also with very deep regret that the death of a senior member of the Institute staff, Mr W. A. Mitchell, on 15 May 1970 at the age of 51, is recorded. His substantial contribution to the work of the Department of Pedology is recognized in the report of that Department. His scientific understanding and his personal integrity led to his advice being frequently sought by colleagues throughout the Institute, all of whom will desire to express their sympathy to his wife, a former member of the Institute staff, and his family.

The construction of new glasshouse facilities for Plant Physiology, Pedology (Peat and Forest Soils), Biochemistry, Microbiology and Spectrochemistry is under way and should be completed early in 1971. Preliminary plans are being made for the modernization of Craigiebuckler House to enable Soil Survey to be accommodated there, thus relieving some of the existing pressure on space in the main building.

Short-term visitors from twenty-eight countries were received during the year, including a party of six senior members of staff of the N. Poushkarov Institute of Soil Science in Sofia, led by the Director, Dr I. Garbouchev, and the UNDP/FAO Project Manager, Dr M. M. Elgabaly from U.A.R. Facilities were provided for longer term workers from Australia, Japan, Nigeria, The Netherlands, Turkey, U.A.R. and U.S.A.

With the aid of funds made available by the Agricultural Research Council and the Department of Agriculture and Fisheries for Scotland, a number of members of staff were able to make very profitable visits to research establishments or attend scientific conferences abroad. Dr B. W. Bache (Soil Fertility) visited research centres in Belgium and Holland; Dr M. V. Cheshire (Biochemistry) attended the fifth International Symposium on Carbohydrate Chemistry in Paris; Mr R. H. E. Inkson (Statistics) attended the seventh International Biometric Conference in Hanover and visited research centres in Germany and Holland; Dr W. J. McHardy (Pedology) attended the seventh International Congress on Electron Microscopy in Grenoble; Mr R. A. Robertson (Pedology) attended meetings of the Presidium and Council of the International Peat Society in Warsaw and a Polish-German Symposium in Nowy Sacz; Dr D. Vaughan (Biochemistry) attended the eighth International Congress of Biochemistry in Montreaux and Dr D. M. Webley (Microbiology) attended the fourth International Colloquium organized by the Soil Zoology Committee of Commission III of the International Society of Soil Science in Dijon.

The Deputy Director, Dr E. G. Williams, participated in an ASCAR Symposium on Agricultural Research and the Use of Mineral Fertilizers, arranged under the auspices of the Anglo-Soviet Cultural Agreement, in U.S.S.R. in May. In addition, he and the other three British delegates visited the Dokuchaev Soil Institute, the Timiryazev Agricultural Academy and the Pryanishnikov Institute of Fertilizers and Agronomical Soil Science in Moscow, the Ukranian Institute of Plant Physiology in Kiev and the Plant Breeding Institute and the Institute of Agrophysics in Leningrad.

Several members of staff were also able to accept invitations to take part in conferences and scientific visits for which the costs were defrayed by the organizers. Dr R. Glentworth (Soil Survey) attended an FAO meeting on Soil Survey and Classification in Ghent, and Mr J. Muir (Soil Survey), on the invitation of the Ministry of Overseas Development, joined the Working Party on a 2-month CENTO Study Tour on the correlation of soil and land classification systems in Pakistan, Iran and Turkey. Dr V. C. Farmer (Spectrochemistry) presented a paper at the 1970 Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy in Cleveland and when in U.S.A. was able to visit several laboratories engaged in relevant work.

Dr R. C. Mackenzie (Pedology), at the invitation of the South African Council for Scientific and Industrial Research and the South African Ceramic Society, gave eight lectures in Johannesburg and additional lectures in Pretoria, Cape Town and Pietermaritzburg in May 1970. Mr R. A. Robertson (Pedology) accompanied representatives of the North of Scotland Hydro-Electric Board to meetings in Amsterdam and Hanover in order to advise them in discussions on aspects of the utilization of peat.

Mr C. J. Bown (Soil Survey) returned to the Institute in March 1970 after a year's leave of absence that enabled him to work with the Soil Survey of Saskatchewan and in the laboratory of the Saskatchewan Institute of Pedology, Saskatoon, Canada.

The opportunity for the exchange of views that arises with visitors to the Institute and on visits overseas by members of staff is most valuable to the work of the Institute and the provision of the facilities that make them possible is much appreciated by all concerned.

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

PEDOLOGY

During the year the department suffered a grievous loss through the death on 15 May 1970 of Mr W. A. Mitchell, who had been in charge of optical and X-ray mineralogical studies at the Institute since 1951. William Anderson Mitchell was born at Inverugie, Aberdeenshire, on 6 September 1918, was educated at Peterhead Academy and joined the staff of the Institute as a scientific assistant in 1936. On the outbreak of war in 1939 he enlisted in the Royal Air Force, with which he saw service in West Africa. Discharged on health grounds in 1943, he matriculated at the University of Aberdeen, graduating B.Sc. with first class honours in geology in 1947. After a period with the Soil Survey of England and Wales, he was appointed in 1951 to take charge of the Section of Mineralogy which was incorporated, with others, into the department of Pedology in 1959.

Mr Mitchell early showed an aptitude for mineralogy and had a particularly extensive knowledge of X-ray crystallography[104] which he put to good use in later studies when he developed several techniques using the X-ray diffraction powder camera method[105, 106, 107]; these enabled more accurate and rapid determinations to be made of the mineralogy of soil clays during the period before an X-ray diffractometer was available at the Institute. Because of his geological and mineralogical background he had a particular interest in the mineralogy of soil parent materials[108, 109, 110, 111] and its relationship with soils derived therefrom[112, 113, 114], as well as in the methods by which such information can be obtained[115, 116]. His field experience gave rise to an interest in the minerals formed by fertilizer-soil interaction[117], in the caking of fertilizers[118], and in the biological decomposition of minerals[119]. He had a wide knowledge of the mineralogy not only of Scottish soils[112] but also of those of many other countries including Northern Ireland[120, 121], Italy[122], Ceylon[123], and Turkey[124, 125, 126]; this knowledge, together with his competence in X-ray diffraction and optical mineralogical techniques, was of great value to the many visiting workers who studied under his guidance. In addition to his scientific studies he also found time to edit Clay Minerals over the period 1966 to 1969. His experience will, indeed, be sadly missed by all his colleagues.

Consequent on the death of Mr W. A. Mitchell a certain amount of reorganization has been carried out within the department. Mr B. D. Mitchell is now in overall charge of chemistry and mineralogy, with Dr M. J. Wilson responsible for X-ray and optical mineralogy, Dr W. J. McHardy for electron microscopy and diffraction, Mr J. M. Bracewell for physicochemical investigations and Mr J. Logan for systematic soil analysis. In addition, Mr R. A. Robertson now supervises all studies on peat and forest soils, with Dr H. G. Miller responsible for forest soil investigations, Mr P. C. Jowsey for peat survey, Dr R. Boggie for studies on plant rooting in peat and Dr S. E. Durno for pollen analysis. This rearrangement is working very satisfactorily.

Collaborative studies with other departments of the Institute have continued and samples have been examined for various outside bodies, including the Forestry Commission, the West of Scotland Agricultural College, the Scottish Horticultural Research Institute, the Universities of Aberdeen, Dundee, Edinburgh, Glasgow, Cambridge, Sheffield, Belfast, Cairo, Heidelberg, Rome and Istanbul, Lincoln College (New Zealand) and the British Museum and F.A.O. Close collaboration with the Forestry Commission in relation to forest soils and with the Department of Agriculture and Fisheries for Scotland on aspects of peat has continued. Contact has also been maintained with the Highlands and Islands Development Board in relation to the survey and utilization of Scottish peat resources, and with the British Standards Institution and other standards organizations on the development and assessment of standards for peat and peat products. Requests for information and advice on various aspects of peat have come from many bodies and individuals, including the North of Scotland Hydro-Electric Board, the Natural Environment Research Council, the Colleges of Agriculture, the Institute of Geological Sciences, the Board of Trade, the United Nations Industrial Organization, local authorities, landowners and tenants.

As is customary, a number of post-graduate workers have contributed to the work of the department during the year. Dr J. Quakernaat, Nederlandse Organisatie voor Zuiver-Wetenschappelijk Onderzoek, The Hague, Netherlands, has completed his studies on the physical chemistry of clay minerals with special reference to saponite, and the work of Dr V. Sölen, Orman Fakultesi, University of Istanbul, Turkey, on the chemistry and mineralogy of Turkish forest nursery soils is virtually complete. Dr S. St. J. Warne, Department of Geology, University of Newcastle, New South Wales, Australia, has carried out thermal investigations on a series of carbonate minerals and mixtures, and Dr A. S. de Endredy, F.A.O., Rome, has assisted between assignments in many ways in the work of the department.

Members of staff have attended, *inter alia*, the seventh X-ray Analytical Conference at Durham, an informal technical discussion on microprobe and X-ray fluorescence techniques, and meetings of the Clay Minerals Group of the Mineralogical Society, the Thermal Analysis Group of the Society for Analytical Chemistry, and the British Standards Institution Panel M79/2/5 on propagation pots.

At the invitation of the South African Ceramic Society and the South African Council for Scientific and Industrial Research, Dr R. C. Mackenzie paid a three-week visit to South Africa. During this period he delivered a series of lectures relating to thermal analysis and its application to clay mineralogy at the University of the Witwatersrand, Johannesburg, and the Universities of Pretoria, Cape Town and Natal. In addition, he had discussions with soil scientists and clay mineralogists at a number of research institutes, the University of Stellenbosch and the Rand Afrikaans University, Johannesburg. During his tour Dr Mackenzie also addressed the Royal Society of South Africa and the South African Ceramic Society. He was fortunate too in being provided with facilities that enabled him to see many South African soils in the field and to gain some knowledge of the geology of South Africa. Dr W. J. McHardy attended the seventh Congrès International de Microscopie Electronique at Grenoble, France, at which he participated in the discussions. Mr R. A. Robertson attended a meeting of the Council of the International Peat Society in Warsaw and later participated in a German-Polish Peat Colloquium held at Nowy Sacz in southern Poland.

Analytical Studies

During the year the scope of systematic soil analyses has been extended by the introduction of a number of physical measurements. Thus, liquid and plastic limits, bulk and particle density and particle-size distribution (using both centrifugal and gravitational methods) are now being determined. Systematic analytical determinations have been completed on all samples collected by Soil Survey during 1968 and 1969 and are well advanced on those collected during 1970. A statistical evaluation, in collaboration with Soil Survey and Statistics, of field and laboratory information for a number of Scottish soil series has shown, on the basis adopted, distinctions between drainage classes; the distinctions were, however, less clear with respect to parent materials for well drained soils[1].

Soils from the principal series of the Stirling, Forfar, Banchory and Stonehaven areas (Sheets 39, 57, 66/67) are being subjected to extractions with various reagents—potassium pyrophosphate, sodium carbonate and sodium dithionite—to estimate and compare the amounts of silica, alumina and ferric oxide extracted: carbon is also being determined in the pyrophosphate extract. The results obtained should enable better chemical characterization of soils.

A semi-micro method for the determination of ferrous and ferric iron on a single sample of 5-10 mg has been developed: this is based on hydrofluoric acid extraction in the presence of vanadate and on subsequent complexing with beryllium sulphate. X-ray fluorescence spectroscopy has been proving its value in the analysis of mineral samples: at present elements of atomic numbers between 12 (magnesium) and 26 (iron) are being determined. This technique has been of particular assistance in a study of the weathering of granite and granulite boulders.

Mass spectrometry has been employed to measure the major constituents of the soil atmosphere in a hydrologic sequence of soils of the Countesswells Association. Carbon dioxide is in higher concentration in the surface horizons of the poorly drained soils than in those of the freely drained members, but in all profiles the concentration of carbon dioxide increases with depth. Several other gases have been identified. The results reflect the degree of gaseous exchange between the soil air and the atmosphere and the investigation is being continued.

Soil Mineralogy

Among the minerals examined during the year has been a montmorillonite of low cation-exchange capacity from Italy; a silica phase in this sample has been identified, on the basis of the results of infrared absorption and electronoptical techniques, as cristobalite. A macrocrystalline saponite from Germany has been subjected to an intensive study by X-ray diffraction, electronoptical, thermoanalytical and chemical techniques, and the same techniques have been used in the characterization of lithiophorite[2], a manganese mineral of wide occurrence in soils.

The first volume of a comprehensive treatise on differential thermal analysis[3] has been edited and published; chapters have been contributed on historical aspects[4], instrumentation[5], techniques[6], oxides and hydroxides[7], phyllosilicates[8], organic compounds[9], and biological materials[10]. A chapter on thermoanalytical instrumentation[56] has been compiled for a forthcoming monograph.

The study of crystallographically poorly ordered inorganic materials in soils continues to be a major subject of research and a detailed study has commenced on a number of Scottish soils known to be rich in these materials. Examination of particle-size separates has shown that aluminosilicate gels are by no means confined to the fine clay ($<0{\cdot}5$ μm) fraction but also occur in the coarse clay (0·5-2 μm) and silt (2-6 μm): indeed the amounts per gram in the coarser fractions exceed those in the fine. In these studies differential thermal analysis, thermogravimetry and derivative thermogravimetry have been used in conjunction with selective chemical methods. The effect of dilute alkali solutions on silica polymorphs[11] and on crystalline aluminium oxides[12] has been examined and it has been shown that poorly ordered gibbsitic material in soils can be determined by differential thermal analysis in conjunction with alkali dissolution techniques[57].

In connection with these studies, attempts have been made to determine by laboratory investigation the likely fate of inorganic gels in the soil. Alumina gels produce bayerite, gibbsite and boehmite on aging under different conditions[58], and aged mixed silica-alumina gels are now being examined. Alumina gels aged for three days before adding ethyl silicate as a source of silica do not crystallize beyond the pregibbsite stage, even after three and a half years, and gels prepared by coprecipitation of silica and alumina fail to crystallize at all after the same time period. A study of the reaction between ammonium pyrophosphate and alumina and ferric oxide gels has also commenced.

The mineralogy of vertisols and entisols from the Sudan has been further examined. The fine fraction ($<0{\cdot}5$ μm) of all samples consists of montmorillonite, but whereas the 2-6 μm fraction of vertisols is also composed almost entirely of montmorillonite the same fraction of entisols contains chlorite and carbonate minerals, montmorillonite being absent. This difference in mineralogy could account, at least in part, for the difference in cracking characteristics of the two soil types.

The value of controlled-atmosphere thermal analysis in detection and estimation of various carbonates of magnesium, calcium and iron has been assessed and the effects of one or more of these carbonates on the differential thermal curve of another has been determined[59]. Mass spectrometry has been employed to monitor carbon dioxide evolution during thermal analysis: by this means carbonate contents as low as 0·5 per cent can be determined in soils even when the carbonate peak on the differential thermal curve is occluded by peaks due to the clay minerals present.

Parent Materials. In collaboration with the Department of Geology, University of Glasgow, the clay mineralogy of a sequence of Upper Old Red Sandstone sediments in Ayrshire has been determined. An illite-montmorillonite interstratification predominates and, in general, the mineral assemblage observed is identical with that in rocks of similar age in other parts of Scotland[60]. From an examination of 120 samples of Carboniferous rocks it appears that in most parts of the sequence kaolinite is abundant in the clay fraction; in the same fraction of rocks of the Cementstone group illite is dominant. In arenaceous sediments the kaolinite is highly crystalline whereas in shales and fireclays it is disordered. The clay mineralogy of Scottish Dalradian metamorphic limestones[13] and the characteristics of plumbogummite minerals occurring in Cretaceous greensands[61] have been described.

In a soil developed directly on a biotite-hornblende rock at Rehiran, Inverness-shire, the biotite initially weathers to hydrobiotite[14]; the mechanism of this transformation[15], as well as that of the oxidative weathering of biotite and vermiculite[62], has been examined in collaboration with Spectrochemistry. The weathering sequence of the hornblende component has also been established[63].

During the weathering of granite and granulite boulders in an Old Red Sandstone conglomerate at Clunas, Nairnshire, the microcline has remained stable but the other felspars have been transformed directly to Cheto-type low-iron montmorillonite. Optical and electronoptical evidence suggests that the clay minerals have crystallized directly from soluble or colloidal decomposition products, there being no evidence of a crystalline transitional stage. Muscovite has been converted to kaolinite but biotite seems to be little altered. All evidence points to weathering in a relatively closed alkaline system.

Clay Fraction. X-ray diffraction, thermoanalytical and electronoptical methods have been used in systematic mineralogical examination of Scottish soil clays. Investigation of clay fractions from the principal soil series of the Forfar, Banchory and Stonehaven areas (Sheets 57, 66/67) and the Black Isle area (parts of Sheets 83, 84, 93, 94) has been completed; soils of the Stirling area (Sheet 39) are currently receiving attention.

It has been established that the principal clay mineral present in Turkish forest nursery soils developed on recent alluvium is smectite, which can be either dioctahedral or trioctahedral, and that, in addition, surface layers contain significant amounts of poorly ordered aluminosilicates. The clay mineralogy of soils from Canada, Egypt, Ghana, New Zealand, Nigeria, Pakistan and South Africa has also been determined.

In a study of the clay mineralogy of soils derived largely from sedimentary and volcanic rocks of Lower Old Red Sandstone age it has been found that, although the contribution of inheritance of clay minerals from the parent rock is important, there are significant differences between the mineralogy of clay fractions of the soils and those of the rocks. For example, although kaolinite is rarely observed in the rocks, it is invariably present in the soils. The most commonly observed effects of pedogenesis are vermiculitization of the micas and introduction of aquo hydroxy aluminium into the interlayer positions of expansible minerals.

A magnesium-rich chlorite predominates in the clay fraction of freely drained brown podzolic soils developed on a glacial till derived from epidiorite in the Loch Awe area. The study of chlorite-bearing soils has been extended to include profiles developed from Middle Old Red Sandstone flagstones in Caithness and from Silurian shales and greywackes in Roxburghshire. The weathering of chlorites in alpine podzols of the Ben Lawers massif[16] has been described.

Clay-Organic Complexes. In collaboration with Microbiology, the conditions governing sorption of nucleic acids by montmorillonite have been established[17] and it has been demonstrated that the progress of microbial degradation of montmorillonite–nucleic acid complexes can be readily followed by X-ray diffraction examination[64].

An electronoptical study of the products formed on complexing ferric chloride with various organic compounds and removing chloride ion by anion exchange resin has shown that on oxidation hematite, goethite, lepidocrocite and magnetite can all be obtained, depending on the conditions employed. Further investigations are in progress.

A study of soil clay–organic complexes by vacuum thermal analysis combined with mass spectrometry has commenced.

Surface Properties of Soils and Clays

The reactivity of soils and soil clays towards the fluoride ion has found increasing application in the detection of poorly ordered material[18]. Because of this the fluoride–hydroxyl exchange technique has been further developed and is now on a semi-automatic basis. The amount of reaction occurring is almost independent of fluoride concentration but increases markedly with hydroxyl concentration; furthermore, the temperature dependence of the reaction corresponds to an activation energy of 5 kcal/mol, which is similar to that for proton-jump reactions. The rate of reaction is strongly dependent on the degree of disorder of ions at the surface of the substrate. The effects on the reaction of particle size and of organic matter are currently being examined.

Methods for measurement of cation-exchange capacity of carbonate-containing soils have been assessed and applied to a series of vertisols from the Sudan. The pH-dependent charges on allophanic soils and soil clays containing interlayer aluminium ions are now being investigated. The water-sorption technique adopted for assessment of specific surface areas of synthetic gels has been successfully applied to allophanic soil clays.

Organic and Biological Materials

A combined thermoanalytical and mass spectrometric technique has now been devised where the temperature of the samples is raised, *in vacuo,* from room temperature to 600°C in about 15 seconds and the volatile products formed are analysed by a low-resolution mass spectrometer. The products from a selection of carbohydrates, amino acids, proteins and hydrocarbons gave characteristic spectra and the method has since been applied with success to total soils in the air-dried condition. Results for genetic horizons of fourteen Scottish soil profiles have shown that the patterns obtained for the decomposition products—in particular, for carbon dioxide, carbon monoxide, methane and benzene—can be used to distinguish A horizons from B horizons and both of these from raw humus: an index for the characterization of soil organic matter can thus be obtained[66].

The technique described above, together with differential thermal analysis in an atmosphere of oxygen, has been applied to air-dried peat samples. The mass spectra obtained showed significant variation in the gaseous decomposition products with degree of humification. Cell-wall materials from fungi, provided by Microbiology, have been successfully differentiated and classified with the aid of these combined techniques. X-ray diffraction is also being employed in the study of these cell-wall materials and, in spite of the poor degree of crystallinity, the results are encouraging.

Peat and Forest Soils

Survey, classification and evaluation of Scottish peat resources[19] have continued to provide both practical and scientific information. Survey technique and expertise are widely employed to support both fundamental and applied field and laboratory investigations—particularly those concerned with Quaternary studies, drainage, agricultural use[67], afforestation[68] and the winning, harvesting and use of peat for horticulture and other purposes. Studies on the nutrition of forest trees, carried out in close collaboration with the Forestry Commission, cover both mineral and organic soils.

To fulfil responsibilities for the recording and exchange of information on peat research and development, close liaison has been maintained with the main national and international organizations connected with peat science and technology. In collaboration with the Torfinstitut, Hanover, Germany, a comprehensive German-English-Russian dictionary of peat terms has been compiled.

Peat Surveys. At present, close-grid topographical and stratigraphical surveys are largely confined to extensive areas of deep peat—particularly those with development potential. Elsewhere, multiple-traverse, air-photo and other techniques are used to establish regional patterns and to provide appropriate information for Soil Survey memoirs.

During the year work in the Perth and Arbroath areas (Sheets 48 and 49) has been completed and a further eleven peat areas ranging in size from 10 to 4050 ha (25-10,000 acres) have been examined and mapped in the Wick and Latheron districts (Sheet 110/116) of Caithness. In the Kinross and Elie areas (Sheet 40/41), where surveys are in progress, peat covers a small percentage of the land surface and most of the bogs are too small for any form of industrial development. The main exception is Moss Morran (100 ha) near Cowdenbeath where sphagnum peat of a low degree of humification is being exploited for horticultural purposes.

At the request of the Department of Agriculture and Fisheries for Scotland and the Highlands and Islands Development Board, a detailed survey has been undertaken of two large bogs in the island of North Uist. Both deposits are considered to have development potential, one as improved agricultural land and the other as a possible source of peat for soil improvement.

In all about 8100 ha (20,000 acres) of deep peat have been surveyed during the year and the recently acquired Snow Trac vehicle has amply demonstrated its worth, especially as a means of access to large, relatively remote peatland areas. Cartographic work, documentation and assessment have progressed satisfactorily and the possibilities of applying the techniques of photogrammetry to peat survey have been closely studied in collaboration with staff of the Universities of Aberdeen and Glasgow.

Pollen Analysis and Quaternary Research. Pollen analysis of peat and other organic deposits in parts of Caithness, Argyll, Perthshire and Northumberland[69] has provided further information which, when combined and correlated with previous results, will lead to a better understanding of past environments and the influence of these on pedogenic processes. A particularly interesting site has been located near Ulbster, Caithness, where a deep basin peat appears to provide a continuous record of the development of vegetation from the late Weichselian onwards. The deposit is currently undergoing detailed investigation.

Pollen analytical dating of three relatively shallow bands of buried peat from different depths and locations in the Aberdeen area has been completed[70]. A study of the pollen diagrams has revealed that, although the deposits are heterochronistic, time overlaps make it possible to combine them into one chronological sequence covering the Late-Glacial to the Sub-Boreal periods.

Work in conjunction with archaelogical excavations continues to be a fruitful source of evidence of prehistoric human activity and its concomitant effects on vegetational history and soil development.

Root, Moisture and Aeration Studies. By growing seedlings of lodgepole pine in soil in sealed containers, investigations on the oxygen requirements of tree roots have been extended in a more realistic manner than has been possible in culture solution. Control in the closed systems is effected by circulating gas mixtures and periodically adjusting moisture contents. The equipment is designed to allow both progressive visual and ultimate quantitative assessments.

Field investigations on the response of lodgepole pine to water-table height in deep peat[71] have continued at Lon Mor, Inverness-shire. Because of the variations observed last year in root growth within treatments, it has been necessary to excavate and examine the root systems of many more trees. Where the water-table is maintained at ground level, only short, dark brown adventitious roots arise from the base of the stem and there is no lateral development. In all other treatments, the root systems are strongly lateral and even in the driest plot, where the water in the surrounding ditch is maintained at 50 cm from the surface, the deepest roots, occasionally penetrating to below 60 cm, are branches of a main lateral. A few trees show incipient tap root development, but more often the base of the stem is club-shaped and root development is predominantly in one horizontal direction. Determination of sulphides, the accumulation of which is indicative of water-logged conditions, has been used in an attempt to investigate aerobic-anaerobic zonation in the peat profiles. Indications are that sulphides do not always accumulate under water-logged conditions and that factors other than anaerobiosis must be involved.

A study of the physical properties of several standard horticultural substrates has revealed considerable differences in moisture-holding capacities, moisture-release characteristics (pF curves) and porosities. Pure peat had a high pore volume and good air: moisture proportionment and gave a uniform release of water over most of the range available for plant growth (pF 0-4·2) and in these respects was the best of the substrates examined[72].

Tree Nutrition. Close attention continues to be given to the nitrogen nutrition of pines growing on wind-blown sand at Culbin forest, Morayshire. Radiographs of stem disks are being used to examine changes in the pattern of wood production, both within the tree and between trees, that occur following application of various rates of ammonium sulphate to middle-aged nitrogen-deficient Corsican pine. Within the same forest, a crop of middle-aged Scots pine is being treated with various forms of nitrogen fertilizer, factorially combined with lime and phosphorus, to assess the relative efficacy of these in promoting tree growth, and to provide humus modified *in situ* for the mineralization studies described below. After the first year of application the greatest increase in foliar nitrogen levels occurred in trees given ammonium nitrate and the least in those given either urea or sodium nitrate, trees treated with ammonium sulphate occupying an intermediate position. In the following year the nitrogen-treated plots exhibited marked increases in growth, some putting on a basal area increment twice that recorded in the untreated control plots. The pattern of increased basal area growth was, as might be expected, parallel to the pattern of foliar nitrogen concentrations found in the previous autumn — that is, greatest with ammonium nitrate but poor with urea and sodium nitrate. However, by the end of this second growing season the pattern of foliar nitrogen levels had altered appreciably: the trees treated with ammonium nitrate continued to exhibit the highest level (*ca* 2·5 per cent nitrogen), closely followed by those treated with urea (2·4 per cent), ammonium sulphate (2·3 per cent) and sodium nitrate (2·2 per cent). The concentration in untreated control trees was 1·4 per cent.

During the year a series of investigations has commenced into some factors that may affect the uptake and level of foliar nutrients in Sitka spruce—a species that now comprises more than half the trees planted annually in Scotland. Whole-tree sampling has been used to determine the amount and distribution of dry matter and nutrients within a stand of 21-year-old Sitka spruce growing on thin hill peat at Fetteresso forest, Kincardineshire. Following the development of a satisfactory scheme for sub-sampling this species, the gross morphology of which differs markedly from that of pine, full-scale sampling of the crop was carried out in late winter.

Greenhouse work with Corsican pine, described in previous reports, has been extended to Sitka spruce. Like the pine this species has a marked preference for ammonium forms of nitrogen and for both species maximum growth occurs at similar levels of supply.

A short-term study has been initiated to check reports that shading of coniferous species results in increases in both foliar nutrient and chlorophyll concentrations. Should there be a marked effect on nutrient levels, it might be necessary to take this into account when using foliar analysis as a diagnostic technique in forests established beneath the protective cover of a pre-existing tree crop. Foliage samples taken at regular intervals from a variety of coniferous species, including Sitka spruce, planted beneath five densities of middle-aged larch show marked variations in chlorophyll concentration with changes in both over-cover density and time of year, there being a fairly consistent increase in concentration with decrease in intensity of incident light. Nutrient levels, however, appear to be much less affected, although by mid-summer nitrogen and, to a lesser extent, phosphorus concentrations were tending to develop a pattern of variation similar to that shown by chlorophyll.

Nitrogen Mineralization in Peat and Mor Humus. Incubation studies on samples of mor humus from the Scots pine experiment at Culbin described above have continued. In fresh humus samples taken from this experiment in August 1969, the second year of the experiment, mineral nitrogen accounted for 0·5 to 14·7 per cent of the total humus nitrogen, the higher values occurring in those plots given fertilizer nitrogen only three months previously. The presence of these high levels of ammonium nitrogen in samples from fertilized plots, however, did not result in any diminution in the rate of accumulation of additional mineral nitrogen on incubation of the samples for nine weeks at 30°C. By June 1970, there having been no application of fertilizer in the interim, the proportion of mineral nitrogen in the fresh humus had fallen to almost pre-treatment levels, ranging from 0·2 to 3·8 per cent of the total humus nitrogen, but on incubation these proportions rose to between 1·7 and 7·5 per cent. Prior to incubation, the proportion of mineral nitrogen in fresh samples was inversely related to the pH of the humus (determined in a 2·5:1 v/v suspension of humus in 1 M KCl). Thus, in the humus samples from unlimed plots the amounts of mineral nitrogen in fresh samples decreased in the treatment order ammonium sulphate (pH 2·87)>ammonium nitrate (pH 2·92)>urea (pH 3·00)>control (pH 3·20)>sodium nitrate (pH 3·37), irrespective of whether or not phosphate had been applied. For the limed plots, the proportion of humus nitrogen in the mineral form was generally lower and showed less variation with pH, despite the fact that this ranged from 3·34 to 4·83.

In similar incubation studies on peat samples from drainage experiments at Inchnacardoch forest, Inverness-shire, and Achray forest, Stirlingshire, the response to incubation for nine weeks at 22°C has usually been one of increasing immobilization of the mineral nitrogen rather than of net production. The results obtained indicate a greater tendency towards net mineralization in the samples from plots that had recently received PK fertilizer. Furthermore, in the samples from Inchnacardoch the effect of increasing drainage on nitrogen mineralization could only be detected in peat taken from sub-plots that had received NPK fertilizer.

Laboratory experiments are now in progress to follow more closely, and in greater depth, some of the observations that have been made on field-treated samples.

Systematic Analysis of Peat and Plant Material. During the year a critical examination has been made of the methods of analysis used in standard laboratory determinations, and of the accuracy of the results they produce. Certain changes have been made and limited automation has been introduced where this is likely to enhance the accuracy of the determinations. In this connection, six standard foliage samples, provided by De Dorschkamp Research Station, Wageningen, have been analysed, in collaboration with Spectrochemistry, as part of an international comparison of methods of soil and plant analysis organized by the International Union of Forest Research Organizations; the results obtained were very encouraging.

A paper on the chemical status of an exposed peat face at Cruden Moss, Aberdeenshire[20], has now appeared.

SOIL SURVEY

With the soils of approximately one-third of Scotland surveyed, 107 soil associations, 464 soil series, 58 soil complexes and 18 miscellaneous soils have now been established. The mapping unit is the soil series, defined as a group of soils with similar morphological properties developed on similar geological parent material. A soil series consists, therefore, of a modal profile about which a limited range is permitted. It is identifiable with a genetic soil group and drainage class. Soil series are grouped into soil associations, which are defined as groups of soil series forming a soil pattern related to parent material and relief. The soil association may often be equated with a land form region.

Studies over six years have confirmed that the drainage classes of free, imperfect, poor and very poor established on profile morphology do indicate progressively increasing wetness. The relative number of days in the year, or in the growing season, when the water table will stand at a given height in each of the four classes can be stated.

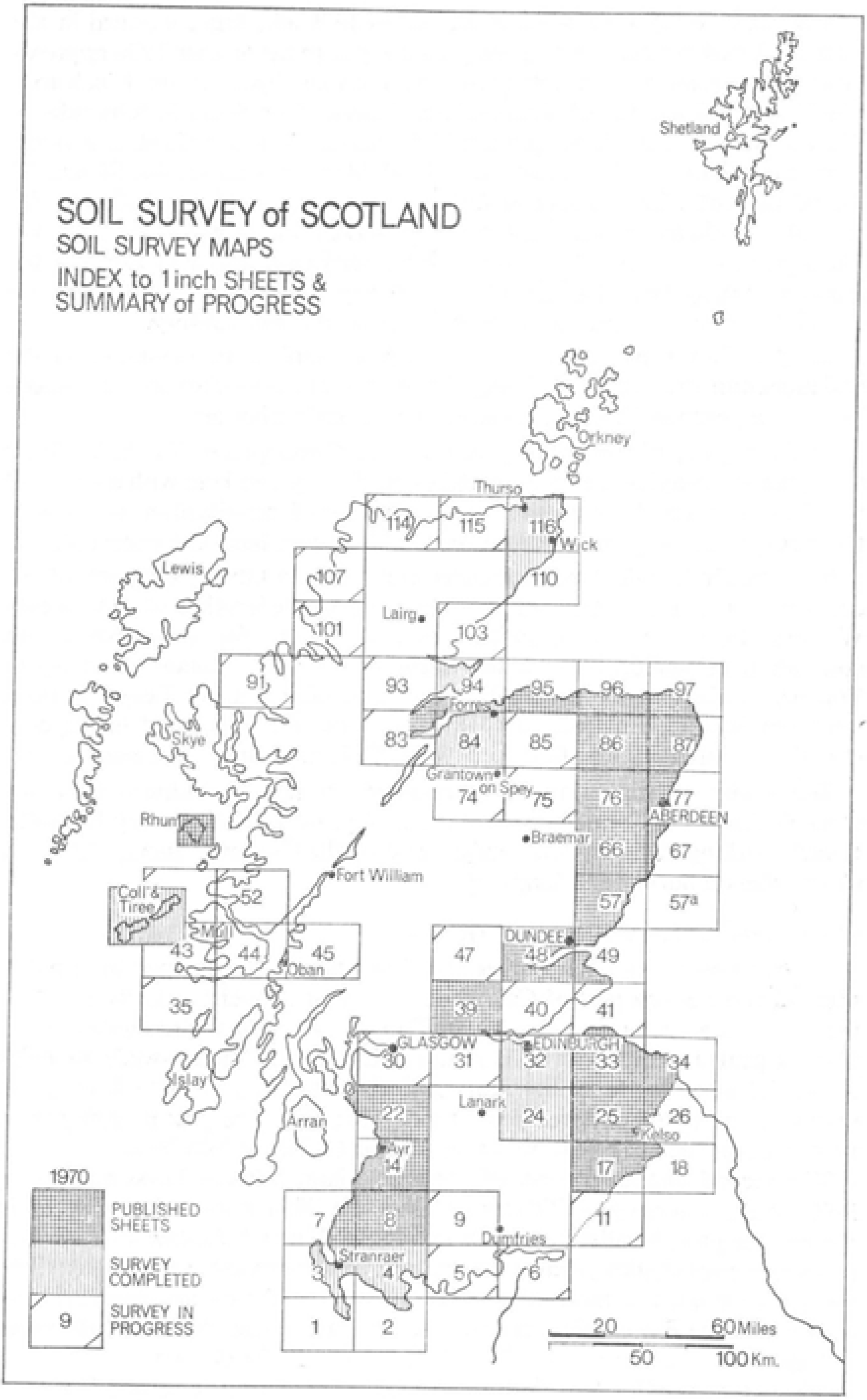
Experience has shown that in Scotland geology and drainage are of fundamental importance to both vegetation and agriculture. The total chemical composition of a soil is related to the geological nature of the rock or rocks from which its parent material is derived. The extractable or available nutrients and trace elements are related to the drainage class or hydrological condition of the soil. Soil texture and soil structure are also related to geological composition and drainage class.

The main emphasis of the Soil Survey of Scotland is the systematic study and mapping of the soils of Scotland, but some attention is being given to land use capability classification. In this classification limitations for agricultural use imposed by soil, site and climate are considered.

Since approximately two-thirds of Scotland consists of land covered by semi-natural vegetation, plant communities are being identified in the course of the vegetation survey. Attention is given to the relationship of the plant community to genetic soil group, soil series and drainage class. A new development has been a study of the factors of climate in terms of accumulated temperature above the growing point of 5·6°C (42°F) and potential water deficit (evapotranspiration minus precipitation), both of which are of significance to plant growth, in relation to four physiographic divisions: lowland (0-200 m), foothill (200-400 m), upland (400-800 m) and mountain ($>$800 m). A map and explanatory pamphlet [21], in which 18 climatic divisions are recognized in Scotland, have been published. A second map and pamphlet[74], based on exposure and accumulated frost, are now at the printers.

From these maps the climate of any locality can be described as, for example, "warm dry lowland, sheltered, with fairly mild winters" or "extremely cold wet mountain, extremely exposed with extremely severe winters." Each term used in these descriptions is specifically defined.

The Soil Survey is therefore now able to classify land into soil association, soil series, land use capability class and sub-class and climatic unit.


SOIL SURVEY of SCOTLAND
SOIL SURVEY MAPS
INDEX to 1 inch SHEETS &
SUMMARY of PROGRESS
Shetland
Orkney
Thurso
Wick
Lewis
Lairg
Skye
Forres
Grantown on Spey
Braemar
ABERDEEN
Rhum
Coll & Tiree
Mull
Fort William
Oban
DUNDEE
GLASGOW
EDINBURGH
Islay
Arran
Lanark
Kelso
Ayr
Dumfries
Stranraer
114
115
116
107
110
101
103
91
93
94
95
96
97
83
84
85
86
87
74
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76
77
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34
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14
17
18
7
8
9
11
3
4
5
6
1
2
1970
PUBLISHED SHEETS
SURVEY COMPLETED
SURVEY IN PROGRESS
20
60 Miles
50
100 Km.

Systematic survey on a scale of 2·5 inches to 1 mile has continued in the ten areas listed below. During the period April to September 1970 approximately 480 square miles (1240 km^2) have been surveyed, 70 on 1 inch to 1 mile Sheets 109 and 115 (Auchentoul and Reay), 30 on Sheet 74 (Grantown), 30 on Sheet 85 (Rothes), 60 on Sheet 75 (Tomintoul), 15 on Sheet 47 (Crieff), 32 on Sheets 40 and 41 (Kinross and Elie), 90 on Sheets 43, 44, 51 and 52 (Island of Mull), 20 on Sheet 31 (Airdrie), 80 on Sheets 24 and 32 (Peebles and Edinburgh) and 50 on Sheets 5 and 9 (Kirkcudbright and Maxwelltown). Three hundred and four soil profiles have been described and sampled for analysis, mostly with the aid of the Smalley excavator. Thirty-five soil monoliths have been prepared for inclusion in the Soil Library.

Mr C. J. Bown has returned from Canada where, at the invitation of the Saskatchewan Institute of Pedology, University of Saskatchewan, Saskatoon, he spent a year working on the soil survey of Saskatchewan.

At the request of the Ministry of Overseas Development, Mr J. W. Muir took part in an eight-week tour of Pakistan, Turkey and Iran with a CENTO working party on the correlation of soil and land classification systems of these countries. A joint report of the working party has been prepared.

In April Dr R. Glentworth attended a meeting in Ghent, Belgium, of the correlators and rapporteurs of the European Confederation of Agriculture Working Party on Soil Classification and Survey for consultation and correlation in connection with the legend for the 1:1 million Soil Map of Europe. Subsequently a meeting of representatives from Belgium, Eire, Northern Ireland, England and Wales and Scotland concerned in the construction of the map was held at the A.R.C. Headquarters in London.

The Survey continues to be represented on the Agricultural Research Council Technical Committee on Soil Fertility, on the Soil Survey Research Board Working Party on Soil Analysis and on the Ordnance Survey Advisory Committee on Survey and Mapping.

Sheets 109 (Auchentoul) and 115 (Reay)

Approximately 70 square miles (180 km^2) have been mapped in two districts of the western part of Caithness. The first district lies to the north of the Rumsdale Water and the River Thurso. It consists predominantly of blanket peat, together with soils of the Strichen and Countesswells Associations. These soils are mainly peaty podzols of the Gaerlie and Charr series, with some peaty gleys developed on indurated till. The peat mapping units present comprise deep peat, thin peat and peat with dubh-lochans.

The second district consists of the arable land between Forss and Reay. Soils of the Thurso and Bilbster series of the Thurso Association occur in the eastern part; locally the drift is extremely thin and shallow soils on rock (Bilbster series shallow phase) are present. Farther west, around Reay, the parent materials are those of the Berriedale Association and the dominant soils are of the Ramscraigs series, a podzol characterized by a reddish brown indurated B_3 horizon above which there may be slight gleying.

Thirty-two profiles have been described and sampled, mostly taken from pits dug by the Smalley excavator.

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

A preliminary investigation has been made of the soils of Orkney Mainland and South Ronaldsay prior to the systematic survey planned to commence next year. Apart from a small area of granite-schist complex, the area is underlain by flagstones and sandstones of Middle Old Red Sandstone age. The soils identified are detailed below.

Soils of the Kirkwall Association are developed on the weak red to reddish brown clay loam or sandy clay loam till which occurs in East Mainland, South Ronaldsay and along the southern edge of West Mainland. Non-calcareous gleys (Kirkwall series) and peaty gleys are most common, while podzols with very compact mottled B horizons are also present. Peaty podzols have been noted, but are not common. This association has affinities with the Canisbay Association previously mapped in Caithness, but the parent materials have a redder hue and a finer texture. Soils of the Canisbay Association, however, have been identified locally.

Soils of the Thurso Association are found on the brown or grey-brown loamy parent materials which occur as till over most of West Mainland and as moraine in parts of East Mainland. Podzols (Bilbster series) predominate, with non-calcareous gleys (Thurso series) and peaty gleys (Olrig series) much less extensive. In addition, peaty podzols (Camster series) and areas of the Achavanich, Ulbster and Bilbster soil complexes have been noted.

Soils of the Strichen and Countesswells Associations have been identified on the granite-schist complex around Stromness. Peaty podzols (Gaerlie and Charr series) predominate.

Soils of the Fraserburgh Association are developed on the windblown shelly sand which occurs around a number of bays. Fraserburgh series is the predominant soil.

Hill peat is present on the higher ground in West Mainland. On the hill tops it is deep and sometimes hagged, but on the slopes it is mainly thin. On the lower ground a few localities of basin peat have been noted.

Sheet 85 (Rothes)

About 30 square miles (78 km^2) of Sheet 85 (Rothes) have been surveyed, with the aid of air photographs, and 36 soil profiles have been obtained. Work has concentrated on the western side of the sheet, mainly within Dunphail, Altyre and Dallas estates. The greater part of the ground is grouse moor lying between 700 and 1500 feet. Soil parent materials are till derived from acid schists, moraines of varying texture and stoniness, and alluvium; soils developed on drifts derived in part from red sandstone have been encountered in the vicinity of Dallas. Soils of the Strichen, Corby, Boyndie and Orton Associations have been distinguished. Soils developed on light-textured moraine which do not appear to belong to any named association may have to be separated into a new unit. The soils of the high moorland are peaty podzols and peaty gleys with extensive blanket peat; on the better drained hummocky moraines and moraine terraces humus podzols with dark, cemented B horizons of 'Moray pan' are frequently encountered.

Sheet 75 (Tomintoul)

During the field season about 60 square miles (155 km^2) have been surveyed and 30 profiles described and sampled; fourteen of the profile pits were dug by the Smalley excavator. Two-thirds of the mapping has been done in the Tomintoul district on mainly hill ground at elevations between 1000 and 2500 feet, a lower (750 to 1500 feet) area around Cabrach and Glenkindie accounting for the remainder.

In the country around Tomintoul the Strichen Association is widespread on the Cromdale Hills, most parent materials being drifts derived from quartz-schists. Dark fine-grained schists are prevalent in upper Glenlivet and soils of the Foudland Association are formed on these rocks and their derived drifts, while the acid but usually fine-grained schists of the Ladder Hills give rise to rather similar parent materials and soils provisionally allotted to the same association. Near the village of Tomintoul Lower Old Red Sandstone conglomerates with some sandstones form reddish brown drifts which include a sandy clay loam till on lower ground. Quartzite outcrops on some hills and gives rise to Durnhill Association parent materials, while soils of the Countesswells and Corby Associations have also been distinguished. Limestone outcrops in a few places and forms *in situ* brown soils having poorly differentiated and usually decalcified horizons overlying the rock.

Most of the soils mapped in the Tomintoul area are peaty podzols and peats, with lesser areas of brown forest soils, iron podzols, gleys and peaty gleys, peaty rankers and two high-elevation soils provisionally named sub-alpine and alpine podzols. The alpine podzols have a loose fabric, with an upper horizon containing bleached sand grains overlying a black layer with coated mineral grains; they are found above about 2000 feet. Sub-alpine podzols have been mapped between 1750 and 2250 feet and have some of the characteristics of both alpine and peaty podzols, the iron pan and B_2 horizons of the peaty podzol being indistinct or absent and a dark-coloured horizon with coated mineral grains being sometimes present. Peaty rankers belonging to the Strichen and Durnhill Associations are found on some steep slopes, usually developed on stabilized scree, while gleys predominate on the till derived from Old Red Sandstone strata. The iron podzols are often suitable for improved grazing where slope and stoniness permit, and some have recently been successfully broken in, for instance at the farms of Nevie in Glenlivet, Dalrachie on the Cromdales and Blairnamarrow south of Tomintoul.

The soil associations distinguished in the Cabrach and Glenkindie areas include those mentioned above and the Insch, Tarves, Leslie, Corriebreck, Corby and Nochty. The Insch Association is the most extensive in the Cabrach area and the Tarves in Glenkindie; the base content of these soils is doubtless partly responsible for the considerable area of arable land which is found as high as 1400 feet. The soils mapped in the Cabrach and Glenkindie areas include brown forest soils (freely and imperfectly drained), gleys and peaty gleys, iron podzols (some suitable for improved grazing), peaty podzols and peat.

Sheet 74 (Grantown)

A further 30 square miles (78 km^2) have been mapped in two main areas, the River Spey alluvial haughs and an area west of Grantown between Achnahannet and Balnespick. The River Spey alluvium has been differentiated on a textural and drainage classification. Many of the upper haughs are very poorly drained and waterlogged for the greater part of the year.

Westward from Achnahannet to Lynmore a belt of morainic sands and gravels lies between the River Dulnain terraces and the 1250 foot contour. The mineral soils are mainly iron humus podzols and peaty podzols with iron pan belonging to the Corby Association. Extensive blanket peat occupies the kettleholes and depressions. Above the moraines the ground rises steeply to 1800 feet, thereafter shelving gently and culminating in a deeply hagged peat-covered plateau at 2100 feet. The soils developed from the underlying felsite and undifferentiated schist and gneiss are mainly peaty podzols belonging to the Strichen Association. Around Creag na h-Iolaire, where glacial erosion has been severe, a complex of peaty podzols, rankers and rock has been mapped.

Sheet 84 (Nairn)

Use of the Smalley excavator has facilitated the examination and correlation of extremely indurated and stony soils, mainly derived from Old Red Sandstone drifts. Eighty-four profiles have been excavated and 47 sampled for analysis. Approximately 50 square miles (130 km^2) of the original mapping have been revised. This followed the general review and correlation of Old Red Sandstone Associations around the Moray Firth prior to the publication of Sheets 84 and 94.

Morainic and fluvioglacial Highland gravels with a high red sandstone content, previously mapped within the Corby Association, have now been placed in the new Darnaway Association. Soils with a loam or silt loam texture developed on deeply weathered red sandstones, and recognized as a residual series of the Cromarty Association, have now been correlated with the Cadboll Association. The new Brevail Association has been identified to accommodate reddish brown soils of varying light textures (sandy loam to loamy sand). These are developed on highly water-modified and morainic Old Red Sandstone drifts with a considerable content of schist and granite stones.

Sheet 94 (Cromarty)

Because of the revision of Sheet 94 prior to publication, the whole of the low raised beach complex adjacent to Sheet 84 has been re-mapped. The area totals 13 square miles (34 km^2) between Loch Loy and Findhorn. In addition, 8 square miles (21 km^2) of the same beach complex within Sheet 84, including the Carses of Ardersier and Delnies, have been re-mapped to correlate with Sheet 94.

The Loch Loy-Findhorn area consists of a 15-foot sandy raised beach, with massive deposits of aeolian sand superimposed in the eastern sector at Culbin. Immature iron podzols are developing in these excessively drained dune sands which are now largely stabilized by afforestation. Occasional imperfectly drained flats, characterized by a birch-grass vegetation, indicate buried cultivated alluvial soils of loam texture. An extensive shingle bar complex occurs between Findhorn and Wellhill. Near Binsness and Cothill 'butte' dunes with a buried well developed humus podzol profile have been exposed by wind erosion. In the Maviston area, apart from a few isolated dunes, the terrain is flat and has a high ground-water table. Poorly drained soils developed on these low raised beach sands are generally underlain by peat bands and alluvium of a silty texture, reflecting the lagoonal evolution of the region.

The Carses of Ardersier and Delnies contain a similar assemblage of aeolian sand, shingle bars and poorly drained low raised beach sands, though neither buried peat nor alluvium has been observed.

Sheet 47 (Crieff)

Mapping in the highland district south of Aberfeldy has been further extended and some 15 square miles (39 km²) of this complex terrain have been mapped. The soils encountered are similar to those described previously (Annual Reports 38, 1967/68, and 39, 1968/69) and are all included in the Strichen Association.

A special survey has been undertaken in the Tyndrum district on the adjacent soil survey sheet to the west. This has involved a further 10 square miles (26 km²) of mapping of mountainous terrain with steep slopes bordering strath and valley bottoms, all with complex soil patterns. Sixteen soil profiles have been described and sampled to provide basic information for this special survey, mentioned in more detail below.

Sheet 31 (Airdrie)

Mapping in the north-western part of Sheet 31 has been continued in the Kelvin Valley between Kirkintilloch and Kilsyth and in the Kilsyth Hills and their footslopes to the north and east. Soils similar to those described last year have been encountered, and in addition several complex areas of mixed till to the north of Kilsyth have been delineated. Most of these soils have been previously described in Ayrshire and have been included in the Sorn, Darleith, Rowanhill and Giffnock Associations. Some 20 square miles (52 km²) have been mapped and 14 profiles described and sampled.

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

During September and October 1969 systematic survey was continued in south and west Mull. The soils of Brolass and Ardmeanach correspond closely to those previously mapped in the north of the island.

The winter period was largely devoted to the preparation of a preliminary report on the soils and land use capability of the Isle of Mull, on behalf of the Highlands and Islands Development Board. This has involved the compilation from air photographs and field data of a soil map at 1:63,360 and the interpretation of soil, topographic and climatic features to produce a provisional land use capability map at the same scale. The co-operation of the West of Scotland Agricultural College was enlisted in this survey.

The transfer of data to a feature card system has also been maintained, and a provisional key to the soil types and mapping units (dominantly complexes) of Mull has been produced.

During the first five months of the 1970 field season the field mapping has been virtually completed, all that remains being the island of Iona and a small area on the gabbro of Ben Buie, mostly bare rock and crags. Ninety square miles (233 km^2) have been covered. The collection of information for statistical purposes from the 1 km grid intersects is also almost complete and it should be possible to undertake preliminary analysis during the coming winter.

Sheets 40 and part 41 (Kinross and Elie)

Survey has continued in the Howe of Fife and Lomond Hills areas described in last year's report. Approximately 20 square miles (52 km^2) have been mapped and thirty-two representative soil profiles described and sampled. In addition, 12 square miles (30 km^2) have been surveyed to the north of Leven in the parishes of Kennoway, Kettle and Cults.

Glacial till, derived mainly from Lower Carboniferous sediments, covers much of the area and soils of both the Giffnock and Rowanhill Associations have been mapped, the main distinguishing features being the predominance of sandstone material in the former and of coals and shales in the latter. Gleyed brown soils occur most commonly, with less extensive areas of poorly drained surface-water gleys. Water-sorted soils of both associations have also been mapped.

Igneous intrusions, mainly of quartz dolerite, protrude through the till cover at several places, and on these residual soils of the Drumain series have developed.

Survey of the Lomond Hills mass has been completed with the mapping of the northern slopes of East Lomond and the south-western slopes of West Lomond and Bishop's Hill. Sedimentary rocks of the Lower Carboniferous formation occur as an escarpment below the summit of the hills, and these are succeeded on the middle and lower slopes by sediments of the Upper Old Red Sandstone. On the upper slopes the soil parent material is a light brown or light yellowish brown sand derived *in situ* from the underlying Carboniferous rocks, while on parts of the middle slopes the same parent material occurs as a colluvial deposit overlying the Old Red Sandstone rocks. The soils have podzolic profiles and have been identified with the Allanhill series of the Rowanhill Association.

On the remaining slopes, till and decomposed rock derived mainly from Upper Old Red Sandstone sediments form the soil parent materials of the Kippen Association and soils of the Fourmerk and Urquhart series have been mapped, together with small areas of the Kippen series. In addition, there are frequent wet flushes, too small to depict on the one inch to one mile soil map, which will be shown in a complex of the Association.

Sheets 24 and 32 (Peebles and Edinburgh)

Surveying this season has been confined to the southern and western parts of Sheet 24 around Biggar. The total area completed is 81 square miles

(210 km^2), but approximately 15 square miles (40 km^2) are on the adjacent margins of Sheets 15, 16 and 23. This work almost completes the Edinburgh and Peebles maps which comprise some 747 square miles (1936 km^2). Only six square miles (15 km^2) on arable land near Linlithgow remain unmapped and these will be dealt with after harvest. The soil sampling programme is also expected to be completed then.

About half of the area surveyed this season is on Ordovician greywacke of the Southern Uplands to the south of Biggar where soils of the Ettrick Association have been mapped. The main series represented are the Dod, Linhope, Merrick and Minchmoor. With the aid of air photographs the mapping of such soils is normally rapid, but many of the photographs available are either of low contrast or have been taken early in the year when vegetation patterns are not clearly seen, and this has retarded work in some localities. The photographs have also been taken at relatively high altitudes, which makes those of the lowland geomorphology north of the Southern Upland fault virtually useless for stereoscopic interpretation. The survey in these areas, which occur on Lower Old Red Sandstone lavas and sediments and Upper Old Red Sandstone facies, has been carried out entirely by ground inspection, in spite of the distinctive relief usually exhibited by fluvioglacial sands and gravels, tills and alluvia. Soils within the Sourhope, Sorn, Hobkirk and Lanfine Associations have been identified, but some are as yet unnamed. Stratified drifts where the surface material is derived mainly from intermediate and basic lavas overlying till of the Sorn Association have posed both mapping and classification problems. The latter remain unsolved, for soils on these drifts cannot be placed in either the Sourhope or Sorn Associations. As they are associated with the lavas giving rise to Sourhope soils, there would appear to be a strong case for enlarging the Sourhope Association.

Large areas of basin peat occur in tributary valleys of the River Clyde. Notable are the Mosses of Cobbinshaw, Stallashaw, Woodend and Carnwath. Extensive blanket peat (hill peat) has been mapped on the Tweedsmuir Hills and at the south-western end of the Pentland Hills.

Sheets 5 and 9 (Kirkcudbright and Maxwellton)

About 50 square miles (130 km^2) have been surveyed in two main areas, one in the south of the sheet area and the other in the north.

In the south the parishes of Kirkcudbright, Rerrick and Kelton are underlain by a variety of rock types, of which the Silurian greywackes and shales are the most extensive. These are interrupted around Auchencairn village by the western extension of the Criffel granitic outcrop and around Stockarton by an area of porphyrite and plagioclase-rich rocks. Along the coast grits and sandstones of Lower Carboniferous age occur in a narrow band. The greywackes and shales have been strongly eroded by ice, and rock occurs at very shallow depths over much of the area. The soil pattern, which has been placed in the Achie complex, is one of freely drained brown forest soils and rock outcrops. Deposits of red brown clay loam till in the form of drumlins occur scattered through the area and give rise to freely and imperfectly drained brown forest soils of the Rhins Association. Soils of the Dalbeattie Association have been mapped on the shallow stony drifts derived from the Criffel granite.

Two new associations have been established provisionally—the Kirkcudbright Association, comprising the soils derived from the porphyritic rocks around Stockarton, and the Dundrennan Association of soils formed on the mixed drifts derived from Carboniferous sandstones and grits, Silurian greywackes and shales and granite.

In Glencairn parish in the north of the sheet area the underlying rocks are greywackes and shales of the Ordovician and Silurian systems, and the parent materials derived from them give rise to soils of the Ettrick Association.

In this hill and moorland area, to which access is often difficult because roads are few, a Gnat cross-country vehicle has proved of great value. It successfullly negotiates both steep slopes and very soft peaty ground, so that equipment and samples can be transported in remote areas. On survey there is a considerable saving of time and energy in crossing difficult country to the mapping area; this means that a greater proportion of the day is spent in active mapping and that remote areas can be tackled under poorer weather conditions than was previously possible.

Special Surveys

Auchtertyre and Kirkton Farms, Tyndrum, West Perthshire. At the request of the West of Scotland Agricultural College a special survey of Auchtertyre and Kirkton Experimental Hill Farm Unit near Tyndrum in north-west Perthshire has been carried out at a scale of 6 inches to 1 mile on the low ground and approximately 2·5 inches to 1 mile on the hillslopes and montane parts. The twin farm unit comprises some 6500 acres of variable terrain from the alluvial flats of Strath Fillan (550 feet) to the mountain tops, of which Ben Challum (3354 feet) is the highest.

The underlying rocks are principally acid schists of the Dalradian Series of Highland Schists. To the west the schists tend to be slaty, with small patches of quartzose and graphitic schists on the slopes and near the summit of Beinn Chaorach, while to the east they are coarser textured and garnetiferous, with some basaltic dykes on the middle slopes of Ben Challum and limited calcareous bands on the Kirkton face of the lower slopes.

The variable topography gives rise to complex soil patterns in broad merging altitudinal zones from the valley floor to the mountain tops. The valley bottoms have alluvial soils of variable texture and drainage, with frequent peaty patches in abandoned meander channels. The alluvium is flanked by fluvioglacial sand and gravel or hummocky moraine, with acid brown soils on the mounds and flush gleys or peat in the hollows. Further up-slope, particularly just above the railway, the acid brown soils grade through podzolic brown soils to podzols, with flush gleys and peaty gleys in the hollows. At altitudes above 1000 feet peat podzols and peaty fragogleys occupy the hummocks, with flush peaty gleys and peat in the hollows. Above 1750 feet peat becomes dominant, with peaty gley ridges and rock outcrops interspersed between broad expanses of deep blanket bog. Montane humus soils of gley and podzolic type are common above 2000 feet, while the more exposed summits are characterized by montane soils under a rubble pavement between large crags or smaller rock outcrops.

The mapping units delineated so far are nearly all soil complexes and it is hoped next year to evaluate semi-statistically the proportions of the various soil types making up the principal complexes. In the meantime a preliminary report has been submitted to the hill farm adviser of the College to assist him in the formulation of his plans for the unit; when the survey is completed next year a soil map and report will be prepared.

Achnairn and Balloan Farms, Nairnshire. At the request of the Horticultural Department of the North of Scotland College of Agriculture, the soils on about 300 acres of these farms have been examined and a detailed map on a scale of 1 : 2500 of 90 acres prepared.

Vegetation Surveys

Mr E. L. Birse visited the Arbeitsstelle für Theoretische und Angewandte Pflanzensociologie at Todenmann, Rinteln, West Germany, in June, and in light of the methods used by Professor R. Tüxen the plant communities of lowland Scotland have been further revised. The communities are now distinguished on the basis of character species of the associations, alliances, orders and classes of vegetation and also of differential species. The tables of the plant communities have been forwarded to Professor Tüxen for comment before being finally adopted.

The vegetation of the Nairn and Cawdor district has been more intensively sampled and the methods for establishing vegetation mapping units have been brought more into line with those used by European plant sociologists. The vegetation of Mull has been sampled by plant sociological methods so that a description of the vegetation can be included in the soil memoir for the area.

The second climatic assessment map and pamphlet[74], based on exposure and accumulated frost, have been completed and are now in the process of being printed. Preparation of a third climatic map, Bioclimatic Sub-regions of Scotland, has commenced. This is based on thermal zonation, oceanicity and moisture level, and most of the boundaries are drawn from the limits shown on the first two maps.

Soil Micromorphology

Some 250 soil thin sections, the majority derived from soils of south-east Scotland, have been prepared.

A micromorphological examination of certain bench mark soils of the Ettrick Association has indicated that some of the features noted may prove characteristic of the process involved in the formation of acid brown soils. A further set of six monoliths has been obtained to extend the investigation.

Other Investigations

The computer program used for the print-out of phytosociological array tables has been updated and considerable use has been made of it. A complementary program for calculation of similarity indices between defined associations has been devised, and some 500 indices of similarity obtained.

The possibility of a land capability classification for forestry has been discussed with members of the Forestry Commission and representatives of the Soil Survey of England and Wales.

The soils of experimental drainage sites at Slamannan, Stirlingshire, and Auchinleck, Ayrshire, have been described and sampled to provide basic chemical and physical data for future comparative studies of these sites, at the request of interested members of staff of the West of Scotland Agricultural College. Advice has been given on the installation of water level measurement equipment at the above sites.

The department has been consulted on drainage problems in several parts of Scotland by officers of the Inspectorate of the Department of Agriculture and Fisheries for Scotland and by advisory officers of the Colleges.

In connection with the Fife fruit and vegetable feasibility study by the East of Scotland College of Agriculture, 48 farms have been visited with Horticultural Advisory Officers. The farms are mostly on previously surveyed land in the Tayside area, but some farms in south-east Fife have been surveyed on a scale of 2·5 inches to 1 mile. The suitability of the soils for horticultural crops has been discussed.

Assistance and advice has been given to various organizations interested in techniques of subsoiling for the purpose of rupturing compacted and indurated layers.

A land use capability map of the proposed extension to the boundaries of the Burgh of Inverness has been made at the request of the Inverness-shire Planning Department.

The Survey was represented on the Drainage Committee organizing the Scottish National Drainage Demonstration held at Tillycorthie Farm, University of Aberdeen. An exhibit of soil maps and monoliths was prepared.

Lectures on the work of the Soil Survey have been given to, amongst others: Lands Officers of the Department of Agriculture and Fisheries for Scotland; students and staff of the Edinburgh School of Agriculture; members of the Botanical Society of Edinburgh and of the Institute of Landscape Architects; students from the Department of Agriculture, University of Aberdeen; a course for geography and biology teachers sponsored by the Aberdeen and Dundee Colleges of Education and held at Kindrogan Field Centre; members of The Welsh Soils Discussion Group; and students of Agricultural Botany, University College of Wales.

Field excursions have been led to demonstrate soils to staff and students of the Department of Agriculture, University of Edinburgh; members of the Forestry Department, University of Aberdeen and of the Royal Scottish Forestry Society; members of the North of England Soils Discussion Group and of the Hill Land Use and Ecology Discussion Group; and consultants from commercial organizations.

Collaboration has been maintained with numerous official organizations, including the Inspectorate and Lands Branch of the Department of Agriculture and Fisheries for Scotland; the Highlands and Islands Development Board; the Hill Farming Research Organization; the British Museum Department of Botany; the Colleges of Agriculture; the Forestry Commission; the Scottish Universities; the Meteorological Office; and the Dee and Don River Purification Board.

An increasingly widespread interest in soil conditions is indicated by the numerous requests for information which come from students, advisory officers and members of the public.

Maps, Memoirs and Cartography

Experimental land use capability maps on the scale of 1 inch to 1 mile have been published for Sheets 7/8 (Girvan/Carrick), Sheet 39 (Stirling), Sheets 48/49 (Perth/Arbroath) and the Black Isle.

Line copies of both the soil and land use capability maps of combined Sheet 110/116 (Latheron/Wick) have been submitted to the Ordnance Survey for printing and the colour proofs are awaited. A scribed negative for the soil map of Sheet 94 (Cromarty) has been completed. A colour model is being prepared and will be submitted to Ordnance Survey for printing in the near future.

The 1:10,000 scale soil map of the Bush Estates, Midlothian, prepared at the request of the East of Scotland College of Agriculture, has been published. A combined soil and land use capability map of Glen Feshie (part of Sheet 64) has been prepared and a report is in preparation.

Considerable progress has been made in the preparation of uncoloured 2·5 inches to 1 mile soil survey field sheets for restricted circulation. Twenty-five further sheets have been prepared, four from Caithness—parts of combined 1 inch Sheet 110/116 (Latheron/Wick), eleven from areas around Aberdeen—parts of 1 inch Sheets 66/67 (Banchory/Stonehaven), 76 (Inverurie), 77 (Aberdeen) and 87/97 (Peterhead/Fraserburgh), four from East Lothian—parts of Sheets 33/34 (Haddington/Eyemouth), and six from Ayrshire—parts of Sheets 14 (Ayr) and 22 (Kilmarnock). Work is in progress on a further twelve sheets from western Aberdeenshire—parts of Sheets 76 (Inverurie), 86 (Huntly) and 96 (Banff).

A corrected galley proof of the memoir for Sheets 7/8 (Girvan/Carrick)[75] has been returned to H.M. Stationery Office. A bulletin on the soils of Candacraig and Glenbuchat, Aberdeenshire[22], together with soil and land use capability maps on a scale of 2·5 inches to 1 mile, has been published. A memoir covering Sheets 48/49 (Perth/Arbroath) and a bulletin covering the soils of the Black Isle are in preparation.

THE SOILS OF EASTER ROSS

With the final revision of Sheet 94 (Cromarty) it is now possible to present a preliminary summary of the soils of the area. Of the 166 square miles (430 km^2) included, about 85 per cent lie within Easter Ross. The area is bounded to the east by the open water of the Moray Firth and heavily indented on its upper and lower margins by the Dornoch and Cromarty Firths. The western margin is a north-south line running half a mile to the east of the A836 at Aultnamain. There is a small strip in the north along the Sutherland coast from Spinningdale to Dornoch, and a more substantial area, including Culbin and the Findhorn estuary, in the south-west corner in the counties of Moray and Nairn.

The land is almost equally distributed above and below the 350 foot contour. The main part of the productive arable land lies east of a line curving down from Tain to Newmore House (about 2½ miles north-west of Invergordon), with subsidiary portions in the Cromarty peninsula of the Black Isle and in Moray and Nairn. The uplands in the north-west consist of four substantial sandstone or conglomerate hills (Struie Hill, Edderton Hill, Cnoc an t-Sabhail and Kinrive Hill) of moderate height between 1000 and 1200 feet, all with wide low angle summit plateaux above the 900 foot contour, and the smaller 800 foot ridge-like Scotsburn Hill. There is an additional isolated gneissic mass, the Hill of Nigg, rising out of the Nigg-Balintore lowlands to dominate the narrow entry to the Cromarty Firth.

Most of the district is underlain by red or yellowish brown sandstones of Middle and Upper Old Red Sandstone age. Conglomerate beds form part of Struie Hill and the north-east end of Nigg Hill; some of the sandstones are slightly calcareous and there are occasional grey shaly bands. Moine gneiss underlies the greater part of the Hill of Nigg, forming the steep cliffs of the North Sutor of Cromarty; there are further outcrops on the Sutor of Cromarty and along the south-east facing cliff line of the Black Isle. Small areas of quartzose Moine schist are present below superficial deposits in the extreme north-west and south-east corners of the sheet.

Superficial glacial and periglacial deposits cover most of the ground. There are two distinctive regional tills, both derived principally from the sandstone, one brown in colour and the other red or reddish brown. The former covers the hilly zone of the north-west, while the red till is more generally distributed over lowland Easter Ross including the Black Isle. The Sabhail Association is developed on the brown till and the Cromarty and Kindeace Associations over the red till. Along the coastal lowlands skirting the hill edge from Alness to Loch Eye, and more locally elsewhere, there are extensive deposits of moraine and supraglacial material derived from schist and sandstone overlying the till, and the Ardvanie, Corby and Boyndie Associations have been distinguished. On the Black Isle the Millbuie Association forms a specialized sandstone-derived analogue of the more generally occurring Ardvanie Association. Below the 100 foot contour, both on the north shore of the Cromarty Firth and on the south shore of the Dornoch Firth, the moraines are frequently planed level to form the high beach terrace, while between Invergordon and Nigg Bay there are quite extensive silty and sandy lagoonal/estuarine low beach deposits. The low beach platform is more widely developed on the Morrich More near Tain and at Culbin on the Moray coast, but is covered over by links, micro-dunes, shingle and larger sand dunes. A less extensive but more spectacular deposit of wind-blown sand extends in a broad tongue right up the south-facing side of Nigg Hill to over 500 feet.

Climatically, lowland Easter Ross, including the coastal part of the Black Isle, is mainly in the category of warm, dry lowland, moderately exposed, with fairly mild winters. The zonal profile developed on the more free-draining sites is the podzol, a humus podzol variant with dark coloured cemented B horizons of 'Moray pan' type being prevalent on sandy moraines and beach deposits at an altitude of 100 feet. Rainfall rises to 30 inches (760 mm) at the hill edge, and ranges from 30 to 45 inches (760-1140 mm) over the north-western upland area where the increasing severity of climate is reflected in the development of peaty podzols, peaty gleyed podzols and blanket peat.

Twelve soil associations have been distinguished, and these have been sub-divided into thirty-one named soil series and one series complex. One series of the Sabhail Association has been sub-divided into two slope phases.

Association	*Parent Material*
Sabhail	Compact till derived from grey-brown and pale yellow flaggy sandstone of Middle Old Red Sandstone age.
Cromarty	Compact till derived from red sandstone of (Middle) Old Red Sandstone age.
Kindeace	Shallow light-textured supraglacial drift overlying compact till of Cromarty type.
Millbuie	Coarse-textured supraglacial moraine derived from sandstone of Middle Old Red Sandstone age.
Ardvanie	Coarse-textured stony moraine derived from schists and sandstone.
Corby	Coarse sandy gravel moraine, and fluvioglacial outwash deposits.
Boyndie	Fluvioglacial outwash sands.
Ethie	Shallow drift derived from sandstone and Moine gneiss.
Cadboll	Thin semi-residual drift derived from soft red sandstone of Middle Old Red Sandstone age.
Mount Eagle	Shallow stony drift derived from yellow and brown sandstone of Middle Old Red Sandstone age.
Kessock	Shallow drift derived from conglomerates of Middle Old Red Sandstone age.
Strichen	Till derived from acid schists.

Soils developed on the raised beaches have not been given association and series names but have been sub-divided on the basis of drainage, which in some parts is natural and in others artificial, into nineteen units of approximately series status. These include the soils developed on high beach deposits not included within either the Corby or Boyndie Associations and non-calcareous gley soils on the sandy and silty low beach sediments. The semi-stabilized links, on which ground-water levels can be very variable, have weakly differentiated profile morphology. In addition, peat, alluvium, peat-alluvium complex, undifferentiated solifluction deposits, windblown sand, saltings and mixed bottom land have been delineated.

Four of the principal associations, Sabhail, Kindeace, Cromarty and Millbuie, cover areas of 15 to 20 square miles. Three natural groupings of associations or sub-units of series status form collective units of the same order of size. These are the Ardvanie, Corby and Boyndie Associations, the differentiated low raised beach soils, and the links together with separated blown sand and shingle deposits. All other associations or delineated units are less than 5 square miles in extent. The Strichen and Kessock Associations, though present on the map, are of negligible proportions and are not discussed further in this account.

The Sabhail Association is the largest in the generally hilly north-western part of the Sheet. It dominates the side slopes and shares the flatter hill tops and the upper slopes of the Aultnamain-Edderton shelf with blanket peat. It shares the lower part of the Aultnamain-Edderton shelf with series of the Cromarty and Ardvanie Associations. Three series, Sabhail, Edderton and Bogrow, have been distinguished. The Sabhail series is the most extensive and has been sub-divided into two slope phases. Peaty gleyed podzols with thin iron pan are usually developed on shallow slopes up to about 5°, while peaty podzols with or without thin iron pan develop on steeper slopes over about 7°. The peaty gleyed podzols are usually found on the upper slopes and flatter tops of Edderton Hill, Cnoc an t-Sabhail and Scotsburn Hill and on the Edderton shelf. The peaty podzols, whose morphology often includes a relatively early stage of active development from podzol to peaty podzol, are most often encountered on the steeper side slopes of these hills where slopes of up to 15° are common and slopes over 20° can be found locally. The peaty gleyed podzol usually has 10 to 30 cm of peat with a sticky black 2-3 cm A_1 horizon at the base, overlying a very dark grey humose A_2 horizon 13 to 25 cm thick. Below the A_2g horizon there is a strong thin iron pan which usually rests directly upon the indurated B_3 horizon below. The peaty podzol has a thick A_0 horizon which consists either of recognizable L, F and H layers (as seen on the slopes of Edderton Hill) or of thin peat up to about 30 cm overlying a dark A_2 horizon (varying in colour from black to dark grey brown) with bleached sand grains.

The lower part of the A_2 horizon is gleyed and a root mat may have developed over a thin iron pan or somewhat cemented thin humus-iron B_1 horizon. Below the iron pan or B_1 horizon is a moderately friable ochreous B_2 horizon, 15 to 25 cm thick, which in turn overlies a massive strongly indurated B_3 horizon. The clay content of the till rarely exceeds 15 per cent and the texture is usually within the sandy loam class.

The other two series of this association occupy less than half a square mile each. The Edderton series includes imperfectly drained soils, which are podzols with gleyed B horizon and a compact indurated B_3 horizon, while the Bogrow series includes poorly and very poorly drained peaty gley soils, generally found around the lowest footslopes of Edderton Hill.

The Cromarty Association is well developed above the high beach level throughout lowland Easter Ross in a composite pattern with the Kindeace, Corby and Boyndie Associations. The soil parent material is a compact reddish brown till with clay content up to 25 per cent. A very high percentage of the soils is cultivated, and semi-natural soils are only found locally on the higher parts of Nigg Hill and on several small areas of land lying just above 100 feet at the base of the Tarbat Ness peninsula. The semi-natural freely and imperfectly drained soils are podzols, but the thickness of the A and B horizons may be such that after cultivation the presence of an indurated B_3 horizon is often the only indication that the soil was not originally a brown forest soil.

Three series have been distinguished, the freely drained Brucefield series, the imperfectly drained Cromarty series and the poorly drained Navity series. The Cromarty series is the most extensive. A cultivated profile of this series from Cromarty Mains, at about 225 feet, had a dark brown sandy loam surface horizon about 30 cm deep overlying a brown to reddish brown compact somewhat indurated sandy loam B_3 horizon which merged gradually down into compact reddish brown sandy clay loam till. A semi-natural soil of the same series from Pitkerrie Moor near the Dornoch Firth, at about 80 feet, had a black to very dark grey brown loamy sand A_1/A_2 horizon, with bleached sand grains, about 18 cm thick, overlying a reddish brown sandy loam B_2(g) horizon about 7 cm thick. Below the B_2(g) horizon there was a sharp change into a brown to reddish brown indurated B_3 horizon which merged gradually down into reddish brown sandy loam to sandy clay loam till. The Brucefield series is about two square miles in extent and is developed on free-draining or 'shedding' sites along the south-east facing coastline of Easter Ross. The cultivated soil is similar to that of the Cromarty series but with a friable, more ochreous coloured B_2 horizon between the plough layer and the indurated B_3 horizon. The soils of the Navity series are poorly drained non-calcareous gleys limited to small hollows and wet spots.

The greater part of the Kindeace Association is concentrated within the western periphery of lowland Easter Ross excluding the Black Isle. Behind Invergordon it forms an intermixed pattern with the Ardvanie and Corby Associations and further east and north with the Cromarty Association. The Rarichie, Kindeace, Torlean and Balnagowan series have been distinguished. The dominant Kindeace series includes imperfectly drained podzolic soils; freely drained podzols and cultivated podzols have been grouped within the Rarichie series. The Torlean and Balnagowan series, of much more limited extent, are non-calcareous and peaty gleys. The soils of the Kindeace series are developed on gently to moderately sloping ground, mostly lying below 500 feet. In both semi-natural and cultivated profiles the indurated B_3 horizon is most often encountered between 25 and 50 cm below the surface, with extreme limits between 15 and 66 cm. In the semi-natural profile 7 to 10 cm of black surface humus usually overlie thin humus-stained A_1 and dark grey to very dark grey brown A_2 horizons with a combined thickness of from 5 to 20 cm. The B_2g horizon is also very variable in thickness and colour, though some rusty mottling (often associated with small fragments of weathered sandstone) is invariably present. A substantial proportion of the soils of this series (and of Rarichie series) is now cultivated, though several square miles remain under moorland or plantation. The texture of the surface horizon of the cultivated soil is usually sandy loam, with loamy sand to sandy loam in the B horizons, and sandy loam (or occasionally loam) in the compact C horizon.

The Millbuie Association is extensive only in the Black Isle, where the parent material is a coarse-textured supraglacial moraine derived from sandstone, sometimes underlain by reddish brown till of Cromarty type. Three series are present, but only the imperfectly drained podzolic soils of the Millbuie series are at all extensive within the confines of Sheet 94. The series of the Millbuie Association, together with that part of the Cromarty Association falling within the Black Isle, are described in the annual report for 1967/68.

The Ardvanie and Corby Associations and the less extensive Boyndie Association are in close complex along the coastal ridge and moraine area between Invergordon and Nigg Bay, while farther east the Corby Association forms part of the north-facing high beach platform and caps some of the till-covered ridges about Fearn; most of the soils are freely or imperfectly drained podzols or humus podzols. The greater part of the soils of the Corby and Boyndie Associations and a substantial proportion of the soils of the Ardvanie Association have been cultivated.

The silty and sandy soils of the low beach between Invergordon and Nigg Bay share a common soil ground-water problem with the extensive blown sand and shingle bar terrain of the links on the Morrich More and at Culbin. But whereas extensive artificial drainage has produced arable land on the Nigg lowlands, land use on the links is restricted to limited grazing or afforestation.

The Ethie, Cadboll and Mount Eagle Associations form a minor group of soils in which thin drift overlies solid rock. The soils of the Ethie and Mount Eagle Associations are mostly podzols or peaty podzols developed on upland or hill and have a limited agricultural potential. The soils of the Cadboll Association, by contrast, are developed on a few small outcrops of soft red sandstone in lowland Easter Ross and have for the most part been developed into arable soils of high quality.

A significant area of blanket peat occurs in the hilly north-western region of the sheet. Basin peats are a localized minor feature of inter-ridge and kettlehole hollows from Alness to Balnagowan and again in small hollows and kettleholes around Cadboll. Most of the basin peats are acid, but are sometimes underlain by calcareous marl, as at White Hills by Alness and at North Cadboll.

Scattered patches of deep cultivated surface soil are a distinctive feature of the arable lands of lowland Easter Ross, comparable with, though less extensive than, similar occurrences in the Insch area of Aberdeenshire. These are generally found on ridge tops or rising ground standing above the formerly marshy low beach levels. Surface soils up to 90 cm thick have been encountered, and below these traces of the A_0 and A_2 horizons of the buried podzol can sometimes be located, though usually they were incorporated in the original cultivation. The occurrence of these improved arable lands around the site of Fearn Abbey (founded in the year 1221) is indicative of their anthropogenic origin. Their extent, though not precisely known, is probably of the order of five square miles. It is therefore no accident that many of the larger contemporary mixed arable farms are found within the parishes of Nigg and Fearn, although, following extensive land drainage works, these now incorporate the low-lying silty and sandy ground between Fearn and Bay of Nigg as well as the improved ridges. In recent years much of the *Calluna* moor on the Hill of Nigg has been ploughed and grassland successfully established, and some experimental liming and direct reseeding of moorland upon which peat and peaty podzols are well developed is currently in progress between Aultnamain and Edderton.

SPECTROCHEMISTRY

Investigations concerned with trace elements and their relationships in rocks, soils and plants require a large number of determinations annually, these being made by direct reading and spectrographic emission methods as well as by flame emission and absorption techniques. Such methods cover many of the elements of known biological importance, but the use of other techniques for the determination of further elements reported to be necessary for plant and animal health is being investigated. If it were available, spark-source mass spectrometry with electronic recording would provide lower limits of detection of elements already being studied and at the same time permit the determination of elements not conveniently assessed by optical emission spectrochemistry.

The vacancy caused by the promotion of Dr R. O. Scott to Head of Department has now been filled by the appointment of Dr B. A. Goodman, whose objective will be to investigate the forms in which trace elements occur in soils and the mechanism of their transference to plant roots.

During the year a far-infrared Fourier spectrophotometer (Research and Industrial Instruments Co.) has been installed; this will prove particularly valuable for the structural analysis of soil minerals. Computer evaluation of the output from this instrument is essential and the recent installation of an IBM 1130 Computer has speeded up this data processing for which the computer at the Rowett Institute had hitherto to be used.

Several visitors have studied the techniques employed for the determination of trace elements. Amongst these were Dr M. Polemio and Dr V. Radogna of the Instituto di Chimica Agraria dell' Università di Bari, Italy, who were specially interested in direct reading analytical instruments, as similar equipment will be employed at their Institute. Dr W. K. Robertson of the Institute of Food and Agricultural Science of the University of Florida came to study the various analytical methods used in the department. Mr H. K. El-Kholy, a former student of Ain Shams University, Cairo, U.A.R., has completed the first year of a research project towards the degree of Doctor of Philosophy of the University of Aberdeen.

Dr V. C. Farmer accepted an invitation to present a paper at the twenty-first Pittsburgh Conference for Analytical Chemistry and Applied Spectroscopy. Members of staff have presented papers to and attended meetings of the Society for Analytical Chemistry (Symposium on Trace Analysis), the Clay Minerals Group of the Mineralogical Society, the Scottish Direct Reading Spectroscopy Group and the Interservices/D.T.I. Panel on Spectroscopy.

Trace Elements in Soils, Plants and Biological Materials

Assessment of soil status continues to be made by means of methods using 0·5N acetic acid, neutral normal ammonium acetate and 0·05 molar EDTA extracts. There has been some preliminary study of the use of the potassium salt of 2-ketogluconic acid, prepared by Microbiology, as an extracting medium. The use of this chelating agent produced by natural soil organisms may result, for certain elements, in a better correlation between the amount extracted from the soil and plant uptake. The paper presented at the Conference on Trace Element Metabolism in Animals in 1969 dealing with possible sources of contamination[23] has been published; in this connection several materials to be used in the construction of equipment for animal nutritional experiments at the Rowett Institute have been investigated. The paper presented four years ago to a NAAS conference on trace element behaviour in soils[80] is still awaiting publication.

Soils and Soil Parent Materials. The examination of trace element distribution in podzol profiles containing iron or manganese pans has continued. Eight more iron pan and two manganese pan profiles have been examined, as well as samples of bog iron ore. The levels of EDTA extractable and acetic acid soluble copper and manganese are generally higher in the iron pan horizons than in those immediately above or below. In contrast EDTA extractable cobalt is usually lower in iron pans than in other sub-surface horizons. Levels of EDTA extractable lead decrease sharply with depth to the iron pan, in which a slight increase generally occurs, followed by a further decrease below the pan. An examination of two further manganese pans confirms the existence of the association, reported previously, between manganese and cobalt. The collaborative study of the manganese-rich minerals lithiophorite and cryptomelane from the Lecht Mines, Tomintoul[2], has now been published.

Determination of the trace element contents of soil profiles sampled by the Soil Survey of Scotland has continued. Areas covered by Soil Survey Sheets 57 (Forfar) and 66/67 (Banchory/Stonehaven) have been completed, while work on Sheet 48/49 (Perth/Arbroath) is in progress.

Soil Status and Plant Uptake. Analyses, on behalf of Soil Fertility, of samples from areas with suspected nutritional disorders in plants or animals have continued on the same scale as in previous years, but the number of copper determinations, in both soil extracts and plants, has shown a steady rise over the past three years.

Analysis of soils and plant materials from long-term field experiments laid down by Soil Fertility has continued. Soils from an experiment to study the effect of different rates and combinations of nitrogen, phosphorus and potassium on trace element uptake by plants have been extracted with dilute acetic acid, ammonium acetate and EDTA. Plants from this and from other experiments designed to test the effect of soil pH on the uptake of copper and other elements are being analyzed, the samples being from such crops as cereals (grain and straw) and pasture species (ryegrass, cocksfoot and clover). From an experiment designed to examine the effect of soil drainage on trace element uptake by plants, soil samples taken at four times of year from seven locations have been analysed for extractable trace elements; the samples came from well drained, imperfectly drained and poorly drained sites. Preliminary assessment of the results indicates that, for each plot, samples taken from April to October show little or no variation in acetic acid soluble cobalt and nickel. Variations in EDTA soluble copper and ammonium acetate soluble molybdenum are also small. A full assessment of the results for these and other trace elements will be made after the analyses of the samples of pasture species, sampled at the same time as the soils, have been completed.

Variations in the trace element content of plants related to differences between species, stage of growth and distribution within the plant are described in a paper[24] that has now been published. In collaboration with the National Agricultural Advisory Service, analyses of plant samples from long-term field experiments to which applications of sewage sludges containing potentially toxic trace elements have been made are being continued. Other collaborative analyses in connection with plant growth studies have been made on soils submitted by the Department of Biology of the University of Lancaster and, for the Hartley Botanical Laboratories of the University of Liverpool, on soils developed on spoil heaps near old zinc and lead mines. Miscellaneous plant samples analysed have included leeks, grain seeds, daffodil parts and poplar stems for Plant Physiology, pea shoots for Microbiology, mixed herbage for the Soil Science Department of the University of Newcastle, and cotton leaves and groundnut leaves for Ahmadu Bello University, Northern Nigeria.

Spectrochemical Methods of Analysis

Few changes have been made in the arc emission methods during the year, although the tendency reported last year for the greater use of flame emission and absorption methods for the analysis of specific elements has continued. A general paper on the application of emission spectrochemical techniques to geochemical and biological problems[25] has now been published.

Arc Emission. No modifications to the methods of direct current arc excitation have been introduced during the year. Up to the present the carbon cathodes for the semiquantitative determination of total trace elements in rocks and soils have had a boring 0·8 mm in diameter into which a mixture of one part sample with one part carbon powder has been filled. However, as other quantitative methods require an electrode with a boring 1·0 mm diameter and a sample to carbon ratio of 1:2, it would be convenient to employ this shape exclusively. A comparison, using both shapes of electrode and the appropriate sample to carbon ratio, showed the limits of detection and the line intensities of trace elements in soils to be similar. It is envisaged that when the semiquantitative method is finally transferred to the polychromator the 1·0 mm bore cathode will be employed.

Very low contents of trace elements, for which the spectral lines barely show above the background on the photographic plate, continue to be evaluated by recording microphotometry.

Direct Photometry. A punched-tape output along with an index entry facility enabling the sample number to be incorporated on the tape has been fitted to the Hilger E789 3-metre Polychromator. In addition, an electromagnetic trip counter has been added to the tape punch in order to check the punched-tape output. Other instrumental changes have included the fitting of permanently sealed silica cells filled with bromine vapour as order sorters for the second order Zn 2138Å and Be 2348Å lines. Double exit slits, similar to that described previously for K 7665Å have been mounted for the easily reversed Li 6707Å and Na 5890Å lines. A description of some of these modifications[26] has now been published.

The determination of copper, iron, manganese, strontium and barium in plant ash has now been completely transferred to the polychromator, thus permitting at the same time the easy indication and determination of other elements present at abnormally high levels. Calibration is almost complete for the determination of molybdenum, nickel, lead, zinc, aluminium, titanium, vanadium, chromium, tin, gallium, germanium, beryllium, lithium and rubidium.

The transfer of the method for the semiquantitative determination of the total amounts of trace elements in soils and rocks is progressing. The great variations in matrix composition in this type of sample affect the line intensities and, with a view to making suitable corrections, methods for estimating their potassium, sodium, calcium, magnesium, iron and aluminium content, using palladium and indium as internal standards, have been developed. Satisfactory results have been obtained for these elements in the U.S. Geological Survey standard rock samples. Several hundred soil profile samples have been analysed for their trace element contents by the semi-quantitative spectrographic method and by the polychromator. Reasonable correlation between the methods has been found, although results obtained for some elements in iron pans (10-85 per cent Fe_2O_3) indicate that further matrix correction will be required. The installation of the IBM 1130 Computer has made additional computer time available to the department and will greatly expedite the transfer of further arc methods to the polychromator. Punched-tape output is available from the polychromator and the recently installed far-infrared spectrometer, and work is in progress to adapt one of the multi-channel flame photometers for this type of output.

The medium direct-reader is still used mainly for plant analysis involving the rotating pressed-disk technique. As the small direct reader, which has been used for fourteen years for the determination of magnesium by the porous-cup solution-spark method, developed an operational fault and has only recently been repaired, magnesium determinations in soil and plant extracts have been made by the atomic absorption technique described below.

Flame Emission. As in previous years some 25,000 samples have been analysed for calcium and potassium and 12,000 for sodium, using a laboratory-built three-channel flame photometer. A small number of calcium determinations have been made with a nitrous-oxide: butane flame and a Techtron AB41 Burner using the Techtron AA4 Spectrophotometer. This allows calcium to be determined down to 0·1 ppm Ca in solution with almost complete freedom from phosphorus interference and reduced aluminium interference.

A four-channel instrument designed to use high-temperature nitrous-oxide: butane and nitrous-oxide: acetylene flames is nearing completion. Calcium, sodium and potassium will be determined by emission and magnesium by atomic absorption. Alternatively, magnesium can be determined by emission if required. Simultaneous analogue output as well as sequential digital punched-tape output will be provided, as mentioned above.

A solvent-extraction concentration technique for the determination of molybdenum in soil extracts is being developed. After extraction by a solution of 8-hydroxyquinoline in chloroform, followed by vacuum evaporation of the chloroform fraction and dissolution of the residue in ethanol, molybdenum is determined by emission in a nitrous-oxide:acetylene flame. Preliminary results indicate a detection limit of 0·01 ppm Mo in the soil.

Work on mechanically separated flames has continued. A separated nitrous-oxide:acetylene flame, on a modified, water cooled Techtron 5 cm AB40 Slot Burner, has shown gains in detection limits of two to five times compared with an unseparated flame for aluminium, chromium, copper, magnesium, molybdenum, titanium and vanadium. This work was reported at the Trace Analysis Conference of the Society for Analytical Chemistry at St Andrews.

Atomic Absorption. One of the advantages claimed for the atomic absorption technique over flame emission has been lower limits of determination for certain elements. Improvements in instruments, burners and combustion mixtures, initially developed for atomic absorption, are however providing equal or superior detection limits in emission for many elements. Since in emission no hollow cathode lamp is required and simultaneous multi-element analysis is possible, developments this year have tended to focus on emission techniques.

The method reported last year for the determination of copper, manganese and zinc directly in EDTA extracts of soils by atomic absorption, using a separated air:acetylene flame, is now in routine operation. A description of the method[81], including a comparison with the porous-cup solution-spark method, has been accepted for publication.

Magnesium in soil extracts and plant materials is at present, as mentioned above, being determined by atomic absorption, using an air:acetylene flame. Sample and standard solution are buffered with strontium chloride to eliminate phosphorus or aluminium interference. During the year some nine hundred soil extracts have been analysed for cobalt, using the atomic absorption method described in the Annual Report for 1963/64.

Other Methods of Trace Element Analysis

The investigation of other methods for the determination of trace elements of biological importance that are difficult to detect spectrochemically has continued. The chlorine content of plant materials (0·02-2 per cent Cl) can be determined by extracting the milled oven-dry sample with cold aqueous sodium nitrate solution and, after filtration, measuring the chloride activity of the filtrate with an Orion No. 94-17 Specific-Ion Electrode and an EIL 2320 pH Meter. The meter reading reaches equilibrium in about two minutes providing the electrodes are immersed in dilute nitric acid for a few seconds between samples. Without acid rinsing the extracts from some plant materials appear to impair the speed of response of the electrode. Preliminary investigations on the determination of fluorine in soil and plant samples, using a Coleman No. 5000-2767 Ion-Selective Electrode, are in progress.

A spectrophotometric method for the determination of selenium in plant materials is being developed. An oxygen flask technique is employed for the combustion of the sample, and after co-precipitation of the selenium with arsenic, the fluorescence of the selenium di-aminonaphthalene complex is measured. The lower limit of determination is about 0·02 ppm Se in solution; investigations to lower the limit are continuing.

Absorption Spectrometry of Soil Constituents.

The far infrared Fourier spectrophotometer that has now been installed extends the frequency range which can be examined down to 40 cm^{-1}, corresponding to an infrared wavelength of 0·25 mm. The availability of a computer within the Institute now permits spectra in the region of 400-40 cm^{-1} to be obtained in less than one hour. Interferometric methods of spectroscopy are critically dependent on a high level of reliability in the associated electronic equipment and on a convenient and rapid method of transforming the output of the interferometer to a conventional spectrum. Computer expertise within the department has played an essential role in the adaption of a rapid method of Fourier transformation to the computer used, and some initial electronic difficulties have been largely overcome.

Absorption in the far-infrared region arises from vibrations associated with heavier atoms or weak interatomic forces and, accordingly, will have its principal application in the field of soil minerals. Thus in a study of some common layer silicates[82] it has been established that this region of the spectrum is sensitive to isomorphous replacement of magnesium by iron or nickel. Replacement of hydrogen by deuterium in these layer silicates has also been examined and this has given firm assignments for some hydroxyl vibrations diagnostic for the mineral species. In the course of this work it has been established that heavy water does not interact with structural hydroxyl groups in expanding layer silicates at room temperature under neutral conditions. It is therefore possible to distinguish such groups from hydroxyl groups in more accessible molecules trapped in the interlayer space which do exchange hydrogen for deuterium with D_2O. Under acid conditions, however, there is a rapid exchange at room temperature between D_2O and some structural hydroxyl groups in montmorillonite. A paper on this subject[83], identifying the hydroxyl groups involved, has been accepted for publication.

The account of a detailed investigation of the structural changes which occur during oxidative weathering of biotites and vermiculites[62] has been accepted for publication. Collaborative studies with Pedology on the weathering of biotite and amphiboles have also been concerned with oxidative processes; oxidation appears to play an essential role in the conversion of biotite to hydrobiotite[15], but ferrous iron in amphiboles resists oxidation unless complete structural breakdown occurs[63].

During the year two papers which will be the subject of future publications were read at a meeting of the Mineralogical Society and at the Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy. A paper on a colorimetric method of measuring cation exchange capacities of clay minerals[27], read at a meeting of the Clay Minerals Group, has now been published, as has a critical discussion of infrared techniques for assessing the surface acidity of clays[28]. Collaborative work with Biochemistry and Microbiology on soil organic matter and with Pedology on soil minerals is continuing.

BIOCHEMISTRY

For a small research group such as this department attendance at scientific meetings has a special importance, making it possible for the senior members of the staff to keep in touch with developments in biochemistry that have not yet reached the stage of publication. The largest of the meetings is the triennial International Congress of Biochemistry, held in 1970 in Switzerland (attended by Dr Vaughan), but smaller, more specialized conferences can be equally valuable. For example, Dr Cheshire attended the fifth International Symposium on Carbohydrate Chemistry in Paris and took the opportunity to visit the laboratory of Dr C. Peaud-Lenoel, who worked in the department in 1966, and saw some of his new techniques of plant tissue culture.

During the year two other members of the department were invited to contribute papers to more specialized conferences, a Welsh Soils Discussion Group meeting in Aberystwyth on podzolization[85], and a symposium on yeast cell walls of the Carbohydrate Discussion Group of the Chemical Society.

Effects of Humic Substances on Plant Tissue

The final realization in the middle of last century that plants obtain most of their carbon from the atmosphere, and not from soil humus, led to a concentration of attention on the inorganic constituents of soils and by comparison a neglect of the organic fractions. The latter might have an effect upon crop growth in several ways:

(1) as reservoirs of plant nutrients, especially nitrogen,

(2) as modifiers of the physical properties and structure of soil,

(3) as substances directly stimulating or inhibiting plant growth.

Although a considerable literature has accumulated dealing with the third category, it is still far from clear how important such effects could be for agriculture. Particularly in Britain, but also in many other countries in the temperate zones, there is usually an appreciable percentage of organic matter present in soils at all times of the year. The amount may be depressed by cultivation, and continuous cereal cropping in recent years has led to fears that the effects in category (2) may have a relevance to English conditions, but there has been little suggestion, as yet, that category (3) effects have much significance in Britain.

The difficulties of interpretation attending experiments on the effects of soil organic matter on plants have several origins. The first is our relative ignorance of the composition of soil organic matter, and our inability to divide it into identifiable fractions; the methods in common use also carry the risk of chemical alterations during its extraction. A second complication is the presence of micro-organisms in most of the test systems. To these must be added the usual variables present in all field experiments.

When it was shown in this department (Annual Report 35, 1964/65) that humic acids had an effect, that could easily be measured, upon disks of red beetroot tissue under aseptic conditions, it seemed justifiable to study the system in some detail. Further experience has led us to extend these studies to plant tissue culture and to whole plants.

The discovery of this *in vitro* effect would not have been made if Plant Physiology had not initiated, some years ago, a programme of research on sliced storage tissue of several species. These roots and tubers are normally quiescent, but when cut with precautions against microbial contamination and placed in an aqueous medium a thin disk of tissue goes through a considerable reorganization of its structure and economy. Respiration increases several fold, the capacity to absorb anions is greatly increased, and certain enzyme activities appear or are enhanced. In this department attention was first focused on the enzyme invertase, which cannot be detected with certainty in freshly cut tissue, but after a day or two is present in amounts substantial in relation to the concentration of its substrate, sucrose, in the disk. The amount of enzyme formed is increased by 50 to 100 per cent by the presence of a humic acid solution[29]. On the other hand, joint work with Plant Physiology, now ready for publication[30], has shown that the capacity to take up chloride ions is markedly depressed under these conditions; phosphate uptake is stimulated to a certain extent.

These effects seem to be due to the organic constituents of humic acid preparations. Some doubt inevitably exists, because typical humic acid preparations are notoriously high in ash content (often exceeding 5 per cent). The ash itself has a negligible effect, and the removal of nine-tenths of the inorganic constituents, by chelating resin and other procedures, does not increase the stimulatory effect. Some 'synthetic humic acids,' that is, black acidic substances produced by the oxidation of polyphenols, with negligible inorganic contamination, are effective, and so are the black pigments, low in ash content, produced by certain fungi.

Fractionation of humic acid preparations by gel filtration shows that it is the components of lower molecular weight (less than 50,000) that are responsible, but it has not proved possible to identify fractions with activities markedly greater than the original mixtures. Examination of the infrared and ESR spectra of several natural and synthetic humic acids has failed to reveal any correlation between chemical structure and the stimulation of invertase synthesis.

Most of the changes that go on in the aging disks are not affected: these include changes in composition (fresh weight, dry weight, protein content) and some metabolic changes (respiration, protein synthesis, increase in phosphatase activity). The effects upon invertase synthesis and anion uptake therefore indicate a degree of specificity in the action of the humic acids.

The significance of the effect upon invertase synthesis would be more easily appreciated if it were known what this enzyme was doing in the plant cell. Always partly, and sometimes wholly, associated with the cell wall, its activity correlates best with cell extension in both stems and roots. The effect of humic acid could therefore be to stimulate processes connected with cell wall growth, and in beet disks the cell wall invertase is stimulated to a greater extent than the soluble invertase. The use of radioactive labelling to measure the quantities of humic acid fractions taken up by the tissue has confirmed that the greater part is associated with the cell wall. As might be expected, plant growth substances also have effects upon invertase activity: gibberellic acid enhances the effect of humic acid.

The beet disk system provides a test system for measuring the biological activity of humic acids and similar materials quite quickly. Samples showing activity can then be tested on more complex systems such as tissue cultures, organ cultures and whole plants. Such work with aseptically grown suspension cultures and with excised roots has failed to show any stimulation of growth by soil organic matter fractions except in the absence of other ion-complexing agents. These experiments illustrate the importance of soil organic matter in increasing the availability to the plants of cations such as iron. They fail, however, to throw any further light on the general stimulation of biochemical activity demonstrated in the beet disk system. With these results in mind, some preliminary experiments have also been done with whole tomato plants in solution culture; they showed no effects on yields of roots or tops.

Humic acid preparations were used in these experiments because humic acid is the most easily obtained and most characteristic fraction of soil organic matter. However, it is not necessarily the material most likely to be present in the soil solution, and so components of the fulvic acid fraction are now under investigation.

Collaboration with Plant Physiology on studies of copper deficiency in oats[87] has continued.

Soil Organic Matter

Studies of the formation of soil polysaccharides from ^{14}C-labelled carbohydrates added to soil have been continued, using stems and leaves from labelled rye plants (obtained from Dr E. Grossbard of the A.R.C. Weed Research Organisation). This material was very slowly degraded, but a hemicellulose fraction from it (chiefly xylan) was more susceptible to attack. In contrast to previous experiments, in which it was added as the free sugar[88], xylose remained the most strongly labelled sugar, up to at least 56 days.

A book on geochemistry, containing a chapter on soil lipids[30] by the late Dr R. I. Morrison, has appeared.

Biochemistry of Soil Micro-Organisms

An account of the enzymes responsible for lysis of yeast cell walls by *Cytophaga johnsonii*[89] has been accepted for publication, and the procedures employed are now being applied to a study of the lysis of cell walls of *Sclerotinia sclerotiorum* by *Coniothyrium minitans*. The pigments elaborated by *Penicillium luteum* on a malt-extract-agar medium have been identified as rugulosin and skyrin. This research is being done in close association with Microbiology and Spectrochemistry.

A collaborative paper with Microbiology on nucleic acid degradation by *Cytophaga johnsonii*[31] has been published.

A contribution has been made to a volume of Essays in Cell Metabolism presented to Sir Hans Krebs on his seventieth birthday[32].

PLANT PHYSIOLOGY

The translocation and mobilization of trace elements within the plant and the elucidation of their function and interaction with the major elements are the main interest in this department. The newer techniques with the electron microscope offer greater possibilities in this field, and radioactive tracers are being applied to study the process of uptake of both major and trace elements.

Dr Y. Ohta, a visiting research worker from the Faculty of Agriculture, Tokyo University of Education, joined the department during July.

Copper

Studies on copper deficiency in oats have progressed and a paper on the electron microscopy of copper deficient oat leaves[87] has been accepted for publication. It has been shown that the typical white tip of the copper deficient leaf is full of a fibrous material, possibly protein.

The failure of the growing point of the copper deficient oat plant to change from the vegetative to the reproductive phase has proved difficult to study, but progress in this direction is being made. Since parts of the flowers or flower initials usually contain greater quantities of trace elements such as copper, zinc and iron than the rest of the plant, it is probable that under conditions of copper deficiency the concentrations of copper necessary for a change-over from the vegetative to the reproductive phase are never achieved in the growing point. Studies on leaves of these plants showed only slight differences in the activities of the various enzymes. A pot experiment to determine how late in the life cycle copper could be added to oats growing in a copper deficient medium showed that the oats grew and yielded better the earlier the copper was added.

Apart from the work on copper deficient oat leaves already mentioned, studies have been conducted on roots of copper deficient and copper sufficient oat plants, but no apparent differences were observed in the fine structure.

Molybdenum

In an experiment with clover grown on peat of very low copper and molybdenum contents with various levels of added copper and molybdenum, it was found that the content of one element was little affected by variation in the level of the other. On the other hand, enzymic measurements of ascorbic acid oxidase, a copper-containing enzyme, and nitrate reductase, a molybdenum-containing enzyme, showed that the activity of each enzyme increased with the addition of the element contained but tended to decrease with increasing levels of the other element.

Calcium

Dr Ohta has extended his earlier work on the calcium nutrition of plants to include the organic acids of fruits and leaves of tomato. A special problem of tomatoes growing in glasshouses is the rapid onset of calcium deficiency, with consequent spoilage of fruit and death of the upper shoots of the cane. Various experiments have been initiated to elucidate this phenomenon, using ^{45}Ca and ^{14}C-labelled oxalic acid. Earlier studies on nitrogen nutrition of tomato and other plants[33, 34, 35, 101, 102] have now been published.

Ion Flux Studies

To understand the mechanism of ion absorption operating in plant roots, it is necessary to establish, at the cellular level, the concomitant influx and efflux of the major nutrient ions. This can be most meaningfully achieved when the fluxes measured relate to an ambient solution containing all the major nutrient ions in concentrations of the order found in soil solutions. This regime has been followed using onion root segments. The flux data for Na^+, K^+ and Cl^-, obtained by using the appropriate radioisotopes, are considered to relate to the cortical cells which make up the bulk of the tissue segments. The cells under study are fully differentiated and the cytoplasm forms an extremely thin layer inside the cell wall. To extend the flux analysis to a study of individual cell compartments, the electron microscope has been employed to allow the mean thickness of the cytoplasm to be assessed and hence its volume to be estimated.

Beetroot storage tissue disks have been used extensively in the department for the examination of the development and functioning of a capacity for ion absorption at the cellular level. When beet disks are freshly cut, the net accumulation of ions is very small compared with its subsequent development. It has been a matter of dispute whether this is due as much to high initial ion efflux rates as to the initial absence of an absorption capacity. As a new and direct approach to solving this problem, beetroots have been grown in nutrient solutions containing high specific activities of ^{22}Na or ^{36}Cl, so that efflux of these ions could be measured directly following the slicing of the beet. Early results suggest that initial efflux of Cl^- is relatively low and subsequent increase in the uptake rate is largely due to the development of an uptake capacity. In contrast Na^+ efflux is initially high.

A paper reporting work on K^+ fluxes in pea epicotyls[103], carried out in the Department of Botany, Washington State University, and a review of electrochemical aspects of ion transport in plants[36] have now appeared.

Ion Absorption and Protein Synthesis

The relation between ion absorption and protein synthesis in plant tissues is in many respects conjectural. That absorption is mediated by proteinaceous carriers is not now disputed, but opinions differ concerning the extent to which ion uptake is directly linked to concomitant protein synthesis. Is the role of protein synthesis confined to the synthesis of the absorption mechanism or is synthesis also involved in the operation of the mechanism? Protein synthesis inhibitors offer a solution to the problem if they inhibit synthesis specifically. Although important, the qualification is rarely established. Cycloheximide (CH) is one of several antibiotics for which specificity, having been established for mammalian ribosomes, was subsequently assumed for plant ribosomes. An investigation into the specificity of CH in relation to ion absorption by storage tissue disks has shown that the antibiotic can affect cellular metabolism other than by inhibiting protein synthesis and that the inhibition of ion uptake may be due to disruption of the energy supply[37]. The preliminary findings suggested that green tissue differed from root and storage tissue in its sensitivity to CH and held out the possibility that the antibiotic might function as a specific inhibitor of protein synthesis on 8OS ribosomes in green issue generally. However, continuing with a survey of green tissue, it was found that ion uptake in some leaf tissue, for example, wheat and coleus, is sensitive to cycloheximide.

Some attention has been given recently to characterizing ion absorption by etiolated wheat lamina in light and dark. When young etiolated wheat lamina are exposed to light a rapid light-induced synthesis of chloroplast protein, chlorophyll and several enzymes occurs. Over a twenty-four hour period the rate of ion absorption is linear in the dark but increases exponentially in the light. This system offers interesting possibilities for investigating the effect of light on ion absorption as well as the relation between absorption and protein synthesis.

Collaborative work has continued with Biochemistry on the effects of humic acids on ion absorption by storage tissue disks[86] and on the effects of amino acid analogues on ion absorption by pea roots.

Other Investigations

A collaborative study with the Department of Botany of the University of Aberdeen on the knob-like structure at the tip of the leaf of *Ranunculus reptans* has established its glandular nature. Pyrenoid-like structures have been demonstrated in the epidermal and sub-epidermal cells at the apertures of the gland. Preliminary studies to establish the exact location of certain enzymes, for example, catalase, in the cell have been made. Earlier work on the effect of amitrole on duckweed[38] has been published.

Radioactivity

A method of gel suspension counting of ^{14}C labelled soils in a liquid scintillation spectrometer has been developed. A counting efficiency of 50 per cent can be obtained using a 30 mgm soil sample. Work with Biochemistry on the origin of the pentose fraction of soil polysaccharide[88] has been accepted for publication.

Analytical work with various departments has been facilitated by an automatic sample change liquid scintillation spectrometer. In particular, studies are now possible with ^{42}K of half life 12 hours which requires that the radioactive assays are done rapidly by the Cerenkov method. Samples involving ionic influx from plant tissues have been analysed.

Beetroot has been grown at high specific activities of ^{22}Na and ^{36}Cl for use in efflux studies. Oat and wheat labelled with ^{59}Fe have again been grown in large quantities for research workers, to be used in studies of human nutrition[91].

^{32}P has been used in determination of L values with Soil Fertility and tritiated water has been used in movement studies in peat with Pedology.

Certain aspects of the work with Soil Fertility on cation exchange capacity of plants[92] have been submitted for publication.

MICROBIOLOGY

Progress made in the investigations in the current year is given below. Collaboration with other departments within the Institute and with organizations outwith the Institute has continued.

Members of staff attended symposia and meetings concerned with developments in electron microscopy, with emphasis on their application to biology, including Micro-70, an exhibition with symposia on all aspects of microscopy organized by the Royal Mircoscopical Society in London. Visits were also made to research organizations with allied interests. Dr D. M. Webley attended a colloquium of the Soil Zoology Committee on soil organisms and primary production held in Dijon, France, in September.

Interrelationships between Plant Roots and Micro-organisms

A description of the apparatus developed for growing plants with axenic roots[40] has now been published. This apparatus is being used in an investigation of the interrelationships between a soil amoeba, *Acanthamoeba palestinensis* (Reich), and several common soil bacteria when present together on the roots of peas. During these investigations it has been noted that stunting and darkening of the pea roots occurred after inoculation with a *Pseudomonas* sp. Electron microscopic examination showed that these symptoms were accompanied by invasion of the epidermal and outer cortical cells of the root by the normally saprophytic bacterium. Inoculation of the roots with the amoeba did not prevent the damage, although many of the bacteria embedded in the mucigel covering the root surface were consumed. Further it was found that the amoeba had entered root cells which had been invaded by the bacterium. A paper describing these results[93] has been accepted for publication.

Work carried out elsewhere between 1926 and 1941 reported increased nitrogen fixation by free-living soil bacteria of the genus *Azotobacter* in the presence of one of a variety of soil protozoa as compared with pure cultures of the bacterium. These experiments used sand, sterilized soil or liquid nutrients as the medium. This neglected phenomenon is now being investigated here, with the help of the department of Soil Fertility, as it is an example of microbial interactions in the soil and because nitrogen fixation by soil micro-organisms is an important aspect of primary production in soil.

Microbial Decomposition of Organic Phosphates

The study of the degradation of nucleic acids by *Cytophaga johnsonii*[31] has now been completed and a description of the findings of a study of the adsorption of nucleic acids by montmorillonite[17], carried out in collaboration with Pedology, has appeared. This investigation has been extended to cover the degradation of free nucleic acids and of montmorillonite: nucleic-acid complexes in soil. The results show that free nucleic acids are rapidly degraded to produce inorganic orthophosphate and that the degradation is accompanied by quantitative and qualitative changes in the soil microflora.

Adsorption of the nucleic acids in the inter-layer spaces of montmorillonite did not prevent their degradation. Montmorillonite-DNA complexes were attacked and a uniform structural collapse of the clay complex occurred. In contrast, X-ray diffration analysis suggested that RNA adsorbed at the periphery of individual montmorillonite crystallites may be more easily degraded by microbial enzymes than that adsorbed in the inter-layer region. These results are presented in detail in a paper[64] accepted for publication.

Lytic Soil Micro-organisms

The work on the incidence of lytic micro-organisms present on the root surface of winter wheat *(Triticum aestivum* cultivar *champlein)* has been continued. The predominant organisms present on the seminal roots, which develop when the seeds germinate under field conditions and persist over the winter until spring growth begins, were found to be non-fruiting myxobacteria. These were also present on the adventitious roots, which develop during the spring and summer growth of the cereal, but in smaller numbers. After harvesting the myxobacteria could be detected on the stubble roots before ploughing, and after ploughing were still present in the field but in very small numbers. Lytic actinomycetes became much more numerous when the plant ears had ripened and were the predominant lytic organisms as the roots of the stubble began to decompose and at the later stage when ploughing took place. They were still present in the soil during the fallow period; non-fruiting myxobacteria were also detected. Isolates were made of the lytic non-fruiting myxobacteria and the actinomycetes. The latter appeared only on the soil extract medium with yeast cell walls. The other medium employed, containing actidione and neomycin (Annual Report 39, 1968/69), inhibited their growth, though not that of the myxobacteria. The predominant non-fruiting myxobacterium was *Cyptophaga johnsonii*. This work is continuing.

A study on the separation of the glucanases produced by *Cytophaga johnsonii*[89] has been undertaken in collaboration with Biochemistry. An account of the biological transformation of microbial residues in soil[94] is to appear in a textbook on Soil Biochemistry.

Work with the Mycology Department, School of Agriculture, Aberdeen, on the parasitism by soil fungi of the plant pathogen *Sclerotinia sclerotiorum*[41] has been published. Investigations (Annual Report 39, 1968/69) are continuing to determine the range of plant pathogens parasitized by *Coniothyrium minitans* and *Trichoderma viride*, both of which destroy the sclerotia of *Sclerotinia sclerotiorum* in soil. It has been found that sclerotia of *Sclerotinia narcissicola* are destroyed when 'coated' with spores of *T. viride* but not when spores of *C. minitans* are used. Neither fungus parasitizes sclerotia of *Sclerotium rolfsii*, a pathogen not indigenous to Britain, or sclerotia of *Sclerotium tuliparum*.

Work is in progress, in collaboration with Biochemistry, on the fractination of enzymes in *C. minitans* culture filtrates which lyse the cell walls of *S. sclerotiorum*. Culture filtrates from *C. minitans* grown on crushed sclerotia of *S. sclerotiorum* have been applied to Sephadex columns and the various column fractions tested for lytic activity. The mode of wall lysis is being followed by optical and electron microscope techniques.

In collaboration with Spectrochemistry, Biochemisty and Pedology, a systematic analysis of the cell walls of certain plant pathogens, and where possible of those of their sclerotia which persist in a resting form in the soil, is also in progress. The pathogens include *Sclerotium tuliparum*, *Sclerotium cepivorum*, *Sclerotinia fructigens*, *Sclerotinia narcissicola* and *Rhizoctonia solani*. The lytic effect of the *C. minitans* culture fluids on the living hyphae and isolated walls of these fungi is being examined.

Ultrastructure of Fungi

In taxonomic studies on fungi, spore surface ornamentation can be an important diagnostic feature. Since optical microscopy has its limitations for resolving spore surface morphology in detail, the electron microscope has been employed by various investigators. However, special techniques are necessary for the examination of spores in the transmission electron microscope. One such technique is the preparation of carbon film replicas of the spore surface, and the spores of various fungi, including plant pathogens, have been examined by this techique for the Commonwealth Mycological Institute, Kew. A joint note on spore surface ornamentation in *Coniothyrium* spp[42] has been published. Other spores examined are those of the rust fungi *Aecidium balansae* and *A. fragiforme*, both pathogens of *Agathis* spp (Kauri Pines). The carbon replicas clearly show the difference in the surface ornamentation of the spores, yet in the past only one fungal species was thought to be involved. Another technique, recently introduced, is that of freeze-etching. A joint paper with the Department of Botany, University of Aberdeen, on the ultrastructure of frozen, fractured and etched pycnidiospores of *Coniothyrium minitans*[43] has appeared. Highly magnified prints of the electron micrographs included in this paper were exhibited at the Botanical Society of Edinburgh symposium held in Heriot-Watt University in September 1970.

Results of investigations on the ultrastructure and composition of the cell walls of *S. sclerotiorum*[44] have been published.

Other Investigations

Work on the production of 2-ketogluconic acid has continued. In addition to the isolate used previously, the potassium salt of 2-ketogluconic acid has also been produced employing a strain of *Serratia marcescens*.. Preliminary trials with potassium-2-ketogluconate as an extractant for trace elements has begun in collaboration with Spectrochemistry.

A method using fluorescein isothiocyanate for the enumeration of soil micro-organisms, recently published by the Soil Science Department of the University of Saskatchewan, is being adapted for direct enumeration of rhizosphere organisms. Preliminary results for the rhizosphere soil are promising, but are more difficult to interpret for the root surface.

Work has commenced on the microbiology of peat, in collaboration with Pedology.

SOIL FERTILITY

Investigations have been continued and extended on the fundamental soil properties and processes which govern nutrient supply, on the mineral composition of different plant species, on the fertilizer requirements of crops, on laboratory evaluation of the nutrient status of soil, and on the effects of soil characteristics and environmental conditions on crop growth and development. The underlying experimental principle is concurrent development and integration of field, pot and laboratory studies, and the ultimate objective remains the improvement of manurial practice and crop production. The programme as a whole is accordingly based on a selection of contrasting soil series mapped in the Soil Survey of Scotland, and covers the main agricultural crops. Relevant experimental findings, especially information about the characteristics of soil series and about forms, rates, times and methods of fertilizer application, are translated into practice through the medium of advisory work in collaboration with the North of Scotland College of Agriculture. This work continues to provide a valuable reciprocal channel between research and practice.

Collaboration has been maintained with other research organizations and with several technical committees. The latter include the Technical Committee on Soil Fertility of the Agricultural Research Council, the Working Party on Soil Analysis set up by the Soil Survey Research Board, the Scottish Sub-Committee of the Sugar Beet Research and Education Committee, and the Scottish Standing Committee for the Calculation of Residual Manurial Values.

Dr E. G. Williams was one of four British participants in a Symposium on Agrochemical Research and the Use of Mineral Fertilizers in Moscow, to which he contributed a paper on factors affecting the availability of soil phosphate and the efficiency of phosphate fertilizers. The Symposium was held under the Anglo-Soviet Cultural Agreement and provided valuable contacts and discussions with Soviet colleagues, including instructive visits to Research Institutes in Moscow, Kiev and Leningrad. During a study tour in the Netherlands and Belgium, Dr B. W. Bache discussed developments in research on soil physical chemistry with workers in Wageningen, Louvain, Gembloux and Ghent. A talk on the effects of fertilizers on the yield and dry-matter content of potatoes was given to a course on Potato Production held in the School of Agriculture of the University of Aberdeen. The department was also represented at meetings of the British Society of Soil Science and the Association of Applied Biologists, and at a Colloquium on Potassium and Systems of Grassland Farming, at the Grassland Research Institute, Hurley.

During the year useful exchanges of views were obtained with numerous short-term visitors, including many from overseas, and Mr A. Odiase, Department of Forestry, University of Ibadan, Nigeria, came for seven weeks to gain experience of experimental techniques and analytical methods used in soil fertility research and advisory work.

Effects of Fertilizers, Soil Characteristics and Environmental Factors on Crop Yields and Composition. As explained in last year's report detailed studies have been started on crop growth and development at selected sites on different soil series, to examine more fully the effects of fertilizers and soil characteristics and assess the implications of environmental differences. A standard programme has been initiated at four farms, representing the Laurencekirk, Countesswells, Insch and Foudland series. The intention is to carry out annual factorial NPK experiments on both barley and swedes at these farms for at least three years. Measurements of soil and air temperatures, rainfall, humidity, wind speed, and soil moisture are being recorded weekly at a central site on each farm, usually with instruments providing a continuous record.

Preliminary work last year established suitable experimental procedures. The barley experiments were sampled at 14 day intervals from the beginning of June until harvest. The total crop, including roots, from 1 m^2 subplots was removed, washed, weighed, and subsampled for dry-matter estimations, chemical analyses and botanical evaluations. These determinations give the required information on changes with time in the total dry-matter and nutrient uptake, and in their distribution between vegetative parts and ears. Other measurements included number of plants per plot; leaf, tiller and ear numbers per plant; grain number per ear; and grain size. The swede experiments were sampled at 21 day intervals from late July when the roots began to swell. Total weights of roots from 2×2 m lengths of drill were recorded, and dry-matter and chemical determinations done on samples of bulbs and tops to follow changes during growth.

The effects of N, P, K and Mg treatment on the yield and composition of cereals, herbage, potatoes and swedes, and on soil nutrient levels, continue to be assessed by annual and longer-term field experiments, supplemented with soil and crop analyses.

Establishment of Grass on Deep Peat. An account of joint work with Pedology on lime and fertilizer requirements for establishing grass on deep peat[67] has been accepted for publication. Without applied lime, the sown grasses and clovers failed when ammonium sulphate and monoammonium phosphate were used, but a poor establishment was obtained with nitro-chalk and single superphosphate. With adequate P, lime at rates as low as 0·25 metric ton Ca per hectare produced a marked improvement. The yields produced by 1, 2 and 4 metric tons Ca per hectare were similar but the herbage from the last rate contained the highest Ca percentage. Even with adequate lime, the grasses and clovers failed in the absence of applied P. Superphosphate and basic slag gave similar establishments but the former produced higher yields. Ground mineral phosphate was inferior to basic slag in the first and second years, but in the fourth, fifth and sixth season was equal to superphosphate and superior to slag. After establishment the 98 kg P rates of the three phosphatic fertilizers produced higher yields than the corresponding 49 kg P treatments. The 490 kg P rate of superphosphate did not produce a bigger yield than the 98 kg level, but it did give a higher percentage of P in the herbage. Dressings of N and K had appreciable effects on establishment and growth, especially on the botanical composition of the sward and on the yield of herbage produced in the second year. The effects of treatment on the pH value of the peat and on the Ca, P and K extracted by 2·5 per cent acetic acid were measured. It is suggested that about 3 metric tons Ca, 35 kg N, 100 kg P and 140 kg K per hectare should be applied to give a satisfactory establishment of grasses and clovers on deep acid peat.

Trace Elements. A summary of the effects of soil properties on the trace element content of herbage has appeared[45]. Samples of herbage and soil continue to be taken from a series of plots covering various soil parent materials and drainage categories to study, in collaboration with Spectrochemistry, the relationship between laboratory soil values and the contents of trace elements, especially molybdenum, in herbage. Results from earlier experiments are being prepared for publication.

Inorganic Phosphate. The behaviour of inorganic phosphate in soils is dominated by sorption and desorption processes. The most significant aspect of the phosphate relationships of soils is therefore their sorption characteristics. Earlier work in this department established the central importance of the concepts of sorption capacity and degree of saturation in interpreting the solubility and availability of soil phosphate and rationalizing effects of parent material and drainage conditions. Subsequent developments have emphasized the importance of the Quantity and Intensity factors in defining soil phosphate status and interpreting laboratory extraction values. The fullest definition of the relationship between these factors is given by the sorption isotherm, the slope of which measures another fundamental characteristic, the phosphate buffering capacity of the soil. For many purposes, however, a single-point sorption index is desirable for rapid characterization of soils. The physicochemical implications and practical interrelationships of various sorption measurements have therefore been investigated with the view to standardizing a widely applicable easily determined index of this kind. Phosphate sorption isotherms covering concentrations from 10^{-6} to 10^{-3} molar in the equilibrium solution have been measured for 42 soils, representing a variety of parent materials and including calcareous samples. The isotherms are best represented as plots of the added phosphate sorbed, x, against the logarithm of the equilibrium concentration, log c. When the existing surface phosphate, E, is also taken into account by plotting $x+E$ against log c, a Quantity-Intensity curve is obtained, and the effects of differential phosphate fertilization are eliminated. The most characteristic feature of a sorption isotherm is its slope, but since soil isotherms are curved it is necessary when comparing different soils to measure the slope at a constant final phosphate concentration, and a value of 10^{-4} molar was selected as suitable. Several other phosphate sorption measurements were correlated with this isotherm slope. The sorption maximum calculated from a Langmuir plot of the data gave the very high coefficient of 0·975, while the quotient $x/\log c$ for a single addition of 150 mg P/100 g soil gave an equally high value of 0·976. This quotient, determined in 0·02M KCl suspensions shaken overnight at a soil:liquid ratio of 1:20, is therefore suggested as a simple single-point comparative index for rapid characterization of the phosphate sorption properties of soils. The crucial feature is that by adding a sufficiently large amount of phosphate and measuring the ratio x/log c, rather than just x alone, the effects of variations in the initial phosphate contents of soils are largely eliminated. An account of this investigation[95] has been submitted for publication, and the proposed index is being further investigated in connection with laboratory evaluation of phosphate status as well as characterization of soil series.

Integrated field-pot-laboratory studies have been continued to examine the Intensity and Quantity aspects of soil phosphate status and laboratory extraction values, and to assess the effects of seasonal differences and soil and site variations on correlations between the latter and crop responses. An account of related studies on the phosphate status of some Nigerian soils[46] has been published.

A paper on residual effects of phosphate and the relative effectiveness of annual and rotational dressings[96], summarized in the 1967/68 report, is in press and expected to appear next year.

Organic Phosphorus and Sulphur. Work has continued on the characterization of these fractions in soils, and papers have been published describing the isolation of nucleoside diphosphates from alkaline extracts[47] and the chromatographic fractionation of organic phosphates from alkali, acid, and aqueous acetylacetone extracts[48]. A considerable portion of the soil phosphate esters which are stable in alkali have now been identified, and extraction with a number of other solvents is being investigated. As mentioned in previous reports, chapters on soil organic P[97] and organic S[98] have been prepared for an Encyclopedia of Soil Science.

Pot experiments with organic phosphates have shown that phenyl phosphonic acid, $C_6H_5PO(OH)_2$, and related compounds have characteristic effects on plant growth and uptake of N, depending on the particular compound, crop and growth medium, and on the rate and method of application. An account of the main effects on oats and barley[49] has been published.

Nitrogen. Investigations are continuing into the usefulness of various laboratory methods for evaluating the nitrogen status of soils. Values by a number of chemical tests and a variety of incubation procedures are being compared with the yields and N uptake of oats grown on a range of 20 soils in Mitscherlich pots. Changes in mineral N have been monitored at monthly intervals in field plots receiving contrasting N treatments, in the four barley and four swede experiments mentioned earlier.

Soil Acidity and Cation Exchange. Work on the measurement of pH, lime potential and aluminium hydroxide potential[50] described in last year's report has now been published. The relationship between these solution potential measurements and soil constituents is being further investigated. It is clear that the balance between exchangeable Al and Ca+Mg is by no means the only determining factor; the solubility of soil aluminium compounds, and proteolytic equilibria involving both inorganic and organic surface groups, are also involved, making it difficult to obtain simple relationships with pH.

Rigorous estimates of soil negative charge and cation-exchange capacity (C.E.C.) are essential for the above studies, and an account has been published of a barium isotope technique which was developed to meet this requirement[51]. An assessment has also been made of the theoretical and practical implications of simpler and more rapid conventional C.E.C. methods. A method devised by Bascomb, involving saturation of the soil with $BaCl_2$ and displacement of the sorbed Ba with $MgSO_4$, is easy to operate and gives direct and relatively unambiguous measurements; it can also be used unbuffered to give C.E.C. at the natural pH of the soil, or buffered with triethanolamine to pH 7 or 8·2. Provided the comparisons are made at the same pH, however, the C.E.C. values are similar to those by the conventional ammonium acetate method and to estimates based on summation of exchangeable cations and exchange acidity. For general purposes, therefore, such as routine characterization of soil series, the choice of method should not normally be critical, and provided a standard procedure is specified and adhered to it can be selected to meet subsidiary requirements, especially determinations of individual exchangeable cations.

Cation-Exchange Properties of Plants. A number of topics under this head are being studied in collaboration with Plant Physiology, to improve the understanding of the mineral composition of different crops.

A joint paper, mentioned in last year's report, on the effects of soil pH on the root cation-exchange capacity (C.E.C.) and mineral composition of oats, barley, wheat, swedes and potatoes sampled at an early stage of growth[92] has been submitted for publication. Further consideration has been given to relationships between the root C.E.C. and dry-matter yields of leek varieties, including the implications of the organic acid content of the tops, as measured by (Ca + Mg + K + Na) - (P + S + Cl) and by so-called excess base obtained by titration of the ash.

C.E.C. measurements on pollen have given standard errors and coefficients of variation similar to those obtained with dried milled roots. Since pollen is particularly uniform with respect to particle size and shape, it is therefore unlikely that variations in these factors are of any importance in C.E.C. determinations on normally milled plant material.

Among the factors suggested as influencing pollen tube growth in plants are boron and calcium. Preliminary work on antirrhinum in 1969 showed that C.E.C., Ca content and Ca/K ratio all followed the sequence ovary > ovary wall > style > stigma. The Ca/K changes were particularly large because the K content followed the reverse trend. Work in 1970 has been directed towards a fuller examination of gradients of major nutrients in flowers of various species, with the supplementary aim of accumulating sufficient dry matter of the various floral parts for trace-element determinations. The plants chosen were daffodil, maize, antirrhinum, and three species of poppy.

Automation of Analyses. A colorimetric method for NH_4^+ in Kjeldahl digests is in routine operation on the AutoAnalyzer, using the green colour produced with sodium salicylate under mildly alkaline conditions, in the presence of sodium dichloroisocyanurate as a source of chlorine. Addition of nitroprusside increases the sensitivity of this reaction and allows highly diluted digests to be used, thereby avoiding interference by Hg from the digestion catalyst; with the less sensitive sodium phenate reagent a complexing agent, such as EDTA, has to be added for this purpose. A description of the method[99] has been accepted for publication.

To increase the time for which the AutoAnalyzer will run unattended, the 40-tube Technicon sampler has been supplemented by a larger sampler of 420-tube capacity, constructed in the Institute workshop by modifying a Pleuger fraction collector.

As an initial step towards automation of advisory soil pH measurements, a digital voltmeter and associated printer unit have been obtained for use with a Model 23A EIL pH meter. The equipment is arranged to provide manual setting of the sample number which is then automatically printed out together with the pH when the operator presses a push-button.

Advisory Work. The pH values and readily soluble phosphate, potassium and calcium contents of nearly 10,000 soil samples were determined during the year to assist the Advisory Officers of the North of Scotland College of Agriculture to make recommendations on lime and manurial requirements for agricultural and horticultural crops. With the assistance of Spectrochemistry, magnesium, cobalt and copper were determined in nearly 1000 of these samples and in about 100 crop samples from areas with problems involving animal health or crop production. Several hundred soil samples from forest nurseries were also examined, in collaboration with Pedology.

In recent years several cases of manganese deficiency in barley have been diagnosed in crops growing on calcareous sands, mainly on the Fraserburgh Association. Field trials have shown that spray treatment with manganese sulphate produced substantial increases in the yield of barley grain.

STATISTICS

The first phase in the provision of computer facilities in the Institute was completed towards the end of the year. The computer installation consists of an IBM 1131-2C central processing unit with 16K core storage capacity and magnetic disk backing store, an IBM 1442-7 card read/punch, a Facit PE1001 paper-tape reader and an IBM 1132 line printer. The line printer is on rental, the other items have been purchased. Use of the computer and of the card and paper-tape punches is open to authorized members of staff of other departments. This department is responsible for training and supervision. An open-shop system is being developed and records of the metered C.P.U. time and class of work are maintained.

Some computer programs have been reorganized and improved. The randomized block option has been removed from the factorial program for dealing with up to three factors. Both these programs now have more options for splitting treatment effects, and the factorial program deals with confounding and the production of regression equations. Another factorial program, incorporating new general subroutines, has been written for more than three factors. Revisions have been made in subroutines for input and output of data, particularly to make available additional data conversion options in the general input of experiment results prior to carrying out statistical analyses. Program listings and descriptions for semi-balanced and balanced lattice squares and for a central composite design have been supplied on request.

Grateful acknowledgement is made to the Rowett Institute for the regular allocation of computer time throughout most of the year and to the Edinburgh Regional Computing Centre for facilities there.

Members of staff have attended courses on FORTRAN and the 1130 Monitor System, and on the 1130 Assembler Language, also meetings of the Royal Statistical Society and of the Biometric Society, and the second A.R.C. Data Logging Symposium. Mr R. H. E. Inkson attended the seventh International Biometric Conference in Hanover from 16th to 21st August. En route to Hanover visits were made to centres of agricultural research at Wageningen, Oosterbeek and Groningen in Holland. The conference and the visits provided an extremely valuable opportunity to meet statisticians from other countries, to discuss with them similar approaches to common problems, and to appreciate variations in conditions which lead to different statistical methods and solutions.

Advisory and Collaborative Work

For a number of departments comparisons between methods of determination have been made. In addition to data processing and analysis of variance, statistical methods in general use on the computer include correlation and regression analyses.

A number of factorial experiments on cereal and swede crops, designed for Soil Fertility, are concerned with the rate of dry matter accumulation and of nutrient uptake. They have provided many sets of observations, both physical and chemical, at intervals throughout the growing season. The amendments to some computer programs referred to above were made to provide greater efficiency in the processing and statistical analysis of such large bodies of data. A more detailed examination of the results of fitting a quadratic response equation to the response of swedes to phosphate has been made for six soil types with four categories of phosphate status of the soils and for three quantities, crop yield, uptake of phosphorus and phosphorus percentage in the dry matter. Experimental maps showing the distribution, in the eastern Ross and Cromarty area, of copper and cobalt, based on soil samples analysed from autumn 1964 to spring 1969, were produced at the Edinburgh Regional Computing Centre, using version 5 of SYMAP, a program produced at the Laboratory for Computer Graphics and Spatial Analysis at Harvard University.

Computer programs have been written for the processing and analysis of data from Pedology. One of these evaluates, from the results of X-ray silicate analysis, the percentage of oxides of various elements corrected for dead time, background and matrix. Others are concerned with the evaluation of the weekly rate of increase of nitrogen in forest litter and the cumulative growth and relative weekly growth rates of trees derived from girth measurements. Collaboration with Pedology has also included an examination of the uniformity of tree height in an experiment area, a comparison between analysis of foliage samples from several tree species, and a split-plot analysis of variance on physical and chemical measurements made on seedlings in a greenhouse experiment.

Several factorial designs have been used for Plant Physiology greenhouse experiments with oats, poplar clones and lemna. Over the time interval of the experiments the lemna growth rate is linear when expressed as the logarithm of the number of lemna. The mathematical properties of the shape of lemna were also investigated. A joint account of factorial pot experiments on oats with iron and phosphorus treatments[35] has been published.

Supervision of computer programming has been provided for Soil Survey for studies of average monthly accumulated temperatures, for the rearrangement of phytosociological arrays, and in producing similarity input card decks and the calculation of similarity indices. A joint account of a comparison between traditional and numerical methods of classification of soil profiles[1] has been published.

The design of experiments and the analysis of results in collaboration with the Crop Husbandy Department of the West of Scotland Agricultural College continues.

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 inter-library lending schemes. A list of periodical holdings is available on request.

High subscription rates and extra costs resulting from increases in journal size meant that little could be done this year to increase the number of relevant journals available. For books the position was more satisfactory; 96 were brought and 32 received by donation. As in previous years, reprints and reports were received from many countries.

Co-operation with other libraries in the provision of books and information continues. This year the number of items borrowed from outside sources was 898 and 351 requests were received for loans.

The Institute maintains a mailing list of individual scientists and institutions interested in the various branches of the research work, and lists of staff papers of which reprints are available are sent out periodically. Reprints distributed this year amounted to 4302. No charge is made for reprints and anyone interested in receiving lists should apply to the librarian.

PUBLICATIONS

(A) *Published*

1. The classification of soil profiles by traditional and numerical methods. By J. W. Muir, H. G. M. Hardie, R. H. E. Inkson and A. J. B. Anderson (Rothamsted Experimental Station). (*Geoderma*, **4**, 81-90, 1970.)

   Sixty-three soil profiles, recognized members of four long-established soil series, are classified by the methods of numerical taxonomy. The results show that all four series exhibit a high internal uniformity; that Ettrick series is quite distinct from the other three; and that Linhope and Countesswells series are reasonably well delineated from each other but not from Foudland. This assessment exactly matches that of the traditional system of classification used by the Soil Survey of Scotland for over twenty years. The reasons why such fundamentally different approaches should yield identical results are discussed in detail.

2. Lithiophorite from the Lecht Mines, Tomintoul, Banffshire. By M. J. Wilson, M. L. Berrow and W. J. McHardy. (*Mineralog. Mag.*, **37**, 618-623, 1970.)

   Lithiophorite, a manganese mineral which occurs extensively in soils, has been characterized by X-ray, thermal, electron microscope and chemical methods. Selected-area electron diffraction reveals a hexagonal pattern from which it was concluded that the *b* parameter is 8·73 Å, three times the value of that currently accepted. Chemical analysis shows that the mineral has a high iron and zinc content but is relatively low in cobalt. A chemical analysis for associated cryptomelane is also given.

3. Differential Thermal Analysis. Vol. 1. Fundamental Aspects. (Edited by R. C. Mackenzie. London: Academic Press. 1970. £12.)

4. Basic principles and historical development. By R. C. Mackenzie (pp. 3-30 of *Differential Thermal Analysis*. Vol. 1. Edited by R. C. Mackenzie. London: Academic Press. 1970.) *No reprints.*

   A description is given of the basic principles underlying differential thermal analysis and the conventions to be used in subsequent chapters of the book. The development of the technique is described from earliest times up to the present.

5. Instrumentation. By R. C. Mackenzie and B. D. Mitchell. (pp. 63-99 of *Differential Thermal Analysis*. Vol. 1. Edited by R. C. Mackenzie. London: Academic Press. 1970.) *No reprints.*

   A review, designed to assist in the selection of suitable apparatus for studies involving differential thermal analysis.

6. Technique. By R. C. Mackenzie and B. D. Mitchell. (pp. 101-122 of *Differential Thermal Analysis*. Vol. 1. Edited by R. C. Mackenzie. London: Academic Press. 1970.) *No reprints.*

   A description of the practical aspects that have to be attended to in pursuing differential thermal studies if meaningful results are to be obtained. Factors relating to apparatus, sample and reference material are all considered and the reproducibility of results under different conditions assessed.

7. Oxides and hydroxides of higher-valency elements. By R. C. Mackenzie and G. Berggren (AB Atomenergi, Sweden). (pp. 271-302 of *Differential Thermal Analysis*. Vol. 1. Edited by R. C. Mackenzie. London: Academic Press. 1970.) *No reprints.*

   Many oxides and hydroxides of elements with valencies greater than two are of considerable importance in pedology and other natural sciences and in technology. Only a relatively limited number have, however, been subjected to intensive investigation by differential thermal analysis in conjunction with supplementary techniques and therefore warrant critical discussion. The oxides and hydroxides of iron, aluminium, manganese, chromium, zirconium and uranium are dealt with consecutively, and some sources of information regarding those of other elements falling into this group are cited.

8. Simple phyllosilicates based on gibbsite- and brucite-like sheets. By R. C. Mackenzie. (pp. 497-537 of *Differential Thermal Analysis*. Vol. 1. Edited by R. C. Mackenzie. London: Academic Press. 1970.) *No reprints.*

   After a review of the nature and classification of the minerals concerned, an account is given of the general differential thermal characteristics of each group. The thermal behaviour of many individual species, particularly those common in soil clays, is discussed in detail and comment is made on the practicability of qualitative and quantitative determination. Some accessory minerals, both silicate and non-silicate, are also briefly considered.

9. Organic compounds. By B. D. Mitchell and A. C. Birnie. (pp. 611-641 of *Differential Thermal Analysis*. Vol. 1. Edited by R. C. Mackenzie. London: Academic Press. 1970.) *No reprints.*

   A review of the application of differential thermal analysis to the investigation of organic compounds.

10. Biological materials. By B. D. Mitchell and A. C. Birnie. (pp. 673-704 of *Differential Thermal Analysis*. Vol. 1. Edited by R. C. Mackenzie. London: Academic Press. 1970.) *No reprints.*

    A review of the application of differential thermal analysis to the investigation of botanical and microbiological materials.

11. The application of alkali dissolution techniques in the study of Cretaceous flints. by S. S. Jørgensen. (*Chem. Geol.*, **6**, 153-163, 1970.)

    Quartz of varying particle size, 'cryptocrystalline silica' (considered to be a disordered intergrowth of cristobalite and tridymite) and amorphous silica were identified by X-ray diffractometry in Cretaceous flints and siliceous material associated with flint. The alkali dissolution technique for distinguishing between crystalline and non-crystalline material in soil clays was applied to the study of flints. The effect of the alkali was determined by chemical analysis, quantitative X-ray diffractometry and specific surface-area measurement. The results obtained are applicable to the study of siliceous material in soils.

12. The application of alkali dissolution techniques in the study of aluminium hydroxides and oxyhydroxides. By S. S. Jørgensen and B. D. Mitchell. (*Israel J. Chem.*, **8**, 343-356, 1970.)

    The effect of treatment with 5 per cent sodium carbonate solution on aluminium hydroxides and oxyhydroxides likely to occur in soils has been investigated. It has been found that particle size and degree of order of the sample influence the amount of alumina dissolved by sodium carbonate solution. Furthermore, both dissolution rate and solubility can be determining factors. It is concluded that extraction with alkali at low temperature and with a low solid:solution ratio is desirable for the preferential dissolution of poorly ordered aluminous material from soil clays.

13. The clay mineralogy of the Scottish Dalradian meta-limestones. By M. J. Wilson and D. C. Bain. (*Contr. Miner. Petrogr.*, **26**, 285-295, 1970.)

    The clay mineralogy of the Dalradian meta-limestones has been studied as part of a long-term investigation into the clay minerals ocurring in Scottish rocks and likely to be inherited by the soil. The limestones contain saponite, regular and irregular interstratified smectite-chlorite, swelling chlorite, normal chlorite, illite and kaolinite, and the origin of these minerals is considered in detail.

14. A study of weathering in a soil derived from a biotite-hornblende rock. Pt. I. The weathering of biotite. By M. J. Wilson. (*Clay Miner.*, **8**, 291-303, 1970.)

The weathering of biotite and hornblende in a sedentary soil developed on appinite at Rehiran Farm, Inverness-shire, was studied by a variety of methods. In the C horizon biotite weathers directly to hydrobiotite, and this stage involves oxidation of ferrous iron together with movement of ferric ions from the octahedral sheet. In the B horizon a fully expanded interstratified vermiculite-chlorite is developed.

15. Experimental conversion of biotite to hydrobiotite. By V. C. Farmer and M. J. Wilson. (*Nature, Lond.*, **226**, 841-842, 1970.)

Fresh biotite from Rehiran, Inverness-shire, has been converted to hydrobiotite in the laboratory. This transformation had been previously observed in Rehiran soil and the experiment has indicated that hydrobiotite forms only when cation exchange proceeds with active oxidation.

16. Alpine podzol soils on the Ben Lawers massif, Perthshire. By J. H. Stevens and M. J. Wilson. (*J. Soil Sci.*, **21**, 85-95, 1970.)

The occurrence of alpine podzols on the Ben Lawers massif is described and soil profile and analytical data given. Characteristics of these soils include well-defined horizons, very low pH values and base saturation percentages, and a slight but general increase in the silt plus clay content down the profile. X-ray diffraction shows that the soil clays are rich in mica and chlorite with subsidiary amounts of kaolinite, goethite and lepidocrocite. The general distribution of the clay minerals in the profiles studied suggests that the weathering of chlorite leads to the formation of kaolinite in the A horizons and to the accumulation of crystalline iron oxide minerals in the B horizons. The presence of kaolinite, taken in conjunction with recent clay mineral studies of Scandinavian and Canadian podzols, indicates that the Ben Lawers soils may pre-date the last glacial period.

17. The adsorption of nucleic acids by montmorillonite. By M. P. Greaves and M. J. Wilson. (*Soil Biol. Biochem.*, **1**, 317-323, 1969.)

The formation of organo-mineral complexes is a process which may have an important effect on the metabolism of organic matter in soils. In this study the conditions affecting the adsorption of nucleic acids by montmorillonite have been examined. It was found that pH plays a major role in the process, internal adsorption increasing as the pH fell below 5·0. Above pH 5·0 adsorption was minimal and occurred on external surfaces of the montmorillonite. X-ray diffraction data suggest that adsorption resulted in a random interstratification of nucleic-acid-expanded and non-expanded units. The results suggest that adsorption by clay minerals may account for the persistence of small amounts of polymeric nucleic acids in slightly acid soils.

18. An assessment of some thermal and chemical techniques used in the study of the poorly ordered aluminosilicates in soil clays. By J. M. Bracewell, A. S. Campbell and B. D. Mitchell. (*Clay Miner.*, **8**, 325-335, 1970.)

The presence of poorly ordered inorganic gel systems in soils may influence properties such as water retention and nutrient balance, especially if they form surface coatings. The usefulness of various techniques for their characterization in clays is considered. Many established instrumental techniques are unsuitable, but thermal methods, chemical dissolution techniques and specific surface reactions are more appropriate. The reaction of fluoride with clays is used as an example of the latter, and methods for detection and monitoring of fluoride uptake are described. Its value for studying gel materials in soils and for relating these to synthetic aluminosilicate gels is demonstrated.

19. Peat resources and development in the U.K. By R. A. Robertson and P. C. Jowsey. (*Proc. III int. Peat Congr., Quebec, Canada, 1968*, 13-14, 1970.)

In the United Kingdom, peat deposits cover an area of about 6000 square miles and contain in the region of 2500 million tons of dry matter. Current production is about 150,000 tons per annum, the bulk of which is for horticultural use. A limited area of peatland is used for agricultural purposes and the proportion afforested has increased in recent years. A number of scientific and other organizations are studying various aspects of peat and peatland use.

20. The chemical status of an exposed peat face. By J. M. Stewart (McMaster University, Hamilton, Ontario, Canada) and R. A. Robertson. (*Proc. III int. Peat Congr., Quebec, 1968*, 190-194, 1970.)

This paper presents the results of an exploratory investigation of the chemical analysis of 110 samples from an exposed peat face at Cruden Moss, Aberdeenshire. The true status of chemical components in the peat face cannot be deduced from the analysis of a single profile because of the horizontal variations that occur in the distribution of these elements. These variations are clearly indicated by the values obtained for carbon and nitrogen and, to a lesser extent, by the pattern observed for iron, sodium, potassium, magnesium and calcium.

21. Assessment of climatic conditions in Scotland. 1. Based on accumulated temperature and potential water deficit. By E. L. Birse and F. T. Dry. (Map and explanatory pamphlet issued by the Soil Survey of Scotland. Aberdeen: Macaulay Institute for Soil Research. 1970. £0.75.)

A map of the climatic conditions prevailing in Scotland, based on accumulated temperature and potential water deficit, has been constructed. The scale is 1:625,000 and when the map is used in conjunction with the tables of calculated values for individual stations a reasonably accurate categorization of the suitability of the climate at a particular site for plant growth can be attained.

22. The soils of Candacraig and Glenbuchat. (With soil and land use capability maps.) By R. E. F. Heslop and C. J. Bown. (*Bull. Soil Surv. Scotl.*, No. 1. 1970. Aberdeen: Macaulay Institute for Soil Research. £1.50.)

The soils of 37 square miles of country around Candacraig and Glenbuchat are described, classified and related to factors affecting their formation. Among the soils distinguished are brown forest and magnesian soils, podzols, gleys, subalpine soils and peats. Analytical data for 83 profiles are quoted and discussed. The potential of the soils is assessed, principally according to their suitability for agricultural use. Coloured soil and land use capability maps on the scale of 1:25,000 accompany the bulletin.

23. Problems in trace element analysis. By R. O. Scott. (*Proc. WAAP/IBP int. Symp. Trace Element Metabolism in Animals, Aberdeen, 1969*, 497-504, 1970.) *No reprints.*

The choice of suitable analytical techniques for the determination of trace elements is discussed, mainly with reference to spectrochemical methods. Single and multi-element methods of analysis are described briefly. In all work connected with trace elements in plants and biological materials, contamination can cause spurious results. It is important to ensure that the trace element concerned is not introduced accidentally from environmental materials in growth experiments or from reagent contaminants in the subsequent laboratory analyses. Possible sources of contamination from these causes are discussed.

24. Vegetational factors affecting the trace element content of plants. By J. C. Burridge. (*Proc. WAAP/IBP int. Symp. Trace Element Metabolism in Animals, Aberdeen, 1969*, 412-415, 1970.) *No reprints.*

Variations of trace element content between different pasture species, changes related to stage of growth, and distribution within the plant are described. The influence of these factors on the trace element content of mixed herbage is indicated, with particular reference to cobalt, copper, iron, manganese, molybdenum and zinc.

25. Trends in applied geochemical and biogeochemical analysis. By R. L. Mitchell. (*Plenary Conf. XV Colloq. Spectros. int., Madrid, Spain, 1969*, 11-23, 1970; also in *Proc. XV Colloq. Spectros. int., Madrid, Spain, 1969*, **1**, 5-11, 1970; and *Boln. Geol. Min. Madrid*, **80**, 395-401, 1969.)

    An account of the application of spectrochemical methods to geochemical and biogeochemical analysis and a discussion of the problems arising from the introduction of direct-reading arc-emission techniques.

26. Geochemical analysis with a multi-channel direct reader employing direct current arc excitation. By R. O. Scott, J. C. Burridge and R. L. Mitchell. (*Proc. XV Colloq. Spectros. int., Madrid, Spain, 1969*, **1**, 56-61, 1970; also in *Boln. Geol. Min., Madrid*, **80**, 446-451, 1969.)

    Modifications to a 49-channel Hilger and Watts E789 3-metre polychromator, which make it more convenient for direct current cathode layer carbon arc analysis of powder samples such as rocks, soils and ashed plant material, are described.

27. A spectrophotometric method for determination of cation-exchange capacity of clay minerals. By A. R. Fraser and J. D. Russell. (*Clay Miner.*, **8**, 229-230, 1969.)

    The application of a reliable spectrophotometric method for the determination of ammonium ion to the evaluation of cation-exchange capacities of clays is described. One of the many advantages of the method over the conventional Kjeldahl procedure is its high sensitivity and consequent need for only a few milligrams of sample.

28. Reactivity of montmorillonite surfaces with weak organic bases: comment on a paper of Swoboda and Kunze. By M. M. Mortland (University of Michigan, U.S.A.), V. C. Farmer and J. D. Russell. (*Proc. Soil Sci. Soc. Amer.*, **33**, 818, 1969.) *No reprints.*

    Difficulties which arise in using organic bases to assess the surface acidity of clays are pointed out, and illustrated for aniline adsorbed on montmorillonite.

29. Effect of humic acid on the development of invertase activity in slices of beetroot tissue washed under aseptic conditions. By D. Vaughan. (*Proc. Symp. Humus et Planta, IV, Prague, 1967*, 268-271, 1969.) *No reprints.*

    Organic compounds in soils are known to influence the growth of plant tissues. Using the development of invertase activity in beet disks as an indication of growth, it has been shown that humic acids derived from a variety of sources can have a marked effect on plant metabolism. The stimulating components are organic in nature and probably have a molecular weight of less than 50,000.

30. Soil lipids. By R. I. Morrison. (pp. 558-575 of *Organic Geochemistry: Methods and Results.* Edited by G. Eglinton and Mary T. J. Murphy. Berlin: Springer. 1969.) *No reprints.*

    A brief survey, mainly from the point of view of the organic chemist, of lipids in soils, including: methods of extraction, isolation and characterization; chemical nature and amounts of individual substances; origins, stability and transformations; effect on soil structure and plant growth.

31. The degradation of nucleic acids by *Cytophaga johnsonii*. By M. P. Greaves, D. Vaughan and D. M. Webley. (*J. appl. Bact.*, **33**, 380-389, 1970.)

Previous studies from the Institute have shown that many soil micro-organisms can degrade nucleic acids. The non-fruiting myxobacterium *Cytophaga johnsonii* is of particular interest in this respect since it can utilize the contents of dead bacterial cells as its sole nutrient source and consequently may be important in the organic matter cycle in soil. The present study has shown that this process results in the degradation of bacterial nucleic acids and the release of purine and pyrimidine bases, as occurs during the degradation of isolated nucleic acids. The nucleases produced by *C. johnsonii* appear to be formed only in the presence of readily available sources of carbon, nitrogen and phosphorus, nucleic acids alone not serving as such sources. The enzymes have been separated from the culture fluid of the myxobacterium and their activities measured fluorimetrically.

32. Life outside the cell, or, What the biologist saw. By J. S. D. Bacon. (pp. 45-66 of *Essays in Cell Metabolism*. Edited by W. Bartley, H. L. Kornberg and J. R. Quayle. London: Wiley. 1970.) *No reprints.*

In animal cells the wall may be only a few molecules thick, but most plant cell walls are massive structures. The essay draws attention to the possibility that this wall region has a characteristic metabolism of its own. A number of enzymes have been identified there and some have been studied in the Institute. The essay ends with a warning that the study of its structure and properties in isolation can never explain fully the functions of a molecule in a biological system. The biochemist must continually prepare himself to deal with ordered systems of considerable complexity, of which the plant cell wall is a striking example.

33. The metabolism of nitrogen in plants. By P. C. DeKock. (*Tech. Bull. Minist. Agric. Fish. Fd*, **No. 15**, 1-6, 1969.)

The enzymic reduction of nitrate in the plant is discussed in the light of modern findings. Ammonia and urea utilization by the plant are similarly discussed and need for further work pointed out.

34. Uptake by plants of various forms of nitrogen and effects on plant composition. By P. C. DeKock and E. A. Kirkby. (*Tech. Bull. Minist. Agric. Fish. Fd*, **No. 15**, 7-14, 1969.)

The effects of nitrate, ammonium and urea on the inorganic composition of plants is discussed. Attention is drawn to the possible significance of such effects in agricultural practice.

35. An investigation into the effect of varied phosphorus and iron concentrations in the nutrient medium on the cation and anion contents of oats. By Linna Bentley (University of London), P. C. DeKock and R. H. E. Inkson. (*Pl. Soil*, **32**, 271-281, 1970.)

Oat plants (variety 'Yielder') were grown in nutrient solution with nine different combinations of phosphorus and iron supply. The inter-relationships between ratios of minerals and organic compounds in these oats are compared with those found for other plants.

36. Electrochemical aspects of ion transport in plants. By A. E. S. Macklon. (*J. Sci. Fd Agric.*, **21**, 178-181, 1970.)

In differentiating between active transport and diffusion of nutrient ions into plant cells, account must be taken of both the chemical and electrical potential gradients influencing ion movement. A brief account of the electrochemical theory adopted for this purpose is given, and its use illustrated with examples of ion uptake studies on uniform populations of cells. Some consideration is also given to the more complex situation occurring across the whole root.

37. Specificity of cycloheximide in higher plant systems. By R. J. Ellis (University of Aberdeen) and I. R. MacDonald. (*Pl. Physiol.*, **46**, 227-232, 1970.)

Cycloheximide is a useful inhibitor of metabolic processes in plants and is generally assumed on the basis of work with micro-organisms and mammalian cells to act by interfering with protein synthesis. This report provides evidence that its inhibitory effect on ion uptake may be due to disruption of the cellular energy supply. It is also shown that while ion uptake by root tissue is very sensitive to cycloheximide, ion absorption by leaf tissue is unaffected. Furthermore its effect on the uptake of organic compounds differs from that on ion uptake. This suggests that there are fundamental differences in those processes and that cycloheximide could be a useful tool for investigating them.

38. The effect of amitrole on duckweed. By P. C. DeKock and Alison M. Innes. (*Can. J. Bot.*, **48**, 1285-1288, 1970.)

Aminotriazole applied to the surface of duckweed fronds as micro drops caused horizontal bands of chlorotic tissue to develop in the daughter fronds. Iron applied simultaneously was found to decrease the chlorotic response. Ultrastructure studies showed progressive disorganization in the affected cells.

39. The complexes of zinc, copper, and manganese present in ryegrass. By I. Bremner (Rowett Research Institute, Aberdeen) and A. H. Knight (*Br. J. Nutr.*, **24**, 279-289, 1970.)

Ryegrass labelled with ^{65}Zn was produced by water culture and used to examine the nature of the complexes in the leaves as part of a study of the availability of metals to ruminants.

40. An improved method for the study of inter-relationships of soil micro-organisms and plant roots. By J. F. Darbyshire and M. P. Greaves. (*Soil Biol. Biochem.*, **2**, 63-71, 1970.)

Comparatively little is known of the inter-relationships between plant roots and micro-organisms, particularly with respect to their effects on nutrient uptake. A method of growing plants with axenic or inoculated roots has been developed to study such inter-relationships. The results show that inoculation of pea roots with a bacterium (*Pseudomonas* sp.) commonly found in the rhizosphere of pasture grasses had no effect on the uptake of phosphorus, sodium, potassium, calcium and magnesium, although some damage was caused to the roots. The significance of micro-organisms in nutrient uptake is discussed.

41. Parasitism and lysis by soil fungi of *Sclerotina sclerotiorum* (Lib.) de Bary, a phytopathogenic fungus. By D. Jones and D. Watson (School of Agriculture, Aberdeen). (*Nature, Lond.*, **224**, 287-288, 1969.)

The fungus *Sclerotina sclerotiorum* attacks a wide range of agricultural and horticultural crops and can cause serious losses. It overwinters in the soil in the form of sclerotia, resting structures consisting of a mass of closely packed mycelium protected by a layer of darkly pigmented cells. These sclerotia are generally resistant to degradation by micro-organisms and can survive long periods before germinating to infect plants. This paper reports the isolation of fungi from sclerotia collected from the field. Two of these fungi actively parasitize and destroy sclerotia when inoculated on to them either on moist sand or buried in soil. Culture filtrates from the parasitic fungi have been shown to bring about destruction of the mycelium and sclerotial material, and electron microscope techniques have been employed to follow this process. These studies are the basis for future research into the mechanism of the parasitism of the sclerotia.

42. Spore surface ornamentation in *Coniothyrium* species. By E. Punithalingham (Commonwealth Mycological Institute) and D. Jones. (*Trans. Br. mycol. Soc.*, **55,** 154-156, 1970.)

Spore surface ornamentation can be an important diagnostic feature in taxonomic studies on fungi. Carbon replicas of the spore surface of four species of *Coniothyrium*, one of which has been shown in this Institute to parasitize a plant pathogenic fungus, have been prepared and examined in an electron microscope. Differences in the spore surface ornamentation in the four species were observed which confirmed studies with the optical microscope, but greater detail was obtained.

43. Ultrastructure of frozen, fractured and etched pycidiospores of *Coniothyrium minitans.* By D. Jones and R. P. C. Johnson (University of Aberdeen). (*Trans. Br. mycol. Soc.*, **55,** 83-87, 1970.)

A description is given of the detailed structure of the spores of a soil fungus *Coniothyrium minitans* which parasitizes the fungal plant pathogen *Sclerotina sclerotiorum*, as revealed mainly by the freeze-etching technique. This method does not require the use of chemical fixitives or embedding resins, both of which may result in distortion of the biological material. Furthermore the technique gives surface as well as sectional views of structures in fractured cells.

44. Ultrastructure and composition of the cell walls of *Sclerotina sclerotiorum* (Lib) de Bary. By D. Jones. (*Trans. Br. mycol. Soc.*, **54,** 351-360, 1970.)

The fungus *Sclerotina sclerotiorum* is a very destructive plant pathogen causing serious losses to certain agricultural crops both in storage and in the field. A study has been made of the fine structure, in the electron microscope, of the cell walls of the fungus, together with the chemical analysis of the walls, in order to throw more light on the processes involved during the destruction of this pathogen by certain fungi found to parasitize the sclerotia in the soil.

45. Soil factors influencing the trace element content of herbage. By J. W. S. Reith. (*Proc. WAAP/IBP int. Symp. Trace Element Metabolism in Animals, Aberdeen, 1969*, 410-412, 1970.) *No reprints.*

The paper summarizes the influence of soil factors, including geological nature of the parent material, drainage conditions, lime status and fertilizer treatment, on the uptake of Co, Cu, Mn, Mo and Zn by herbage. Attention is drawn to the large effects of lime and fertiliser N on both Mn and Mo. The application of N can change the trace element content of mixed herbage indirectly by altering the proportions of grasses and clovers in the sward.

46. Soil phosphate values in relation to phosphate supply to plants from some Nigerian soils. By B. W. Bache and N. E. Rogers (Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria). (*J. agric. Sci., Camb.*, **74,** 383-390, 1970.)

The phosphate relationships of some Nigerian soils were investigated by comparing the growth of a grass in pot experiments with a number of laboratory values. The latter were chosen to emphasize either the quantity of available phosphate or its concentration in the soil solution. Quantity values gave better predictions of plant performance than did concentration measurements, but a combination of the two was necessary to give the best prediction. Phosphate extraction with anion-exchange resin was the best single method, appearing to reflect both aspects of the phosphate supply. Organic phosphate was not important.

47. The isolation of nucleoside diphosphates from alkaline extracts of soil. By G. Anderson. (*J. Soil Sci.*, **21,** 96-104, 1970.)

Although nucleic acids are thought to constitute an appreciable proportion, possibly about 2 to 5 per cent, of the organic P in the soil, it has not yet been possible to devise a method of isolating them. The best evidence until now for the presence of deoxyribonucleic acid (DNA) has been the isolation of the nitrogenous bases adenine, guanine, cytosine and thymine, all of which are present in that substance. Further evidence has now been obtained by the detection of two pyrimidine nucleoside diphosphates, namely thymidine—3′:5′ diphosphate and deoxyuridine—3′:5′ diphosphate, in sodium hydroxide extracts of soil. The esters were purified by chromatography and their identity confirmed by comparison with reference compounds prepared by hydrolysis of calf thymus DNA. It has been confirmed that the conditions of extraction cause a breakdown of authentic DNA, with the conversion of about 3 per cent of the P to nucleoside diphosphates, and it is possible that the soil nucleotides are artifacts, derived from DNA polynucleotides.

48. Chromatographic fractionation of organic phosphates from alkali, acid, and aqueous acetylacetone extracts of soils. By R. L. Halstead (Soil Research Institute, Canada Department of Agriculture, Ottawa) and G. Anderson (*Can. J. Soil Sci.*, **50**, 111-119, 1970.)

The use of a mild extractant, aqueous acetylacetone at pH 8, has given further evidence that a considerable amount of the organic phosphorus in soil exists in a complex form, or as large molecules which cannot be adsorbed by ion-exchange resins without prior hydrolysis. Chromatography of the phosphates extracted with NaOH showed the presence of a number of inositol phosphates and of esters similar to glycerophosphate and glucose-1-phosphate. Gas chromatography of hydrolysis products revealed substances comparable to glycerol and ribitol, but their identity was not confirmed.

49. Effects of phenyl phosphonic acid and related compounds on plant growth and uptake of nitrogen. By E. G. Williams. (*Nature, Lond.*, **227**, 84, 1970.)

Pot experiments have shown that phenyl phosphonic acid and related compounds have novel effects on plant growth and nitrogen uptake, which can vary from markedly positive to strongly negative, depending on the particular compound, crop and growth medium, and on the rate and method of application. The main features are the marked concurrent increases which can be produced in the yield and nitrogen content of oat and barley grain, and in the ratio of grain to straw.

50. Determination of pH, lime potential and aluminium hydroxide potential of acid soils. By B. W. Bache. (*J. Soil Sci.*, **21**, 28-37, 1970.)

As a necessary preliminary to detailed studies on acidity in Scottish soils, conditions are defined for the accurate determination of pH, lime potential and aluminium hydroxide potential of acid soils. The pH values of calcium chloride suspensions of such soils should be measured within about an hour of making the suspension, to avoid an increase of pH with time that occurs thereafter. To obtain unique values from a single extraction, the dominant exchangeable soil cation must be Ca^{2+} for lime potential measurements and Al^{3+} for aluminium hydroxide potentials. Otherwise an interpolation procedure has to be used, and a method for this is described.

51. Barium isotope method for measuring cation-exchange capacity of soils and clays. By B. W. Bache. (*J. Sci. Fd Agric.*, **21**, 169-171, 1970.)

The cation-exchange capacity (C.E.C.) of clays and soils has been measured by saturating their exchange sites with barium ions, suspending the samples in 0·0025 *M* $BaCl_2$ solution and introducing the radioactive isotope ^{133}Ba. C.E.C. is calculated from the distribution of the isotope at equilibrium. The rate of isotopic dilution of the ^{133}Ba, the efficiency of displacement of the soil cations by Ba^{2+}, and the precision of the method were critically assessed. The method is reliable and convenient, and can be used with both buffered and unbuffered systems.

(B) *Awaiting Publication at 30th September, 1970*

52. 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. Sect. D. Berlin: Springer.

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

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

55. The thermal characteristics of soil minerals and the use of these characteristics in the qualitative and quantitative determination of clay minerals in soils. By R. C. Mackenzie and S. Caillère (Paris, France). (To appear in *Encyclopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2. Sect. D. Berlin: Springer.)

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

57. Assessment of gibbsitic material in soil clays by DTA and alkali dissolution methods. By S. S. Jørgensen, A. C. Birnie, B. F. L. Smith and B. D. Mitchell. (Submitted to *J. therm. Anal.*)

58. Conditions for the formation of bayerite and gibbsite. By W. J. McHardy and A. P. Thomson. (Submitted to *Mineralog. Mag.*)

59. The thermal dissociation of some carbonate minerals. By S. St. J. Warne and R. C. Mackenzie. (Submitted to *J. therm. Anal.*)

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

61. Plumbogummite-group minerals from Mull and Morven. By D. C. Bain. (Submitted to *Mineralog. Mag.*)

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

63. A study of weathering in a soil derived from a biotite-hornblende rock. Pt. II. The weathering of hornblende. By M. J. Wilson and V. C. Farmer. (Submitted to *Clay Miner.*)

64. The degradation of nucleic acids and montmorillonite–nucleic acid complexes by soil micro-organisms. By M. P. Greaves and M. J. Wilson. (Submitted to *Soil Biol. Biochem.*)

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

66. Characterization of soil by pyrolysis combined with mass spectrometry. By J. M. Bracewell. (Submitted to *Geoderma.*)

67. Lime and fertilizer requirements for the establishment and growth of grass on deep peat. By J. W. S. Reith and R. A. Robertson. (Submitted to *J. agric. Sci., Camb.*)

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

69. Flandrian history of the Wooler Water, Northumberland, provided by pollen analysis. By C. M. Clapperton (University of Aberdeen), S. E. Durno and R. H. Squires (University of Aberdeen). (Submitted to *Scot. geogr. Mag.*)

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

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

72. Moisture characteristics of some peat-sand mixtures. By R. Boggie. (Submitted to *Scient. Hort.*, **22**, 87-91, 1970.)

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

74. Assessment of climatic conditions in Scotland. 2. Based on exposure and accumulated frost. By E. L. Birse and L. Robertson. (Map and explanatory pamphlet to be issued by the Soil Survey of Scotland.)

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

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

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

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

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

80. Trace elements in soils. By R. L. Mitchell. (Submitted to *Proc. NAAS Conf. Trace Elements in Soils and Crops, London, 1966.*)

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

82. Replacement of OH by OD in layer silicates, and identification of the vibrations of these groups in infrared spectra. By J. D. Russell, V. C. Farmer and B. Velde (Laboratoire de Pétrographie, Tours, France). (Submitted to *Mineralog. Mag.*)

83. Infrared spectroscopic evidence for interactions between hydronium ions and lattice OH groups in montmorillonite. By J. D. Russell and A. R. Fraser. (Submitted to *Clays and Clay Minerals.*)

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

85. Some aspects of the chemistry of the Glentanar podzol profile. By H. A. Anderson. (Submitted to *Rep. Welsh Soils Discuss. Grp.*)

86. Effects of humic acid on protein synthesis and ion uptake in beet disks. By D. Vaughan and I. R. MacDonald. (Submitted to *J. exp. Bot.*)

87. The fine structure of leaf cells of copper-deficient oats. By P. C. DeKock, Marjorie Rutherford and M. V. Cheshire. (Submitted to *Ann. Bot.*)

88. The origin of the pentose fraction of soil polysaccharide. By M. V. Cheshire, C. M. Mundie and H. Shepherd. (Submitted to *J. Soil Sci.*)

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

90. Fundamental aspects of iron nutrition of plants. By P. C. DeKock. (Submitted to *Proc. NAAS Conf. Trace Elements in Soils and Crops, London, 1966.*)

91. The absorption of iron from chapattis made from wheat flour. By P. C. Elwood, I. T. Benjamin, D. Newton, D. A. Fry, J. D. Elkins, D. A. Brown (M.R.C. Epidemiological Unit, Cardiff), P. C. DeKock and U. Shah (M.R.C. Epidemiological Unit, Cardiff. (Submitted to *Am. J. clin Nutr.*)

92. Crop composition in relation to soil pH and root cation-exchange capacity. By W. M. Crooke and A. H. Knight. (Submitted to *J. Sci. Fd Agric.*)

93. The invasion of pea roots (*Pisum sativum* L) by soil micro-organisms *Acanthamoeba palestinensis* (Reich) and *Pseudomonas* sp. By J. F. Darbyshire and M. P. Greaves. (Submitted to *Siol Biol. Biochem.*)

94. Biological transformation of microbial residues in soil. By D. M. Webley and D. Jones. (To appear as Chap. 15 of *Soil Biochemistry*. Vol. II. Edited by A. D. Maclaren and J. J. Skujins. New York: Dekker.)

95. A phosphate sorption index for soils. By B. W. Bache and E. G. Williams. (Submitted to *J. Soil Sci.*)

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

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

98. Sulphur in soil organic substances. By G. Anderson. (To appear in *Enclyopedia of Soil Science*. Edited by J. E. Gieseking. Vol. 2. Sect. C. Berlin: Springer.

99. Determination of ammonium in Kjeldahl digests of crops by an automated procedure. By W. M. Crooke and W. E. Simpson. (Submitted to *J. Sci. Fd Agric.*)

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

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

101. Nutrient status of alfalfa showing poor growth on some Alberta soils. By G. R. Webster (University of Alberta, Canada) and P. C. DeKock. (*Can. J. Pl. Sci.*, **50**, 277-282, 1970.)

102. The mineral nutrition of plants supplied with nitrate and ammonium nitrogen. By P. C. DeKock. (pp. 39-45 of *Nitrogen Nutrition of the Plant*. Edited by E. A. Kirkby. Leeds: Waverley Press. 1970.)

103. Active and passive transport of potassium in cells of excised pea epicotyls. By A. E. S. Macklon and N. Higinbotham (Washington State University, U.S.A.). (*Pl. Physiol., Lancaster*, **45**, 133-138, 1970.)

(D) *Publications of Mr W. A. Mitchell*

104. Calcined cold-precipitated hydrated iron oxide. By W. A. Mitchell. (*Min. Engng*, **5**, 904, 1953.)

105. Oriented-aggregate specimens of clay for X-ray analysis made under pressure. By W. A. Mitchell. (*Clay Miner. Bull.*, **2**, 76-78, 1953.)

106. A double focusing X-ray powder camera. By W. A. Mitchell. (*Clay. Miner. Bull.*, **3**, 36-39, 1956.)

107. A method for quantitative mineralogical analysis by X-ray powder diffraction. By W. A. Mitchell. (*Mineralog. Mag.*, **32**, 492-499, 1960.)

108. Mineralogy (of interbasaltic rocks). By W. A. Mitchell. (pp. 115-117 of *Tertiary lava succession in the northern part of the Antrim plateau*. By E. M. Patterson. *Proc. R. Ir. Acad.*, **57B**, No. 7, 1955.)

109. The red glacial drift deposits of north-east Scotland. By R. Glentworth, W. A. Mitchell and B. D. Mitchell. (*Clay Miner. Bull.*, **5**, 373-381, 1964.)

110. The mineralogy of some Scottish sedimentary rocks. By W. A. Mitchell and B. D. Mitchell. (Paper given to the Geology Section, British Association for the Advancement of Science, Aberdeen Meeting, 1963. Abstract: *Advmt. Sci.*, **20**, 447, 1964.)

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

112. A review of the mineralogy of Scottish soil clays. By W. A. Mitchell. (*J. Soil Sci.*, **6**, 94-98, 1955.)

113. The clay mineralogy of Ayrshire soils and their parent rocks. By B. D. Mitchell and W. A. Mitchell. (*Clay Miner. Bull.*, **3**, 91-97, 1956.)

114. Mineralogical aspects of soil formation on a granitic till. By W. A. Mitchell. (*Proc. int. Clay Conf., Stockholm, 1963*, 131-138, 1963.)

115. Methods of mineralogical analysis of soils. By W. A. Mitchell. (pp. 49-52 of *Lectures given at the First Meeting of the International Study Group on Soils, Cambridge, England, 1964*. 1967.)

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

117. Infrared, X-ray and thermal analysis of some aluminium and ferric phosphates. By E. Z. Arlidge (D.S.I.R. Soil Bureau, Christchurch, New Zealand), V. C. Farmer, B. D. Mitchell and W. A. Mitchell. (*J. appl. Chem.*, **13**, 17-27, 1963.)

118. An investigation into the caking of granular fertilizers. By W. A. Mitchell. (*J. Sci. Fd Agric.*, **9**, 455-456, 1954.)

119. A plate method for studying the breakdown of synthetic and natural silicates by soil bacteria. By D. M. Webley, R. B. Duff and W. A. Mitchell. (*Nature, Lond.*, **188**, 766-767, 1960.)

120. Studies on the basaltic soils of Northern Ireland. IV. Mineralogical study of the clay separates ($<2\mu$). By D. M. McAleese (School of Agriculture, Cambridge) and W. A. Mitchell. (*J. Soil Sci.*, **9**, 76-80, 1958.)

121. Studies on the basaltic soils of Northern Ireland. V. Cation-exchange capacities and mineralogy of the silt separates (2-20μ). By D. M. McAleese (School of Agriculture, Cambridge) and W. A. Mitchell. (*J. Soil Sci.*, **9**, 81-88, 1958.)

122. The mineralogy of some soils from central Italy. By C. Lippi-Boncambi (University of Perugia, Italy), R. C. Mackenzie and W. A. Mitchell. (*Clay Miner. Bull.*, **2**, 281-288, 1955.)

123. The mineralogy of some Ceylon soils. By F. S. C. P. Kalpagé, B. D. Mitchell and W. A. Mitchell. (*Clay Miner. Bull.*, **5**, 308-318, 1963.)

124. Turkish forest soils. By W. A. Mitchell and A. Irmak (University of Istanbul, Turkey). (*J. Soil Sci.*, **8**, 184-192, 1957.)

125. Some granitic and andesitic soils in north-west Turkey. I. General description of the soils. By A. Irmak and F. Gulçur (University of Istanbul, Turkey) and W. A. Mitchell. (*Agrochimica*, **11**, 176-183, 1967.)

126. Some granite and andesitic soils in north-west Turkey. II. Analytical and mineralogical studies. By A. Irmak and F. Gulçur (University of Istanbul, Turkey) and W. A. Mitchell. (*Agrochimica*, **11**, 237-245, 1967.)

AGRICULTURAL RESEARCH INSTITUTES IN GREAT BRITAIN

The research programmes of the following agricultural research institutes supported by public funds are co-ordinated by the Agricultural Research Council. These institutes generally publish annual or periodical reports summarizing the research work that is in progress. Full details can be obtained from the secretaries of the institutes concerned.

A.R.C. Institutes

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Institute of Animal Physiology	Babraham, Cambridge, CB2 4AT.
Institute for Research on Animal Diseases	Compton, Newbury, Berks.
Food Research Institute	Colney Lane, Norwich, NOR 7OF.
Meat Research Institute	Langford, Bristol, BS18 7DY.
Poultry Research Centre	King's Buildings, West Mains Road, Edinburgh, EH9 3JS.
Letcombe Laboratory	Letcombe Regis, Wantage, Berks.
Weed Research Organisation	Begbrooke Hill, Sandy Lane, Yarnton, Oxford, OX6 1PF.

State-aided Institutes (Scotland)

Animal Diseases Research Association	Moredun Institute, 408 Gilmerton Road, Edinburgh, EH17 7JH.
Hannah Dairy Research Institute	Ayr, Scotland.
Hill Farming Research Organisation	29 Lauder Road, Edinburgh, EH9 2JQ.
Macaulay Institute for Soil Research	Craigiebuckler, Aberdeen, AB9 2QJ.
National Institute of Agricultural Engineering (Scottish Station)	Bush Estate, Penicuik, Midlothian.
Rowett Research Institute	Bucksburn, Aberdeen, AB2 9SB.
Scottish Horticultural Research Institute	Invergowrie, Dundee, DD2 5DA.
Scottish Plant Breeding Station	Pentlandfield, Roslin, Midlothian.

State-aided Institutes (England and Wales)

Animal Virus Research Institute	Pirbright, Woking, Surrey.
East Malling Research Station	East Malling, Maidstone, Kent.
Glasshouse Crops Research Institute	Worthing Road, Rustington, Littlehampton, Sussex.
Grassland Research Institute	Hurley, Maidenhead, Berks, SL6 5LR.
Houghton Poultry Research Station	Houghton, Huntingdon, PE17 2DA.
John Innes Institute	Colney Lane, Norwich, NOR 7OF.
Long Ashton Research Station	Long Ashton, Bristol, BS18 9AF.
National Institute of Agricultural Engineering	Wrest Park, Silsoe, Beds.
National Institute for Research in Dairying	Shinfield, Reading, Berks, RG2 9AT.
National Vegetable Research Station	Wellesbourne, Warwick.
Plant Breeding Institute	Maris Lane, Trumpington, Cambridge, CB2 2LQ.
Rothamsted Experimental Station	Harpenden, Herts.
Welsh Plant Breeding Station	Plas Gogerddan, Aberystwyth, Cardiganshire, SY23 3EB.
Wye College, Department of Hop Research	Ashford, Kent.