No. ______

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
TOPICAL REPORT NO. 58

FOR DEPARTMENTAL USE ONLY
NOT TO BE QUOTED AS A PUBLICATION

VISITS TO ORGANIZATIONS CONCERNED WITH MINERALOGY, PETROLOGY, ISOTOPE ANALYSIS AND ANALYSIS OF ROCKS AND MINERALS

Great Britain and Northern Europe - Autumn 1961

BY
S. C. ROBINSON

OTTAWA
1962

Geological Survey of Canada

Topical Report No. 58

by

S.C. Robinson

ERRATA

Due to the author's bad writing and to an error in the M.S. used for cutting stencils, a very large number of errors, some of them ludicrous, appear in this report. The more serious of these are noted hereunder. For the sake of brevity corrections are in order of page, paragraph, line, incorrect word and correct word, (e.g. "18, 2, 5, regrettable, vegetable" means "on page 18, paragraph 2, line 5, for 'regrettable' substitute 'vegetable'").

1, 2, 2	insert 'visited' after 'period'
1, 2, 6	Hegan, Hegau
4, 3, 2	Hegan, Hegau
5, 4, 3	Dr. H.N. Wiik, Dr. H.B. Wiik
7, 3, 1	insert a comma and 'the' after 'Brussels'
10, 2, 1	analogues, analogous
15, 2, 2	even, ever
18, 2, 1	chains, chairs
18, 2, 5	regrettable, vegetable
21, 3, 3	Geiger, Geijer
27, 3, 5	Arkir, Arkiv
28, 4	delete 6th and 7th lines
29, 4, 1	Cohen, Cahen
37, 1, 10	delete repetitive wording

38, Table I, 3	Under H_2O+ substitute "Penfield" for "Classic Wet"
39, Table I, 1	Er_2O, Cs_2O
39, Table I, 4	carbizide, carbazide
40, 1, 4	capitol, capital
40, 3, 2	Finildioxim, a-Furildioxime
40, 4, 4	8-Hydroxy-quinoline, 8-Hydroxyquinoline
41, 6, 3	$ZrMoD_4$, $ZrMoO_4$
43, 5, 6	Eriokeomcyanin, Eriochromcyanin-R
44, 1, 10	insert 'not' after 'does'.
44, 1, 10	differentiation, different
45, 8, 1	thermal balance, thermobalance
46, 2, 3	interpreted, interrupted
46, 2, 4	seems, serves
46, 5, 1	in, is
47, 1, 3	Landerglen, Landergren
47, 1, 7	insert 'the' after 'that'
47, 3, 1	ued, used
49, 1, 1	Zu, Zn
50, 1, 1	and or, and/or
50, 1, 3	add 'spectroscopy' to end of line
50, 2, 1	iron-, non-
50, 3, 3	single, simple
51, 5, 2	my, by
53, 4, 5	even, ever

55, 1, 2	insert a comma after 'required'
55, 3, 3	Milleman, Millman
57, 4, 1	thermal balance, thermobalance
58, 1, 1	Pd:An, Pb:Au
58, 1, 2	Melthey, Matthey
58, 5, 3	dept, kept
58, 6, 3	Rubr, Ruhr
61, 2, 3	Coast, Cost
63, 4, 2	Norari, Notari
69, 4, 4	859, 850
74, 5, 2	insert 'valves' after 'vacuum'
76, 2, 2	Mines, Mmes.
77, 2, 4	pressed, passed
90, 2, 2	Stuntevant, Sturtevant
90, 5, 4	powdered, power-driven
94, 5, 1	and, an
95, 3, 2	halves, haloes
98, 2, 2	acinite, acmite
99, 3, 2	canerinite, cancrinite
99, 4, 3	acinite, acmite
100, 2, 5	Lane, Laue
100, 3, 3	springs, spacings
101, 2, 5	5.42, 42.5
101, 6, 2	Buinier, Guinier
102, 4, 2	Hegan, Hegau
102, 4, 2	Censtance, Constance
109, 1, 5	Te/Rb, Tl/Rb
109, 1, 8	Radios, Ratios
112, 2, 2	peripherical, peripheral

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

TOPICAL REPORT No. 58

VISITS TO ORGANIZATIONS CONCERNED WITH MINERALOGY, PETROLOGY, ISOTOPE ANALYSIS AND ANALYSIS OF ROCKS AND MINERALS

GREAT BRITAIN AND NORTHERN EUROPE - AUTUMN 1961

by

S. C. Robinson

OTTAWA
1962

CONTENTS

INTRODUCTION

The trip was undertaken for the purposes of:

1. Reviewing research programmes in the fields of petrology, mineralogy, isotopic analysis and age determination, analysis of rocks and minerals and allied subjects;
2. Establishing personal contact with overseas research personnel;
3. Obtaining details of laboratory procedures and equipment;
4. Of studying administration and organization of research projects; and
5. Obtaining data on laboratory design, flowsheets etc.

Among subjects of particular interest to the writer were opinions on the interpretation of age determinations, the quantitative determination of the mineral composition of rocks, and the integration and statistical evaluation of quantitative data in mineralogical and petrological studies. It was found however, that development in these three fields was no further advanced than in Canada.

The writer was away from Ottawa a total of 60 days from 22 August to 20 October, and in this period more than 80 scientists in 35 institutions in 9 countries of northern Europe. The institutions visited were Universities and Government Surveys and Research organizations. In addition the opportunity was taken of joining the annual field trip of the German Mineralogical Society in the Hegan district on the Swiss border.

The summer holidays of Universities in France and Germany extend into October and September is a popular month for meetings of Geological Societies in Europe. The autumn, therefore, is not a satisfactory season to visit Geological departments of European Universities. Many geologists are away in the field during the summer, and air travel in winter is subject to delays. The concensus of opinion therefore is that the best period to visit geological institutions in Europe is from February to April.

In planning the trip advice of other scientists in the department was invaluable. This was supplemented by very useful suggestions from former post-doctorate fellows and of European scientists who had visited the Geological Survey. Once the principal institutions to be visited were selected, a tentative itinerary was drawn up arbitrarily and arrangements were made by writing to the Directors of the various departments and institutes. In some cities arrangements for visits to two or three institutes were coordinated through the kindness of an acquaintance in one of them. Length of visits exceeded one day in fewer than half of the institutions visited, because of the imposition on the time of those being visited. The itinerary was made sufficiently flexible that an additional half day could usually be arranged by change of flight or train reservations. Hotel reservations were made by a travel agency in Ottawa and were unsatisfactory in nearly half the cities visited. It would be preferable to ask for recommendations with respect to hotels when writing for appointments.

Scientists and Institutions Visited

Date	City	Institution and Address	Scientists
31 Aug.-2 Sept.	Amsterdam	Vrije Universiteit, De Lairessestraat 142.	Professor W. Uytenbogaardt
		University of Amsterdam, Nieuwe Prinsengracht 130.	Professor W.P. DeRoever
		Nuclear Research Laboratory,	Dr. Boelrijk
2 Sept.-4 Sept.	Brussels	Musee Royale de l'Afrique Central, Tervuran.	Prof. L. Cahen
		Service de Physique Nucleaire, Universite Libre de Bruxelles, Avenue F.D. Roosevelt, 50	Professor E. Picciotto
		Inst. Royal de Sciences Naturelles, Rue Vautier 31.	Dr. P. Sartenaer Dr. Van Tassel
4 Sept.-9 Sept.	Paris	Bureau de Researches Geologiques et Minieres, 74, Rue de la Federation.	Dr. C. Guillemin Ing. Capitant Dr. Laffitte
		University of Paris, Sorbonne.	Professor Hocart
		Museum National d'Historie Naturelle, 60 bis boulevard Risso.	M.J. Prouvost
9 Sept.-12 Sept.	Basle	University of Basel, Bernoullianum.	Professor J. Haller Dr. Vogt M.J. Hunziker

Date	City	Institution and Address	Scientists
12 Sept. - 14 Sept.	Bern	Institute of Physics, Physikalisches Institut der Universitat, Langgasstrasse 7.	Professor J. Geiss Dr. H. Oschger Dr. Goldberg
		Mineralogisch-Petrographisch Institut, Universitat Bern, Sahlistrasse 6.	Dr. E. Jaeger
14 Sept. - 16 Sept.	Tubingen	Mineralogisches Institut, Universitat Tubingen, Wilhelmstrasse 56.	Professor W. von Engelhardt Dozent Dr. S. Haussuhl Dr. G. Muller
16 Sept. - 17 Sept.	(Field Trip) Hegan		Dr. F.J. Eckhardt, Petrologist, Hannover
		Bundesonstallt fur Bodenforschung	Dr. G.A. Deicha Dr. E. Lippman Dortmund Dr. Walenta Stuttgart
18 Sept. - 19 Sept.	Gottingen	Sedimentpetrographisches Institut der Universitat Gottingen, Lotzestrasse 13.	Professor C.W. Correns Dozent Dr. H.K. Wedepohl Dr. H. Nielsen Dr. H.G. Bachmann

Date	City	Institution and Address	Scientists
19 Sept.-21 Sept.	Hamburg	Mineralogisches Institut, Grindelallee 48.	Professor T.A. Schrodel
21 Sept.-23 Sept.	Oslo	Mineralogisk-Geologisk Museum, Oslo University, Sarsgt. 1.	Professor T.F.W. Barth Dr. H. Neumann Dr. R.H. Filby Mr. Bruun Professor I. Oftedal Mr. Brynhi
27 Sept.-27 Sept.	Stockholm	Geologisk Museum, Frescati 50.	Dr. O. Gabrielson Dr. Per Geijer
		Geological Survey of Sweden, Stockholm 50.	Dr. J. Eklund Mr. B. Runnholm Dr. Gote Ostlund
		Stockholms Universitet, Drottninggatan 116.	Professor Sven Gavelin Dr. Rayment
27 Sept.-30 Sept.	Helsinki	Geologinen Tutkimuslaitos Otaniemi	Dr. Alti Simonen Dr. H.N. Wiik M.V. Hoffren
		Helsingin Universitat	Professor M.O. Saksela Dr. Waasjoki
30 Sept.-10 Oct.	London	Overseas Geological Surv., 64-78 Gray's Inn Road.	Dr. S.H. Shaw Dr. K.A. Davies Mr. T. Deans

Date	City	Institution and Address	Scientists
30 Sept. -10 Oct.	London	British Museum of Natural History, Cromwell Road.	Dr. M.H. Hey Mr. P. Embray
		Atomic Energy Division, Geological Survey of Great Britain, Young Street Office.	Mr. H.S.U. Bowie Dr. A.G. Damley Mr. J.E.T. Horne
		(Royal School of Mines) Imperial College of Science and Technology, University of London, Prince Consort Road.	Professor D. Williams Professor J. Sutton Dr. A.P. Millman Dr. I.S.E. Carmichael Dr. J.R. Butler Dr. G.P.L. Walker
	Cambridge	Department of Mineralogy and Petrology, Downing Place.	Professor W.A. Deer Dr. J.V.P. Long Dr. S.O. Agrell Mr. J.H. Scoon
		Department of Geophysics	Mr. J.A. Miller
		Department of Quarternary Research.	Dr. E.H. Willis
10 Oct. -13 Oct.	Oxford	Department of Geology and Mineralogy, The University.	Professor L.R. Wager Dr. E.A. Vincent Dr. B.W. Evans Mr. A.W.G. Kingsbury

Date	City	Institution and Address	Scientists
10 Oct. -13 Oct.	Oxford	Overseas Geol. Surv. Dating Group, 64-78 Gray's Inn Road	Dr. N. J. Snelling Mr. Eric Hamilton
16 Oct-17 Oct.	Manchester	Department of Geology, University of Manchester	Professor J. Zussman Dr. W. S. MacKenzie Dr. R. A. Howie
18 Oct. -20 Oct.	Aberdeen	Aberdeen University	Professor T. C. Phemister Dr. Fraser Dr. Munro
		Macaulay Institute for Soil Research	Dr. R. L. Mitchell

3-1 ADMINISTRATION, ORGANIZATION, BUILDINGS, ETC.

Information on the administrative organization of various Government Institutions and of Universities was obtained incidentally to discussions of other matters. In most instances therefore, it is brief and incomplete.

Belgium

Institut Royal de Sciences Naturelles
Musee Royal de l'Afrique Centrale
Universite Libre (Brussels)

In Brussels Free University, the Institut Royal de Sciences Naturelles (Dr. P. Sartenaer Sous-Director de Laboratoires), and the Musee Royale de l'Afrique Centrale, (at Tervuren), are all engaged in geological research. There seems to be some overlap in functions of the two latter organizations, both of which have extensive collections. The Institut Royal de Sciences Naturelles is housed in a magnificent new 19-storey building with a huge storage wing which is largely air-conditioned for proper storage of biological and other specimens. Luxurious offices, laboratories and public spaces in this building are unique in my experience. The Museum at Tervuren is housed in an erstwhile palace in magnificent grounds. It is being progressively renovated for its new use.

At the University, only the Nuclear Physics Centre under Professor Picciotto was visited. Here the laboratories are scattered in various basement rooms and special plastic hoods cover work in progress. Nevertheless these laboratories have made major contributions, and their staff members are able and enthusiastic. I was particularly impressed by the wide and productive scientific collaboration with Universities elsewhere in Europe and in the United States that has been initiated by Picciotto's group.

Finland

Geological Survey of Finland

The Geological Survey of Finland is in a new functional building at Otaniemi, approximately 10 miles from Helsinki. It is one of a group of laboratory and research buildings scattered through the forest. Roads leading to these buildings are narrow and not landscaped so that on a first visit one wonders whether the taxi-driver knows his way.

The Finnish Survey is a vigorous organization which has been given strong government support as a result of its contributions to the discovery of several flourishing mines in the post war period. In mentioning this, Dr. Simonen stressed the importance of embodying the prospecting functions of government in the Geological Survey. It is estimated that another 60 years will be required at the present rate to complete mapping at a scale of 1:100,000. Emphasis is on production of geological maps but a considerable number of project studies are also undertaken. They use university students as field assistants in much the same way as we do. However, the whole country is well served by roads, so that little use is made of aircraft.

They are organized in 4 departments:

1. Petrology - primarily Precambrian mapping and includes mineralogical and petrological studies.
2. Ore Department - which is the prospecting arm and combines Economic Geology and Geochemistry.
3. Pleistocene Department - with which the radiocarbon laboratory is associated.
4. Chemical Department - which includes most of the laboratories.

The Geological Survey of Finland seemed to be more similar to the Geological Survey of Canada in all aspects than any other organization that I visited.

University of Helsinki

The University of Helsinki has departments of Geology and Palaeontology and of Geology and Mineralogy. The latter under Professor Saksela has Professor Rankama and Sehama on its staff. The building is old but ornate and is to be evacuated by geology in favour of a discipline to which its architectural design is better suited.

France

Bureau de Recherches Geologiques et Minieres

In France there is no geological survey analogues to the G.S.C. Apart from areal mapping, the institution most closely resembling ours is the Bureau de Recherches Geologiques et Minieres which combines many functions of the Canadian Geological Survey, Mines Branch, Mineral Resources Division and Crown Companies such as Eldorado Mining and Refining. A complete listing of this organization was given to me and is now in the library under the title "Bureau de Recherches Geologiques et Minieres - Organization des Services".

Its President is M. Pre, Governor of France d'Outre Mer, and it is directed by an administrative council made up of officers of state, of commercial organizations and of University professors etc. It has also a guiding scientific committee made up of professors and officers of various research groups.

The B.R.G.M.'s technical responsibilities may be divided into two main groups.

(i) Geology and Prospecting

(ii) Technical Assistance and Missions

Geology and Prospecting has 5 divisions:

1. Geology Department; Mr. Castany, Chief, comprising water resources, general and sedimentary geology, geology of coal, geology applied to nuclear energy, hydrogeology, engineering geology and geological information.
2. Mining Geology Department; Mr. Lambert, Chief.
3. Geophysics Department; Mr. Bollo, Chief, comprising gravity, subsurface geophysics, special studies and topographic and cartographic studies.
4. Department of Statistical Evaluation of Deposits; Mr. Matheron, Chief.
5. Laboratories Department; Mr. Guillemin, Chief, comprising chemistry laboratories, geochemistry laboratories, mineralogy, study of deposits, crystalline petrography, and geochemical prospecting.

Although the larger part of this group is situated in Paris, it has associated laboratories in Nancy and Clermont-Ferrand, and branch offices throughout France and its overseas territories. Through its scientific committee the B.R.G.M. is kept in close touch with the Geological Mapping Service of France, the Agricultural Research laboratories, the main Universities and the Research Centre for studies of the Sahara. Activities of the metallurgical research, collaboration with and assistance to private companies etc. were not discussed.

National Mineral Collection

The handsome building housing the magnificent national mineral collections of France, has been closed for repairs for some time and the mineralogical laboratories attached to it (Professor Orcel) appear to be in need of modern equipment.

University of Paris (Sorbonne)

Geological visitors to the University of Paris (Sorbonne) may not realize that in addition to the extensive laboratories at 1 rue Victor Cousin, there are also laboratories in Applied Geology under Dr. G.A. Deicha at the Centre National de la Recherche Scientifique at 191 rue Saint-Jacques. Unfortunately I learned of them only when I met Dr. Deicha in Germany.

Another institution worth visiting in Paris is "L'Ecole Superieure des Mines de Paris", which is devoted primarily to applied science studies.

Germany

University of Gottingen

Geology at the University of Gottingen is divided into three Institutes, partly to facilitate raising funds and partly to provide chairs for full professors. The three institutes are: Mineralogy and Crystallography, Mineralogy and Petrology, and Sedimentary Petrology. It is expected that in the near future an Institute of Geochemistry will be added. Although the mass spectrometer laboratory is the only new building at Gottingen, I was impressed by vigour of the staff and the high calibre of the research being done.

University of Hamburg

The new Institute of Mineralogy and Petrology at the University of Hamburg is housed in its own modern laboratory building. This building is undoubtedly the best designed functionally of all those that I saw on this trip. Certainly any Canadian University contemplating a new Geology building would be well advised to obtain plans from the University of Hamburg. The Institute specializes in crystallography, crystal physics, geochemistry and physical chemistry. Separate analytical laboratories are provided for geochemistry. I did not visit the Institute of Geology and Palaeontology.

University of Tubingen

At Tubingen the original University buildings are in the old castle that dominates the town. The meetings however were held in the exceptionally spacious and handsome administration building, now about 100 years old. The Mineralogical Institute shares a modern and well-equipped new building with the Institute of Chemistry. There is a separate Institute of Geology and Palaeontology.

Great Britain

British Museum (Natural History)

The British Museum (Natural History) has one of the World's finest collections of rocks, minerals and meteorites. Research is governed largely by interests of individual members of staff. X-ray equipment is very good indeed but other laboratories are not impressive. No mention was made of collaboration with the Geological Survey of Great Britain. Apparently the Museum functions in part as an independant research institute.

Geological Survey of Great Britain

The Atomic Energy Division was the only branch of the Geological Survey of Great Britain visited on this trip. It is almost wholly separated from the main Survey both in location and in functions, and salaries of its staff are paid by the Atomic Energy Authority.

Work of this division has been reduced as interest in sources of uranium, thorium and beryllium has subsided. Had the division been established at a later date, it is probable that it would have been assigned to the Overseas Geological Surveys with which it has very much more in common that it has with its present parent body.

Field work of the division has been primarily in Commonwealth countries, largely in Africa. Its mineralogical and analytical laboratories are modern and its dwindling staff is composed of a very able mineralogists and petrologists. It has plans for a geochronological laboratory that would parallel those of the Overseas Geological Surveys.

My understanding is that other divisions of the Geological Survey are devoted to local studies in Great Britain in even greater detail. The association of a museum with the Geological Survey and its relationship to the British Museum (Natural History) was not ascertained.

Imperial Institute

No attempt will be made here to unravel the many schools that constitute the University of London. Only Imperial College of Science and Technology was visited. There geology is taught in the College of Science and in the Royal School of Mines. The latter course is equivalent to courses of Geology in Applied Science faculties in Canada. The combined resources of Imperial College comprise the largest and most comprehensive department of Geology in Great Britain.

Macaulay Institute for Soil Sciences

The Macaulay Institute for Soil Research at Aberdeen is possibly the World's best known organization in its field. It is a private company but has been given extensive financial support from Public funds.

It is interesting to learn that in administration and personnel matters, it is modelled on the Civil Service. It has a staff of 150 of whom 50 are university graduates. Its chief fields of research are Pedology, Soil Survey (whose maps look very like our Pleistocene maps), Biochemistry, Spectrochemistry, Plant Physiology, Microbiology and Soil Fertility.

The Institute was established in the house and outhouses of a large estate. Its large new building was occupied about a year ago and is being extensively enlarged at present. Cost of the whole building, including access roads, was 7:0:0 per square foot. The building is primarily functional in design and has two floors and a basement. Its machine shop has a floor space of 40' x 40' with adjoining space for offices, stores etc.

Overseas Geological Survey

The Overseas Geological Surveys are in new quarters at 64-78 Gray's Inn Road. This organization is supported by the United Kingdom to provide specialized services to the geological surveys of the smaller overseas territories. It collaborates with the ore-dressing and mineral processing laboratories of the Department of Scientific and Industrial Research at Warren Springs, Stevenage, with the British Museum (Natural History) and with the Geological Survey of Great Britain to provide services that are not available in its own organization.

It is subdivided into three main divisions.

1. Mineral Resources Division, which maintains modern chemical, mineralogical, spectrographic, X-ray and ceramic laboratories;

provides a mineral intelligence service in fields of statistics, mining law, technological development and marketing trends; and through collaboration with Warren Springs provides ore dressing investigations. Laboratories of the division itself are notable for their progress in mineral separation.

2. Photogeological Division, which provides interpretations and prepares reconnaissance geological maps from air photographs in collaboration with Overseas Geodetic and Topographic Surveys. Officers of this division travel to various territories and coordinate this work with visits to the field.

3. Geophysical Division provides standard ground geophysical equipment and staff for surveys in various territories as required.

In addition financial assistance is provided to a team of geologists working at the British Museum on identification of palaeontological material from overseas territories.

Two members of the staff have been seconded to the geochronological laboratories of Oxford University and provided with the necessary equipment to supply age determinations required by Geological Surveys in the Territories.

Bursaries are provided for work on the Geology and Geochemistry of various territories by University staffs and others.

University of Aberdeen

At Aberdeen University there is a single department of Geology. It is housed in one wing of the main University building and seems to need more space for laboratories and research.

University of Cambridge

At the University of Cambridge, separate chains of Geology, Mineralogy and Petrology and Geography comprise the Faculty of Geology and Geography. Geophysics is in an old house called Madingley Rise on the Madingley road. Its mass spectrometer laboratory is established on the edge of the University farm and regrettable gardens are used for landscaping. The Radiocarbon laboratory is at 5 Salisbury Hill, Station Road and is part of the subdepartment of Quarternary Research of the Department of Botany. The department of Mineralogy and Petrology flourished under Professor Tilley and is well housed (at Downing Place) and well equipped.

University of Manchester

At the University of Manchester the department of Geology has excellent quarters and very good laboratories in a relatively new building. All geological sciences are combined in the one department.

University of Oxford

At Oxford all aspects of geology are taught in the department of Geology and Mineralogy. This department is closely associated with the Museum, where there is a curator of mineralogy. The department is housed in a substantial building to which many temporary additions have been made. These are to be torn down and a large new wing built to provide adequate laboratory space.

Netherlands

Nuclear Research Laboratories

In the Netherlands, nuclear research laboratories have been established as a state operated institute to serve all disciplines. Mass spectrographic analyses for purposes of geology are made by the laboratory and results are evaluated by geologists.

Universities in Amsterdam

In Amsterdam, there are two major universities; the older and larger University of Amsterdam and the state-operated Vrije University. Both have departments of Geology. The Vrije University is scattered in buildings throughout the city but a magnificent new campus is being developed on the outskirts.

Norway

Geological Museum

The most vigorous programme of research in Norway is being done in the Geological Museum at Oslo, founded by Goldschmidt and now directed by Professor Barth. The museum links to the University are tenuous and it appears to operate more as a research institute than as a museum. Fields of interest include petrology, mineralogy, geochemistry, ore deposits and radiochemistry. The last is being developed for them by Dr. Filby, a Canadian from McMaster. I also met Dr. Vokes who left the G. S. C. to join the Museum staff. The museum is generally well equipped and has an excellent rock analysis laboratory as well are various instrumental laboratories.

Geological Survey of Norway

The Geological Survey of Norway is in the process of moving from Oslo to Trondjheim. A few senior officers only were granted leave to remain in Oslo. As a result of the move, I was informed that a majority of the younger and abler geologists have left the Survey, with the result that at Trondjheim the man next in seniority to the Director is only 33 years of age.

University of Oslo

The Geology department of the University of Oslo under Professor Oftedahl is housed in a new building but is as yet primarily a teaching organization.

Sweden

Geological Survey of Sweden

In Stockholm, the Geological Survey of Sweden and the Museum are housed in opposite wings of a single building. The Geological Survey has a second adjacent building of 3 storeys that houses its laboratories. The laboratory organization is in three sections each with one floor of the laboratory building to itself: 1. Chemistry laboratories, which include wet and instrumental methods and X-ray diffraction and fluorescence; 2. Geochemistry which is wholly based on emission spectrography and 3. Geophysics, which combines prospecting methods with a soils laboratory.

The Radioactive Dating Laboratory which combines C^{14} and tritrium analysis is listed as part of the Geological Survey of Sweden but is in fact governed by a board of directors representing the Royal Academy of Antiquities, and the University of Stockholm as well as the Geological Survey. Part of its funds have been contributed directly from the King's private purse because of his personal interest.

I was interested to learn that the Swedish Survey binds all notebooks and catalogues them. It also retains and catalogues all field samples. Dr. Geiger an ex-Director told me that recently he required specimens from an area he had mapped 50 years previously and they were in his hands in an hour.

National History Museum

The National History Museum is a separate entity under the Royal Academy of Sciences. It has excellent geological collections but there is relatively little research being done in geology other than Dr. Wickman's work on age determination. Isotopic analyses for this are provided through Dr. Welin of the Atomic Energy Commission.

University of Stockholm

The University of Stockholm has separate departments of Mineralogy and Petrology and of General and Historical Geology. They are currently housed in old buildings but expect to have new buildings provided soon adjacent to the Geological Survey. There seems to be quite a high degree of collaboration and integration of work between the university and government departments.

Switzerland

University of Basel

Geology at the University of Basel is divided into two institutes which are both housed in one well appointed building. Despite this proximity, I received the impression that there is rather little collaboration between the two. The Institute of Geology comprises Palaeontology, Stratigraphy and Geophysics and the Institute of Mineralogy and Petrology is made up of mineralogy, petrology and chemical geology.

University of Bern

At the University of Bern there is an Institute of Geology, an Institute of Mineralogy and Petrology (Professor Niggli) and the Institute of Physics (Professor Houtermans). The latter two collaborate closely in the field of age determination, Dr. E. Jager doing the geology, chemistry, and mineralogy and Dr. Geiss and others doing the mass spectometry in the excellent new Physics Institute building. I was impressed by the coordination of research in this field between Swiss, Belgian and German Universities and the age laboratories of the Riksmuseum in Stockholm.

3-2 AGE DETERMINATION K/Ar, Rb/Sr, Zircon, Os/Re, etc.

In Europe, age determination is carried out largely on a cooperative basis. Geology, collection of samples and mineral segregation may be done by one organization, chemical preparation by another and the isotope analysis in yet another. It is difficult, therefore to discuss this field of endeavour coherently. In the following notes, mention will be made of K/Ar, Rb/Sr, Pb/U, Pb/Th, 'ore lead' Al/Be and Re/Os methods. Radiocarbon dating is described under a separate heading. Details of equipment are described under the heading of 'mass spectrometry'.

The Physics Institute at the University of Bern is a major centre for isotope studies and has carried out the isotopic analyses for several of the European scientists interested in geochronology. Methods in use at this institute are Pb/U including work on zircons, Rb/Sr and K/Ar. There are 6 mass spectrometers in use at the institute.

Currently Dr. E. Jäger of the Mineralogical and Petrological Institute at Bern is working on Rb/Sr and Pb/U dating of alpine rocks. She collects the specimens, concentrates the minerals and does the chemical separation but the isotopic analyses are done in the Physics Institute. Dr. Grünenfelder at Zurich is primarily interested in dating zircons. He does the mineral separation and chemistry but the isotope analyses are made at Bern. The Physics Institute now has a mineralogist, Dr. Grogler on staff for geochronological studies of Austrian rocks. The necessary chemical preparation and analyses for him will be done at Zurich.

Emphasis at Bern seems to be largely on zircon and on Rb/Sr dating. Relatively little work is now being done on K/Ar. Of particular interest is the work being done by Dr. Hirt on the Re/Os method using material from Professor Herr of the Max Plancke Institute. (It may be recalled that we supplied coeval uraninite and molybdenite from Bancroft to Professor Herr for his study). At present the half-life of the decay of Re^{187} is not sufficiently well established for the method to be reliable. While in Bern my attention was drawn to the possibility of using Al^{26}/Be^{10} ratios to determine age. Professor Lal at Bombay is investigating this possibility.

Lead isotopes are analyzed by a solid source mass spectrometer. Lead is deposited on a rhenium or tantalum filament as the sulphide from NH_4NO_3 solution and the lead must be extremely pure. Alternatively $Pb(NO_3)_2$ is evaporated to dryness and taken up in a drop of concentrated boric acid. This is dried to form a bead on a tantalum filament. A single filament is preferred to a triple filament to avoid possible impurities. Traces of Sn or Ti are found to seriously inhibit ionization from solid source filaments.

When dating mica by the Rb/Sr method, it has been found that the common strontium content of mica should be less than 1 microgram per gram of mica. Minute apatite needles in mica are the most common source of strontium contamination. In order to facilitate separation of Rb and Sr in the mass spectrometer, a second filament or heating unit is used to drive the rubidium well away from the source before analysis of the strontium is begun. Usually analyses of potassium, rubidium and strontium in that order are done on each sample in the mass spectrometer.

In the osmium/rhenium method, the chemical separation is done by Professor Herr. Total osmium and rhenium contents of samples are determined by neutron activation. Osmium is converted to osmium tetraoxide, a solid with a high vapour Pressure which is stable only in the presence of excess oxygen. The sample tube is sealed to the sample line of the mass spectrometer and the osmium tetraoxide is frozen down by liquid air and the oxygen pumped away. Osmium is then allowed to evaporate into the mass spectrometer at a temperature slightly above -78°C. Flow is controlled by temperature. Osmium tetraoxide is very active chemically and will oxidize most components of a mass spectrometer.

It is therefore allowed to be in contact only with glass, teflon and gold plated filaments. Usually a sample containing 100 micrograms of osmium is sufficient.

I was informed that Professor Rogues at Clermont-Ferrand is determining ages by the Rb/Sr method, and that nearly 200 dates on African samples will soon be published. This work is being done under the aegis of Bureau de Recherches Geologiques et Minieres.

In Amsterdam age determination has only recently been undertaken and work was in progress on zircons. Lead is expressed from zircons in a quartz tube centered in a graphite cylinder and heated in a high frequency induction furnace. Temperatures up to 2200°C. are used. The lead deposits on the walls of the quartz tube, and is applied to the solid source as PbS. All work is performed in the laboratories of the new National Nuclear Research Centre by Dr. Boelrijk and his assistants on samples supplied by University geologists.

In the same laboratories preparations are being made to determine the palaeotemperature of marine shells by measuring the isotope ratio of the oxygen (O^{16}/O^{18}) in their composition. It is expected that the shells will be burned at 900°C to yield CO_2.

Thermoluminescence is a possible means of determining the length of time rocks have been buried under a glacier. The method, which is being tested at Bern, is based on the fact that electron traps in minerals that are emptied at normal temperatures may be filled in the colder temperatures under the ice. The degree of filling is time dependent and may therefore be used to determine duration of burial under ice.

Dr. Wickman who has long been known for his interest in age determination, is senior curator of mineralogy in the Natural History Museum in Stockholm. He has cooperated in papers with Dr. Jäger and now does much of his work in collaboration with Dr. Welin of the Swedish Atomic Energy Commission who makes the isotopic analyses. Unfortunately Drs. Wickman and Welin were both away when I visited Stockholm.

A fairly large number of ore lead ages from Swedish deposits of Caledonian age have been computed by Wickman on 4 different mathematical models. Some of these check with Pb/U ages and with geological data but a larger number are anomalous. These results are to be published by Wickman and Jäger in the Arkir fur Mineralogie in 1962.

At Cambridge the new age laboratory is concentrating on K/Ar determinations. They have shown a great deal of initiative and have already determined ages on biotite, muscovite, amphibole, pyroxene, sanidine, feldspar, basalt and hornfels. A fairly extensive programme of dating micas from the Moyne Schists gave results that checked very well with work done independently by Rb/Sr at Oxford.

Using unground pieces of whole rock and fusing them directly with an induction furnace, they have obtained reasonable ages on known Carboniferous basalt and Precambrian hornfels from the Charnwood area (1000 m.y.). They are now going to try this whole rock approach on Charnwood syenite, on granite and on older basalt. Evidence so far suggests that fine-grained basalt yields better results than the coarse-grained facies.

They have evidence that suggests that argon in micas occupies 2 sites, one a high energy site and the other requiring only low energy to drive it off. They plan to test this by determining ages of micas in the Moyne Schists at various distances from the intrusive strontium granite to see whether they are transitionally lower as the granite is approached or if there is a step-like break in the curve.

A good many innovations in equipment have been developed at Cambridge and these will be described in the section under mass spectrometry. They are remarkably productive and had determined 61 K/Ar ages between June 1st and my visit to the laboratory on October 3rd.

In discussing the pattern of ages determined in Sweden, Dr. Eklund compared them with those of the Canadian Shield. In southwest Sweden ages are uniformly equivalent to the Canadian Grenville at about 1000 m.y. This group of ages have been determined on granites, on highly metamorphosed rocks, and on rocks of very low grade metamorphism. To the northeast this belt of ages have been determined on granites, on highly metamorphosed rocks, and on rocks of very low grade metamorphism. To the northeast this belt of ages gives place to a general age of about 1500 m.y. In this area, a few ages greater than 2000 m.y. may represent a third and older province.

Dr. Eklund pointed out that the Swedish 'Grenville', like that of Canada, contains abundant anorthosites with associated Fe-Ti deposits, whereas again as in Canada, the Swediah sedimentary iron deposits are in the older 1500 m.y. area.

In Finland, Dr. Simonen's studies of granites included a number of age determinations by the K/Ar, ore lead and zircon methods. He found that K/Ar ages are usually less than those of the other methods on minerals that on gological evidence are thought to be coeval. He cited two examples:

Pb method 2600 m.y. vs. K/Ar method 1600 m.y.

and from another rock, zircon age 2400 m.y. and K/Ar age 1600 m.y. He concludes that K/Ar ages give only the latest period of metamorphism and that argon is readily lost under the increased temperatures associated with metamorphism. He believes that zircon ages are likely to be the best method of dating formation of a granite.

Professor Cohen of the Musee Royale de l'Afrique Centrale near Brussels is interested primarily in age determination of rocks from the Congo and adjacent territories. Most of his work has been concerned with Pb/U dates from various uranium minerals and zircon. He has also found that 60% of ore lead dates are useful but does not trust them unless they agree with Rb/Sr dates. Rb/Sr dates have been measured on muscovite, biotite and whole rock. He believes that K/Ar ages serve only to date the latest period of metamorphism and said that he believes that the Canadian Shield is the only one that can be sub-divided on this basis.

He judges authenticity of Pb/U dates by the degree of concordance of the three ratios, but finds the Pb/Th ratio is usually anomalous. He does not believe that loss of radon is a factor in discordance of Pb/U ratios. In computing ore lead ages, he does not use the University of Toronto model. In general K/Ar dates on biotite are lower than those on muscovite.

In the Congo, Professor Cahen has established two consistent periods of intrusion at 520 and 625 m.y.

Professor Barth cited one example in which pegmatites had intruded granite and K/Ar ages (on biotite?) from the granite, decreased inward toward the intruding pegmatites.

Age determination is one of the services provided by the Overseas Geological Survey. This is done by arrangement with Oxford University where Dr. Snelling and Mr. Hamilton work in the University's laboratories, where St. Lambert and Moorbath have established a well-known geochronological centre. The laboratories are well fitted and are working primarily with K/Ar and Rb/Sr methods. A major recent paper is "A Geochronological Study of Metamorphic Complexes of the Scottish Highlands" by Giletti, Moorbath and Lambert.

Work being done by the Overseas Geological Survey has been largely in the K/Ar field so far. They are now preparing to date zircons and ore leads and Mr. Hamilton has established a very compact and ingenious line to extract and convert lead from feldspars so that there is no likelihood of lead contamination from the air or reagents. It is done in a teflon system using HF and Perchloric Acid to digest the rock or zircons. Lead is analyzed in a solid source mass spectrometer as PbS.

In their Rb/Sr work they have been concerned over the possibility of progressive fractionation of isotopes in the mass spectrometer. To avoid this, they have developed sintered tantalum filaments. These are made by placing a slurry of 1:1 Ta powder and Ta_2O_5 in water on a tantalum filament. This is evacuated in the mass spectrometer and heated by passing a 5-ampere current through it. Sintering is almost instantaneous.

They have also found trouble when liquid Rb/Sr standards are stored in polythene containers. Water loss is 0.16% in 70 days at room temperature. This is equivalent to concentration of Rb and Sr of 2% per year due to loss of water. In bottles that are only partly filled the loss is greater. All standards are now stored in quartz or glass containers.

3-3 AGE DETERMINATION - RADIOCARBON AND TRITIUM

Only 4 radiocarbon-laboratories were visited at:

Bern, Switzerland	(Dr. Oschger)
Cambridge	(Dr. Willis)
Otaniemi, Finland	(Dr. Hoffren)
Stockholm	(Dr. Ostlund)

At Bern the laboratory is in the basement of the new Physics Institute building and therefore benefits from 5 floors (160 cm. of concrete) of shielding from cosmic radiation. As a result in a counter having a sensitive volume of 1.5 litres with acetylene at 1 atmosphere pressure, the background count is only 0.6 c.p.m.

No ring of anti-coincidence tubes is used in this counter. Instead there is an inner and an outer shell that is so designed that external pulses are not counted. This counter is described in Helvetia Physica Acta, Vol. XXXI, pp. 117-126, (1958). The main 'castle' is built of lead rather than iron bricks which reduces the space required. In addition, lead is used instead of mercury as an inner shield. Oschger believes that bismuth would be the best inner shield.

Although acetylene is presently the form in which the C^{14} is counted, Oschger believes that methane will prove to be much more efficient because it can be counted safely at higher pressures (5 atms.) and because it has much better counting characteristics. It will tolerate 1000 times as much impurity as will CO_2. With a 5 litre counter now being designed, filled with methane at 5 atm. it is expected that it will be possible to determine ages as great as 60,000 years without enrichment.

Tritium from meteorites is also measured in this laboratory, in the form of ethane. The ethane is made by mixing hydrogen and ethylene and circulating the mixture over a palladium catalyst at 200°C.

At Cambridge the radiocarbon laboratory is in a single storey prefabricated building that provides virtually no intrinsic shielding. The 'castle' and inner shields are standard except that Willis believes that lacking shielding from the building, paraffin shielding is useless. Radiocarbon is counted as CO_2 at 3 atmospheres pressure in a counter having a sensitive volume of 1.1 litres. In this counter the background count is

8 c.p.m. and modern wood is 17 c.p.m. A new 2-litre counter was nearly ready for operation at the time of my visit.

Rather than storing their samples as CO_2, they burn them in oxygen to yield CO_2 and the CO_2 is then precipitated as $BaCO_3$ in which state it is stored. When it is to be counted, the CO_2 is liberated by dissolving the $BaCO_3$ in H_3PO_4. The resulting CO_2 is then purified and led into the counter.

Willis is particularly pleased with the anti-coincidence tubes made by Twentieth Century Electronics, New Addington, Croydon, Surrey. Before use he checks these with a ratemeter and has found they have a long flat plateau of 250-300 volts. He refills his own tubes and can replace all of them in one week.

The laboratory is working mainly on samples provided by the University's sub-department of Quarternary Research. Studies include changes in sea level; late glacial movements, recurrent surfaces in peat bogs, (here a cyclic process of 600 years duration is indicated); bomb carbon monitoring and the time for atmospheric equilibrium to be achieved.

At Otaniemi, the radiocarbon laboratory is a part of the Pleistocene Department of the Geological Survey of Finland. It is in the basement of a modern concrete building with about 5 floors above it. Compared with other castles that I had seen, I thought the one in this laboratory was rather lightly built and that its geometry could be much improved. The laboratory is only recently installed and is to use the

De Vries type of counter. Their present counter has a sensitive volume of 1 litre and counts CO_2 at 3 atm. For reasons as yet not ascertained, they have a high background of 13 c.p.m. and a net modern wood count of 17.3 c.p.m.

In a rather hurried visit, I was not able to discuss details with Dr. Hoffren. However, I understand that their work is very largely devoted to geological samples collected by Survey personnel.

The Swedish radiocarbon laboratory is housed in the basement of the Natural History Museum and is the largest laboratory visited by the writer. It has a board of governors on which the Geological Survey of Sweden, The Royal Custodian of Antiquities and the University of Stockholm each has 2 representatives. The seventh member is Dr. Ostlund, chief of the laboratory.

There are to be 4 radiocarbon and 1 tritium counters in three castles. The staff consists of Dr. Ostlund, 1 chemical engineer, 1 mechanical engineer and 2 technicians. In addition technical help in electronics is provided by the Nobel Institute. Samples analyzed are 35% geological, 35% archaeological, 15% for geophysics and 15% for paying customers. The board of governors decides what samples shall be counted.

Shielding from the large museum building is probably equivalent to 5 floors of concrete. The castles are standard, except that old lead (from a church roof 180 years old) is used in place of the inner mercury Shield, and this in the 1 litre counter, reduced background by 0.3 c.p.m.

Equally good lead for this purpose is Boliden's Laisvall A-bly. Inside the castle, each counter has its own ring of anti-coincidence tubes. CO_2 is counted at 3 atm. in both the present counters. In the 1 litre (effective volume) counter the background is 2.5 c.p.m. and background plus modern wood count rate is 18.5 c.p.m. In the 1/2 litre (effective volume) counter equivalent rates are 1.5 c.p.m. and 9.5 c.p.m.

Ostlund uses a quenching circuit housed inside the castle to reduce the large pulse that must otherwise be provided by the anti-coincidence tubes. This greatly increases the life of the tubes and stabilizes their plateaux so that all operate at the same voltage. He finds the HZ-100 cosmic ray counters, 33 mm. diameter, 1000 mm. long made by Zentralwerkstaat, Bunsenstrasse 10, Göttingen, W. Germany at 100 D.M. each are very satisfactory.

Ostlund's choice of CO_2 is determined principally by the likelihood of carbon isotope fractionation in the preparation of acetylene or methane and the fact that this cannot be checked in the mass spectrometer as CO_2 can. A further disadvantage of methane is that it has a vapour pressure of 4 to 10 mm. of mercury at liquid air temperature.

Ostlund believes that the Oschger type of counter may be capable of extending the range of age by about 1 half-life over the standard counter with anti-coincidence tubes. He noted too, that construction from poor material makes less difference with the Oschger counter than with the standard one. He estimates that if ages of 40,000 - 45,000 years can be determined on 2 gm. of carbon in a standard counter, ages of 45,000 -

50.000 years may be possible on 4 gm. of carbon on an Oschger counter Where sample material is abundant therefore, the Oschger counter may be an advantage. However, Ostlund pointed out that in samples giving ages greater then 40,000 years, the limiting factor is not so much the technique used, as the uncertainty as to whether the whole of the very small amount of C^{14} being measured is in fact residual, or whether there has been contamination through geochemical or biogeochemical processes by later C^{14}.

There is a growing demand for tritium analyses from this laboratory by engineering geology for tracing water flow, for determining replenishment of fossil groundwater supplied for determining sources of groundwater, and for combined meteorological groundwater research, to determine partition of water in the troposphere, atmosphere and in the Earth, to determine rate of evaporation and the partition between rain fall going into streams and into groundwater etc.

5.4 ANALYTICAL METHODS - CHEMICAL AND INSTRUMENTAL

It was not practicable to record details of all the methods in use for elemental analysis of geological materials. It is the purpose of this section of the report to draw attention to various methods in use and to give skeletal outlines of the procedures used in some of the principal laboratories carrying out rock and mineral analyses. Special precautions and methods for extraction of lead and its preparation for isotope analysis are treated under a separate heading.

Procedures for Rock Analysis

The general procedures for the various components of a complete or partial rock analysis by various laboratories are shown in abbreviated form in Table 1. There is a considerable divergence of opinion as to accuracy and speed resulting from use of the various methods. In general Mr. Bruun, Mr. Scoon, and Dr. Wiik prefer the classical wet methods of rock analysis and turn out a good volume of analyses. Younger and as yet less well-known analysts tend to use the rapid methods of Shapiro in Scandinavia and of J. P. Riley in England. There is little doubt that accuracy of the various rapid and intrumental methods is approaching and instrumental methods is approaching and even exceeding that of the classical methods for some components.

Dr. Wiik believes that he can turn out analyses by the classical methods as fast as they can be done by rapid methods. On the other hand it is claimed that Dr. Riley's rapid methods are 5 to 6 times as fast as the classical methods. An interesting comparison on accuracy of the classical methods compared with rapid methods introduced by J. P. Riley was made by Mr. Bradshaw, a graduate student at the University of Manchester. The method giving best results is listed for each element in Table 1 against his name. Dr. Bernard Evans at Oxford expressed the opinion that Riley's rapid methods are now slightly more accurate than classical methods.

TABLE I

Laboratory (Analyst)	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	$H_2O^{\pm}$
Geol. Surv. Finland (H.B. Wiik)	Wet Anal.	Wet Anal. (by difference)	Wet Anal. $KMnO_4$, Zn etc.	Wet Anal. Classic	Wet Anal. NH_4HPO_4 etc.	Wet Anal. $CaCO_3$ at 520°	Wet Anal. or flame phot.	Wet Anal. or flame phot.	Penfield
Geol. Museum Oslo (Mr. Bruun)	Classic Wet	Classic Wet	Classic Wet	Classic Wet	Classic Wet	Classic Wet	Classic Wet	Classic Wet	Classic Wet
Cambridge (J.H. Scoon)	Wet Anal.	Wet Anal. (by difference)	Ag. reductor $CuSO_4$ etc.	HF + NH_4VO_4 etc.	Classic Wet	Classic Wet	Flame phot.	Flame phot.	Penfield
Manchester (Bradshaw)	Combined Grav. & Photom.	R.M.* in duplicate	R.M.	Wet Anal.	R.M.	Classic Wet	Flame phot.	Flame phot.	Penfield
Tubingen	---	Flame phot. need Correction	---	---	Classic Wet	Classic Wet	Flame phot.	X-ray	---

* R.M. are methods of J.P. Riley (Liverpool). Mr. Bradshaw ran tests and the methods listed here are those he found more accurate as between R.M. and classical wet method.

TABLE I (cont'd.)

Laboratory (Analyst)	TiO_2	MnO	P_2O_5	S	CO_2	BaO	Rb_2O Er_2O	
Geol. Surv. Finland (H.B. Wiik)	Colour H_2O_2	Colour KIO_4	Wet Anal. molybdate	Grav. as $BaSO_4$	Grav.	Spectr.	Flame phot.	---
Geol. Museum Oslo (Mr. Bruun)	Classic Wet	Classic Wet	Classic Wet	Classic Wet	Classic Wet	Classic Wet	Classic Wet	
Cambridge (J.H. Scoon)	Colour H_2O_2	Colour KIO_4	Colour NH_4 vanadate & molybdate	Fuse NA_2CO_3 Grav. as $BaSO_4$	Grav. by absorption	---	---	Cr_2O_3 Colour diphenyl carbizide?
Manchester (Bradshaw)	R.M.	R.M.	---	---	---	---	---	Cr_2O_3 Sandell's method
Tubingen	---	---	---	---	---	---	Rb, Sr by X-ray	

It is apparent that as yet rock analysis in Europe is still being done primarily by wet methods. A few laboratories are trying instrumental work, particularly in emission spectroscopy but there is a distinct distrust of instrumental results. Probably too, the large capitol expense is a factor in countries where conventional analysis is still reasonably inexpensive.

The Berylometer. This instrument built by the Atomic Energy Division of the United Kingdom Geological Survey is used solely to determine the beryllium content of a rock or mineral, and can detect as little as 20 p.p.m. Its radioactive source Sb^{124}, emits gamma radiation which reacts with Be to yield neutrons. The neutrons slowed down by paraffin are absorbed by a boron fluoride counter. By use of a standard of known composition, the correction factor for density is determined. Only beryllium reacts with gamma radiation from Sb^{124}, the process is therefore unique for beryllium. It is a rapid, stable and non-destructive method of analysis.

Colourimetric Methods. At the Geological Survey of Finland soil samples are analyzed for Ni using Finildioxim, for Zn and Pb using Dithizone and for Co using Nitroso-R-salt. In a small laboratory 3 women analyze over 10,000 samples a year.

At the British Museum of Natural History, Dr. Hey uses colourimetric methods for determination of the principal components of very small samples (1 mg.) of minerals from meteorites. He determines Al using Alizarin-S or 8-Hydroxy-quinoline in chloroform.

Nb is determined colourimetrically using H_2O_2 at the Overseas Geological Survey.

Flame Photometry. For determination of K in the K/Ar age programme, the sample is dissolved in HCl + H_2SO_4, evaporated to dryness, and the residue dissolved in H_2O with a drop of H_2SO_4. R_2O_3 and Ca are precipitated with NH_4CO_3 (twice). The resulting solution containing Mg and the alkalies is analyzed in an E. E. L. flame photometer.

At Manchester flame photometry is used for Sr, Rb, Cs, Li, Ca and Mg. It has given particularly good results for Mg. There is some interference from aluminum in determining Ca.

At the Macauley Institute in Aberdeen a flame photometer built in their shop gives readings for Na, K, and Ca simultaneously. For elements in solution it is sensitive in the range 1 - 10 p.p.m.

Fluorimetry. A new type of fluorimeter expected to be even more sensitive to low contents of uranium has been developed by Dr. Wedepohl at the University of Gottingen.

Ion Exchange. Ion exchange columns are used for a wide variety of separations in the Geological Museum in Oslo. Dr. Filby uses $ZrWO_4$ (complexed) and $ZrMoD_4$ for separation of alkalies and alkali earths. A 10 cm. column is reported to be able to effect complete separation of Na, K, Cs, Rb and Ca, Sr, Ba. These salts must however, be freshly made. See "Ion exchange properties of hydrous oxides" by K. A. Kraus et al. (Oak Ridge). Mr. Bruun uses ion exchange as described by

J.L. Hague and J. Machlan "Determination of Ti, Zr, Nb and Ta in steels - Separation by ion exchange" in the Journal of Research of the National Bureau of Standards, vol. 62, No. 1, January 1959, for separation of Nb and Ta in complex minerals with good results.

Magnetic Resonance is used by Professor Wyart at the Sorbonne to determine water content and water mobility in chabazite.

Neutron Activation is used by Dr. J.R. Butler at the Imperial College to determine the Cs, Tl and Ta contents of granites. They are to try determining Hf by this method. Irradiation of one capsule containing 20 samples and 4 standards costs 5 pounds per week plus 7 pounds overhead charge.

At Oxford neutron activation is used by Dr. Vincent for trace amounts of Au, Ag, Tl, Cd, As, Sb, P, Ga, Sc and for K in ultrabasic rocks. The method for P_2O_5 is sensitive to 1 p.p.m. but is complex and has not yet been published. The proximity of Harwell to Oxford (15 miles) makes it convenient to determine any element whose radioactive isotope has a half-life of 12 hours or more. A gamma ray spectrometer is just being completed for this work.

They put a total of 12 samples plus standards in a 3" x 1" Aluminum container for irradiation. Costs of irradiation in this case are about 12 pounds per week or 20 pounds per month. They are considering use of a tritium source whose flux is $10^8/cm^2/sec$ which is only 10^3 to 10^4 less than Harwell's Beppo reactor. It is estimated that such a source would cost about 6,000 pounds. Old radium beryllium sources are being considered for use in assaying for gold.

Polarography. In Professor Picciotto's laboratories of the Nuclear Physics Centre of the Free University of Brussels, I was told that lead in amounts down to 1/10 microgram can be determined by an oscillographic polarograph. This method is used in Russia, but some details are published in a paper emanating from Picciotto's laboratory on the separation of uranium and thorium.

Polarography has been used for analysis of many elements by Dr. Smales at Harwell.

At Imperial College, Dr. Butler uses a polarograph for determination of cadmium in preference to other methods.

Spectrophotometry. At Gottingen extensive use is made of a Zeiss spectophotometer in rock and mineral analysis. They have proved good stability and lack of trouble in 5 years of use.

The chemical laboratories of the Geological Survey of Sweden make extensive use of the spectrophotometer for analysis of Si as discussed in the Analyst for June 1961. Silicon is determined as the molybdate. A similar method is used for Al and it is reported that there is no problem with interference from Fe or Ti. The reagent used is Eriokeomcyanin. A Zeiss filter spectrophotometer has proved very satisfactory for this work.

X-ray Absorption and fluorescence. At the University of Tubingen absorption of X-rays of different wavelengths has been used to determine the composition of minerals of various solid solution series. A thin section is mounted on a coverglass of known absorption. This is interposed in the beam of the strongest diffracted ray from a calcite crystal. This ray is focused on the counter of the goniometer. Size of the beam is controlled by an aperture in a lead shield. Intensity of the beam can be varied by use of aluminium filters. In this way the linear coefficient of absorption of crystal grains in a thin section can be measured. Within limits of measurement this does vary significantly with differentiation orientations even of highly anisotropic crystals. Using two different wavelengths it is possible to determine the composition of a grain in 2-component solid solutions and with three different wavelengths the composition in more complex solid solutions can be ascertained.

A Siemens vacuum X-ray spectrograph at Tubingen gives sensitivity for Mg. about equivalent to that in our laboratory. They use the X-ray for determination of K, Sr and Rb in rock analysis.

An improvement in reproducibility of X-ray analyses is achieved by thermostatic control of the counter.

At Gottingen X-ray fluorescence is used for analysis of Ca, K, Si and Al. For Ca and K, Se is used as an internal standard. Al and Si are determined by adding known amounts of each element to the sample.

It has been found that only Cu target tubes are sufficiently free from Cr to be used for determining Cr in trace amounts.

At Imperial College an A.R.L. multi-channel X-ray spectrograph has been installed. They hope to be able to determine as many as 22 elements on it simultaneously. So far only an air path has been used but they are considering use of a hydrogen path. It is not equipped with a vacuum spectrograph.

In general they are very pleased with this instrument and have done a lot of work on Rb and Sr down to concentrations of 20-40 p.p.m. At 100 p.p.m. the standard deviation is less than 10%.

Material for analysis is prepared by mixing equal amounts of sample and powdered cellulose and compressing the mixture into discs under high pressure.

Miscellaneous Notes on Analysis

At the Overseas Geological Survey, they place beakers in an ultrasonic cleaning bath to speed up solution of solids.

At the Geological Survey of Finland, all analyses are kept on small filing cards.

To determine the end point in complexometric titration for Ca and Mg, fluorescence of 'calcein' under ultraviolet light is used at Manchester.

Imperial College had found the thermal balance useful in determining water loss from hydrous minerals and in determining when solution of precipitates is complete.

At the Bureau de Recherches Minieres et Geologiques in Paris they are specially equipped for microchemistry. They have carried out analyses on 40 mg. of such complex minerals as germanite.

3-5 ANALYTICAL METHODS - EMISSION SPECTROGRAPH

Dr. Hans Schwander is chief spectrographer at the University of Basel. They pelletize their samples and analyze them on a Jarrell Ash spectrograph using an interpreted arc to ensure constant current throughout the exposure. CO_2 through a Stallwood jet seems to stabilize the arc and remove gases.

They have installed a direct-reading Jarrell Ash spectrograph to be used for analyzing the following major components of rocks: Si, Al, Fe, Ca, Mg, Alkalies, Ti and Mn. They will use the spark technique with Cu as the internal standard.

Dr. Wedepohl at Gottingen developed a double electrode (described in Geochimica Acta for 1953), to increase the sensivitity of the volatile elements. The sample is heated slowly in the first electrode and the volatiles driven off are excited in the second arc. Using this method concentration of volatiles by a factor of 100 is achieved. Zinc can be determined in amounts down to 1 p.p.m.

A further use in a rough determination of the distribution of volatile elements between coexisting minerals. For example by slow heating the Zn present in sphalerite comes off first and subsequently zinc present in silicates can be measured.

The geochemistry department of the Geological Survey of Sweden depends almost wholly upon spectrographic analyses. Unfortunately at the time of my visit Dr. Landerglen was away. Probably many of their methods have been modelled on those developed by Dr. Allen Danielsson at Bolidens Gruv. AB, Skelleflehamar. At Boliden several quantometers are in use and one of them is reserved entirely for research. It was there that continuous tape method of carrying samples into the quantometer was developed, (possibly the Russians will challenge this).

Silicate samples are fused and then pulverized before analysis. For trace element work, ion exchange columns are used and the resin with the adsorbed ions is fed into the spectrograph on the tape.

At Imperial College cathode layer excitation is ued in a Hilger E742 quartz prism spectrograph for determination of V, Cr, Co, Ni, Mo, Sn and Pb in basic rocks, using a Li internal standard.

Imperial College also has a spectrograph made specially by Mannkopff for determination of rare earth elements. It is fitted with a glass prism. The rare earths are first concentrated chemically with thorium and then determined spectrographically. All rare earths except Ho can be determined.

The emission spectrograph at Oxford is used only in the trace range in combination with the Riley rapid method procedures and neutron activation. For Rb and Sr based on standards determined by isotope dilution, a precision for Sr of ± 7% standard deviation and for

Rb of ± 10% have been achieved. It is believed that this is as good as work done with the Stallwood jet.

A method of employing the spark technique on solutions of rock is being developed. The rock is first broken down in a fusion of Na_2CO_3 and Na_2O_2. The crucible is lined with molten Na_2CO_3 to prevent rock from coming in contact with it. Pd is used for volatiles. Fourteen trace elements are determined by this method. A large variation in the Co:Ni ratio from acid and from basic rocks has been noted.

Dr. Evans believes that an aliquot of all solutions of rocks should be retained in polythene bottles for trace element analysis.

At Manchester standards made up of mixtures of Gl and W1 were compared with standards made up from 'Spec-Pure' oxides and no difference was found. Oxide standards are now used entirely. Earlier work on major components has been discontinued and work is limited to elements present in amounts of 3% or less.

To determine optimum conditions and best internal standard, samples are burned for 10 minutes and the plate racked down each minute. This shows time at which the different elements come off and the agreement of the internal standard with each.

3 general procedures are in use:

1. For Sr Ba V Ni Co Cr Ag, a mixture of C (powdered electrodes) containing 1000 p.p.m. Pd is made up. Two parts of this mixture is mixed with 1 part of sample.

2. For volatiles Pb Cu Ga Ge Au Ag Zu Cd, a mixture of Na_2CO_3 containing 650 p.p.m. In as the oxide is made. Two parts of sample are mixed with 1 part of this mixture.

3. For refractories, Rare Earths, Sc Sr Ba Zr Hf, 1 part of a mixture of powdered carbon containing 1% Ta is mixed with 1 part of sample.

In general, all samples are burned for 10 minutes.

The spectrochemistry department of the Macaulay Institute at Aberdeen is devoted primarily to analysis of vegetation and soils. It has a staff of 24 of whom 8 are university graduates. Three chemical laboratories are needed for chemical preparation of samples. A large majority of analyses are in the trace range, but a general analytical service is also provided.

Most samples are in solution when they are analyzed. Plants are ashed at 450°C. Greatest interest is taken in the fractions extracted by different liquid solvents.

Much of the work is done in a medium Hilger direct-reading spectrograph that provides 11 channels and costs 4,000 pounds. Liquid samples are burned in a porous cup. Using this solution method the difference between 0.01 and 0.02 p.p.m. is readily discernible for many elements. Plant ash is pressed into carbon discs which are rotated and burned by a triggered a/c arc.

For Mg they use a 2 channel direct-reading spectrograph built in the Institute, using a small Hilger quartz spectrograph. Again

Mg in solution in acetic acid and or HNO_3, (0.1 to 10 p.p.m.) is burned in a porous cup. This instrument is capable of analyzing 200 samples per day. Interference effects are less than in atomic absorption.

All main resistances in the Institute are in a small iron-air-conditioned room. These are tapped as required for each instrument and the current is controlled from the operating position at the instrument panel.

At the University in Aberdeen, Dr. Fraser has devised a method for accurate spectrographic analysis of feldspars using a relatively single technique. The method is particularly useful for determining the composition of plagioclase in perthites and the percentage of orthoclase.

3-6 ELECTRON MICROANALYSIS AND DIFFRACTION

In the laboratories of the B.R.G.M. in Paris an electron microanalyzer as developed by Castaing is operated by Mr. M. Capitant. The instrument has 2 spectrographs available; one for wavelengths 1-4 1/2 angstroms, the other for wavelengths of 4 1/2 to 12 angstroms. In the first a curved quartz crystal is used for elements Nos. 18-92 in the periodic table and in the second a curved mica crystal is used for elements Nos. 11-17. Detectors used are a Geiger Muller counter for the range 1-5 lambda, a scintillometer for the range 3-8 lambda and proportional gas counting for the range 5-10 lambda. Provision is made for optical examination simultaneously with analysis by transmitted and reflected light using lenses having a long focal distance. X-rays come off at an angle of 16° to the surface.

Areas of ore sections are selected and cut out with a small diamond drill. The section is then set in an alloy of Bi-Pb-Sn at 70°C M.P. The whole is then grounded. Thin sections are coated with a metal film of Al, Ni or Cu about 250 angstroms thick which is grounded. This film is transparent to transmitted light but reflects incident light. When the grounded film is in place the whole is embedded in cold-setting plastic. This preparation takes about one hour. Metal flashing is done under vacuum in a model No. 12E/146 unit made by W. Edwards and Company, London, S.E. 26.

In the Castaing instrument automatic scanning of an area of 300 x 300 microns is possible. It requires 10 minutes to scan an area of 100 x 100 microns.

Normal procedure is to focus on sample, and scan across to determine what elements are present. Knowing what interferences and absorption may exist, peaks are counted against background and against a standard. Statistically 30,000 counts are required and preferably 50,000 are counted. Corrections are made and the elemental content of the grain is computed.

At present sodium (Z=10) is the lowest element for which analyses can be made. It is hoped that my removing the mica crystal and using direct absorption techniques it may be possible to determine carbon (Z=6).

The 2 principal corrections are: 1. for absorption by the sample, and 2. for secondary fluorescence. In France, L'Association Nationale de la Recherche Technique has organized the 7 laboratories having electron microanalyzers in a project to determine absorption constants of all elements for the various wavelengths. This is a major task in which they would like assistance of laboratories throughout the world.

Sensitivity for any element by this method is very largely governed by the absorption constant of other components in the grain. For example, sensitivity for Mg in a grain composed of uranium would be 2.0% but for uranium in a grain composed of magnesium would be 0.01%. Precision is of the order of ±1% of the amount present (e.g. Cr would be reported as Cr 25% ± 0.25) providing absorption constants are known and corrections are made.

At the University of Tubingen, electon diffraction has proved praticularly useful for study of clay minerals and other layered minerals. They have developed a system for interposing a crystal in the electron beam and obtaining a 2-dimensional lattice. Correct orientation is established by use on a shadow microscope. All degrees of freedom are available for orientation of the sample.

Dr. Long at Cambridge has certainly had more experience in the analysis of geological samples by this technique than anyone else known to the writer. Because Dr. Traill had discussed instrumentation with Dr. Long the writer restricted his discussions with Dr. Long to applications of the method.

In Long's opinion it is essential that the operator and geologist work together on the instrument because neither can interpret results without assistance from the other.

Three main uses of the instrument are:

1. Study of fluorescence colours in unfocused electron beam provides a quick and useful means of identifying minerals that is particularly useful when studying intergrowths.

2. Quick qualitative or comparative analysis:
   - a. to bring out zoning and intergrowths
   - b. to identify main constituents of minerals
   - c. for comparative analysis of different elements in coexisting minerals.
   - d. for study and identification of glasses and metamict or isotopic minerals.

3. Quantitative analysis of minerals on areas that under the microscope are seen to be free from inclusions etc. Long finds accuracy is of the order of 1% of the amount present. If analyses are done on several such grains, the average is almost certain to be more accurate than a good chemical analysis on a concentrate that is rarely, if even, pure. This type of analysis can also be used to determine diffusion in minerals and in some cases will indicate a temperature gradient between minerals at time of formation.

Long states that it is an advantage to have 2 and possibly 3 goniometers but thinks that more are impractical because it is improbable that conditions in the electron beam would be suitable for more than 2 or 3 elements. Moreover differences in geometry would cause differences in absorption if there is any irregularity in the surface. An optical microscope is essential because there is too little difference between the electron microscope images of many minerals for them to be recognized on the screen.

Some problems arise in specimens in which the thermal conductivity is low and temperatures rise almost instantaneously to 1000°C. and more with loss of volatiles by distillation. Thickness of the metal film is a major factor in this connection.

All elements down to, and including sodium can be detected. Magnesium can be detected in light minerals where it is present in amounts of 1/2 of 1% and probably down to 1/4 of 1%. The crystal must be removed to detect sodium. Work in the Cavendish laboratory at Cambridge suggests that by use of a proportional gas counter with direct absorption techniques, C, N, O, B and possibly Be may be detected for purposes of distinguishing between oxides, carbides, nitrides etc. in steels. Where peaks of one element overlap those of another, the shape of the peaks is used to determine the contribution of each element.

Dr. Long stressed the importance of having a flat polished surface for optimum results. All his specimens are therefore cut and polished with diamond paste. He uses a 16 mm. interference objective made by Watson to determine the relief to 1/10 of a wavelength.

Where precision in variation of composition at contacts and in zoning is required. Counts from a series of points are alternated with counts on a standard to correct for any instability in the ion beam. As an alternative the beam is automatically compared with a broad scan.

An interesting example of the use of an electron microanalyzer is reported on pages 19 and 20 of bulletin 194 of the Geological Survey of Finland by Dr. Vaasjoki, showing variations in composition of chromites etc.

At Imperial College a microanalyzer made by Cambridge Instruments was delivered in early 1961. It has been used by T.K. Kelly and A.P. Milleman for a variety of mineralogical, petrological and metallurgical studies.

An extensive study of fine-grained and intergrown Mn minerals by Miss K. Spathi has proved the value of the instrument in showing variation in composition of various minerals, in demonstrating zoning and in identifying minute inclusions.

Dr. A.R. Burkin of the Metallurgy Department sent in some minute wolframite crystals coated by oxide films as a result of treatment. It was found that these films were in fact composed of discrete layers of Mn, W and Fe oxides.

Spectrographic analysis of some dolomite showed that it contained 50 p.p.m. of Zn. It was necessary to know how this Zn occurred. The electron probe showed that its distribution outlined the shape of relict crystals.

An interesting study, undertaken to investigate loss of Pt in tailings of the J. C. I. mine in South Africa proved the presence of cooperite, braggite, laurite, Au, and a ferro-platinum alloy composed of 84% Pt, 14% Fe and 2% Pd, Os etc.

Analyses were made of the newly-described mineral eskolaite.

A study made of pyrite crystals whose microhardness indicated zoning, proved that the crystals were homogeneous and that differences in hardness were due to twinning.

Other studies were made of basalts showing different magnetic properties and of the Ti and Fe contents of fine-grained lavas.

The principal difficulty at present is lack of understanding of all the physical factors involved in use of the instrument. A study is being made of absorption factors and other corrections.

3-7 EQUIPMENT

Instruments and equipment for a wide variety of uses were noted in various laboratories. Some of these have been mentioned under other headings. The purpose of this section is to draw attention to items not otherwise described, and to items that may be useful for more than one purpose. For convenience they are listed under the following broad headings:

Analytical

Filing

Mineral Separation

Mineral Synthesis

Mineralogy

Miscellaneous (a large and diverse category)

Radiocarbon and Counting

Spectrographic Ancillary

Vacuum

X-ray

Analytical

Special equipment to record the end point in titration of solutions of complex ions is used at the University of Gottingen and has been found to be more accurate than visual estimation.

The automatic titrator and pH meters made by Radiometer, Copenhagen have proved to be very satisfactory in use in the Geological Survey of Sweden.

For very small samples (e.g. gold beads) the Cahn electrobalance has proved successful and fast. It is made by Cahn Instrument Co., Downey, California.

A thermal balance particularly useful for determining water loss etc., is made by:

Stanton Company,
119 Oxford Street,
London, W. 1.

At Manchester University Palau crucibles are used instead of platinum for Na_2CO_3 fusions. Fusions come cleanly out of these crucibles without adhering. The crucibles are made of a Pd:An alloy by Johnson, Melthey and their cost is less than half that of equivalent platinum crucibles.

Filing

The geological reading room at Basel University has special open-topped boxes for storing reprinted papers, of each major author. Cross reference by subject is also used. This seems to work well.

At Basel and also at Cambridge the Technicon Laboratory Aid File System is used for storing thin sections. Basel like it but Agrell at Cambridge prefers their own system and uses this only for duplicates etc.

A good file for vertical storage and viewing maps or plans in constant use is made by E. N. Mason and Sons Ltd., Arclight Works, Colchester, England.

Mineral Separation

At Basel the Frantz magnetic separators are often in use 24 hours a day. In order to keep the coils cool, they are 'wrapped' by copper tubing through which cold water is dept flowing.

In the Geological Survey of Finland they use a vibrating ball mill made of ceramic with ceramic balls, made by Schwingmühle "Vibration", Siebtechnik, Mulheim, Rubr, W. Germany.

Several excellent instruments for mineral separation are described by L. D. Muller: "Some Laboratory Techniques Developed for

Ore Dressing Mineralogy", Group IX, paper 52 International Mineral Processing Congress 1960, published by Institute of Mining and Metallurgy, 44 Portland Place, London W. 1.

Among them are:

a. Diffusion Column made to order for about £6 by

QuickFit and Quartz,
Heart of Stone,
Staffordshire.

b. A Micropanner sold by Charles Cook, Birmingham.

For clean separation of mineral fractions in heavy liquids, the Overseas Geological Survey uses a special centrifuge tube. It is 4" long and 1" diameter and made of pyrex glass. About 1" from the bottom the tube is drawn into a constricted neck of about 1/2" diameter so that the bottom of the tube is virtually spherical.

When the minerals have been separated a glass ball on the end of the glass rod is inserted so that it acts as a stopper in the constricted neck. The light fraction is poured off and subsequently the heavy fraction may be poured off. Alternatively the heavy fraction may be frozen down at 9°C and the light fraction poured off.

Very inexpensive tetrabromethane made in Israel is sold by

Baker Perkins Ltd.,
Mineral Processing Division,
Blackhorse Road,
Letchworth, Hampshire.

for £2:2:0 per 7 lb. bottle.

The Sturtevant Electrostatic Separator, used by the Overseas Geological Survey, is particularly satisfactory for separation of zircon, rutile, ilmenite, cassiterite, scheelite, and wolframite

Sturtevant Mill Co.,
Park and Clayton Streets,
Dorchester, Boston 22, Mass.

Banks of infra-red heating lamps are widely used in Britain for drying mineral concentrates and evaporating liquids. They are made by

English General Electric Co.,
Magnet House,
Kingsway, London W.C. 2.

For separation of sulphides and other minerals from small (1/2 gram) samples, the Hallimond Flotation Tube is particularly useful. Some of these were being made up for Professor Fleming of the Royal School of Mines, Imperial College, London.

A quick method of removing the very fine particles from a sample is by use of the Laboratory Hydrocyclone Test Set, made by

Liquid Solid Separators, Limited,
2 Anderson Street,
London S.W. 3.

Use of this equipment was described in the Mining Magazine (London) for July 1954.

The ultra sonic cleaner used at the British Museum and by the Overseas Geological Survey is the Disontegrater 90 k/c type. The slower cycle is rough and will damage specimens. Coast is about £70:0:0, from

McPhar-Roberts Ltd.,
139 Bond Ave.,
Don Mills, Ontario,

who are the Canadian representatives for

Bronson Ultra Sonic Corporation,
Stanford, Connecticut.

Mineral Synthesis

For high pressure work, Professor von Englehardt at Tubingen has a press capable of 75,000 kg. pressure.

For studies on synthesis of minerals in the new laboratories at Hamburg, presses capable of 60 tons are used which are provided with recording equipment. They are made by Losenhousewerk, Dusseldorf.

They also have large and very complex autoclaves made by Andreas Hofer, Hochdruck-Apparatebau, G. M. B. H., Mulheim, Ruhr, W. Germany.

Furnaces capable of temperatures up to 3,500°C at 200 amps and 15 volts are made by Gebr. Ruhhstrat, Gottingen, W. Germany.

Autoclaves and valves for mineral synthesis have been designed and built at the University of Aberdeen capable of withstanding pressures of 60,000 p.s.i. at 1000°C.

Mineralogy

For use in cutting material from thin and polished sections, diamond mounted dental burrs are particularly useful. Such burrs, the 'Viking F.G.' are made by Hallvard Foss and Co., Fetsund, Norway and are sold by Dental Instruments and Accessories Limited, 320 Regent Street, London W. 1.

A new needle counter which is excellent for finding radioactive minerals in thin or polished sections is made by Twentieth Century Electronics Limited, King Henry's Drive, New Addington, Croydon, Surrey.

Hilger and Watts make a monochrometer using a rotating basal quartz section which is very satisfactory but requires a light source of high intensity.

Miscellaneous (a large and diverse category)

Liquid counters, 10 ml. capacity for Radium D (yield 3%) and for UXI (beta) (yield 10%) are available from: 20th Century Electronics,

King Henry's Drive,
New Addington,
Croydon, Surrey.

At B.R.G.M. in Paris a new type of Differential Thermal Analysis equipment capable of use under argon or other gas has been developed. This unit is reported to be exceptionally sensitive. Publication is being delayed until patents are granted.

Unit for applying metallic coating to thin sections is Model 12E/146 made by Edwards High Vacuum Limited, Crawley, Sussex.

Dozent Dr. S. Houssühl at Tubingen uses specially designed equipment for growing large crystals up to 3 inches, from seed crystals suspended on platinum or nylon filaments in solutions at room temperature and pressure.

For accurate determination of the Specific Gravity of dry powders the Volumeter 'Norari' is very useful. It is made by F. Suffert

Burner A.G.,
Basel, Switzerland.

Dr. Long at Cambridge recommends the Edwards, model 6E2 which costs £230, for metallic coating of thin sections.

Instead of buying molybdenum crucibles Mr. Miller at Cambridge makes them from 2/1000" molybdenum sheet. Bottoms are made by forcing sheet through a cylindrical die. The tube and bottom are spot welded. He demonstrated making one in less than 2 minutes.

Argon^{38} spike material is available from

Professor K. Clusius,
Physics and Chemistry Institute,

Federal University of Technology,
Zurich, Switzerland.

For work in lead-free laboratories, Professor Jäger recommends a lead-free polyvinyl plastic called 'Somoplas' that is made by

Societe pour les Metaux Ouvres,
Geneva, Switzerland.

<u>Radiocarbon and Counting</u>

In the Swedish radiocarbon laboratories, excellent anti-coincidence tubes No. HZ-100, made by Zentralwerkstatt Gottingen, G.M.B.H. Bunsenstrasse 10, Gottingen, W. Germany, have a diameter of 33 mm., length 1000 mm. and cost 100 DM.

Lead with an exceptionally low background suitable for shielding radiocarbon counters is Laisvall A-bly by Bolidens Grufaktiebolag, Sturegatan 22, Stockholm.

The radiocarbon laboratory at the Geological Survey of Finland uses a 'de Vries type' counter made by Laboratorium Professor Dr. Berthold, Calmbacher Strasse 22, Wildbad i Schwarwald, W. Germany.

Anti-coincidence tubes used in the Radiocarbon laboratory at Cambridge are made by

Twentieth Century Electronics,
King Henry's Drive,
New Addington, Croydon,
Sussex.

Dr. Willis says they have a long flat plateau of 250-300 volts and have proved reliable in operation.

Spectrographic Ancillary

A good calculating table for spectrographic laboratories is the 'Respektra' made by

Dennert and Pape,
Hamburg.

At the Macaulay Institute for Soil Research they have designed an instrument for cutting carbon electrodes into 1" lengths automatically so that there is no chance of contamination.

Vacuum

Picciotto's Laboratory recommends special metallic valves that will hold vacuum of 10^{-7} mm. of Hg. They are made by

Palatine Tool and Engineering Co. Ltd.,
64 Brighton Road,
Surbiton, Surrey.

In Houterman's labortories (Bern) an Alpert type of metallic valve has given good service. They are Balzer's UV 8-H made by Balzers, Lichtenstein and cost $200.00 each. Geiss also referred to a good metallic valve made by

Edwards High Vacuum Limited,
Crawley, Sussex.

Geiss recommends Van Hespen glass vacuum pumps blown in Chicago.

Mr. Miller of the Mass Spectrometry laboratory, Madingley Rise, Cambridge has designed and constructed a fairly simple type of metal valve for vacuum lines that has been in use for 2 years. It holds a vacuum of at least 10^{-6} mm. Hg against atmospheric pressure. It can be baked without dismantling.

At Oxford, Alpert type metal valves used in the vacuum lines, made by Edwards High Vacuum Limited, Crawley, Sussex are quite satisfactory and cost £40 each. Rotary pumps, ionization and Pirani gauges made by this firm were all recommended but with the comment that they are expensive.

X-Ray

Reference was made at the Geological Survey of Sweden to the X-ray spectrograph made by Hilger which uses a split beam to control the counter and thus allows for any fluctuation in intensity. The counter itself is thermostatically controlled to increase its stability.

For clay minerals particularly the Nonius Guinier X-ray Powder Camera is particularly useful.

3-8 GEOCHEMISTRY

No attempt was made to compile information specifically in this field. The few facts reported here were incidental to discussions concerning mineralogy and petrology. Other data of interest to geochemists is described under these headings. For convenience, these notes are written under two headings: field studies and laboratory studies.

Field Studies

Work done at the B.R.G.M. in Paris indicates that bacteria are able to effect movement of copper and gold. Some of this work was reported in the Symposium de Geochimie at Royaumont in 1959.

I was informed that Saukov in Russia has shown that many orebodies can be detected by an aureole of mercury in the surrounding rocks. However, the mercury is present only in the parts per billion range and there is still some doubt as to the efficacy of the methods of detection used.

A geochemical study of the occurrence of uranium and other elements in black shales is being made by H. S. U. Bowie and his staff in the Atomic Energy Division of the Geological Survey of Great Britain.

Laboratory Studies

A fairly exhaustive study of the solubility of the sulphides galena, sphalerite and chalcopyrite in various aqueous solutions at elevated temperatures and pressures is to be published shortly by the B.R.G.M. in Paris. Results of this work indicate solubilities from 10 to 100 times as great as those reported by Garrells.

Professor Hocart at the Sorbonne is studying solid state reactions between $BaCl_2$ and $CaCl_2$.

Professor Wyart is working on synthesis of cordierite and chabazite and other zeolites. He has used magnetic resonance to determine the water content and water mobility in chabazite.

Dr. Wedepohl at Gottingen informed me of a study being done by Goguel on liquid gas inclusions in rock-forming minerals. The gases are released by grinding the minerals in a quartz ball mill under vacuum. The liberated gases are segregated and measured by freezing them at different temperatures. The noble gases are analyzed in a mass spectrometer.

Dr. R.H. Filby (Ph.D. McMaster) has established a radiochemical laboratory in the Geological Museum in Oslo. The Norwegians and Dutch have a joint atomic energy programme through which Filby gets his hot isotopes and disposes of radioactive waste. Neutron sources are stored in their shipping containers.

His counting equipment includes Philips and Nuclear (Chicago) Scalers of which the latter is much the better one. Beta counting is done by simple Geiger Muller counter in a lead castle. He also has a small proportional gas flow counter. He uses a 2" x 2" sodium iodide crystal in conjunction with a Nuclear (Chicago) pulse height counter which he uses as a gamma-ray spectrograph.

His research is principally on the distribution of trace elements in crystals as part of an investigation of the distribution laws during growth of crystals. He grows his own crystals in a constant temperature bath and uses neutron activation to analyze different parts of a single crystal.

He intends to investigate the trace element content of various reduced chemical sediments. To start with he expects to make adsorption measurements of trace elements on sulphide precipitates.

He is studying the distribution of Ag and Tl in galena, initially by precipitation of PbS.

Alan Edgar, Ph.D. student at Manchester University has been synthesizing various minerals in the cancrinite, analcite, sodalite nepheline group. Most of his work has been done using gels rather than glasses. These are heated at 15,000 p.s.i. and 859°C.for 2 days.

3-9 LAPIDARY METHODS

A. At Amsterdam University I was told of a diamond saw that will cut rock slices as thin as 1/10 mm. The rock is bonded to a microscope slide and the latter held by suction to a jig that controls the slice thickness. This equipment is made by

Wolfgang Conrad,
Clausthal - Zellerfield,
West Germany.

Cost is approximately $1,200.00.

B. A complex grinding lap designed by Mr. E. Glauser, lapidary at Basel University, produces 8 sections simultaneously. This equipment is particularly useful for making large sections with uniform thickness. It has a braking device so that pressure is exerted at the thickest part of each section. Arrangements have been made for manufacture of this instrument by

Mr. A. Wenzler,
Maschinenfabrik,
Boltighofen,
Switzerland.

Although this is an excellent instrument, it is admittedly difficult to bring it into production and to maintain it. Probably better production could be achieved by a simpler machine even though more hand finishing may be needed.

In this shop all glass slides are numbered with a diamond point.

C. At Cambridge University 8 sections are bonded to microscope slides and placed in a specially designed jig on a surface grinding machine. They are ground automatically by the edge of a diamong-impregnated wheel to thickness yielding 1st order red interference colour. The University of Manchester has adopted this method but uses a jig that accommodates 15 sections in a batch. Manchester recommends use of a diamond wheel 1/4" thick impregnated with 120-150 mesh diamonds. The coolant used is important and Manchester uses a sulphonate fatty oil base with opaque emulsion. A commercial version of this machine that will take only six sections in a batch is made by Cutrock Engineering Co. Ltd., 35 Ballards Lane, London N3. This machine is used by Overseas Geological Surveys.

Professor Howie at Manchester told me that their technician had little trouble in converting to the 15 batch machine and that they have few broken slides. Manchester also have a machine for cutting very thin slices but prefer the batch grinding because it is faster.

D. At Cambridge all thin sections are mounted in an artificial resin called Lakeside 70, and polished sections in 'Araldite MY 753' with HY 951 as a hardener.

E. Polishing of ore sections in the Overseas Geological Survey and in the Geological Survey of Great Britain is done primarily with diamond-impregnated paste. Softer minerals are usually finished magnesia on cloth. The diamond paste is applied on lead laps and on cloth laps. Recently the Overseas Geological Survey has adopted Hallimond's method of using paper-backed aluminium foil on a plate glass lap at 100 r.p.m. under a pressure of about 3 lbs. per square inch of surface being ground. Initial cutting is done with 3 micron diamonds and final cutting with 1 micron diamonds, both in '5Cs' silicone.

F. H.S.U. Bowie has a bulletin of the Geological Survey of Great Britain in press which describes a method for obtaining a good flat polished surface in minutes. Polished sections made in his laboratory are superior to any I have seen elsewhere.

3-10 MASS SPECTROGRAPHY AND SAMPLE PREPARATION

This section describes mass spectrographic equipment and methods of preparing samples for isotope analysis.

Equipment and Filament Preparation

At the National Nuclear Research Laboratory in Amsterdam, there is an 8-inch 180-degree mass spectrometer for solid source work and two smaller 60-degree mass spectrometers none of which are fitted with electron multipliers. The large instrument is fitted with a sliding vacuum lock device so that samples can be changed without breaking the vacuum. In essence this is a sleeve arrangement whose tolerance is better than 0.001 cm. and which is coated with 'molycote' high silicone grease. For lead analysis they use a double filament.

In Professor Picciotto's laboratories at the Nuclear Physics Centre in Brussels, M. Delwiche is chief of mass spectrometry. They use a 32 cm. radius, 60 degree mass spectrometer. This instrument is fitted with a new type of vacuum lock that has been developed in conjunction with Professor Geiss at the Physics Institute in Bern. Inexpensive metal valves made by the Palatine Company (see Equipment) have proven quite satisfactory in holding vacuums down to 10^{-7} mm. of mercury. For lead analysis, PbS in a drop of NH_4NO_3 solution is dried on a single tantalum filament. This has given very consistent results.

There are 6 mass spectrometers of various kinds in the large new Physics Institute at the University of Bern (Professor Houtermans).

For argon analysis they use a small 10 cm. radius, 60 degree, glass mass spectrometer with metal valves that can be baked out to provide an ultra high vacuum system. A dry ice trap is used between their forepumps and diffusion pumps and two traps between the diffusion pumps and the mass spectrometers to reduce hydrocarbon seepage.

They have one commercial model made by the Atlas-Werke A.G. at Bremen. This is a solid source instrument provided with a vacuum lock. It can be ordered with complete and versatile sample systems to suit the customer's needs. It is reported to be very satisfactory and to be cheaper than equivalent English or American instruments.

All other mass spectrometers in this Institute have been built for specific purposes.

Filaments used are 1/30 mm. thick, 1 mm. wide and 1/2 cm. long. Rhenium is generally preferred to tantalum. Tungsten is satisfactory for alkalies only. Re is obtained from Chase Brass and Copper Co. Inc., Waterbury 20, Conn; U.S.A. Ta is purchased from Fansteel Metallurgical Corporation, 2200 Sheridan Road, North Chicago, Illinois.

Professor Geiss insists on slow heating of filament to ensure stable ion current, particularly in analysis of Rb and Sr.

Three methods used for lead analysis are:

1. If abundant samples, heat as PbS in crucible in the mass spectrometer.

2. Lead is precipitated as PbS in NH_4NO_3 solution and a drop is dried on a rhenium filament. Extreme purity of Pb is essential and contamination by Sn or Ti particularly inhibits ionization of lead. This is satisfactory for Pb in amounts down to 5 micrograms.
3. Lead as the nitrate is dried on a rhenium filament at 100°C. One drop of boric acid is then dried on top. The filament is subsequently baked so that a bead forms. This method has proved satisfactory for lead in amounts of less than 1 microgram.

A new mass spectrometer laboratory at the University of Gottingen is devoted entirely to isotopic analysis of sulphur at present. The mass spectrometer is made by Atlas and is reported to be very satisfactory. The vacuum is obtained by a mechanical pump to 10^{-4} mm. of mercury and by a Vac-Ion pump to 10^{-8} mm. of mercury. These pumps had been in satisfactory operation for 8 weeks at the time of my visit.

In order to reduce possiblity of 'memory effect', the source end of the mass spectrometer tube is kept at 150°C.

At Cambridge the only mass spectrometer is used for the argon work. They have developed metal vacuum in the laboratory which have proved satisfactory. They are also working on methods of glass to glass seals using an indium ring. This laboratory is notable for the initiative and inventiveness shown in developing their own equipment.

At Oxford, three mass spectrometers are in operation. One is commercial Metropolitan Vickers instrument and another is a glass Reynolds-type instrument made in California.

To avoid possibility of fractionation of samples, a sintered Ta filament made by coating a Ta filament with a slurry of Ta_2O_5 in water and heated in vacuum, is used.

Preparation of Lead Samples

A great deal of trouble is taken by all laboratories to avoid contamination by the air, dust and reagents when preparing lead for analysis in the mass spectrometer.

At Amsterdam a special air filtering system is provided to ensure freedom from contamination. It comprises the following units in order from the inlet to the room:

a. Heating system
b. Conical water spray to clean the air
c. Rotoclone, Type D to remove water by centrifuge action
d. Air filters to remove residual dust
e. Electrostatic filter
f. 'Absolute filter'

This equipment is in a room 12' x 4' x 8' but could be fitted into less space. The lead-free laboratory has close fitting doors and the clean air is fed in at ceiling opposite the fume hoods and goes out through the fume hoods. Heavy mats are placed outside the door.

Using a 6 Kw Philips induction furnace and precisely made water-cooled coils embedded in plastic insulation around a quartz, water-cooled vacuum chamber they are able to heat a graphite crucible at 2800°C.

They can thus fuse zircons at 2200°C. and collect the lead on the cool quartz wall of the vacuum chamber.

In the laboratories of the Nuclear Physics Institute at Brussels Mines, Deusch and Ledont do not have the advantage of special laboratories for extraction and purification of lead. Instead their work is done under plastic hoods on the chemistry benches. Vessels are all flushed with nitrogen before use and evaporations are carried out in glass vessels continuously flushed with nitrogen.

Dr. Geiss at Bern when discussing contamination of lead during its preparation made these points:

1. Contamination during mineral separation is negligible.
2. Filtered air should cause a positive pressure in the chemistry laboratory.
3. Part of filtered air should be introduced directly into the fume hood and part to the laboratory as a whole.
4. Use air lock between doors if possible and change shoes, use clean laboratory coats etc. Personal cleanliness and avoidance of smoking are essential.
5. Have drain in the floor so that the laboratory can be washed down periodically.
6. Paint should be Ti oxide only - avoid all products containing lead.
7. Air inlet and fume hoods should be stainless steel or fibre glass coated. Bench tops should be covered with clear plastic.
8. Fume hoods should be so designed that they can be completely washed.

9. Additional precautions such as plastic hoods over benches and nitrogen flushing may still be advisable.

Dr. Jaeger at the Mineralogical Institute at Bern does most of the chemistry in preparation of lead samples analyzed in the Physics Institute at Bern. She uses wet mats outside the door of the laboratories to remove dust from shoes. Air is pressed through a series of filters culminating in an absolute filter. Part of air is fed directly to fume hood. Laboratory is painted with special TiO_2 paint that contains less than 30 p.p.m. lead. Floor of the laboratory is covered with a lead-free asphalt mix that contains more than 90% quartz and less than 10% asphalt. The fume hoods, ducts, and water drains are coated with Samoplas, a lead free polyvinyl chloride. All metal is painted with pure TiO_2 paint. All reagents are double distilled. Dr. Tilton when working in this laboratory found his blanks were lower in lead than any that had been reported from Patterson's laboratory.

At Oxford, Mr. Hamilton of the Overseas Geological Survey had developed a method of purifying air as part of a chain of vessels leading into a closed teflon reaction vessel in which the lead minerals are decomposed by HF and Perchloric acid.

The chain of reaction vessels for cleaning air is:

1. Dry silica wool filter.
2. Concentrated H_2SO_4 and silica wool.
3. Concentrated H_2SO_4 and silica wool.
4. Distilled water containing a trace of NH_3.

5. 1 normal HCl with Dowex No. 1.

6. 1 normal HCl with Dowex No. 1.

7. Dowex No. 1 resin less than 200 mesh in 1 normal HCl.

8. Distilled HCl.

9. Air trap.

Air from this air trap is bubbled through the reaction vessel. The HF and perchloric fumes displaced from the reaction vessel are condensed in a closed teflon vessel packed in dry ice. Fumes from this vessel are washed down the sink.

In 6 hours the liquid in the reaction vessel is evaporated leaving a mush of chlorates. Double distilled, demineralized water is added followed by purified NH_3. The reaction vessel is then placed in a centrifuge and the hydroxides are centrifuged off. The precipitate is washed with dilute NH_4OH. 3N HCl is added yielding a 1 N HCl solution. This solution is poured from the reaction vessel into a Dowex No. 1 anion exchange column. Additional 1 N HCl is passed through another Dowex No. 1 column and is used to elute everything except Pb, Bi and Tl from the main column.

The column is now eluted with 10% perchloric acid into a closed teflon flask with an air leak. This removes 99.9% of the lead. The residue is taken up in 2 1/2% NH_4NO_3 with heat. H_2S prepared from pure Sb_2S_3, is then passed into the solution precipitating PbS. This is centrifuged, washed with distilled water and is ready to be applied to the filament of the mass spectrograph.

Preparation of Sulphur Samples

At Gottingen, Dr. Neilson is particularly concerned over the possibility of fractionation of sulphur isotopes during the production of SO_2 from sulphides and sulphates.

Impure sulphides are heated with HCl and Sn and the H_2S evolved is precipitated as CdS which is treated as a pure sulphide.

Sulphates are reduced by heating with excess powdered iron to yield FeS. If barite is being reduced it is heated at 950°C. but anhydrite and gypsum are only heated at 800°C. The resulting FeS and BaS or CaS are then treated as pure sulphides.

Pure sulphides are baked at 150°C. to remove adsorbed gases and water. They are then mixed with V_2O_5 under nitrogen in a quartz tube and heated for 10 minutes at 150°C. to yield SO_2 quantitatively. This is the method described by Gavelin.

It was suggested that if SO_2 is frozen down and then heated slightly to release CO_2, some fractionation of sulphur may occur.

An interesting check on possible fractionation was made by dissolving galena (PbS) in HCl to yield H_2S. H_2S was then passed into an aqueous solution of H_2O_2 and NaOH to yield Na_2SO_4 which was in turn converted to $BaSO_4$. $BaSO_4$ was roasted with metallic iron to yield FeS and BaS which in turn were dissolved in HCl to yield H_2S. This H_2S was precipitated as CdS. The isotopic composition of the sulphur from the original galena and from the CdS were compared and found to be isotopically identical.

A new method for extraction of sulphur as sulphur vapour at 200°C. directly from sulphides by an electrical method without thermal dissociation has been developed by Dr. Neilson and is to be published early in 1962.

Natural Distribution of Sulphur Isotopes

Professor Gavelin at the University of Stockholm stated that the isotopic ratios of sulphur from deposits in the highly metamorphosed rocks of Sweden are very consistent. This is in marked contrast to the highly variable ratios of sulphur from the well zoned deposits of Cornwall. Ratios in Cornwall show greatest variation where sulphates are present, which suggests that there has been local fractionation. Professor Gavelin noted that isotope ratios of sulphur from the Tri-State lead-zinc deposits are in the normal sulphate range. It would be interesting therefore to check the ratios of sulphur from the Pine Point deposits.

3-11 METEORITES

Although most mineral collections seen contained abundant specimens of meteorites, relatively little work appears to be in progress in this field.

At the British Museum, Dr. Hey is working on both irons and stones.

By careful metallographic study of irons combined with precise measurement of the true width of kamacite bands he hopes to be able to trace the reheating of the meteorite. With this is combined the distribution of the nickel in kamacite and taenite. This together with accurate determination of the cell dimensions of kamacite may yield data concerning palaeotemperature.

Relatively little work has been done to determine the trace element distribution between metals and silicates. As a start on this work, Dr. Hey has developed the use of clean dry Cl_2 at 150-350°C to break down the iron and sulphides and to leave the silicates untouched. The material is leached with water which dissolves the chlorides and leaves the silicates as a residue. Any silicon that may be in the iron or sulphides forms $SiCl_4$. The clean silicates are separated by gravity and megnetic methods.

Dr. Hey uses colourimetric methods extensively in determining the main constituents of various minerals using samples as small as 1 mg. He also uses neutron activation done at Harwell. When analyzing meteorites as a whole, the size of sample is determined by the minimum required to be representative of the facies of the meteorite to be analyzed.

At the Geological Survey of Finland Dr. H. B. Wiik is working on the analysis of stony meteorites. He is particularly interested in the ratio of iron as sulphides versus iron as oxides and oxygen salts.

Dr. Geiss and Dr. Biere at the Physics Institute in Bern have been working on the rare gases and radioactive isotopes in meteorites. The Abee meteorite was found to contain an unusual abundance of rare gases.

3-12 Microscopy

Relatively little of interest was encountered in equipment or methods used in microscopic study of minerals.

Zeiss has developed a new integrating ocular for determining the mineral content of thin and polished sections. There are 25 points mathematically distributed over the field of view and the minerals lying under each of these points are recorded. It has been found that for most rocks observation of 400 points gives a satisfactory quantitative determination of the mineral content. The method has been tested by Professor de Roever's students in the University of Amsterdam and has proved to be much faster and more reproducible than standard methods of traversing the surface.

In the same laboratory, Mr. Zwartkruis showed me a method of plotting 4 components in a single plane. This method was devised by the Russian, Koryensky, and is described in his textbook on metamorphism.

Professor Uytenbogaardt has tested the new Leitz 'Durimet' which is used for accurate determination of the hardness of minerals. It is a complete microscope with a centered diamond that swings out of the way for observation and measurement of the indentation it makes. This instrument has proved to be the best hardness tester used by Professor Uytenbogaardt and is very useful aid in determining opaque minerals in polished surfaces. Its cost is in excess of $1000.

At the University of Paris, I was told that Mlle. Oberlin is making very successful use of the electron microscope in the study of clays.

In the Atomic Energy Division of the Geological Survey of Great Britain, H. S. U. Bowie has developed a simple system for identification of opaque minerals in polished sections by determining their reflectivity and microhardness. This method is simple to learn and is very precise. It is, however, dependent upon a good and reproducible method of polishing sections. The reflectivity is determined by a photosensitive cell placed in the ocular tube of a microscope. The reading of reflectivity of the unknown mineral is compared with the reading from an equal area of pyrite. The hardness is determined by a microhardness tester that swings in and makes an indentation in the mineral whose size is accurately measured.

Dr. Munro at the University of Aberdeen has been studying errors in measuring the angle 2V in olivines using the conventional glass spheres in a mineral stage. Where 2V is greater than 30° appreciable errors as great as 3° occur; due to refraction in the central glass plate and to other factors. Using spheres of albite, olivine and topaz, Dr. Munro is making precise determinations of 2V. From these it is expected that corrections can be calculated for determinations made on the universal stage.

3-13 MINERAL COLLECTIONS

In Belgium there are two major mineral collections; a more general one supervised by Dr. Van Tassel in L'Institut Royal des

Sciences Naturelles in Brussels and the unique collection of minerals from the Congo in the Musee Royale de L'Afrique Centrale at Tervuren, a few miles south of Brussels. The latter has been largely the work of the present curator, Professor L. Cahen and contains an outstanding and unique collection of uranium minerals from Shinkolobwe.

In Paris there are three notable collections:

1. In the National Museum of Natural History under Professor Orcel;
2. In l'Ecole Nationale Superieure des Mines de Paris under Professor Guillemin;
3. In the faculty of Science of the University of Paris under Professor Wyart.

Mr. Jean Prouvost very kindly showed me the mineralogical laboratories of the National Museum and arranged for me to see the National Collection even though the building housing it was closed for repairs. This building is in the form of a long gallery at least 2 stories high and lighted by windows and a long skylight. The collections are well displayed on a systematic basis of the anions. In addition, special collections in distinctive cases illustrate the mineralogy of specific elements, of various mines and mining camps, of various crystal systems etc. This is France's premier collection and as would be expected of a nation that has been a pioneer in mineralogy, this collection is unique.

Specimens are listed in accession books in the order in which they were acquired and also by name and by locality. The catalogue compiled by Professor A. Lacroix in 1931 is still the most complete listing of this collection.

A smaller collection but one that contains some magnificent specimens has been recently revised by Professor Guillemin in L'Ecole Nationale Superieure des Mines de Paris. This collection was started in 1735 and contains over 100,000 specimens. Specimens on display occupy most of the first floor of the handsome Hotel Vendome that was built in 1707.

Many private collections were purchased or received as gifts and some of these have been kept intact. They contain some of the finest specimens and are of exceptional interest on account of their arrangements and labels. The systematic collection consists of 8,000 specimens arranged according to the classification of Strunz (1958).

The Norwegian National Collection of minerals is housed in the Geological Museum and is under the supervision of Dr. H. Neumann. It has particularly valuable and rare pegmatitic minerals from such classic Norwegian localities as the Langesund Fiord. Some of these localities are now protected and further collection from them is prohibited.

The Swedish National Museum of Natural History in Stockholm under Professor Wickmann assisted by Dr. O. Gabrielson is in the same building as the Geological Survey. It has an exceptionally fine mineral collection, with special collections of rare minerals from such famous localities as Ytterby, Lanban and Boliden.

In the Geological Survey, all mineral and rock specimens and notebooks are catalogued and retained for reference.

The National Mineral Collection of Finland is housed in the University of Helsinki and is now supervised by Dr. Waasjoki. Although the Kola peninsula has now been seized by Russia there is a fine collection of rare minerals from that well-known area. The collection is organized in accordance with the classification of Strunz.

The mineral collection in the British Museum is the finest seen on this trip. The collection is based on the classification of Dana, 6th edition, modified by atomic structures. Within each species, the specimens are arranged by geographical location. A much smaller duplicate collection for exchange is to consist largely of specimens from Great Britain.

The collection is catalogued primarily in order of accession and locality, source, and a considerable volume of data for specimens are recorded in the main accession books. The collection is also catalogued on a card system arranged in order of the Dana classification. In addition the following records and cross indexes are maintained:

1. Donors and others from whom specimens have been obtained are recorded on cards.
2. For each species, lists of localities, synonyms and varieties are maintained in file sheets - not on cards.
3. A list of prominent localities and minerals available from each.
4. Special index of gems.
5. Special index of pseudomorphs.

6. List of discredited specimens.
7. List of meteorites.

The normal specimens do not exceed 4" x 6" and most are smaller.

Labels are made of good rag, (banknote), paper with permanent data recorded in india ink. Labels are affixed to specimens with seccotine and if the following procedure is followed will not flake off:

1. A spot of seccotine is applied in a slight depression on the surface of the mineral where the label will be protected.
2. A few fibres of cotton wool are then worked into the seccotine and more seccotine added.
3. The label is soaked with water and excess water shaken off.
4. The wet label is pressed firmly into the spot of seccotine so that all excess seccotine is squeezed out.

A fairly large amount of research is being done by the professional staff of the British Museum. Laboratories include complete X-ray, chemistry, mineral separation and spectrographic laboratories. There is a staff of 5 professional mineralogists under the Head Keeper, Dr. Claringbull.

A second major collection of minerals, is maintained in the Museum of the Geological Survey of Great Britain.

In the course of work on sources of radioactive materials, the Atomic Energy Division of the Geological Survey of Great Britain has collected quite a large number of uranium and thorium minerals.

The mineral collection at Oxford is now in the care of a very able and keen collector, Mr. A. W. G. Kingsbury who is an authority on the minerals of Great Britain and Cornwall in particular.

Mr. Kingsbury is currently making a complete review of the collection at Oxford, which in common with other university collections, has suffered depredations by lecturers seeking specimens for teaching purposes. The collection is to be arranged in accordance with the new classification of Dana.

Of particular interest is a cabinet of 19th century specimens in which perfect crystals were glued on to the surface of pieces of rock or ore. Usually the crystals were imported from a locality in which they were abundant and glued on to rock specimens from other localities in which similar crystals were known but rarely found.

3-14 MINERAL SEPARATION

Unusual equipment for mineral separation that is available from dealers is listed in section 3-7 Equipment. This brief section deals with a few other devices and some methods that were not known to the writer. The methods and equipment in common use in Canada are not listed.

At Basel University clays containing foraminifera are impregnated with a solution of $FeCl_2$. This solution is absorbed differentially by the foraminifera. After drying, the clays are passed through a Frantz magnetic separator which removes the foraminifera.

Also at Basel a very effective instrument for concentration of mica has been developed. It consists of a sheet of plate glass 12" long and 10" wide, suspended by coil springs at the 4 corners stretched diagonally, parallel to the plane of the glass. The shorter side of the glass is tilted at 15 degrees to the horizontal and the longer side is horizontal. The plate is vibrated parallel to the longer side by a rod attached to the middle of the under side of the plate and at an angle of 30 degrees to the plate (measured on a vertical plane parallel to the long edge). The rod is driven by an eccentric having a throw of 2 mm. by an electric motor whose speed is varied by a Variac. Details of this instrument can be obtained from Johannes Hunziker, Min.-Pet. Institut, de Universitat, Bernoullianum, Basel, Switzerland.

At Cambridge samples are crushed and sized. The sized fractions are then passed into an elutriator to make a rough gravity separation. Products of this separation are then passed through a Frantz Isodynamic Separator. Final separation is effected in Bromoform, Clerici solution of Methylene Iodide in a centrifuge.

It was noted that in virtually all laboratories, heavy liquid separations were expedited and made more effective by use of a centrifuge.

The Overseas Geological Survey has a very well-equipped mineral separation laboratory. They rarely use the Wilfley table and use the Superpanner only for rough separations. For precise work they use the micropanner described by L.D. Muller in paper 52, Group IX of the International Mineral Processing Congress, 1960.

The fine dust in light powders is removed by the Laboratory Hydrocyclone. For mineral separation these powders are accurately sized and then passed over a Raymond air separator. This is particularly useful for separation of diatoms and for cleaning up industrial minerals.

For mineral separations that are difficult by gravity or magnetic methods, they use a Stuntevant Electrostatic separator. Samples must be dry, clean and perfectly sized. The ultrasonic disontegrator is used to clean samples that have coatings on the grains. It is usually an advantage to heat the sample to 300°C under a bank of infra red lamps. Optimum grain size for this instrument is 85-100 mesh but fractions down to 200 mesh can be separated. This separator is effective for concentration of zircon, rutile, ilmenite, cassiterite, scheelite, and wolframite.

Commonly three fractions are made and usually it is necessary to pass the concentrate through 2 or 3 times.

Tetrabromethane is the heavy liquid commonly used and separations are always made in a centrifuge with the special tube described under 'Equipment'.

At Imperial College samples that are to be analyzed are all crushed by hand with a tungsten carbide mortar and pestle. The mortar has a cylindrical tube of perspex around it to prevent grains scattering. Final grinding is done in a powdered agate mortar. Screening is done through cylindrical sieves made of perspex and nylon bolting cloth.

Mineral separation is done largely in Frantz separators and heavy liquids. Clerici solution is commonly used, and always in a centrifuge.

Thallium contamination is inevitable when this solution is used.

When preparing mica for Rb/Sr age determination, Dr. Jager recommends that mica be separated at the largest possible size of flake. After crushing, the product is passed through a bank of shaking sieves. First separation is then made using a vibrating or shaking glass plate (see above). Only perfect flat flakes are retained. These are then ground in an agate mortar under alcohol using light pressure. This is essential to split the mica flakes and release the apatite inclusions. The product is then passed through a magnetic separator. Finally it may be necessary to remove the heavy fraction. Dr. Jager advises that heavy liquids should not be used for this purpose.

3-15 MINERALOGY

This section deals primarily with work in progress in mineralogy including X-ray methods and synthesis of minerals. No attempt is made to give details of the studies; the purpose is to indicate as briefly as possible the scope of the work so that those interested in each field may write for information. Studies of rock forming minerals particularly are providing some evidence of their genesis.

For convenience, these notes are grouped under the following sub-headings:

General mineralogy

Metallic minerals

Rock-forming minerals

Supergene minerals

Synthesis of minerals

X-ray methods and data

General Mineralogy

A study of the relation between reflectivity, hardness and atomic structure of ore minerals is being made under Dr. C. Guillemin at the B.R.G.M. in Paris.

Mr. H.S.U. Bowie of the Atomic Energy Division of the Geological Survey of Great Britain is developing a method for identification of ore minerals based on a combination of their reflectivity and hardness.

Dr. G.A. Deicha of the University of Paris is studying liquid and gaseous inclusions in minerals.

At Gottingen, Mr. Goguel is also studying liquid inclusions in rock-forming minerals. To release them he grinds them under vacuum in a quartz ball mill using quartz balls.

Dr. Joachim von Valtee has written in German a very useful and complete paper on oriented intergrowths in minerals with an excellent bibliography.

Professor Barth has found that most K feldspars are highly triclinic or not at all, and that therefore triclinicity is of little use as an indicator of the genetic history of the rock. He believes that the rate of cooling of the rock is a major factor in the development of triclinic K feldspars.

At the University of Oslo, Professor I. Oftedal is working on trace element distribution in minerals. Where there is evidence of exsolution, Professor Oftedal contrasts the trace element content of the high temperature phase with the contents of the low temperature phases.

At the University of Stockholm, Docent Dr. O. Brotzen is working on the paragenesis of minerals in various types of pegmatites.

Research on the distribution of trace elements in sulphides and its relation to the Kullerud method of palaeotemperature determination is being done under Dr. Guillemin at the B.R.G.M.

Dr. A.P. Millman of Imperial College is a specialist in ore microscopy and is pioneering use of the electron microanalyzer in this field. (See also under 3-6, Electron Microanalysis and Diffraction).

Metallic Minerals

M. Capitant at the B.R.G.M. Paris is studying minerals of the Pb-Sb-S system by use of the electron microanalyzer.

Atomic structures of sulphosalts are being studied jointly by Professor Novacki at Bern and Professor Curien at the University of Paris (Sorbonne).

A study is being made at the B.R.G.M. in Paris in the alteration of cassiterite, wolframite and chromite. As part of this work, reasons for the different Fe/Cr ratios in chromites in placers and chromites in the original rock source of the placers, are being sorted. In part it may be due to substitution of Mg for Fe.

Dr. Waasjoki of the University of Helsinki has published an excellent paper on the chromites of the Kemi deposits, northwestern Finland; Bull. Comm. Geol. Finlande, No. 194, p. 1-26, 1961. This paper contains illustrations of the variation in the Cr/Fe content of adjacent grains determined by the electron microanalyzer.

In a study of the tailings from the J.C.I. Mine in South Africa, Dr. A.P. Millman at Imperial College identified a new mineral which is essentially a ferro-platinum alloy containing 84% P, 14% Fe and 2% Os + Pd. Associated with it were traces of cooperite, braggite, alurite and gold.

Dr. Vincent at Oxford is making a thorough study of the opaque minerals of the famous Skaergaardt intrusion, particularly ilmenite, titano-magnetite and ulvospinel. In his study of the sulphides from this intrusion he is associated with Professor Wager and Dr. Smales of Harwell.

At Oslo, the analyst, Mr. Bruun has analyzed and as yet unnamed niobate-tantalite mineral with the following composition: SiO_2 4.09%, TiO_2 4.04, Nb_2O_5 38.51, Ta_2O_5 3.06, Fe_2O_3 2.63, FeO 0.56, MnO 0.32, PbO 1.1, $((RE)_2, Th)O_2$ 10.5, UO_2 11.22, UO_3 5.16, CaO $\begin{smallmatrix}4.05\\3.87\end{smallmatrix}$, H_2O^+ 6.25, H_2O^- 3.39, $Al_2O_3 + Cr_2O_3 + BeO$ 5.75. Total 100.13

Rock-Forming Minerals

Professor de Roever at the University of Amsterdam has worked out a sequence of minerals indicative of various stages of metamorphism. In Alpine rocks; the association of glaucophane, jadeite (usually mistaken for diopside) and lawsonite are indicative of dynamic metamorphism; the albite-epidote-amphibolite association (green schist facies) may be indicative of either dynamic or static metamorphism; and the amphibolite-almandine facies is usually indicative of static load.

Professor Uytenbogaardt has completed a paper showing that Fe and Ti minerals uniformly exsolved in amphibolites, are indicative of a volcanic rather than a sedimentary origin.

Professor Picciotto has written extensively on pleochroic halves in micas. He has found that they may be used to interpret the thermal history of the mica but are not very suitable for age determination. Because haloes are destroyed by metamorphism, they can indicate only the age of latest period of metamorphism. A biotite from Eganville, Ontario studied by Henderson at Dalhousie in 1934 is unique in that haloes in it indicate that a 2 m.e.v., α - emitting isotope, previously unknown, is present in it.

Professor Rosenquist at the University of Oslo is studying layered minerals, clays and micas. His work shows that land slides are likely to occur where clays that were deposited in salt water have been subsequently leached by fresh water and the salt has been removed.

At the University of Helsinki, Professor Sahama is working on kalsilite and other minerals of volcanic rocks.

Work done by the Atomic Energy Division of the Geological Survey of Great Britain, principally in Rhodesia, has shown that a very high percentage of beryl present in pegmatities is much too fine-grained to be sorted by hand cobbing. In very many instances the fine-grained beryl was recognized only by use of a beryllometer.

Dr. M.J. O'Hara at Edinburgh is working on the composition of coexisting pyroxenes, garnets etc. from the Lewisian gneisses in the Scourie district of Scotland.

Mrs. G. Borlay at Imperial College has completed research on amphiboles from Nigerian granites which is to be submitted to the Journal of Petrology for publication.

Dr. G.M. Brown at Oxford is doing extensive work on the composition and lattice parameters of clinopyroxenes. One of his students, Mr. B. Atkins is working on the pyroxenes of the Bushveldt Complex.

A great deal of work on rock-forming minerals is being done at Oxford. Dr. Vincent is a specialist in the analysis of silicate minerals and using modifications of classical methods, makes complete mineral analyses on as little as 1/10 gram. Dr. Lambert is working primarily on amphiboles and other metamorphic minerals. Dr. Butler is particularly interested in micas.

Of particular significance to mineralogists and petrologists alike is the forthcoming publication in 1962 of "Rock-Forming Minerals" by Deer, Howie and Zussman in 5 volumes. I was shown part of this work in page proof and there is little doubt that it will be the major reference work in its field for many years.

Mr. John Rucklidge at Manchester is classifying serpentines on the basis of their X-ray powder patterns. He is particularly interested in nickel-serpentines and is studying separation of nickel in the thermal decomposition of serpentine. This is a major contribution and Mr. Rucklidge is employing 2 diffractometers in the work. He noted that sepiolite is commonly mistaken for serpentine.

Another student at Manchester, Mr. Frost, is studying the structure of amphiboles by powder diffraction methods and uses a computer to calculate parameters. Much of his work has been devoted to tremolite and riebeckite. His intention is to work out a method of estimating the composition of amphiboles from powder diffraction data. Mr. Woodraw is working on the structure of astrophyllite, whose structure has something in common with mica and with amphibole.

Professor R.A. Howie is studying the composition of orthorhombic proxenes from charnockites and other metamorphic rocks. Curves based on the analyses of these pyroxenes differ significantly for those of pyroxenes from igneous rocks. Dr. Hamad from the Geological Survey of the Sudan has been working with Professor Howie on Pyroxenes in olivine 'bombs' from volcanic rocks. On the Mg-Ca-Fe trigonal diagram, analyses by Hamad lie on a line cutting the Mg-Ca side near the Ca end and the Mg-Fe line near the Mg end. The latter intersection coincides with work done in the United States, but the U.S. work lies along a line intersecting the Ca-Fe line near the Ca end.

Another Manchester graduate student, Mr. J. Nolan is working on the albite-acinite system.

Supergene Minerals

At the Royal Institute of Natural Science in Brussels, the senior mineralogist, Dr. Van Tassel is particularly interested in supergene minerals and particularly sulphates, phosphates etc. of iron. At present he is working on ferri-tungstite which he has found to be unexpectedly common in many ocher deposits. He showed me remarkably fine specimens of crandallite and of banded autunite-torbernite from Belgium.

At the B.R.G.M. in Paris particular attention is being given to description of a wide group of arsenates, vanadates, phosphates, copper silicates and other supergene minerals. This work is being checked against synthetic products.

Studies of supergene manganese ores by Mr. T. Deans at the Overseas Geological Survey has shown that they are scavengers of other metals. In one case they were found to contain over 1% Mo and W, V etc. have also been found in significant quantity.

Synthesis of Minerals

Mention was made above of synthesis of supergene arsenates, vanadates, phosphates etc. in the B.R.G.M. in Paris.

At the University of Tubingen, Dozent Dr. S. Haussühl grows artificial crystals at normal pressure and normal but controlled temperature from aqueous solutions. Using seed crystals suspended on platinum wire or monofilament thread he grows magnificent crystals of $NaClO_3$ $AgClO_3$ $AlSO_4.6H_2O$ and Guanidine (?) up to 3" diameter in periods of 2 to 6 months. Impurities in the parts per million range in the solution can alter the habit of a growing crystal.

In the Geological Museum at Oslo, Dr. H. Neumann has synthesized euxenite both by sintering and from aqueous solutions.

Mr. Alan Edgar a graduate student at Manchester is making an intensive study of the cancrinite series by synthesis at controlled temperatures and pressures and has established 8 separate phases. His work has been done with gels in aqueous suspension between 200 and 800°C. and between 10,000 and 30,000 p.s.i. He is also investigating relationships between nepheline-cancrinite and nepheline-anorthite.

The laboratory for synthesis of minerals at Manchester is extensive and well-equipped. In a study of feldspar phenocrysts in granites, Dr. Carmichael has shown that addition of 8.3% acinite and 8.3% sodium silicate to the granite synthesis shifts composition of the feldspar phenocrysts toward the orthoclase end of the albite-orthoclase equilibrium.

As mentioned under geochemistry, Professor Hocart at the Sorbonne has synthesized cordierite and chabazite and other zeolites.

X-ray Methods and Data

Precise X-ray diffraction patterns from powders are made in the B.R.G.M. and at the Sorbonne using the double focusing arrangement developed by Dr. A.J. Rose of the Centre National de la Recherche Scientifique Bellevue (Near Paris).

At Hamburg, Professor Schrodel showed me an ingenious method of distinguishing between natural pearls and cultured pearls. It is based on the fact that the grain of $CaCO_3$ inserted into oysters to cause development of cultured pearls is usually in the orthorhombic form, aragonite. Lane X-ray powder photographs of a cultured pearl are taken in two directions at right angles to one another, one of them will yield an orthorhombic pattern. If the pearl is a natural one, both patterns will be hexagonal.

In the Geological Museum at Oslo, Dr. H. Neumann has systematized identification of X-ray powder patterns by line drawings in which the springs between lines are the same as on a 9-cm. film and the height of the line is indicative of the intensity of the line on the film. Line patterns are published for all sulphides, oxides, carbonates and silicates. In his laboratory these drawings are mounted on plastic in front of a large panel of ground glass to diffuse the light. They are arranged in decreasing order of the spacing of the strongest line. Most unknown patterns can then be readily identified by direct comparison. This scheme might be used for 57 mm. cameras by using the films mounted on a similar lighted panel.

At the Geological Survey of Sweden, research under Dr. A.M. Asklund, supported by the porcelain industry has produced a successful method of determining the amount of feldspar in a fine-grained rock by X-ray diffraction.

In the same laboratory quantitative determination of mixtures of minerals by X-ray diffraction is achieving results equal to laborious point counting under the microscope. One example was a mixture of cordierite, plagioclase and quartz in proportions of 30, 30, 40 was determined by X-ray diffraction as 28.5, 29.5, 5.42.

At the British Museum the X-ray laboratory is equipped with Integrating Weissenberg and Precession cameras.

A 6 cm. Unicam oscillating camera is used for single crystal and powder diffraction patterns so that patterns from each may be compared directly.

All unknown X-ray diffraction patterns are filed in order of the spacings of the three strongest lines. All new patterns are checked against these.

In the Atomic Energy Division of the Geological Survey of Great Britain, a Nonius-Buinier X-ray powder camera is used with a horizontal X-ray tube. This camera gives excellent resolution and permits 4 patterns to be made simultaneously. It is used largely for identification of clay minerals. It requires a larger amount of sample than other cameras.

The X-ray camera made by the University of Aberdeen which permits two patterns to be taken on one film was described under 3-7 Equipment.

3-16 MISCELLANEOUS

A few notes are added under this heading which might be overlooked if they were included in one of the other sections.

At Tubingen, Dr. S. Hanssuhle measures the elastic constants of the crystals that he grows from solution. This is done by measuring the elastic wave speed by passing monochromatic light through a crystal to which ultrasonic vibration is applied and measuring its diffraction. From these data the elastic constant can be computed.

The writer was fortunate in being able to join a field trip to the Hegan district of southwest Germany, west of L. Censtance on the Swiss border. It is a rolling countryside with a large farming population. Rock exposures are rather sparse and occur mainly in quarries and in a few prominent small hills, each crowned with ancient fortifications.

This area of 'Tertiary' volcanics has been repeatedly studied in the past century with apparently divergent conclusions. In view of the sparse exposures and deep weathering, this is understandable. The present study is supported by K/Ar dating and this for the first time has made possible a coherent reconstruction of events. The following table indicates present ideas of the volcanic sequence:

Melilite	6 m.y.
Melilite tuffs	
Hornblende tuffs	
Phonolites	9 m.y.
Intermediate tuffs	
Upper bentonites	12.5 m.y.
Sheet tuffs	14 m.y.
Basal bentonites	
Tuffites	

Most of the tuffs and bentonites were much softened and only the abundance of glass and some distinctive minerals were indicative of their original nature. The melilites are exceptionally fresh and exhibit pronounced columnar jointing. Phonolites and hornblende tuffs are also well preserved. There is little doubt that this is an exceptionally interesting area and one in which diamond drilling could provide much critical data.

In the new building of the Institute of Mineralogy and Petrology at Hamburg, electrical power is supplied through a master control panel in the basement, to all rooms. Constant power at any voltage from 2 up is available. The main lecture theatre in this building is a model of efficiency with almost startlingly good acoustics. It has most facilities such as lanterns lighting, etc. controlled by the lecturer from the desk.

Dr. Per Geiger, retired Director of the Geological Survey of Sweden, told me that emergence of the north coast of Sweden is well documented in historic times. Existing towns that were ports when they were founded have had to move their port-facilities.

Dr. J. Eklund of the Geological Survey of Sweden drew a very interesting parallel between the area in the S. W. part of Sweden and the Grenville region of the Canadian Shield. In both remarkably consistent ages are near 1000 m. y. and in both this is independent of the degree of metamorphism. Charnockites and large areas of anorthosites with associated titaniferous iron deposits are characteristic of both regions. In Sweden as in Canada the 'iron formations' are found in the older Precambrian rocks in the 1600 m. y. age group.

At Stockholm, Dr. Rayment, a palaeontologist on the University staff, is particularly interested in statistics. He stressed the importance of having a statistician consulted before geological sampling is done. If the sampling is not statistically sound results are apt to be misleading. Dr. Rayment mentioned a Canadian palaeontologist, Pierre Jolicoeur who is applying biological statistical methods to palaeontology at the Walker Museum of the University of Chicago.

At Manchester, Professor Zussman uses the method of fusing powdered samples in borax for X-ray fluorescence analysis, that was developed by Dr. Claisse at the Quebec Department of Mines.

3-17

PETROLOGY

The brief notes in this section are intended to draw attention to some of the work that was drawn to my attention in Europe. No attempt is made to do more than indicate the type of the study in most cases. For convenience of the specialist the notes are written under the following five sub-headings:

a. Basic and Ultrabasic Rocks

b. Granites and Pegmatites

c. Metamorphic Rocks

d. Volcanic and Dyke Rocks

e, Miscellaneous Studies

a. Basic and Ultrabasic Rocks

A study of the geophysics of ultrabasic rocks by use of a magnetometric survey of a special type, is being made by Professor Dr. G. Angerheister, Luisenstrasse 37, Munchen II, West Germany.

A major paper in German on Mantle Rocks and Magmas of Deep Provenance by Professor Dr. W. P. de Roever of the University of Amsterdam in Fortschritte der Mineralogie, June 1961, contains some fundamental concepts of the origin of ultrabasic rocks.

In studies of basic and ultrabasic rocks, Dr. J.R. Butler at Imperial College has analyzed that Sr content of monoclinic pyroxenes, olivines and feldspars. In feldspars a plot of the Sr content versus the anorthite content has indicated a clear distinction between different intrusions and facies.

Professor J. Sutton of Imperial College is to study a layered basic and ultrabasic intrusion in Somaliland early in 1962.

Dr. Munro is working on the Huntly layered basic to ultrabasic mass 40 miles northwest of Aberdeen. This body is well exposed in a quarry and consists of vertical layers varying from dunite to anorthosite. The mass consists of repeated units. In each unit the ultrabasic facies in the west grades to the felspathic facies in the east. Boundaries between units are sharp.

At Oxford, Professor Wager and other members of the staff are continuing work on the mineralogical, analytical and geochemical aspects of the study of the Skaergaardt Intrusion.

b. Granites and Pegmatites

At Basel, Dr. Haller has magnificent air photographs taken in Greenland of a section of a cliff 3,000 feet high and more than 5 miles long in which almost perfect exposures of palingenic and diapyric granite intrusions occur. Grade of metamorphism of the gneisses and schists below the granite diapyre decreases downwards. In another exposure development of a band of granite following the schistosity around the nose of a recumbent fold is illustrated.

Professor Neumann of the Geological Museum in Oslo is to start a detailed study of the pegmatitic nepheline syenites of Langesund Fiord. This will involve: detailed mapping of the dykes and their relation to the host rocks,

: a complete study of all minerals and their interrlations, textures, variations in composition and atomic structure, and occurrence in zones.

: geochemical study of the dykes as a whole and of each facies and mineral.

: precise mineral distribution to determine what minerals crystallized together.

The study is intended to determine the origin of the dykes and the processes by which they formed.

Professor Barth uses the compositions of coexisting alkali and plagioclase feldspars to determine the temperature of crystallization in granites. This can be expressed:

$$\frac{\%\ \text{Albite in alkali feldspar}}{\%\ \text{Albite in plagioclase}} = K_T$$

Based on this method, magmatic granites in the Oslo area crystallized at 750°C.

Some new data by N. L. Carter on temperature gradations in a granite diapyr indicate cooler temperatures in the centre of the mass.

Scott Smithson of the Geological Museum working on gravity anomalies over a large body of granite, is able to suggest that it has the shape of a diapyr.

Dr. A. Laitakari in Finland has been working on suites of heavy minerals segregated from granites. He has found a number of unusual minerals such as dumortierite.

Professor Gavelin of the University of Stockholm has been working on the origin of various granites in southern and central Sweden. Currently he is studying the Vastervik granites which appear to be products of granitization.

At my request, and without reference to notes, he listed these phases of his current work.

1. Detailed geological mapping.
2. Solution of the stratigraphic succession of original sediments and volcanics.
3. Mapping of tectonic features.
4. Complete structural study.
5. A special doctoral thesis on a spotted gneiss which may be the product of the first stage of metamorphism.
6. Study of the transformation and transition from sediments to gneisses and granitic rocks.
    a. by field studies
    b. by microscopic studies
    c. detailed mineralogy
    d. chemical analyses to determine whether metamorphism resulted from straight recrystallization
7. Extensive chemical studies of rocks and component minerals, particularly feldspars.

8. Mineral content of rocks by X-ray diffractometer checked by point counting.
9. Study of the physical behaviour of the rocks under high temperature and pressure.
10. Microphotographs to record texture changes are made authomatically by Zeiss attachment.
11. Oxygen isotope studies are being considered.
12. Petrofabric studies, macroscopic and microscopic.
13. Orientation of inclusions.
14. Studies of accessory minerals.

Dr. J.R. Butler at Imperial College has obtained some interesting results on various phases of intrusive granites by plotting the Rb/K and Rb/Tl ratios determined on the whole rocks. In a series of Nigerian granites the Rb/K ratio increases rapidly in the later stages of intrusion as does the Ga/Al ratio. The Te/Rb ratios show a clear distinction between normal Nigerian granites and late phase calc-alkaline granites: These ratios were plotted for soda rhyolites from all over the world and proved to be remarkably consistent. Radios of Cs/Rb and Cs/Tl could not be correlated with different granites even when these elements were determined by neutron activation.

Dr. Butler intends to see whether determining these elements on segregated feldspars or micas will provide even sharper correlations.

At the Macaulay Institute in Aberdeen work on residual soils suggests that cobalt content of magmatic granites is low whereas in metamorphic granites the cobalt content is much higher.

c. Metamorphic Rocks

As noted previously, Professor de Roever has suggested that in Alpine rocks presence of glaucophane, jaderite and lausonite is indicative of dynamic metamorphism wheras the amphibolite-almandine facies forms under static conditions. The green schist facies, (albite, epidote, amphibole) may form under either static or dynamic conditions.

In the Petrographic Section of the B.R.G.M. much of the work is being devoted to studies of skarn rocks, migmatites and granitization in the Pyrenees.

Mr. Brynhi at the University of Oslo has studied an area in which quartzite was intruded by anorthosite. These rocks have been metamorphosed to an albite-chinozoisite schist containing large 50 x 100 in. relicts of anorthosite. The chemical composition has not been altered.

Professor J. Sutton has completed a detailed study of the structures in the Lewisian gneisses of the Scourie district. In this belt the transition zone (2-3 miles wide) between rocks of the 2500 m.y. group and the 1600 m.y. group is marked by change in dip of the gneisses, change from diabase to amphibolite bands and development of granite sheets. This change in age is determined by the Rb/Sr method; it is not apparent in K/Ar dating.

Throughout the Lewisian gneisses, Professor Sutton has mapped the structures in detail. In general the axes of folds and trend of pegmatites are parallel to a series of shear planes further south. Geochemical studies are to be done where the time sequence is best known.

One of his students is working on the structure of the Lewisian rocks on the southern tip of the island of Skye in collaboration with a student at Cambridge who is doing the chemical petrology.

Professor Sutton with Dr. Watson and Dr. Ramsay and students has completed a very detailed study of the relation between small and large structures in an area spanning the Moyne thrust in the Highlands. Although this work has been published in detail, an agreed text integrating all the work done, is being prepared.

Drs. Sutton and Watson are going to apply the principles developed in this work to migmatite complexes and Dr. Ramsay is going to test them in the Alps where the stratigraphy is well known.

d. Volcanic and Dyke Rocks

Dr. G.A. Deicha at the Sorbonne is studying glass inclusions in volcanic rocks.

As noted previously in 3-8, diabase dykes in S.W. Sweden are associated with occurrence of undifferentiated metal suites up to and including Hg. Dr. Gavelin suggests that the fractures in which these dykes occur may penetrate the upper mantle.

Dr. de Roever at Amsterdam is working on olivine bombs and nodules from volcanic rocks.

An exceptionally rewarding study of the Triassic volcanic rocks of eatern Iceland is being made by Dr. G.P.L. Walker and his students at Imperial College. The rocks are mainly basalts and rhyolites. They are flat-dipping (8° -9° W) but when dips are corrected for the regional dip it is found that the volcanic rocks dip outward from the volcanoes. Over the volcanic vents collapse structures are marked by steep dips.

Basalts generally thin out in the vicinity of the volcanoes and are overlain by rhyolites which are always peripherical to the volcanoes. Earlier flood basalts are depressed by the volcanic basalts and the two may be interfingering at their contact. Rhyolites too are known to be interfingered with basalts in amazingly intimate mixtures. Specimens shown to me suggest that both rhyolite and basalt were liquid when they were mixed.

In this mixture of basalt and rhyolite glasses phenocrysts of bytownite, forsterite, oligoclase and ferroaugite occur. Zeolites are also present and show some change with depth. Propylitization of both the basalts and the rhyolites is highly developed.

Dr. R.A. Howie at Manchester is working on Li-rich aplites from Devonshire.

e. Miscellaneous

In Bulletin 189 of the Geological Survey of Finland, Dr. Simonen has listed and defined the accepted names of plutonic rocks.

On page 93 et seq. Simonen discusses opinions and criteria concerning the origin of these rocks.

At the University of Helsinki, Dr. Sahama is working on carbonatites and their constituent minerals.

A memoir of the Geological Survey of Nyasaland is to be published shortly on carbonatites and associated Nb-U deposits.

When sampling a rock unit, Dr. Agrell at Cambridge takes samples of the average rock and of the extreme types included in the unit. All are analyzed and modes are computed. Once the petrological balance has been determined between the mineralogy and the chemical analyses, the average composition is computed. A good student completes a point count on a thin section in 30 minues.

At Aberdeen, Professor Phemister has made a study of petrofabric methods and expressed the opinion that such methods add little to results of normal mapping. He thinks that such details are affected by local variations in dynamic metamorphism resulting from differences in competence of the various rock facies.