



GEOLOGICAL  
SURVEY  
OF  
CANADA

DEPARTMENT OF MINES  
AND TECHNICAL SURVEYS

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PAPER 62-30

SUMMARY OF RESEARCH:  
OFFICE AND LABORATORY, 1961

Compiled by  
P. Harker and S. E. Jenness



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## INTRODUCTION

In 1958 the Geological Survey issued an Information Circular reporting the results of the field work of the previous summer. Similar reports have been issued annually since that date; all have met with considerable public interest.

During the 1950's an increasing part of the work of the Geological Survey was in basic geological research, undertaken as office and laboratory projects. Some of these activities have been reported in geological and other journals; many others, however, have received little or no publicity.

This report is the first of a series, to be published annually, stating in brief form some of the many office and laboratory projects under investigation, and where possible giving some indication of their results. Most deal with activities during the 1961 calendar year; a few contributions prior to 1961 were considered of sufficient general interest to include them as background information for future results.

Many other office and laboratory projects were in progress at the end of 1961, but for various reasons are not included in this report. Some had not progressed far enough for significant results to be available. Others were omitted on the grounds that they are geological compilations rather than basic research; some 15 projects fall into this category, including the compilation of 4-mile aeromagnetic composite maps (A. S. MacLaren), metallogenic maps (W. D. McCartney), 1:1,000,000 geological maps (A. H. Lang), and the Tectonic Map of Canada (C. H. Stockwell).

On the other hand, palaeontological projects have been treated with considerable latitude, mainly because of the difficulty of reporting their results in the present format. Several such projects are reported more to indicate the nature of current palaeontological research by the Geological Survey than to present significant results.

Individual projects, described in more or less abstract form, are arranged in broad subject categories for easy reference. Within each category the projects are in alphabetical order according to names of participating personnel.

Organization and compilation of the many projects have been shared by Harker and Jenness. Statements followed by initials were written by personnel conducting the research.

Many omissions and shortcomings in this first "Summary of Research" will be obviated in future issues, in which most if not all project statements will be written by the scientific personnel concerned.

STRATIGRAPHY AND PALAEOLOGY

PROJECT: Silurian Coralline Faunas of Canada

PERSONNEL: T. E. Bolton

Some progress has been made in the study of Silurian corals from Manitoulin Island, Ontario, Anticosti Island, Quebec, and Western Canada. Work on this project is continuing.

PROJECT: Subsurface Upper Cretaceous Stratigraphy of West-central Alberta and adjacent British Columbia

PERSONNEL: C. F. Burk, Jr.

A regional correlation and stratigraphic analysis of Upper Cretaceous rocks with special attention to potential oil and gas reservoirs, such as the Cardium and Dunvegan Formations. A study of the electric logs of 400 wells in the area has been completed and a report is being prepared on the apparent correlations of marker horizons and sandstones. This report will provide a basis for the construction of structural and isopachous maps, the mapping of sandstones, and their areal limits and thickness.

PROJECT: A Middle Ordovician Ostracod Fauna from Lake Temiskaming, Ontario

PERSONNEL: M. J. Copeland

Well-preserved ostracoda from the Liskeard Formation near Lake Temiskaming are of Middle Ordovician age and indicate close faunal similarities with those of the Decorah Formation of Iowa. Further studies may show faunal affinities with the Middle Ordovician ostracode faunas of the Baltoscandian region.

(M. J. C.)

PROJECT: Ostracods from the Stonehouse Formation of Nova Scotia

PERSONNEL: M. J. Copeland

Recent geological investigations in Antigonish and Pictou counties, Nova Scotia, have disclosed several occurrences of Upper Silurian ostracoda. Specimens were obtained from strata of the Stonehouse Formation near Arisaig, Cape George, Lochaber Lake, Telford Brook, and Springville, and from pebbles and boulders of Silurian age

in the Lower Mississippian Horton conglomerates at Livingstone Cove and Upper River John. Study of these specimens is in progress.

(M. J. C.)

PROJECT: Canadian Fossil Ostracoda, Conchostraca

PERSONNEL: M. J. Copeland

Palaeontological studies are in progress on some leperditiid ostracods from northern Canada; some Silurian ostracoda from the Canadian Arctic; Silurian ostracoda from Anticosti Island, Quebec; Upper Silurian beyrichiid ostracods from New Brunswick; a Devonian conchostracan fauna from Melville Island, Canadian Arctic; and ostracoda from the Silurian Rochester Shale, southern Ontario.

PROJECT: An Upper Devonian Malacostracous Crustacean from Burlington, Iowa

PERSONNEL: M. J. Copeland

Unusually well preserved specimens of Palaeopalaemon iowensis Walter have been obtained from the Upper Devonian Maple Mill Shale near Burlington, Iowa, which reveal several previously unknown features. A new genus is to be proposed for this species.

(M. J. C.)

PROJECT: Graptolite Faunas, Gaspé Peninsula

PERSONNEL: L. M. Cumming

Preparation of systematic descriptions and illustrations of graptolite faunas from Ordovician and Silurian rocks of Gaspé Peninsula, with an account of their stratigraphic significance.

PROJECT: Lower Jurassic System of Southern Yukon and North-west British Columbia

PERSONNEL: H. Frebold

A systematic study and description of the index fossils and stratigraphy of the Lower Jurassic System, and the correlation of these beds with Lower Jurassic rocks elsewhere in Canada. The study is expected to yield an interpretation of the palaeogeography of the area during Early Jurassic time.

PROJECT: Study of Scaphites Fauna from the Bearpaw Formation of Alberta and Saskatchewan

PERSONNEL: J. A. Jeletzky

By means of a study of Geological Survey collections of Scaphites from the Bearpaw Formation it is hoped to zone the formation and its equivalent formations, and to correlate these formations throughout the Prairie Provinces. Preparation of a systematic description and accompanying fossil plates is proceeding.

PROJECT: Cretaceous Marine Zones of the Western Interior of Canada

PERSONNEL: J. A. Jeletzky

Comprehensive and systematic description of the palaeontology and stratigraphy of the marine Cretaceous strata of the western interior of Canada, and their correlation with standard divisions in the western interior of the United States and Europe. This work is in progress.

PROJECT: Monograph of the Canadian Buchia (= Aucella) Faunas

PERSONNEL: J. A. Jeletzky

Comprehensive description of Canadian Buchia faunas, adequately illustrated with fossil plates, figures, etc. Special attention is being paid to the zonal values of all Buchia species dealt with in the monograph.

PROJECT: Monograph of Canadian Belemnites

PERSONNEL: J. A. Jeletzky

Comprehensive description of Canadian belemnite faunas, adequately illustrated by fossil plates, figures, etc., with special attention to the stratigraphic value of the belemnite species and genera found in Canada. The project is proceeding in conjunction with the work of the author on the Dibranchiata Volume of the "Treatise on Invertebrate Palaeontology" (R. C. Moore, Editor) now in progress.

PROJECT: Description and Evaluation of Plant Fossils from the Type Section of the Ghost River Formation of Alberta

PERSONNEL: D. C. McGregor

This project involves a systematic study and description of plant megafossils from the type section of the Ghost River Formation, with a reassessment of the type section in the light of recent stratigraphic and palaeontological research. The study is being undertaken with the collaboration of R.D. Greggs (Shell Oil Co., Calgary) and G. E. Rouse ( University of British Columbia).

PROJECT: Plant Microfossils from the Ordovician Red River Formation, Manitoba

PERSONNEL: D. C. McGregor

The systematic study of plant microfossils in this limestone deposit has some bearing on the elucidation of the palaeontology of the Cat Head Member of the Red River Formation; the microfossils are also of some significance in the palaeobotanical record of the Early Palaeozoic.

PROJECT: Palaeobotanical Study of Early Devonian Megafloras and Microfloras of Eastern Canada

PERSONNEL: D. C. McGregor

A morphologic and taxonomic revision of the Gaspé and related floras, which will be related to the stratigraphy of the areas.

PROJECT: Age and Fauna of a Late Middle Devonian Reef, Horn Plateau, Northwest Territories

PERSONNEL: D. J. McLaren and A. W. Norris

An unusual fauna is associated with a reef developed in the Middle Devonian rocks of Horn Plateau. Systematic study of fossils collected from the reef on Operation Mackenzie is well advanced and should permit conclusions to be made on the age and relationships of the fauna and on the precise stratigraphic position of the reef.

PROJECT: Faunal Study of 'Halysites' beds, Cirrus Mountain, Banff National Park, Alberta

PERSONNEL: B. S. Norford

Comprehensive faunal study of collections from a measured section on Cirrus Mountain, with special reference to the age and correlation of the 'Halysites' beds.

PROJECT: Faunal Study of Late Ordovician and Silurian Rocks of Southern British Columbia

PERSONNEL: B. S. Norford

Systematic description and illustration of the faunas of the Beaverfoot-Briscoe Formation. The project includes lithologic and biostratigraphic correlation of the rocks, with special reference to the position of the Ordovician-Silurian boundary in the region.

PROJECT: Subsurface Study of Lower Cretaceous Rocks of South-eastern Saskatchewan

PERSONNEL: L. L. Price

Two major groups of contrasting lithology are recognized. The upper group (Ashville) is mainly shale, and contains marine fossils and glauconitic beds. It thins to the northeast where increasing amounts of sand may indicate the approach to shoreline conditions. The lower group is highly variable in thickness and shows no sign of depositional limits within those now imposed by subsequent erosion, and compared with the Ashville Group shows considerable stratigraphic complexity. Study is based on electric logs and samples from oil and gas wells.

PROJECT: Subsurface Study of the Mississippian, Pennsylvanian, and Permian Systems of Northeastern British Columbia

PERSONNEL: R. M. Proctor

A description of interpretation of the main features of the rocks of both systems, with cross-sections showing correlation with adjacent areas based on study of data obtained from electric logs, cores, and samples from wells drilled for oil and natural gas.

Work to date has shown that erosion is the basic influence on the present distribution of Upper Palaeozoic rocks. The Peace River "Arch" appears to have had only minor influence on sedimentation of the Banff and Debolt Formations, but played a significant role during deposition of the Pekisko and Shunda Formations. Deposition of the Stoddart Formation appears to have been most strongly influenced by a zone of weakness on the north flank of the "Arch".

PROJECT: Subsurface Studies, Cambrian to Devonian Strata,  
in Southwestern Ontario

PERSONNEL: B. V. Sanford

Southwestern Ontario, an area of approximately 40,000 square miles, is underlain by marine sedimentary rocks that reach a maximum thickness of about 5,000 feet. All geologic systems from Cambrian to Mississippian are represented, each of which contains important petroleum- and natural-gas-producing reservoirs. By means of well-sample cuttings the various formations within each system are being traced from outcrop to subsurface. Two reports of this series have now been completed: "Subsurface Stratigraphy of Upper Cambrian Rocks in Southwestern Ontario" (GSC Paper 58-12), and "Subsurface Stratigraphy of Ordovician Rocks in Southwestern Ontario" (GSC Paper 60-26). Due to the greater number of stratigraphic tests to Silurian strata, this system is being mapped in considerable detail. Special emphasis is being placed on the blanket sandstone reservoirs of the Clinton and Cataract Groups, now being exploited offshore under the eastern end of Lake Erie, and Middle Silurian Niagaran reefs of the Windsor-Sarnia-Goderich area.

(B. V. S.)

PROJECT: Ordovician Fossils from Sherman Inlet

PERSONNEL: G. W. Sinclair

Preparation of systematic descriptions and illustrations of fossils collected in 1960 on Operation Bank River, and a report on their stratigraphic and correlative values.

PROJECT: Permian of Northern British Columbia

PERSONNEL: J. G. Souther; J. K. Rigby (Brigham Young Univ.)

A detailed study of the stratigraphy and fauna, with special reference to the fusulinids, of the Permian formations of northwestern British Columbia, particularly those of the Stikine area.

PROJECT: Identification of Organic Remains from Offshore  
Dredged Samples

PERSONNEL: F. J. E. Wagner, J. Terasmae

Study and identification of material collected by the Canadian Hydrographic Service from Exeter Bay, Baffin Island, have been undertaken to provide information on depth and geographic distribution of recent species as an aid in the interpretation of fossil assemblages from Pleistocene deposits.

GEOFYSICS

PROJECT: Electromagnetic Radiation Studies

PERSONNEL: L. S. Collett, B. K. Bhattacharyya, and others

Studies commenced in 1961 on the effect of earth materials and moisture in the ground on the propagation of electromagnetic waves and pulses. When energy is transmitted from a loop antenna and received by a second loop, the conductivity and dielectric constant of the medium near the loops influence the shape of the pulse, or, in the case of a continuous sinusoidal signal, the phase and amplitude. Water has a dielectric constant of 80 compared to air, while that of rocks ranges from 4 to 10. One application is the tracing of groundwater aquifers.

The approach to the problem is fourfold: theoretical, scale-model measurements, instrumentation, and field work. Already completed is a theoretical study on the fields of a vertical magnetic dipole excited by half-sine pulses of duration  $0.8 \times 10^{-6}$  and  $40 \times 10^{-6}$  seconds. The transmitter and receiver were calculated to be on the surface of the earth and separated by 50 and 150 metres respectively. Also completed is a theoretical analysis of the radiation resistance of a horizontal loop antenna placed above the surface of the earth. These theoretical curves of radiation resistance with height above the ground indicate that it may be possible to determine the conductivity and dielectric constant of the earth's surface from the measured values of radiation resistance of a loop antenna on an aircraft.

For the scale-model measurements, a site that has low local radio interference has been acquired in Gatineau Park north of Ottawa, and a wooden hut has been set up housing a  $15' \times 15' \times 4'$  tank. Measurements have not yet commenced. A start on instrumentation was made during the year, but no field work was done.

This is the start of a long-term project to aid in the understanding and interpretation of electrical and electromagnetic data in terms of geology.

(L. S. C.)

PROJECT: Gamma-ray Spectrometer Studies

PERSONNEL: A. F. Gregory; J. Horwood (Mines Branch)

The aims of this project, started in 1959, are: (1) to make a laboratory study of thick source gamma-ray emission spectra as a forerunner to in-situ measurements on rocks, and (2) to investigate the degradation of energy spectra with increasing air

distance, and the significance of diurnal variations in the gamma field of the earth.

Thickness of source and air distance from source to detector were varied to determine their effects on the net total intensity and the net energy spectrogram of gamma radiation from uranium, thorium, and potassium. A 100-channel gamma-ray spectrometer was used in the investigation.

Source thickness was varied from 1/2 inch to 48 inches in a series of measurements made with the detector close to the source. A quasi-exponential increase in intensity and build-up of scattered radiation in the spectrum accompanied an increase in thickness.

Air distance from source to detector was varied from 36 to 730 feet in a series of measurements from a high wooden tower. A quasi-exponential decrease in intensity accompanied by a gradual build-up of scattered radiation in the spectrum was observed with increasing air distance.

The experimental results were compared with theoretical evaluations. Some of the more important conclusions are:

1. Rocks have distinctive gamma-ray spectra, which reflect the proportions of radio elements in them.
2. For common rocks, the intensity of gamma radiation from potassium predominates over that from either uranium or thorium and may exceed their sum.
3. The ratio of total intensity to the intensity of a primary radiation may be a useful factor in evaluating distance between source and detector.
4. The total intensities of gamma radiation from uranium, thorium, and potassium vary at the same rate for air distances ranging from 300 to 600 feet approximately.

(A. F. G.)

PROJECT: Palaeomagnetic Studies

PERSONNEL: A. Laroche, R. F. Black, G. Freda

Palaeomagnetic studies were started by the Geological Survey in 1955 to measure the direction of remanent magnetism in rock samples as a means of determining the direction of the earth's magnetic field during geologic history. During 1961, construction neared completion on an astatic magnetometer, compensated for building variations and magnetic-field gradient variations. Laboratory

measurements were completed on 225 oriented specimens from the Sudbury Basin area, 272 specimens from Prince Edward Island, and on specimens collected from the Mount Megantic area in Quebec, the Lewis thrust plate in Alberta, and from several anorthosite bodies in Quebec. Palaeomagnetic data on the Sudbury specimens indicate that the norite was emplaced into a gently dipping structural basin and subsequently folded into its present position. The palaeomagnetic pole position derived from the Mount Megantic specimens was found to be relatively close to that of the other Monteregion Hills; this supports other recent geological evidence that the Mount Megantic rocks were intruded at the same time (post-Triassic) time as the other Monteregion rocks. Data from the Lewis thrust plate near North Kootenay Pass, Alberta, indicate no measurable rotation of the plate, but suggest rather that it moved as a single coherent tectonic unit. This distinct change in trend direction of the thrust fault in this area owes its origin to another cause. Interpretation of the data on Prince Edward Island and anorthosite specimens is proceeding. To date three Survey bulletins and nine outside papers have been published on the results of this project. Two other Survey bulletins are in press.

GEOCHEMISTRY

PROJECT: Isotope Studies of Sulphur from Canadian Petroleum Deposits

PERSONNEL: H. R. Belyea, J. A. Maxwell, R. K. Wanless

The first phase of this study was the comparison of the isotopic ratios in sulphides selected from various wells in Alberta. This preliminary work indicated that the ratios within a given formation were relatively constant with depth, and that rather large variations in isotopic composition existed in the transition zones between formations. It was also found that the sulphides in adjacent formations, while internally consistent, commonly varied markedly from one another.

It was not known however, whether the isotopic ratios were constant for a particular formation in various parts of the province. Plans were therefore made to select additional samples from a particular formation from various wells in the region. The results of the second phase are not yet available, although the sulphide samples have been converted to  $\text{SO}_2$  and now await mass spectrometric analysis.

(R. K. W.)

PROJECT: Lead- and Sulphur-Isotope Geology of Keno and Galena Hills, Yukon

PERSONNEL: R. W. Boyle, R. K. Wanless

This project parallels the studies outlined for the Sullivan Mine and East Kootenay district deposits and for the gold-quartz deposits of the Yellowknife district. In this investigation, however, both lead- and sulphur-isotope measurements are to be carried out.

The lead-isotope determinations are now complete and preliminary compilation is underway. All sulphide minerals have been converted to  $\text{SO}_2$  and are awaiting mass spectrometric analysis.

(R. K. W.)

PROJECT: Isotope Chemistry of Sulphur in Rocks and Minerals

PERSONNEL: R. W. Boyle, R. K. Wanless, J. A. Lowdon,  
R. D. Stevens

Two major projects and four minor projects involving the study of sulphur-isotope variations in nature have been undertaken.

The study of the sulphur-isotope distribution in the Yellowknife region is now complete. Interesting trends in the isotopic composition of sulphides found in the granodiorite, in the greenstones, and in the main ore zones were found. The results, which have been published (Economic Geology, vol. 55, pp. 1591-1621, 1960), indicate a direct correlation between the  $S^{34}$  content and the thermal history of the particular rock type. The sulphides in the granodiorite, the porphyries, and in the greenstone belts have all been enriched in the heavier  $S^{34}$ , to varying degrees, during the early phases of development of the region. The ore zones also contain sulphides enriched in  $S^{34}$  and the average values for the ore reflect a kinship to the sulphides in the enclosing country rock.

A second major study has been started in the Keno Hill region. A large number of sulphides have been selected and converted to  $SO_2$  in preparation for isotopic analysis. In this study the lead-isotope abundances will also be determined in an attempt to shed light on the processes responsible for ore concentration.

Four minor projects, essentially of a reconnaissance nature, have been completed. These include studies of the sulphides at the Sullivan Mine, Kimberley, B. C. (G. B. Leech); sulphides from the Blind River region of Ontario (S. M. Roscoe); sulphides in radioactive deposits in the Bancroft area, Ontario (S. C. Robinson); and a preliminary survey of the sulphides from various iron deposits in Canada (G. A. Gross).

(R. K. W.)

PROJECT: Radiocarbon Dating

PERSONNEL: W. Dyck, R. K. Wanless, and others

In order to provide dates in the relatively recent past (0 - 35,000 years), the Geological Survey in 1959 commenced construction of a radiocarbon ( $C^{14}$ ) dating laboratory. This unit comprises (1) a low-level counting laboratory in the sub-basement of the Survey building, where it takes advantage of the excellent shielding provided by the concrete floors of the building, and (2) a sample-preparation laboratory. Sample materials are converted to  $CO_2$  and the concentration of radiocarbon is determined in proportional counters. In January 1961 the dating laboratory became operative, and during the ensuing months a total of 62 age measurements were completed, using a single, 2-litre proportional counter. Many of the age measurements are reported in Radiocarbon, vol. 4, 1962. Work was also conducted on the design and fabrication of a 5-litre counter; by the end of 1961 this counter was completed and was undergoing tests.

PROJECT: Chemical and Spectrographic Analyses of Rocks and Minerals

PERSONNEL: J.A. Maxwell, S. Abbey, W.H. Champ, S. Courville, and others

This project is an active part of the Survey's laboratory research. Many of the results are published in areal geological reports published by the Survey; others are in outside publications. During 1961 almost 9,000 chemical determinations were made. Work is continuing to develop new chemical and spectrographic methods of analysis and to improve the accuracy, range, sensitivity, and speed of existing methods.

PROJECT: Investigation of Recent Methods for Determining Ferrous Iron in Rocks and Minerals

PERSONNEL: J.A. Maxwell, J.M. Moore, Jr. (Carleton University)

Investigation of the applicability of a rapid colorimetric method (developed by L. Shapiro of the U.S. Geological Survey) revealed that it did not give complete recovery of the iron but that further work might produce a useful method.

PROJECT: Origin of Sulphides in Radioactive Conglomerate

PERSONNEL: S.M. Roscoe

The systematic difference in isotopic composition in a few sulphide samples from Elliot Lake, Ontario, has led to further isotopic studies of sulphides in various rocks at Elliot Lake and the adjacent region. These studies have revealed that sulphides associated with radioactive minerals in conglomerates have a limited range of  $S^{32}/S^{34}$  ratios, which differs significantly from those of other groups of sulphides in the area including: pre-Huronian and post Huronian hydrothermal sulphides (both lower), sulphides in Huronian black argillites (much lower), and epigenetic, probably sedimentogenic, sulphides in Huronian strata (higher). A slight but significant difference is found between sulphur-isotope constitution of pyrite in ore-grade conglomerates and that in sub-ore-grade conglomerates.

Neither local metamorphism nor local intense hydrothermal alteration of ores has significantly affected the isotopic composition of their sulphur. Extreme sulphur-isotope differentiation has occurred in certain late sulphides.

The data support deductions and mineralographic and chemical evidence that a mixture of pyrites of different origins is present in the conglomerates.

(S. M. R.)

PROJECT: Isotopic Study of Canadian Ore Leads

PERSONNEL: R.K. Wanless, G.B. Leech, R.W. Boyle,  
R.D. Stevens

A study of the lead-isotope distribution of the Sullivan Mine, Kimberley, B.C. and of smaller lead deposits in the East Kootenay District has been completed. The results are to be published in the Buddington Volume of the Geological Society of America.

The isotopic distribution within the large Sullivan deposit was found to be extremely constant. The average of this deposit has been compared with the isotopic values found in the other deposits of the district, many of which contain lead with a much higher radiogenic lead-isotope composition. Detailed calculations based on a model for lead evolution since the formation of the earth have been carried out. From this, one may postulate the type of source responsible for the production of a lead body with the isotopic distribution now found in the Sullivan Mine.

The lead-lead age of the Sullivan deposit has been compared with K-Ar age measurements on a lamprophyre dyke within the mine and on mica from a granitic intrusion nearby. This work indicates that the Sullivan deposit is between 765 and 1,250 m.y. old.

(R. K. W.)

PROJECT: Magnesium-Isotope Studies

PERSONNEL: R.K. Wanless, J.A. Maxwell, C.H. Smith,  
W.D. Loveridge

A reconnaissance survey of magnesium-bearing minerals was undertaken to establish the possible existence and range of natural magnesium-isotope variations. This study involved the development of special techniques required to produce and detect satisfactory ion currents in a solid-source mass spectrometer. Several methods of sample preparation were studied and a series of samples were analyzed.

This initial survey has shown that small magnesium-isotope variations do exist in natural materials and that the lighter magnesium-isotope,  $Mg^{24}$ , is slightly enriched in low-temperature hydrous-mineral phases.

A preliminary report was made to the American Geophysical Union's Annual Meeting in Washington, D. C., April 1961.

(R. K. W.)

PROJECT: Age Determinations of Rocks and Minerals

PERSONNEL: R.K. Wanless, R.J. Traill, S. Abbey, J.C. Paris,  
S. C. Robinson, J.A. Lowdon

Age determinations, based on the U-Pb, and Th-Pb ratios, the  $K^{40} - Ar^{40}$  ratio and the  $Rb^{87} - Sr^{87}$  ratio, are currently being carried out by the Geological Survey. During the early stages of development of the laboratory, age measurements were restricted to the determination of U-Pb and Th-Pb ratios in uraniferous minerals. As the isotopic analyses are carried out on a gaseous sample of  $Pb(CH_3)_4$ , requiring a relatively large quantity of lead, the application of the method was restricted to regions containing radioactive deposits. The regional restrictions are not as severe in the case of the K-Ar method however, and consequently increased emphasis has been placed on the application of this method. During 1959 a reconnaissance age program based on the K-Ar method was initiated, and a total of 454 determinations have since been published in GSC Papers 60-17, 61-17, and 62-17. This study is continuing. The completion of a new solid-source mass spectrometer provided an opportunity for the application of the Rb-Sr method to age problems, and late in 1961 work was started on the calibration of the isotope-dilution solutions required. Rb/Sr ratios are now being determined on whole rock and separated mineral fractions.

The sample-size restrictions referred to above, in the case of lead analyses, have been removed with the development of solid-source mass-spectrometric techniques. It is now possible to carry out isotopic analyses of lead samples in the 20-to-40-microgram range, on a routine basis. This development has facilitated the extension of age studies to determinations based on the radiogenic lead accumulated in zircons and other minerals. A special lead-free chemical laboratory is now being equipped to handle the extremely small quantities of lead required for this work.

The mass-spectrometer laboratory is at present equipped with two mass spectrometers, one designed to analyze gaseous samples and one equipped for the analysis of solids. Two new instruments, of somewhat smaller design, are now being fabricated. The new gas-source instrument will be employed exclusively for the analysis of argon while the new solid-source unit is designed to handle the expanded Rb/Sr age program. The existing solid-source mass spectrometer will then be available for studies involving trace quantities of lead and for the development of techniques required for other projects dependent on analyses in the solid form.

The results of the K-Ar reconnaissance age study of the Canadian Shield are being used in the development of the tectonic map of Canada. As the general age patterns are established, problems requiring more detailed study are unveiled. Where possible, the various age-measurement techniques will be applied to help elucidate the time relationships of rocks in complex geological settings.

(R. K. W.)

PROJECT: Study of Trace-Element Adsorption by Silicates

PERSONNEL: R. A. Washington

An investigation commenced in 1961 to obtain quantitative data on the amounts of trace elements adsorbed by silicate minerals and rocks, in order to develop a reasonable theory of the mechanisms operative in the formation, metamorphism, and metasomatism of silicate rocks. The effects of pH and temperature on the adsorption of trace elements from solution on finely ground quartz, feldspar, and other minerals are being studied. These studies have revealed that the adsorption of  $\text{Co}^{++}$  (from dilute solution as chloride) on quartz at room temperature is negligibly small at pH values below ca. 3.5. The amount adsorbed, however, increases markedly as the pH is increased from 3.5 - 4 to 6.5 - 7. Preliminary results also indicate that there is a slight difference in the amount of  $\text{Co}^{++}$  adsorbed by crystalline quartz from Lyndoch, Ontario, and by massive quartz from Buckingham, Quebec. No firm explanation of this result can be offered at present. Further study will be required to establish whether this small difference is real and to find the reason for it.

Experiments using feldspar (from South March, Ontario, and Buckingham, Quebec) are being carried out, and later experiments will include tests at different temperatures and concentrations, and using other silicate minerals (e.g. mica, olivine, hornblende, pyroxene, etc.) and other trace elements (e.g. Ni, Fe, Tl, Pb, Sr, Zn, etc.). The results of these tests should provide data that can be used to estimate the energy requirements for adsorption, and to explain some of the processes that may be important in regulating the concentration and distribution of trace elements in silicate rocks.

(R. A. W.)

MINERALOGY AND PETROLOGY

PROJECT: Composition of Olivine Grains

PERSONNEL: J. L. Jambor

During the year a satisfactory X-ray powder-diffraction method was devised for determining the composition of olivines. The powder-camera technique was developed for use with the small amounts of olivine normally found in thin sections of altered ultramafic rocks, thereby avoiding the task of preparing concentrates as is generally required in the diffractometer method. The accuracy of composition determinations by the powder-camera method is  $\pm 3$  mol per cent forsterite. The technique has been successfully used in outlining compositional variations in the Mount Albert, Tulameen, and Muskox ultramafic intrusions. The variation between forsterite and fayalite shows a marked departure from a straight-line relationship.

(J. L. J.)

PROJECT: Rare-Mineral Studies

PERSONNEL: J. L. Jambor

X-ray diffraction studies during 1961 have revealed the following: (1) The existence in Keno Hill (N. W. T.) ores of a new mineral species—a member of the kieserite group with the composition  $\text{ZnSO}_4 \cdot \text{H}_2\text{O}$ . The mineral was successfully synthesized, and named "gunningite" in honour of H. C. Gunning, a former member of the Geological Survey. (2) Another new mineral, in a specimen from Lillooet, B. C.; it also is a member of the kieserite group, with the composition  $(\text{Cu}, \text{Fe})\text{SO}_4 \cdot \text{H}_2\text{O}$ . (3) Two new sulphantimonide minerals at Madoc, Ontario— $\text{Pb}_2(\text{Sb}, \text{As})_2\text{S}_5$  and  $\text{Pb}(\text{Sb}, \text{As})_2\text{S}_4$ —representing the antimonian analogues of defrenoyssite and sartorite. (4) The existence of two distinct species—rozenite ( $\text{FeSO}_4 \cdot 4\text{H}_2\text{O}$ ) and siderotil ( $\text{FeSO}_4 \cdot 5\text{H}_2\text{O}$ )—which had previously been regarded as identical minerals.

PROJECT: X-Ray Spectrographic Methods

PERSONNEL: G. R. Lachance

This project involves research and development work on X-ray spectrographic methods of analysis and their application to geological specimens. During the year a method was developed for the determination of percentage of potassium in micas for age determination. The variables found to affect X-ray intensity of K radiations were particle size and Fe concentration. In addition, a method was developed for the determination of individual rare earths

in a chemically separated rare-earth fraction. Using a combination of the ratio and fusion techniques, it is possible to determine individual rare earths down to a concentration of approximately 0.1 per cent on a sample weighing 20 to 30 mg. This method was extended to the analysis of major and minor (i. e. down to approximately 0.5 per cent) constituents in minerals. The elements that can be analyzed by this method are those having an atomic number greater than 18. Studies are continuing on the development of a reliable X-ray method for the determination of Mg, Al, and Si in igneous rock specimens.

PROJECT: Study of Micas

PERSONNEL: J. Y. H. Rimsaite

Studies of the chemical composition of 27 micas, for which chemical analyses had been prepared and atomic percentages and formulas calculated, revealed that regardless of the calculation method employed, all fresh biotites show a variable deficiency of the (OH, F) group, which appears to be related to oxidation of ferrous iron at the expense of the hydroxyl. In the micas analyzed the atomic percentages of total octahedral iron and magnesium vary from 1.5 per cent Fe and 98.5 per cent Mg to 70 per cent Fe and 24 per cent Mg, thus covering the composition range of natural micas.

The following relationship was established between the chemical composition of biotites and their physical properties: with increasing quantity of iron-group ions in the octahedral sites by 10 per cent, specific gravity increases by 0.03, refractive index ( $N_{\gamma}$ ) increases by 0.02, and intensity ratio of the fourth to fifth basal reflection on the diffractometer charts increases by 0.3.

Some trace elements are related to the major constituents of the mica, which in turn are related to the type of the host rock and sequence of crystallization. Some trace elements exhibit local variations, being related to the composition of the associated minerals—e. g. Rb is high in micas associated with rare-earth-bearing minerals. Trace-element content can be affected by alteration. The most useful trace elements in correlating trace elements of micas with the type of rock are Cr and Ni; the most useful major constituents in such correlation are Mg and Ti.

The most striking difference in chemical composition was found between paragenetically early and late mica varieties from the same rock. Difference in Rb and Sr content of early and late mica from the same rock was interesting in connection with Rb-Sr dating of micas.

(J. Y. H. R.)

FUELS

PROJECT: Petrographic Examination of Coking-Coal Blends from Michel, British Columbia

PERSONNEL: A. R. Cameron, P. A. Hacquebard

A detailed petrographic study of mined coal and seams in situ to determine the most suitable coking-coal blends of the Michel area. Preliminary examination of two size-fractions (+1/4 inch and -1/4 inch) of the Balmer seam showed a pronounced effect of the petrography on the variable coking properties of this seam. Work on the petrographic characteristics of this seam as well as on the "A" and No. 1 seams from the Michel area is continuing.

(A. R. C.)

PROJECT: Review Article on Industrial Application of Coal Petrography

PERSONNEL: A. R. Cameron, P. A. Hacquebard; J. A. Harrison (Ill. Geol. Surv.)

Since 1945, much work has been done in Europe (including Russia) and the United States on the industrial applications of coal petrography in such fields as research on coking coals, cokes, sized coals, hydrogenation of coal, etc. In order to summarize and evaluate all research done in this field, an exhaustive literature survey was made during 1961, the results of which were reported at the 1961 annual meeting of the Geological Society of America. A manuscript suitable for publication is being compiled.

PROJECT: Commonwealth Committee on Fuel-Research Exchange of Coal Samples for Petrographic Analyses

PERSONNEL: P. A. Hacquebard, T. F. Birmingham

The exchange of coal and coke samples among British Commonwealth organizations was recommended by the Second Specialist Conference on Fuel Research, London, 1956, so that each organization would acquire experience in working with a wider range of solid fuels than was available in any one country. Each participating country submitted up to six seam samples which were then analyzed by all countries concerned.

The Geological Survey has analyzed samples from Australia (four), Great Britain (five), Canada (six), India (six), South Africa (five) and New Zealand (four). The results of the petrographic

analyses have been circulated to the participating laboratories. Reasonably good concordance was apparent in the maceral (or ultimate) analyses, but considerable divergence existed in the microlithotype (rock type) determinations.

The project's value lies in the revelation and explanation of such differences, and will be continued in the future.

(P. A. H.)

PROJECT: Research on the Petrography and Spore Analysis of Coal

PERSONNEL: P. A. Hacquebard, A. R. Cameron, J. R. Donaldson, T. F. Birmingham, M. S. Barss

Investigations of the character and correlation of various coal seams in the maritime and western Canadian coal fields were commenced in 1948 by the Geological Survey. The project includes studies in both coal petrography, for geological and coal-use purposes, and Carboniferous palynology, for stratigraphic interpretations. Results to date have been published in two Survey bulletins and nineteen outside papers.

Early petrographic studies have dealt with the following (author's name and date of publication are given where applicable):

1. A comparison of coal petrographical methods and nomenclature employed in transmitted light with those used in reflected light, to attempt a compromise between the European and American systems of coal microscopy (Hacquebard, 1950, 1955).
2. Petrographic studies of: (a) coal seams in the Sydney, N. S. field (Hacquebard, 1949, 1952); (b) seams from Mabou coal-field, N. S.; (c) column and bore-hole samples from Pictou and Springhill coalfields, N. S.; (d) Inverness county, N. S., coals (GSC Bull. 19); (e) coal from the Groundhog field, B. C.; and (f) high-rank coals of the Crow's Nest Pass area, Alberta and British Columbia.
3. A study of the opaque constituents in coal (Hacquebard, 1952).

Recent petrographic studies include:

1. In cooperation with the Fuels Division of the Mines Branch, studies on coking properties of coal, with a number of samples of Harbour seam coal (Sydney coalfield, N. S.) and western Canadian coals from the Crow's Nest Pass area (Hacquebard and Tibbetts, 1960).

2. Detailed studies on reflectance properties of various coal constituents, commenced in 1961, to see how such information might be used to delineate coal types, especially with reference to coking properties.
3. Studies of the sub-bituminous coals from the Edmonton Formation of Alberta, commenced in 1961, to acquire more knowledge on the petrography of low-rank, high-moisture coals and to test the possibility of correlating such coals by means of petrographic profiles. Because of the high moisture content a new impregnating technique had to be developed to permit satisfactory polishing of the samples for reflected-light studies.

Palynological investigations have been concerned with questions of a local extent such as the correlation of coal seams within a basin, and with research of a more regional nature. The spore assemblages of many samples of Carboniferous rocks throughout the Maritime Provinces have been studied in order to: (a) establish age relationships between the various isolated occurrences of Carboniferous rocks in this area; (b) establish the correlation of the Maritime Carboniferous succession with that found in other parts of the world; and (c) to identify and describe new forms and establish their ranges.

Early palynological studies were made of: (a) the fossil-spore content of the Lower Jubilee and Phalen seams, Sydney coalfield, N. S. (G. Somers, 1952a, 1952b); (b) peculiar spores in the Tracy seam, Sydney coalfield, N. S. (Hacquebard, 1952); (c) Mabou coalfield correlations by means of spore content (Hacquebard, 1961); and (d) coal specimens from South Nahanni River area, N. W. T., by means of which it was possible to establish the age of the Nahanni River coal and correlate it with Lower Carboniferous coals in Russia and Spitsbergen (GSC Bull. 40).

Recent palynological work includes studies on spore assemblages of Carboniferous rocks in the Maritime Provinces for regional correlation purposes. Hundreds of samples of shales, sandstones, and thin coals from Nova Scotia, New Brunswick, Prince Edward Island, and Newfoundland have been studied: (a) for their spore content, the results of which have permitted establishment of age relationships of Carboniferous rocks in the Maritimes with those elsewhere; and (b) to reveal patterns of Carboniferous sedimentation in the Maritimes (Hacquebard, 1957, 1960; Hacquebard, Barss, and Donaldson, 1960). Work is also continuing on spore studies within the Pictou and Springhill coalfields, N. S.

MISCELLANEOUS

PROJECT: Preparation of Papers for Oral Presentation and/or  
Publication in Scientific Journals

PERSONNEL: Staff of Geological Survey

Each year many of the Survey's staff prepare technical papers to be given at scientific meetings or published in scientific journals. These papers are based on office, laboratory, and/or field work. They are additional to the many maps and reports prepared each year for publication by the Survey. In 1961, nineteen papers were presented at scientific meetings, and thirty-nine papers were published in scientific journals. Several more papers were in press at the end of the year.

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