Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

ACTIVITIES OF THE SCIENCE AND TECHNOLOGY SECTOR

1974-75

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foreword

The Science and Technology Sector possesses within its constituent branches a great wealth of expertise and facilities dedicated to providing Canada with information and advice on its landmass and resources. This publication presents the objectives and describes the activities of each branch, written by the scientists and research managers concerned. By this approach it is hoped that the reader will gain a meaningful insight into the way all the individual units of the Sector participate in and contribute to the broader mission of the Department. However, it is not intended that this should be a mere description of objectives, goals and physical plant; by summarizing current research and accomplishments during the past year, it also documents a record of not inconsiderable achievements, achievements that demonstrate that goals are there to be met and that management by objectives is a realistic concept within the Sector.

A bibliography of the year's publications for each branch is a tangible record of the research output as reports, maps and public files. Although many of these reports have been published in scientific journals, an equally large proportion appears in established serial publications of the various branches. These have a world-wide circulation and provide clear evidence that the Department is one of Canada's major scientific publishing houses.

For many years the mainstream of departmental research has been carried by its own scientists. In keeping with government policy, an increasing amount is being contracted to industry and universities. Such contracts and research agreements are serving to strengthen our link with the community of science and foster the development of Canadian expertise.

Charles H. Smith,
Assistant Deputy Minister,
Science and Technology Sector,
Department of Energy, Mines and Resources.

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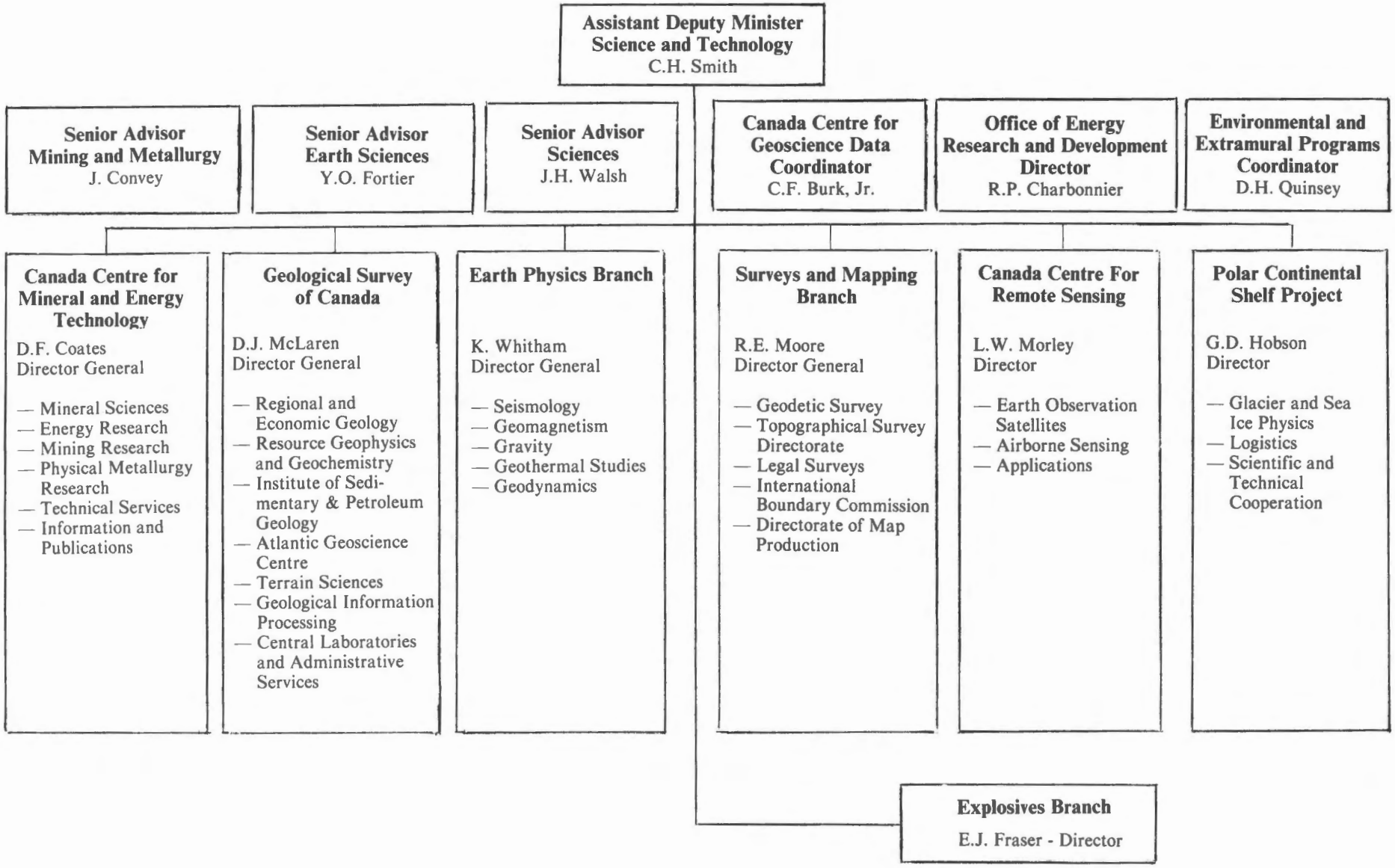
Organization of the Science and Technology Sector



geological survey of canada

D.J. McLAREN, Director General
J.O. WHEELER, Deputy Director General

The fundamental role of the Geological Survey of Canada is to provide a comprehensive inventory and understanding of the geological framework of the country interpreted in terms of all national activities that make use of or are affected by geology. A geological survey should be in a position to warn in advance of resource depletion or degradation of the landmass. Because the data required to respond to a particular need may require many months or years to collect, it is essential that on-going programs be maintained with the aim of accumulating data within certain broad objectives. The objectives of the Geological Survey are to provide a comprehensive inventory and understanding of the geological framework and processes in Canada as a basis for national policy and planning. The main objectives follow seven main thrusts directed to: ascertaining Canada's energy and mineral resources; facilitating exploration and development; encouraging regional development; promoting effective use of the Canadian terrain; identifying and assessing natural hazards; identifying geological features affecting environmental equilibrium, and disseminating information on Canada's landmass and the resources it contains. In pursuance of these objectives the Survey carries out investigations in geology, resource geophysics, geochemistry, geomorphology and in the physical geography of the landmass of Canada, including the adjacent continental shelves and adjacent ocean floors. In addition to systematic mapping and comprehensive topical studies, these investigations require the formulation of nationally consistent standards for chronology and stratigraphic correlation and are dependent on paleontological, petrological and mineralogical studies. In certain other fields such as geophysics and geochemistry, there is a continuing need for the design, development and testing of methods and equipment appropriate for Canadian needs. New fields embrace shipborne geological and geophysical studies, application of statistics to estimation and prediction of mineral potential, regional limno-geochemistry and researches into geotechnics and the application of geoscience to engineering planning.

During 1974-75 Canada was faced with several major issues in the field of natural resources, issues that will continue to dominate in the coming years. The availability of energy and mineral commodities, a greater ability to use the resources of our offshore areas and an increased appreciation of environmental concerns gained in part through an understanding of Canada's terrain are concerns to the solution of which the Geological Survey can make significant contributions.

The Geological Survey of Canada, a branch of the Science and Technology Sector, employs a staff of nearly 800. This number includes more than 300 university graduates, two-thirds of whom hold doctoral degrees. The headquarters is in a modern office and laboratory building which forms part of the complex of buildings occupied by the Department of Energy, Mines and Resources in Ottawa. The Survey is organized in seven divisions based on major functions and also on geographic requirements. Five divisions are located in Ottawa. The Institute of Sedimentary and Petroleum Geology is located in Calgary, Alberta, and the Atlantic Geoscience Centre at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. A subdivision of the Regional and Economic Geology Division has its offices in downtown Vancouver, British Columbia. During the year the Canadian Centre for Geoscience Data was transferred from the administrative direction of the Branch to the office of the Assistant Deputy Minister.

In 1974-75 the Branch had more than 400 active projects. The few highlights that follow were selected to show the range of work done. Preliminary results of much of the work done in 1974-75 were published in the 900-page, two-part "Report of Activities" or in individual reports all of which are listed at the end of this section.

As in previous years the largest component of the Geological Survey's program was devoted to regional mapping and studies on land and offshore areas. Since the early sixties a major thrust of government agencies responsible for offshore programs has been the collection of a data base. Canada is well in advance of most countries in offshore multidisciplinary hydrographic-geophysical surveys and by the end of 1974, 72 bathymetric, 33 magnetic and 34 gravity (free air anomaly) charts had been issued. If this program is continued at the same rate, Canada will by the end of the century have the best mapped continental shelf in the world. Data derived from commercial exploration is providing a major contribution to our knowledge of offshore geology. Samples from offshore wells are curated by the federal government. During 1974 data for 19 wells or 60,000 metres of stratigraphic information on east coast geology was released from government files for public use.

The nature and degree of detail of regional studies vary with our degree of understanding of the major elements of the geological framework of Canada. Moreover, the measure of accomplishment in any year may not be impressive but over a sufficient period is significant. For example, 25 years ago our knowledge of the Cordillera consisted of local islands of well understood geology within a larger matrix of relatively unknown geology. In the meantime systematic surveys at 1:250,000 scale have provided nearly complete, reasonably uniform regional coverage that has permitted regional syntheses resulting in the recognition of the nature and distribution of the main tectonic elements. This information has provided the principal focus for the current work — regional, multidisciplinary studies of broad tectono-stratigraphic units, bearing in mind factors that relate to current concepts of mineral and fuel exploration. Similar stages of development have been attained in the Arctic Islands and in the Appalachian regions. Examples of recent findings in these areas include the recognition of Late Devonian granitic plutons within the Shuswap Metamorphic Complex in the Cordillera, of subaqueous accumulation of Upper Paleozoic saline deposits in the Arctic Islands in contrast to a sabkha evaporite origin, and of the building of Lower Paleozoic volcanic arc edifices upon a granitic crust in Newfoundland.

The status of knowledge of the geology of the Canadian Shield is in many ways similar to that of the Cordillera about 15 years ago — many local well known areas within a much larger region in which the nature and distribution of complex major rock units are known from the 1:500,000 scale reconnaissance. This information has guided the current more perceptive multidisciplinary approaches that will achieve a clearer understanding of the evolution of the Shield and form a surer basis for modifying and applying mineral exploration concepts there. Examples of recent advances include the recognition of several localities of granitic basement about 3 billion years old, part of which is overlain by strata containing significant showings of base metals, and that Archean volcanism was roughly synchronous 2650 million years ago in widely separated parts of the Shield.

The mapping program for the surficial geology of Canada is not nearly as advanced as is the bedrock program and only 15 per cent of the country is mapped at the scale of 1:250,000 and less than 5 per cent at 1:50,000. Systematic surficial mapping is only being done in areas of immediate importance — 1:250,000 in northern regions and 1:50,000 in the southern populous regions.

Resource evaluation is an important part of the Geological Survey's work and during the year a uranium program designed to gather and interpret data on uranium and thorium deposits and to determine their nature and genesis was started. In September a reserve appraisal team composed of staff from CANMET and the Geological Survey began an on-the-site evaluation of the reserves and inferred resources of uranium and thorium in Canada and by March 1975 they were able to submit reports to the Departmental Uranium Resource Appraisal Group.

Terrain evaluation is essential in understanding and assessing terrain hazards and in maintaining and restoring the physical environment. In relatively fragile environments such as that occupied by the Mackenzie Valley Transportation Corridor understanding the nature of surficial deposits is especially necessary, and in 1974 the Geological Survey completed mapping of 43 map-sheets at a scale of 1:125,000. Similar work is currently underway in the Arctic Islands where information is needed to evaluate potential gas pipeline routes.

Interisland pipelines and pipelines in shallow seas in the Arctic will be subject to damage at the land-water/ice interface. During the year considerable advances were made in understanding the origin of bottom scours, a prime indication of past and present ice movement. Markings in depths exceeding 30 metres have been observed.

Parts of the Ottawa-St. Lawrence Lowlands, a highly populated part of Canada, are underlain by sensitive clays. Using existing distribution maps and by studying the behaviour of the clays under dynamic loading and the influence of regional hydrology on slope stability, a better understanding has been gained of the occurrence and mechanism of landslides in this area.

As Canada's population becomes more urbanized more efficient uses must be made of the land within the confines of our cities. During the year a prototype geoscience atlas of the National Capital Region neared completion and a similar set of maps is being prepared for the Hamilton area. Plans were also made to make the large amount of data available on 28 major urban centres available to users in microform.

The distance flown in aeromagnetic surveys was higher in 1974/75 than in 1973/74 both in Canada and for CIDA Projects overseas. A gradiometer for measuring small differences in the vertical gradient of the Earth's magnetic field has been constructed and installed on one of Geological Survey's two experimental survey aircraft. Initial flights of this unique system have been extremely encouraging. This technique will permit the calibration of existing maps and will allow for the preparation of a 1:5,000,000 magnetic anomaly compilation map for Canada.

Good progress has been made in the development and testing of methods for detecting and mapping the distribution of permafrost, both on land and below the sea-bed. A significant new development has been made, in

co-operation with the Communications Research Centre, with the construction of a practicable radar device for soil moisture measurement. High sensitivity airborne gamma-ray spectrometer test surveys were undertaken in 5 provinces (Saskatchewan, Ontario, Quebec, Prince Edward Island and Newfoundland) and compiled during the year. A major (20,000 sq. mile) lake sediment geochemical survey was undertaken in Saskatchewan at the request of the provincial government and DREE, and this contracted operation is the precursor of larger operations under Uranium Reconnaissance Program. A useful start has been made in the co-operative development project with industry relating to borehole exploration methods.

During the year advances were made in developing statistical theory to predict hydrocarbon resources. The techniques developed will be applicable to other resource appraisal programs. In addition adequate documentation is being compiled on the settings in which hydrocarbons occur. One file will contain a comprehensive compilation of all the geological, geochemical and production data of all the major hydrocarbon-producing areas of the world. A second file will contain data on the oil and gas pools of North America. The results of some of these activities in the study of hydrocarbons will be of great value in preparing a second assessment of Canada's hydrocarbon potential scheduled for late 1975.

ATLANTIC GEOSCIENCE CENTRE

B.D. LONCAREVIC, Director

Scientific surveys and data gathering are the backbone of geoscience. Since the early sixties the major thrust of government agencies responsible for offshore programs has been the collection of a data base. Canada has taken an early lead and remains in the forefront with offshore multidisciplinary hydrographic-geophysical surveys. As a result of these surveys, a folio of charts at a scale of 1:250,000 is in preparation. To date (October 1974), 72 bathymetric, 33 magnetic, and 34 gravity (free air anomaly) charts have been issued. In addition, all the data points used in the preparation of these charts have been released in digital format on magnetic tape. This is a long-range program initiated 10 years ago. If the momentum of the program is maintained, by the end of the century Canada will have the best mapped continental shelf in the world.

Surficial and bedrock mapping is proceeding in parallel with the above program. Careful analysis of echo sounding and high resolution seismic reflection records is combined with selective sampling of surficial sediments to produce interpretative maps. A number of sheets have been published covering the Nova Scotia continental shelf and parts of the Grand Banks of Newfoundland. A part of the surficial studies is the evaluation of terrain sensitivity with respect to pipeline construction, pollution of beaches, dredging, dumping, etc. Studies of pipeline crossings in the Arctic and of beach morphology and dynamics around the southern Gulf of St. Lawrence are in progress. This field of research is picking up momentum.

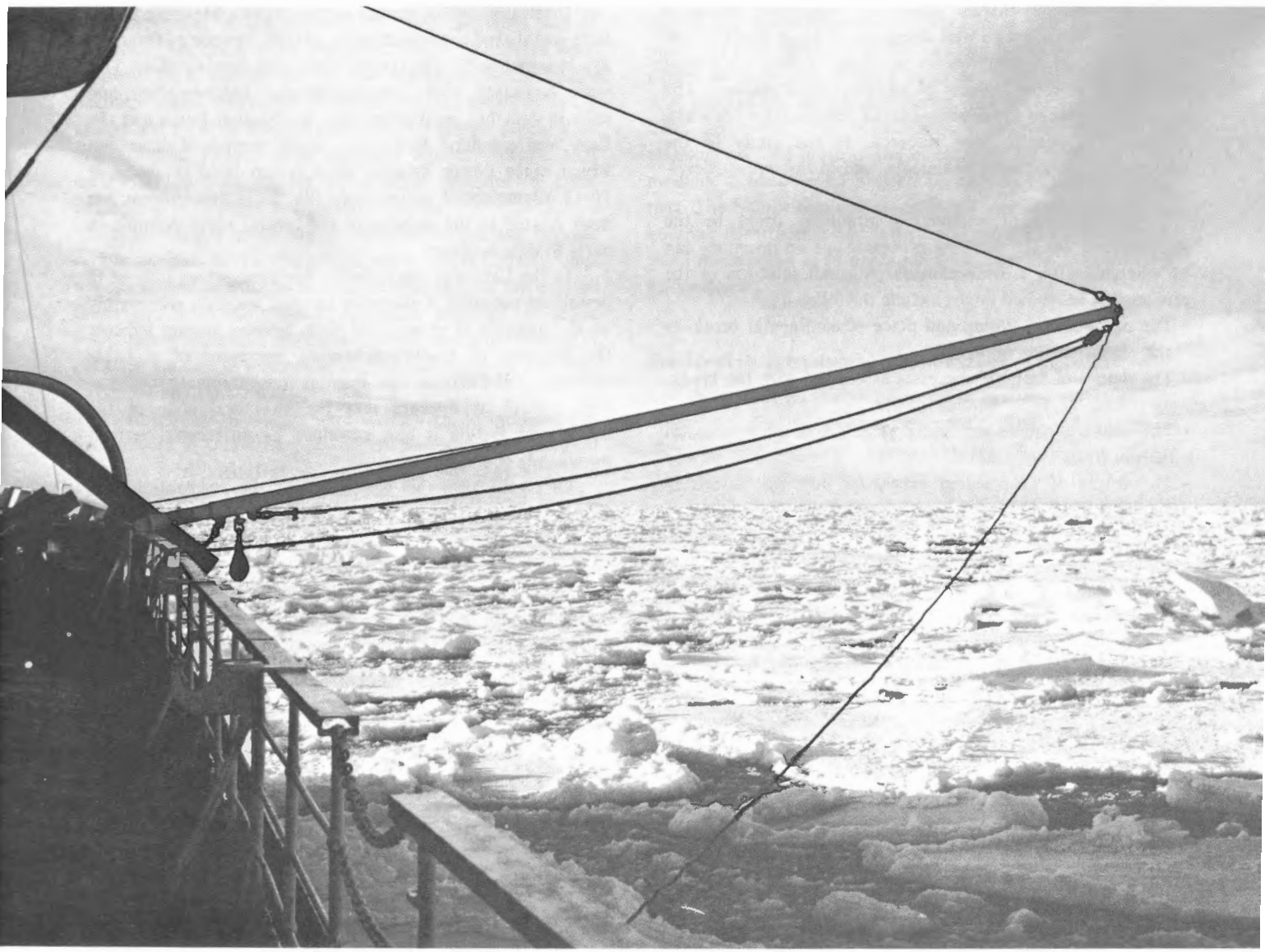
A major contribution to the knowledge of offshore geology has been the spinoff from offshore oil exploration. For resource inventory purposes, the offshore industrial geoscience data are available to the federal government. The samples from offshore wells are curated by the government and are made available for study by qualified scientists two years after the completion of a well. During 1974, nineteen wells or 60,000 metres of stratigraphic data on the east coast of Canada have been released. The Geological Survey of Canada is establishing a biostratigraphic reference system for the east coast and is compiling and integrating all the available data as a part of the Basin Analysis Program. Some of the results of these studies as well as studies by universities and industry were presented at the International Symposium on 'Canada's Continental Margins and Offshore Petroleum Exploration' held in Calgary, Alberta, September 29 to October 2, 1974.

Despite these advances, Canadian marine geoscientists suffer from a lack of scientific exchange and interchange schemes. This is especially true for younger scientists who are often trained in a rather parochial atmosphere. One of the reasons for this is the absence of global oceanographic expeditions originating from Canada. Only two Canadian scientific expeditions have ventured outside the North Atlantic and Northwest Pacific Oceans (HUDSON-70 circumnavigation of the Americas, and the *Parizeau* voyage to Japan in 1972).

Another big gap in the Canadian program is the weakness and paucity of research projects in the coastal zone. Canada has failed to develop an ambitious and well-supported program of research in this zone. As pressure on the environment from industrial activities increases, as recreational demands expand, and as the public becomes more conscious of the need for conservation in the littoral zone, the present gap in the Canadian program will become even more obvious.

The weakness of Canadian deep-ocean geoscience is impairing our ability to play an active role in the search for and eventual exploitation of deep-sea mineral deposits. This rapidly expanding activity is dominated at present by the U.S.A., Germany, Japan, and France. A major mining nation like Canada will experience economic dislocation if deep-sea mineral exploitation becomes an economic competitor to conventional, land-based mining.

Umel underwater camera system being lowered in Lancaster Sound



Ice conditions in Lancaster Sound

The list of weaknesses includes a concern for the availability of modern research ships. The existing fleet is fast becoming obsolete. Even if a construction program were initiated tomorrow, a major research ship would not be available before 1979.

People are our most important resource. Today, the GSC employs approximately 60 professionals who are working on geological problems offshore. Other government agencies may employ 20 professionals and it is possible that the provinces engage another 10. There may be as many as 50 professionals in universities (including graduate students). An estimate of the total number of professionals in Canada engaged in marine geoscience would not exceed 150 (excluding those working directly in industry).

The noted geologist, Sir Edward Bullard, when asked by a funding agency to present a 4-year plan of research, retorted: "If I knew what I was going to do in four years' time, I'd do it now." Nevertheless, consideration of outstanding

problems, of the strengths and weaknesses of ongoing programs, and of the availability of resources inevitably leads to selection of some topics and activities and rejection or postponement of others.

The Canadian marine geoscience program is strong in scientific data collection and mapping, in basin analysis and regional geological synthesis, in petrology of deep-sea crustal rocks, and in some aspects of environmental geology. The program is weak in the development of conceptual models and synthesis, in coastal zone research, in the study of the engineering properties of sediments, and in instrument development.

An inventory of outstanding problems could be the starting point for the planning process. Such an inventory can be compiled after a wide canvass. A small selection of the problems to be studied might include the following:

- The mechanisms, timing and place of continental break-up and reconstruction of pre-drift fit
- The nature of tectonic processes associated with the break-up
- The nature of the deeper crustal structure at the continental margin (transition zone)
- The origin of deep-seated evaporites and the nature of diapirism at the base of the continental slope
- The nature of unconformities within the sedimentary sequence on continental shelves
- The source and nature of continental shelf sediments and neritic zone sedimentary processes
- The engineering properties (consolidation, mobility) of surficial sediments
- The geochemical flux through the water-sediment interface.

While a scientist can perceive the problems, it is society that decides on priorities through its adopted political mechanism. A scientific organization must be responsive to society as well as to the beckoning of the unknown and the need to challenge the boundaries of scientific knowledge. It is this balanced appreciation of all social influences that is the cornerstone of well-managed, well-supported, and successful scientific programs.

Eastern Petroleum Geology Subdivision

Eastern Petroleum Geology Subdivision directs its efforts toward the investigation of the sedimentary basins of eastern Canada in the onshore and offshore areas. This analysis of the various basins facilitates the assessment of resources, particularly with regard to oil and gas potential. To meet these objectives, individual and co-operative scientific programs are carried out in the following areas: (1) the Mesozoic and Cenozoic basins that lie along the continental margins of eastern Canada from Georges Bank to Baffin Bay, (2) the Upper Paleozoic (Late Devonian to Permian) basins of the Atlantic Provinces, Gulf of St. Lawrence, Grand Banks, and Northeast Newfoundland Shelf, and (3) the Lower Paleozoic basins, including the St. Lawrence Platform, the Hudson Platform and the adjacent southeast Baffin Shelf.

Biostratigraphical studies in the offshore Mesozoic basins have established a comprehensive Middle Triassic to Quaternary biozonation for the Grand Banks and Scotian Shelf. This work combined with lithostratigraphy, sedimentology and seismic data has established that the Scotian Basin and the East Newfoundland Basin were active centres of deposition which, since Lower Triassic, have accumulated in excess of 10-12 kilometers of sedimentary fill. Basin development has been related to the opening of the central north Atlantic in early Middle Jurassic.

In the Labrador Sea - Baffin Bay area, where interest in petroleum potential is currently focused, we must rely mainly on the analysis of geophysical data. Seismic studies indicate the presence of thick sedimentary sequences of probable Mesozoic and Cenozoic age. Pending more complete stratigraphic control, it appears that the structural style of the continental margin is best explained by differential vertical movements of continental crust.

Of significance this past year was the preparation of a series of maps at a scale of 1:2,000,000 as a co-operative effort of the Subdivision. The maps depict the surface physiography, geology, and basement configuration of the various onshore - offshore sedimentary basins. Deep reflection seismic data were integrated with the field data collected by other groups of the Atlantic Geoscience Centre. Geological contacts offshore were mapped from high-resolution seismic records. These maps are the first of their kind to be constructed.

Our basin analysis program facilitated our work in identifying potential hydrocarbon "plays" and contributed towards the first detailed evaluation of hydrocarbon potential.

Environmental Marine Geology Subdivision

The Environmental Marine Geology Subdivision is engaged in research to evaluate contemporary and ancient events that are recorded in the marine geologic record and to understand the effects of natural processes that may alter these records. Geological interpretation of the marine environment is achieved by understanding sediment facies, diagenesis and biostratigraphy. Environmental geology processes and properties are identified by studying hydrodynamics, elemental pathways and ecology while environmental quality concerns are evaluated by collecting information relating to geodynamic stability, geochemical anomalies and paleoecological biotopes.

Coastal geodynamic research was aimed at evaluating the beach and nearshore sedimentological processes in the Magdalen Islands. A study of bedforms and sedimentation was

started in the Minas Basin area in order to study the formation of mud flats resulting from a newly constructed causeway. Other involvements included the establishment of a terrain management policy for Sable Island.

Assessment of the evidence of man's activities and of processes that cause metal accumulation in the marine environment were carried out by the Inorganic Geochemistry Section. Metal speciation in water and sediments is being understood by using selected conditions for sample preparation and analysis. Results from sediment studies indicate that metals will accumulate on fine-grained particles in areas adjacent to fresh water and industrial inputs.

Hydrocarbon geochemistry consisted of gas and organic carbon analysis for 16 offshore oil wells. Heavy hydrocarbons were examined in order to estimate the maturity of the organic facies and to evaluate the hydrocarbon potential. In other work, recent sediments were analyzed for methane content to evaluate the rate of sedimentation and the degree of anerobic fermentation of the organic matter.

Paleontological studies were undertaken to interpret the fossil record in Quaternary sediments. Biological and physical processes were identified as mechanisms that may alter the fossil tests and therefore affect the interpretation of the records. Environmental stability was evaluated by comparing the distribution of total foraminifera populations in various areas. Benthonic foraminifera and molluscs were studied in Arctic Archipelago samples, indicating that some of the channels had longer open water seasons than occur today. Paleoecological and geochemical data from the environmental impact study in Canso Strait indicate that the influence of Gulf of St. Lawrence water has moved 4 km to the south of its previous limit as a result of constructing the Canso Causeway. In addition, the industrial and municipal influence in the area was identified in the form of stressed environments found in the sediment samples.

Program Support Subdivision

The support required for the division's marine and field projects covers a broad range. In the early stages of project planning this involves equipment and technical personnel assignment and equipment acquisition, design and modification. In later stages of the project, equipment and supplies must be assembled and loaded on the ship or transported to the field site. Instrument installations and modifications are carried out, liaison with other agencies established, and final equipment installation and calibrations are completed. During the operation, launches, vehicles, instruments and other equipment have to be maintained and operated, special services such as seismic shooting, scuba diving, etc. provided, watchkeepers allotted and data processed. Following the operation, equipment has to be disassembled, refurbished and repaired for stowage maintenance and overhaul, contracts raised, damaged equipment repaired or new equipment ordered and data and samples properly curated, classified and sent for analysis required. The Subdivision is responsible for a whole range of field support services as illustrated above.

The Subdivision also has the continuing responsibility to maintain a central geoscience data file so that all raw and processed data collected by the Division is easily available, to curate all geological samples collected, maintain and publish data indexes and sample inventories, and operate the regional GSC open file. The Subdivision is actively engaged in planning all field projects and in carrying out instrument and methods developmental projects on request by division scientists. The Subdivision also co-ordinates and arranges all AGC building construction and laboratory and office space allocation and facilities in co-operation with other Bedford Institute Laboratories.

Regional Reconnaissance Subdivision

As part of its overall objective of studying the geological framework for the eastern continental shelf and margin of Canada, the Regional Reconnaissance Subdivision efforts during 1974 concentrated on developing four new thrusts:

(1) A multidiscipline approach to geological and geophysical studies in the eastern Arctic offshore.
(2) The development of new technology to improve the quality and quantity of data that could be acquired as part of the surficial studies of the eastern shelves.
(3) The broadening of the multiparameter surveys carried out in conjunction with the Canadian Hydrographic Service to include a regional survey of the entire Labrador Sea.
(4) Participation in the Candrill Project through the assignment of project leader.

The first three main thrusts are discussed in more detail below.

(1) *Eastern Arctic Offshore Studies*

During the summer of 1974, *CSS HUDSON* carried out a multidisciplinary survey in the eastern Arctic offshore. The cruise was oriented toward answering some of the major geological and geophysical questions in Davis Strait, Baffin Bay and the adjacent continental shelves and Arctic Sounds. The cruise which included participation from other Divisions of the Geological Survey plus other Canadian and foreign organizations provided geophysical information on the sedimentary basins of northern Baffin Bay, Smith Sound and Lancaster Sound; bottom samples and photographs in Barrow Strait, Lancaster Sound and Smith Sound; bedrock cores obtained with the Bedford Institute electric drill in Lancaster Sound and off southeastern Baffin Island; seismic refraction data on the Baffin Island continental margin, Davis Strait and northern Labrador margin and detailed magnetic field coverage of a small portion of Baffin Bay.

(2) *New Technology for Marine Surficial Studies*

With the increasing demands for more and better information on the geotechnical properties of the unconsolidated sediments covering the continental shelf, Regional Reconnaissance Subdivision has been involved, along with engineers from the Atlantic Oceanographic Laboratory at Bedford Institute, in the evaluation of new techniques for the quantitative mapping of the seafloor sediments. The emphasis has been on an integrated survey approach to the problem using high resolution acoustic systems and the correlation of reflected signal characteristics with sediment type, and sidescan sonar. Backing up the survey program there is a requirement for in situ measuring devices to determine such things as shear strength of the sediments and a systematic sampling program to provide ground truth for the interpretation of the seismic data. As a result of the evaluation of a deep-towed seismic profiling system developed by Huntec ('70) Ltd., the Atlantic Geoscience Centre has accepted a proposal from Huntec ('70) Ltd., to undertake a research and development project on the remote sensing of geotechnical properties of marine sediments from a regular survey ship. Field work associated with this project will provide the major thrust in our studies of surficial geology during 1975.

(3) *Regional Geophysical Survey of Labrador Sea*

The joint DOE/EMR multiparameter surveys of the eastern offshore Canada were broadened during 1974 to include a regional survey of the entire Labrador Sea. Lines were placed at 20 mile intervals running from the Labrador continental shelf across to the west Greenland margin, seismic data being collected on every second line across the sea plus all lines over the Labrador Shelf. The program was terminated prematurely by the grounding of MV MINNA in Brewster Bay, Resolution Island. The uncompleted portions of the survey will be carried out in 1975. The data acquired has provided excellent control for the regional interpretation of Labrador Sea and complemented by refraction data and additional geophysical information from other sources has led to a wealth of new ideas on the formation of the Labrador Sea and margin.

CENTRAL LABORATORIES AND ADMINISTRATIVE SERVICES DIVISION

J.A. MAXWELL, Director

The success with which the Geological Survey of Canada meets its major scientific objectives is dependent to a large extent on the strength of its internal support units. It is the role of the Central Laboratories and Administrative Services Division to provide chemical and mineralogical scientific support; mechanical and electronic technical support; and to co-ordinate the operations of administration, financial and personnel services. In addition, the Division encourages a greater interest in Canada's rock and mineral resources by Canadians through the preparation and sale of sets of rocks, minerals and ores; free mineralogical examination of specimens submitted by the public; and through preparation and publication of guidebooks to those Canadian mineral areas of most interest to amateur mineral collectors.

A suite of modern laboratories provides facilities for chemical analysis and mineralogical study of the wide variety of rocks and minerals collected by field geologists to achieve Branch objectives. Analytical techniques range from classical wet chemical analysis of rock samples to the *in situ* electron microprobe analysis of micron-sized areas of minerals. X-ray fluorescence, X-ray diffraction, atomic absorption and emission spectrography are used to a considerable extent. Sample preparation and mineral-separating laboratories provide essential preparatory services for the techniques and for specialized laboratories in other Divisions. In order to meet the analytical requirements of the Branch as efficiently as possible and within an acceptable time frame, our scientists pursue an on-going program of instrument and technique development, adaptation and modification, commensurate with the state-of-the-art. For example, adaptation of the energy-dispersive technique to electron microprobe analysis has given our laboratory a new and powerful investigative tool that provides Branch scientists annually with several thousands of complete microanalyses of minerals.

Earth science reference standards, prerequisite to the recognition, identification and analysis of minerals, are of vital importance to the scientific activities of the Branch. This Division is concerned with maintaining and extending the Systematic Reference Series of the National Mineral Collection; a national collection of meteorites; a reference and study collection of suites of ore minerals from Canadian and other representative mineral deposits; X-ray powder pattern standards for the identification of minerals; and various analytical standards for the analysis of minerals and rocks. The chemical laboratories play an important role in the international study and certification of rock and mineral standard samples.

Technical support to the Division and Branch is provided by a small but highly-skilled staff and shop facilities for mechanical and electronic design, modification and servicing of scientific instruments. Noteworthy accomplishments have been made in the fabrication of new and improved geophysical field equipment, and in the adaptation of mini-computers to the collection and processing of analytical data in the chemistry laboratories. Paralleling the scientific and technical support units, a staff of 33 persons performs the unsung but vital tasks of Branch administration and financial support, including such services as secretarial, accommodation, inventory, vehicles, registry, messenger, purchasing, stores, supplies and accounts.

The staff of the Mineral and Rock Sets Laboratory prepare and distribute about 8,000 collections annually to the Canadian public. (GSC Photo 202598-Z)

Analytical Chemistry Section

During the year, the Section continued to provide Branch scientific projects with compositional data on rocks and minerals, to develop new techniques and to provide analytical advice to Branch geologists, to other organizations in Canada, and to groups in other countries. The most significant development was the installation and effective operation of a new Philips 1450 Automatic X-ray Fluorescence Spectrometer. More versatile than the previous instrument used in our laboratory, the new spectrometer has been programmed to provide analyses not only for the eight elements formerly determined by X-ray fluorescence but also for sodium, phosphorus, sulphur, chromium and six additional "trace" elements. The effect has been a considerable reduction in the backlog of samples awaiting analysis. A newly-designed technique for the determination of rare-earth elements involves preliminary chemical enrichment followed by determination by atomic absorption or emission in a nitrous oxide – acetylene flame. Statistics for the year show that the Section provided compositional data on 5,100 samples involving 16,500 chemical, 48,500 X-ray fluorescence, and 33,400 emission spectrographic determinations. Work continued on the proposed certification of three Canadian rocks as international reference samples. Analytical results were provided by one or more laboratories in each of 50 institutions in 19 different countries. A report on the collaborative study has been compiled and the manuscript is undergoing review.

Electronic Services and Equipment Development

The functions of the unit are to maintain and service scientific equipment and to assist scientists with modification and up-dating of laboratory instrumentation. Use of small on-line computers for control of instruments and for the collection and processing of analytical data has become so prevalent that work related to the installation and use of these systems accounts for about 90 per cent of the activities of the electronics unit. Servicing of the minicomputers has been minimal during the past year, involving only location of faults and replacement of defective circuit boards. A new minicomputer, the tenth such unit in use in the Branch, was installed in the emission spectrographic laboratory and the staff was given a short course of instruction.

Mechanical Services and Instrument Development

During 1974-75, the staff of the Mechanical Services and Instrument Development shops provided technical support for Branch projects in the form of mechanical engineering, design, drafting, fabrication, inspection and maintenance of laboratory and field instruments and equipment. In addition to in-house work, the unit was responsible for recommending, ordering and supervising the considerable amount of mechanical services work that is contracted out by the Branch to commercial shops. A new milling machine was purchased to provide greater capacity and versatility in machining. Two major projects in the past year were: fabrication of re-entrant cavity Q meters for the Electrical Methods Section; and re-design and fabrication of new indexing instrumentation for an Astatic Magnetometer, at the request of the Paleomagnetism Section.

Mineralogy Section

The scientists and support staff of the Mineralogy Section provide the Branch with facilities and expertise to undertake mineralogical studies, including the specialized fields of crystallography, X-ray diffraction, X-ray fluorescence and electron beam analysis. During 1974-75 the total output of service work, which included sample preparation, mineral separation, mineral identification, mineral analysis and study of samples for age determination, showed an increase of 15 per cent over the previous year. This increase was made possible by development of new and improved techniques. The electron microprobe laboratory has gained recognition as one of the most advanced in the world in the use of energy dispersive analysis and on-line computer correction of matrix and other effects. In the X-ray laboratory, techniques were developed for mini-computer recognition of X-ray powder patterns of minerals. This involved creating a magnetic tape reference file of standard X-ray powder patterns, and writing a search program to compare the data for an unknown pattern with those in the standards file. A six-year study of lunar rocks from the Apollo series of missions in co-operation with NASA was terminated in February, and a detailed study of rocks drilled from the ocean floor at the mid-Atlantic ridge was started. Studies of ore samples from the massive sulphide Kidd Creek deposit revealed the presence of a previously unsuspected suite of minerals; a finding which has a bearing on the process of ore treatment. Examination of a very old specimen in the National Mineral Collection from Ontario's first gold producer, the Richardson Mine in Madoc Township, led to the discovery of the radioactive mineral brannerite associated with the gold. Radioactive dating established an upper limit for the age of the gold deposits and suggested a genetic relationship with the Deloro stock that is worthy of further exploration. Services to the public included preparation and shipment of 8,000 sets of minerals and rocks, and examination and identification of 208 samples. Additions to the National Mineral Collection amounted to 352 specimens including 25 minerals new to the collection. The Reference Series now contains about 1,700 different, or 75 per cent of all known species.

GEOLOGICAL INFORMATION PROCESSING DIVISION

P. HARKER, Director

The principal objectives of the Division are the communication of the results of the scientific program of the Geological Survey to users and potential users; the maintenance of a scientific library and associated data systems as an earth science information base and the provision of geoscientific information services to the public. In support of these objectives, the Division maintains capabilities and facilities in scientific editing and information, cartography, library services, technical photography and publication distribution.

As publisher for the Survey the Division manages a comprehensive publication program and issues Memoirs, Bulletins, Economic Geology Reports, Miscellaneous Reports and Papers together with various categories of maps. All have a long publication record and an established reputation in the world community of earth scientists. 75 printed reports were issued during the year ranging from a few pages to several hundred pages in length and extensively illustrated. The number is somewhat reduced from the previous year and this undoubtedly reflects the growing popularity and usefulness of the Survey's Report of Activities. Issued in two volumes last year and comprising almost a thousand pages of text in the new large format, these reports are certainly providing an important outlet for short summary reports of current Survey research and three volumes are proposed for next year. 31 geological maps were published, many of them in colour. 341 aeromagnetic maps were issued.

Continued increase in the cost of printing has required maximum economy in order to maintain a reasonable volume of output. Such economies have been achieved by means of the larger page size and increased use of offset printing from

typescript produced in the Geological Survey on magnetic card typewriters which simplify the editorial process and give an aesthetically acceptable product that compares well with the much more expensive conventional letterpress.

Many reports and maps were placed on Open File at the principal offices of the Survey as the fastest way of releasing information, local arrangements are made for users to obtain copies at their own expense. Open Files provide a means of advanced publication and they may also provide an outlet for large and bulky data compilations that cannot easily be handled as formal publications. 65 Open Files were released during the year bringing the total number of items on open file to 260.

A significant part of the total research output of the Geological Survey finds an outlet for publication in scientific journals and 120 papers were published in this way. Outside publication complements the in-house program by providing external standards of acceptability and a degree of visibility not always available to government publications.

Maps and illustrations for reports are prepared by the Geological Cartography Section which provides a comprehensive service to the Branch. In addition to the preparation of edited manuscript material for printing as multicoloured final maps, uncoloured preliminary maps and figure illustrations, the Section, with its well equipped Photomechanical Unit, provides base maps on which field officers plot and compile their data and prepared manuscript geological maps. The Section also performs a great variety of drafting, display and reproduction services. Considerable progress has been made in computer-assisted cartography and most of the programming problems have been worked out. The second experimental map was completed and printed essentially as a final test before embarking on the principal objective of the automated project, namely the production of a series of 1:1,000,000 geological maps of Canada. The commitment of staff and equipment to this objective has been a great stimulus and several maps are well in hand. Computer assistance promises long term savings in time and labour, but equally important is the multi-use geological data base that will be developed as the geological data for each map is digitized and put into retrievable and machine processable form.

All maps and reports are released through the Publications Distribution Section and a monthly information circular announcing all publications and Open Files is mailed to several thousand addresses in Canada, the United States and overseas. More than 250,000 items were distributed through this office and 18,000 requests for publication or information were handled. Sales facilities for geological reports and maps are also maintained in Calgary and Vancouver, both offices report high volume of business and serve a large clientele of over the counter enquirers.

The Library of the Geological Survey is the principal earth science data base for the branch and it contains a large and nationally important collection of books and periodicals on geology and related sciences, occupying more than 2 miles of shelving. It comprises over 125,000 volumes as well as a large number of microfilms and microfiche. As a result of long standing exchanges with foreign scientific institutes, many unique sets of serials are held. An extensive map library is part of the main library and there are branch libraries at Dartmouth, Calgary and Vancouver. In addition to providing a bibliographic service for the research program of the Survey, its resources are used by the scientific community at large and nearly 6,000 interlibrary loans were made; on the other hand interlibrary borrowings have increased considerably, an indication of the changing pattern of Survey research and the need for information outside the mainstream of geological thought. The Library is responsible for release of information on Open File, for the operation of several data files, for data storage and retrieval and for keypunching into the Departmental computer system as a service to branch scientists. A computerized information dissemination service provides bibliographic references on a monthly basis according to the user's scientific interest profile. This service—CAN/SDI—is offered in collaboration with the National Research Council's Canada Institute for Scientific and Technical Information. There are 100 users who pay an annual subscription for this service. The feasibility of offering retrospective bibliographic services using a mix of commercial and institutional earth science data bases is being explored and it is hoped to offer such a service at cost in the coming year.

The Division provides geoscience information on a wide variety of topics through a technical enquiries telephone listing and by correspondence, and on many occasions the Division staff form the first contact between the Department and the enquiring public.

INSTITUTE OF SEDIMENTARY AND PETROLEUM GEOLOGY

D.F. STOTT, Director

The role of the Institute of Sedimentary and Petroleum Geology (ISPG) is to provide a comprehensive inventory and understanding of the geological framework of the sedimentary basins of western and arctic Canada. These activities are concerned with: ascertaining and evaluating Canada's energy minerals (specifically petroleum, gas, coal and other minerals); facilitating exploration and development by providing geological information related to the occurrences of hydrocarbons, coal, and other minerals; establishing standard chronology and biostratigraphic correlations by paleontological methods; and disseminating information on Canada's landmass and resources.

All of the mainland area for which the Institute has responsibility has been mapped at a scale of 1:250,000

although final compilations of some areas will not be published for several years. Much of the southern and central Foothills and Rocky Mountains have been mapped at 1:50,000 and future mapping, particularly that relating to coal evaluation and structural style, will be at more refined scales. On the Arctic Islands, recent mapping has been concentrated in the Queen Elizabeth, Axel Heiberg, and Ellesmere Islands. New projects are being initiated in the western part of the Sverdrup Basin, northern Ellesmere Island, and in the Somerset-Boothia region; the latter area being of considerable interest as a potential route for a gas line from the Arctic Islands to eastern Canada.

Major advances have been made in the development of methodology for the determination of potential hydrocarbon resources. The techniques being developed will have application to other resource appraisal programs. Potential resource data on petroleum and gas have been prepared for the second Department report on "An Energy Policy for Canada" and the assessment of potential hydrocarbon regions is an ongoing activity.

Advances have been made in integrating palynological, organic geochemical, and inorganic geochemical (clay mineralogical and clay chemical) studies directed toward the determination of the presence or absence of petroleum source rock, degree of thermal alteration, depth of burial, and other parameters related to the development and accumulation of hydrocarbon and migration of fluids within sedimentary rocks. The areas of the Mackenzie Delta, Beaufort Sea, and Sverdrup Basin continue to be of major concern because of the hydrocarbon potential and current discoveries of oil and gas.

New field projects have been initiated that are directed toward the understanding of zinc-lead mineralization in the carbonate-shale sequences, as well as other minerals which occur within sedimentary rocks. Recently, clay studies in the carbonate-shale facies suggest some direct applications in the field of lead-zinc mineralization. Emphasis is being given also to investigation of minerals other than hydrocarbons. Investigations of evaporitic rocks are being continued to determine the occurrence of additional sources of industrial minerals such as potash and barite, and as potential sites for the storage and/or disposal of radioactive waste.

The quantitative and qualitative assessment of the coal resources of Canada is developing into a major program within the Division. Many of the activities parallel those of the hydrocarbon assessment. The development of adequate methodology to assess the total coal resources of Canada is a major challenge at the present time. Data are being accumulated on coal resources of Nova Scotia, New Brunswick, Prince Edward Island, Ontario, Saskatchewan, Alberta, and British Columbia. The first report on the Joint Federal-Provincial Program for the evaluation of the lignite coal resources of southern Saskatchewan was prepared in late 1974. The final report is scheduled for the fall of 1975.

Studies in the various fields of paleontology are establishing and refining models of biostratigraphic and paleoecological zonations. Such models contribute not only to the geoscientific core-program but are directly applicable to the investigations required for resource evaluation. Many of the paleontological studies are concentrated in the regions of Mackenzie Delta and Sverdrup Basin but others are being utilized in conjunction with investigations of the carbonate-shale mineralization in the coal program.

All maps and illustrations required by Institute staff for publications by the Geological Survey, or in scientific journals, are prepared within the Division; the work includes all drafting for black and white and multicolour illustrations as well as photomechanical and reproduction work. Scientific activities are supported also by a photographic laboratory, and library services.

The building which ISPG occupies is owned by the Department of Energy, Mines and Resources and, as a result, the Division has responsibilities related to building and engineering services. The building houses, in addition to the Division's staff, members of the Terrain Sciences Division, the Mining Research Centre of the Canada Centre for Mineral and Energy Technology and an office of the National Energy Board.

The building also serves as a major repository for drilling cores, samples, and other data from both onshore and offshore exploration activities in Yukon and Northwest Territories, and for samples from all provinces and from the continental shelves. A distribution office is maintained for the sale of departmental publications, including topographical maps and aerial photographs.

Regional Geology Subdivision

The Subdivision's major role is the development of the geoscience data base for the sedimentary basins of western and northern Canada that lie east of the Rocky Mountain Trench and west and north of the Canadian Shield. Data are obtained through surface mapping; stratigraphic studies; subsurface studies of well samples, cores, and mechanical logs; and, under the marine environment, from geophysical records. These studies are augmented by laboratory investigations and collated with the output of other units, particularly the Paleontology Subdivision, to document the geology and conceptual models as interpreted or developed by the Subdivision's Research Scientists. This, in effect, constitutes the Basin Analysis Program, rather than the narrower aspect of just the subsurface component as it has been construed in the past. The results of these investigations are made available to the public through publications or by oral presentation.

The Subdivision acts, also, in a secondary role as an internal advisor to the Energy Subdivision, assisting them in their evaluation of the hydrocarbon potential of the sedimentary basins. Within the context of Canada's energy supplies, it

requires little foresight to recognize the re-emergence of coal as a major resource. Anticipating the need for a much stronger data-base, some of our man-power has been redirected to investigate the geology of coal.

During the fiscal year 1974-75, four GSC Bulletins, 20 GSC Papers, 2 A series Maps, 4 preliminary maps, and 13 papers for scientific journals were approved for publication documenting the productivity of this Subdivision.

Northern Mainland

Research interests of scientists concerned with studies of the Northern Mainland pertain to stratigraphic and structural studies in the Interior Plains, the Mackenzie Delta, and the thrust and fold belt of the Cordillera, in general between 64 degrees north latitude and the Arctic Ocean. Research during 1974-75 included both surface and subsurface studies, aimed at energy and mineral resource evaluation in conjunction with the establishment of a sound geoscience data base. Surface studies included a field study of Proterozoic stratigraphy, preparation of stratigraphic reports on Mesozoic stratigraphy, and preparation of geological maps and reports of northern Yukon Territory, northern Mackenzie Mountains, and northern Franklin Mountains. Subsurface studies dealt primarily with Mesozoic and Cenozoic strata in Mackenzie Delta, and Paleozoic and Mesozoic strata in the northern Interior Plains including Porcupine Plateau.

Southern Mainland

Stratigraphic, sedimentological and structural studies in the eastern Cordilleran Orogen and southern Interior Platform of Alberta and British Columbia continue to improve our knowledge of the nature, origin, deformational history and economic potential of the sedimentary suites involved. During 1974-75, regional work in the Cordillera of northeastern British Columbia was continued, involving synthesis and interpretation of data for both reconnaissance and detailed scales of mapping. Progress was made in the northeastern British Columbia Cordillera on defining the relationship between Paleozoic carbonate-shale transitions and the zinc-lead occurrences in the area. Detailed geological studies of the Foothills of southwestern Alberta, an area in which there is considerable interest in coal and hydrocarbon occurrence, were continued; several detailed geological maps and cross-sections of this area were completed. A surface study of coal-bearing Mesozoic rocks in the Central Alberta Plains nears completion. New projects begun during the year include a study of coal-bearing Mesozoic rocks in the southern Foothills of British Columbia, and a regional compilation and synthesis of salt deposits in western Canada, initiated at the request of Atomic Energy of Canada Ltd. and primarily involving published data.

Arctic Islands

Work in the Arctic Islands is directed mainly toward the interpretation of the stratigraphic and structural history of Phanerozoic sedimentary rocks of the Arctic Archipelago, and the evaluation of the economic potential of these strata. A secondary objective is research on the relationship of tectonic features of the Arctic Islands to continental and ocean structures and history. The field phases of two major projects were completed; one on Banks Island, the other on King Christian Island and the Ringnes Islands. Advance preparations were made to initiate two other major field programs; one on northern Ellesmere Island, and one on Somerset Island and Boothia Peninsula.

Marine Geology

In August, 1974, in co-operation with the Atlantic Geoscience Centre, a cruise was undertaken in northern Baffin Bay and Lancaster Sound. The purpose of the project was to obtain samples of the seafloor bedrock with the use of an electric core-drill designed by the Metrology Division of the Atlantic Oceanographic Laboratory. A number of short, bedrock cores were successfully recovered, and these, in conjunction with high-resolution seismic records, will be used to add to the growing understanding of the geology of this region.

In the Beaufort Sea-Mackenzie Delta region, donated industrial deep reflection seismic data were used in support of structural and tectonic studies in order to define the major structural sub-provinces of the area.

Paleontology Subdivision

The Subdivision is responsible for scientific studies in paleontology and biostratigraphy in support of exploration for, and assessment of, the non-renewable resources of western and northern Canada. The program is closely co-ordinated with those of the other Subdivisions of the Institute, with similar programs of the Atlantic Geoscience Centre, the Regional and Economic Geology Division and with those of a number of universities in Canada, the United States, France and the United Kingdom. A substantial and increasing part of the program of the Subdivision is conducted by consulting companies and by university scientists. In addition, a postdoctoral fellow, three doctoral students and four EMR Research Agreements were supported by the Subdivision.

Detailed field investigations throughout western and northern Canada, together with associated laboratory and office studies, establish and refine models of biostratigraphic zonation and paleoenvironments for application throughout most of Canada. A large component of the program involves dating, correlation and determination of depositional environments of rocks in the subsurface of northern Canada by means

of detailed studies of palynomorphs, foraminifers, conodonts and other microfossils and macrofossils recovered from the cuttings and cores derived from wells drilled in the Yukon and Northwest Territories in search of petroleum and natural gas.

The Paleontology Subdivision consists of three scientific sections supported by laboratories. The Micropaleontology Section is responsible for palynological and foraminiferal investigations of Mesozoic and Cenozoic rocks and for micropaleontological (conodont and organic-walled microfossils) studies of Paleozoic rocks. The Macropaleontology Section carries out detailed studies of Paleozoic rocks and the Ottawa Paleontology Section is responsible for macropaleontological studies of Mesozoic rocks throughout Canada.

The Subdivision submitted for publication 7 GSC Bulletins, 4 GSC Papers and contributions to 2 others, 7 manuscripts for scientific journals, and 186 reports for restricted circulation.

Macropaleontology Section and Ottawa Paleontology Section

These Sections are responsible for research in the paleontology of invertebrate macrofossils and in the biostratigraphy and interpretation of depositional environments and paleobiogeography by the use of fossils. The area of responsibility includes the western provinces, Yukon Territory, and Districts of Mackenzie and Franklin. The establishment and continued refinement of biochronological zonation of Phanerozoic sediments is a vital part of searching for and assessing the economic resources of the rocks of this vast region. Activities of the Sections are closely integrated with other sections of the Institute, and the Division of Regional and Economic Geology, particularly in stratigraphical, paleoecological, sedimentation and economic studies.

Current stratigraphic and biostratigraphic studies include the Devonian rocks and fossils of southern Manitoba, Yukon Territory, District of Mackenzie, and Ellesmere Island; Mississippian corals of western North America; Carboniferous biostratigraphy of northeastern British Columbia; Carboniferous ammonoids and evaporite deposits of the Canadian Archipelago; Upper Permian ammonoids of northeastern British Columbia; Lower Cretaceous mound-like carbonate rocks of Ellef Ringnes Island; and Triassic, Jurassic and Cretaceous rocks and fossils of western and northern Canada. Several members of the Sections are involved in international committees and commissions on problems of faunal correlations and stage and series boundaries of the Phanerozoic Systems.

Micropaleontology Section

Research in the paleontology of microfossils, and in biostratigraphy and interpretation of depositional environments and paleogeography by the use of microfossils aids in a proper understanding of depositional history and for precise dating of strata necessary for correct evaluation of potential hydrocarbon deposits including coal. The responsibility extends country-wide for some disciplines, and more particularly to the Yukon, the Northwest Territories, and western Canada for others. In many rocks, microfossils are the only fossils present, and are particularly useful in subsurface studies owing to their durability and minute size. Studies are conducted in close co-operation with other geologists of the Geological Survey of Canada, and of industry and universities.

Scientists conducted field studies on Tertiary rocks of Axel Heiberg and Ellesmere Islands, and collected comparative material from mondial standard sections of the Devonian System in Belgium and of the Cretaceous System in southern England. Subsurface collections include samples from wells drilled on the Mackenzie Delta and the Arctic Islands, offshore British Columbia, and coal seams from southern Saskatchewan. Some specific studies include palynology (spores, megaspores, pollens, and dinoflagellates) of the Jurassic through Tertiary rocks of the Mackenzie Delta area and of the Arctic Islands; Paleocene megaspores from coal seams of southern Saskatchewan; Mesozoic Foraminifera of the Mackenzie Delta area and the Arctic Islands; and Siluro-Devonian conodonts of the Arctic Islands, western District of Mackenzie, and southern Manitoba.

Energy Subdivision

The Subdivision is responsible for the basic work necessary for the evaluation of the energy commodities of coal and petroleum occurring in the sedimentary basins of western Canada. The geological studies are done either within the Subdivision or co-ordinated through the Regional Geology Subdivision of the Institute and contribute to national inventories of the resources of petroleum and coal. Two groups operating within this Subdivision also have a national responsibility through departmental headquarters for the preparation of quantitative estimates of the national resources.

The Subdivision comprises four sections. Two of these are responsible for the two main energy commodities: one for information and data pertaining to petroleum and one for all matters related to coal. A third section is responsible for geochemical investigations. Organic geochemistry data support directly the petroleum evaluation programs, whereas the results of inorganic geochemical studies are integrated, in large part, with the work of the Regional Geology Subdivision. The fourth section, a small unit, is responsible for selecting that material used for detailed studies in support of the petroleum evaluation program from the large amount of basic geophysical data available. The evaluation of petroleum and coal resources is based on the integration of the work of the four sections.

A greatly improved assessment of the petroleum resources of Canada was completed this year through a departmental committee whose work is co-ordinated and centralized in the

Energy Subdivision. The committee comprises members from four different agencies of the federal government including the Resources Branch of the Department of Indian and Northern Affairs, the Resource Conservation and Management Branch of our own department, as well as the Atlantic Geoscience Centre, Dartmouth, and the Energy Subdivision of the Institute of Sedimentary and Petroleum Geology in Calgary, both of which are units of the Geological Survey of Canada. Considerable improvement has been made in the methods used in this work and much improvement in the data base has occurred over the last year. Nevertheless, much remains to be done that could further improve the estimates. It is anticipated that the 1974 estimate will be published by the time this report appears. The Coal Section has continued its work on the evaluation of the Saskatchewan lignite and, in co-operation with the Saskatchewan government, a series of reports will be prepared soon on this large program. Other major projects in coal evaluation have been anticipated but their initiation must wait for the resolution of several problems in federal-provincial relationships which, hopefully, will be achieved in the coming year.

A large monograph on the organic geochemistry of the Western Canada Sedimentary Basin is now in press. This publication comprises the results of a three year co-operative project with the Institut Français du Pétrole, and is probably the largest and most thorough piece of work ever attempted over such a large region anywhere in the world. It will provide an important bench mark, both in international co-operation and in the rapidly developing field of organic geochemistry. Besides this volume, the Subdivision submitted four manuscripts for publication in the Geological Survey Paper series and six in other scientific journals.

Geology of Petroleum

The Geology of Petroleum Section is responsible primarily for co-ordinating the assessment of Canada's potential petroleum resources, and conducting research on the habitat of oil and on methods of resource evaluation. A secondary responsibility is the development and maintenance of computer data files related to well data, oil and gas pool data and others.

During 1974-1975, the computer programs used in resource assessment were modified and translated into FORTRAN to increase the flexibility of analysis and to increase precision of the system. The new system was used in the assessments of Canada's hydrocarbon potential completed in March 1975.

Members of the Section, in conjunction with members of Regional Geology Subdivision, documented the various hydrocarbon plays in the Northwest Territories mainland and Yukon Territory south of the Mackenzie Delta. Members of the Section presented information regarding hydrocarbon potential of the Northwest Territories and Yukon to the assessment committee and ran the computer system for the Canadian assessment. Documentation of hydrocarbon plays in the Mackenzie Delta and Arctic Islands areas is now underway.

The computer file of data from wells north of 60° is now up to date and is being used, as is the file of information on oil and gas pools in western Canada. Data from nine petroleum zones in western Canada have been put into a data file that will contain information on all major hydrocarbon zones in the world. The file and retrieval systems are being developed in conjunction with Institut Français du Pétrole and will be used in the Canadian assessment.

Geology of Coal

This Section is responsible for planning and conducting national coal inventory programs and for co-ordinating and assessing scientific studies concerned with the depositional and structural history and with environments of the sedimentary complexes of Canada's coal deposits.

Preliminary evaluation of the coal resources of southern Saskatchewan was completed in late October 1974. Data for this evaluation were generated by a two-summer joint federal-provincial drilling program. The total estimate for Saskatchewan lignite coal resources is 5.7 billion short tons of coal with a specific gravity of 1.29. Evaluation studies are continuing and final publication of the geology, evaluations and conclusions is expected in the spring of 1976.

Considerable effort was expended in planning a proposed exploration program to be conducted on the Dominion Government Coal Blocks in southeastern British Columbia. This five-year program is designed to include surface mapping, diamond core drilling, reverse circulation drilling, downhole geophysical logging, adit construction and sample analysis.

Petrographic analyses of Saskatchewan lignites confirmed an earlier observation that there is a concentration of certain components in the seams toward the bottom of the coal-bearing section, and that coals from the Wood Mountain area have somewhat different petrographic composition than those from the Estevan and Willowbunch areas.

Petrographic examinations were made of potential coking coals from certain areas of the Foothills Belt of British Columbia with a view to determining detailed information pertaining to coking quality and ash content.

In the application of coal rank data to the search for hydrocarbons, information from coals and coaly material from Alberta was related to existing occurrences of hydrocarbons in the province. Studies on similar materials from the Mackenzie Delta, using both reflectance data and spore and pollen transmittance data, were used to interpret maximum temperatures to which the rocks in the section had been exposed. Temperature is a critical factor in the generation and preservation of hydrocarbons.

Inorganic Geochemistry, Mineralogy and Clay Mineralogy

The inorganic geochemistry, mineralogy and clay mineralogy group provides scientific services to the Division; develops, adapts and publishes analytical techniques in X-ray diffractometry, X-ray fluorescence and analytical chemistry and carries out research in the field of diagenesis related to the oil generating potential of source rocks. The mineralogy and clay mineralogy laboratories determine, qualitatively and semi-quantitatively, minerals and clay minerals in sedimentary rocks, as well as performing X-ray fluorescence analyses. In conjunction with the inorganic chemistry laboratory, they investigate clay syntheses, diagenesis, methodology in clay mineralogy and mineralogical transformation of clays. The inorganic geochemistry laboratory determines the elemental composition of sedimentary rocks and makes quantitative studies of minerals and clay minerals in sedimentary rocks by differential dissolution, differential fusion, wet chemical analyses and a combination of instrumental analytical methods such as thermal, thermogravimetric, differential thermogravimetric.

The use of clay minerals in determining the degree of diagenesis and oil generating potential of sediments continues to be investigated. The application of clay minerals to the study of palaeosols has been investigated.

Organic Geochemistry

The main activity of the organic geochemistry group is concerned with potential petroleum source rocks and levels of thermal diagenesis in the Arctic Islands and District of Mackenzie, and the characterization and correlation of crude oil types in these areas. In addition, a geochemical study has been carried out on oils and source rocks in Alberta in conjunction with the Institut Français du Pétrole. Crude oils in the central part of the Alberta Basin have been classified into three types and have been related to specific source rocks. The heavy oils in eastern Alberta have been shown to have been derived from the central part of the basin, but have been altered extensively by water washing and biodegradation. Biodegradation has been observed also in oils from the Mackenzie Delta, and appears to be a common process.

The organic geochemistry laboratory carries out routine analyses of organic carbon and low molecular weight hydrocarbons; detailed analysis of heavy hydrocarbons by extraction, liquid chromatography, thin layer chromatography and gas chromatography; and develops techniques for the analysis of the organic material in sediments.

Geophysics

This unit is responsible for the compilation, analysis and interpretation of geophysical data and other information. Information derived from non-confidential records is made available to other scientists in the programs, to assist in describing the structural configurations within and between the sedimentary basins of northern Canada in support of petroleum resource evaluation and basin analysis. Priorities have been given to the evaluation of the Sverdrup Basin, offshore and onshore Mackenzie Delta and the Beaufort Sea.

Geological Information Subdivision

The Subdivision provides scientific editing as well as cartography, photography, and library services for the Institute. It is responsible, also, for the distribution of publications of the Geological Survey and of other major branches of the Department of Energy, Mines and Resources. A major activity is the processing for publication of all scientific manuscripts presenting the results of research at the Institute. After preparation, manuscripts are forwarded either to Ottawa for printing or to the editorial staff of one of the scientific journals.

All maps and illustrations required by the Institute staff for publication by the Geological Survey, or in scientific journals and guidebooks are prepared in the Cartographic Section; the work includes all drafting for black and white and multi-colour illustrations as well as photomechanical and reproduction work.

A photographic laboratory provides general and specialized photographic services for the Institute staff.

All publications of the Geological Survey, publications west of the Canadian Shield of the Surveys and Mapping Branch, and various miscellaneous departmental publications are sold and distributed from the publications office. The unit includes, also, an order office of the National Air Photo Library. Aerial photographs may be viewed and ordered through this office.

The library contains an important collection of scientific books, journals and documents relating to the mission of the Institute. It serves the scientists in their research and also offers services to oil and mining company personnel, staff members of the University of Calgary, and the general public. The library also provides an outlet for the Geological Survey Open File system, a valuable means of releasing data and information to the user public with the least possible delay.

REGIONAL AND ECONOMIC GEOLOGY DIVISION

J.E. REESOR, Director

This Division is responsible for all aspects of the geological framework of Canada, excluding the western Canada and Arctic Sedimentary Basins, but including the Pacific Continental Shelf. In addition, units of the Division are charged with responsibility for integration of the regional geological framework with mineral deposit data and metallogenic concepts and using the results in projecting the mineral resource potential of the country.

The objectives of the Division are: to provide a systematic study of the geological framework across the country to standards consistent with the needs for mineral resource discovery and evaluation of future resource potential; to provide standards, controls and reference material to ensure consistent correlation and uniform presentation of the geology of Canada; to establish the geological settings favourable to the occurrence of mineral deposits and fuels; and to establish the potential abundance and probable distribution of mineral resources of Canada.

Objectives of the Division are expressed not in square miles covered nor in pages of data accumulated, but in terms of a sophisticated data-base consistent with leading current concepts and ideas. A measure of accomplishment in any year may not be impressive.

Twenty-five years ago, Cordilleran geology consisted primarily of gaps with local 'islands' of well understood geology. After years of systematic accumulation of geological information, regional syntheses were possible, embodying stratigraphy, intrusive rocks, structure and metamorphism, all interrelated through paleontologic and geochronologic studies. Now, tectono-stratigraphic units can be studied on a broad regional basis, problems are well-defined and current work is designed to contribute a broad range of criteria for exploration and resource evaluation of contained mineral deposits. In the process there is a constant improvement of the data-base as portrayed on 1:250,000 scale geological maps.

At present, geology of the Canadian Shield consists in large part of gaps dotted with well-studied localities. The objective of the next twenty-five years is to provide sufficiently detailed coverage over most of the more important regions of the Shield, particularly in the least well known areas of the Northwest Territories. Steps toward this goal are measured in the increasing number of geological maps, better understanding of the chronology of igneous or metamorphic successions in a few areas, a beginning attempt at regional correlation of some major rock groups and progressive accumulation of necessary data bearing not only on the prime objective of mineral resource discovery and evaluation of mineral resource potential, but having a myriad of uses requiring a broad, sophisticated geological data-base. This is not accomplished in a year, but can be measured in terms of projects completed in three to four year cycles.

Resource discovery and resource potential forecasts build upon the accumulating data-base by adding ever increasingly sophisticated knowledge of Canadian deposits and those known elsewhere in the world for which favourable geologic settings may be known in Canada. As with the data-base, such knowledge builds slowly and often depends upon the growing expertise of one or several individuals in broad fields of mineral deposit geology combined with an understanding of regional geology and metallogenic concepts. Measurements of accomplishments are visible in the rapidity with which new ideas, new mapping information and new discoveries of mineral deposits can be integrated into an overall appreciation of mineral potential in Canada.

Studies within the Division contributing to the geological data-base emphasize geological mapping, with publication at 1:250,000 scale, and accompanying reports. Regional syntheses are compiled and published at a scale of 1:1,000,000.

Current activity in the Canadian Shield is concentrated mostly in the Northwest Territories with a view toward providing a geological data-base consistent with modern standards in a region less well-known than that farther south. Work in the Bear-Slave Province on the stratigraphy of the Yellowknife Supergroup showed some of the details of the relationship of the basal units to the granitic basement of the supracrustal rocks; laboratory work showed the basement rocks to be 3 billion years old. A narrow zone of massive sulphides was found to be associated with volcanic rocks near the basal unit of the supracrustal rocks. Work in the Foxe fold belt on Melville Peninsula proved the presence of ultramafic flows and a number of acid volcanic centres within the Prince Albert Group. As a result, the potential for eventual discovery of mineral deposits within this belt is much enhanced. A new project across central Baffin Island was directed mainly toward study of the stratigraphy, structure and metamorphism of the Piling Group of Aphebian age. These complex sequences were selected for further investigation on the basis of previous regional 8-mile reconnaissance studies.

Similarly, regional mapping studies in the Cordillera were concentrated in St. Elias Mountains, previously unmapped, and in Selwyn Basin, as a basis for guiding current extensive mineral exploration in Lower Paleozoic strata. In the latter area preliminary attempts are being made to integrate regional geology, paleontological and biostratigraphic studies and the occurrence of all mineral deposits into a metallogenic synthesis as a sophisticated guide to further mineral exploration and evaluation of the extent of future mineral resources.

The economic geology group within the Division carries a continuing mandate to study and keep informed of developments in major mineral commodities across the nation. This serves as a basis for evaluation of resource potential in Canada and utilizes the accumulated expertise of this group in assessing many types of potential resource discoveries in Canada. To accumulate and use such information, much effort has been expended in the past year to develop suitable systems for computer storage, treatment and retrieval of mineral deposit data. New federal-provincial agreements for mineral development in areas of provincial jurisdiction and for non-renewable resource evaluation projects make ever increasing demands on the wide-ranging expertise of commodity geologists of the Division.

Underlying all mapping and mineral deposit studies of the Division is the common concept of geological time. This concept is essential in establishing the succession of geologic

processes in the formation and evolution of the crust and its contained mineral deposits. For Precambrian rocks most paleontological methods so well established in Phanerozoic rocks are not applicable, so great emphasis is put on isotopic geochronology and, to some extent, paleomagnetism. Isotope geochronology using Pb-U, Rb-Sr, and K-Ar methods seeks first to establish the geological succession in individual areas, then over broad tectonic units and finally to provide basic data for broad regional correlation. For example, current results show Archean volcanism to have taken place at essentially the same time in widely scattered regions of the Canadian Shield from the Slave Province in Northwest Territories to northeastern Ontario. Current paleomagnetic studies indicate that extensive crustal plate movements did not occur in Aphebian or later times, thus the Archean volcanism took place in widely separated areas and was not dispersed from a single centre through crustal plate movements.

Experts within our staff continue involvement in Canadian International Development Agency projects such as the Omo River project of Ethiopia with the responsibility for mapping a large territory and training Ethiopian geologists in the whole process from reconnaissance mapping to final publication of the results.

Economic Geology Subdivision

The Economic Geology Subdivision identifies and interprets through field and laboratory investigations the geological characteristics of mineral deposits and their relationships to their geological environments. It develops and applies metallogenic and geomathematical methods to evaluate the non-hydrocarbon mineral resources of Canada. It provides information to government agencies and industry in support of the management and development of these resources.

The objectives of the Economic Geology Subdivision are:

1. to relate the genesis of economic concentrations of commodities to the evolution of the geological framework of Canada and thereby to
2. determine regional and local geological features that are favourable to the occurrence of mineral deposits and are guides to their discovery and to use this understanding to
3. evaluate the distribution, character and amount of Canada's mineral resources.

The Subdivision integrates four main types of activities toward these objectives:

1. Commodity metallogeny, which is the comprehensive study of all aspects of the geology of specific mineral commodities to determine the ways in which they are concentrated in the Earth's crust and the consequences in terms of quality, distribution and identification of such concentrations. Selected commodities among the major components of the Canadian mineral economy receive ongoing study whereas other commodities, selected on the basis of economic and strategic priorities and the availability of manpower, are studied on a term basis.
2. Regional metallogeny, which relates the nature and distribution of the mineral deposits in a specific large segment of a geological province to its geological features. These studies that embrace numerous mineral commodities and extensive regions, integrate commodity metallogeny with regional geology in its broadest sense.
3. Geomathematical research and development in quantification, statistical analysis and interpretation of geoscience data, with emphasis on the evaluation of specific mineral resources on a regional basis.
4. Development and operation of data banks of documentary and computerized information required for and generated by the other activities.

This year marked the initiation of regional metallogeny in its own right, with the appointment of a scientist to study the metallogeny of the northern part of the Canadian Cordillera on a full-time basis.

The inexorable increase in advisory and liaison work arising from federal-provincial agreements, the development of mineral policy and the Non-Renewable Resources Evaluation Program was partly met by the new appointment of a co-ordinator and the strengthening of two programs in the metallogeny of major commodities.

The Uranium Program now centres upon a continuing series of quantitative evaluations of resources of uranium additional to measured reserves and on assistance in evaluating the latter. The increased responsibilities and deadline pressures were partly offset by the new appointment of an experienced uranium specialist. The evaluations now demanded will increasingly require specifically uranium-oriented regional geological studies in addition to studies of identified uranium deposits.

The pioneering nature of the geomathematics program is reflected in the progress of Project Appalachia, an intradivisional project that seeks to combine regional geology, metallogeny and geomathematics in the development and application of computer-based methods of regional resource appraisal. At this stage, progress depends heavily upon the development of mathematical models whose assumptions and restrictions are geologically acceptable but which can nevertheless accommodate the unavoidably imprecise nature of many geological data.

The systematic evaluation of national mineral resources requires the strong support of computer-based files of mineral deposit data. This year saw good progress in the development of specifications for broadly based files at index and deeper geological levels and on certain specialized files. Realization of these computerized files requires additional support.

Special Projects

Special Projects comprises the Uranium Program and the Iron and Manganese Program.

The objectives of the Uranium Program are to gather and interpret data on uranium and thorium deposits and to determine their nature and genesis, in order to assess Canada's resources of uranium and thorium and to assist and encourage exploration.

Following the first meeting of the Departmental Uranium Resource Appraisal Group (URAG), in early June, the Uranium Program personnel made a preliminary calculation of the reserves and resources of the Elliot Lake area, Ontario. In September, a reserve appraisal team, comprising two members of each of CANMET and the Geological Survey began an on-the-site evaluation of the reserves and inferred resources of uranium and thorium in the major uranium deposits of Canada. In October, V. Ruzicka joined the group and spearheaded the operation. A report on reserves in the major deposits was submitted jointly by the Reserves and the Additional Resources Sub-committees to URAG in March, and a preliminary report on additional uranium and thorium resources in and near the major uranium deposits was submitted by the Additional Resources Sub-committee. Research on improved methodologies for resource appraisal of various environments throughout Canada for each type of uranium deposit was begun in March.

The objectives of the Iron and Manganese Programs are, firstly, to study and evaluate Canadian resources of these commodities and, secondly, to investigate the wider metallogenic significance of certain iron deposits and their use as guidelines in exploration for base metals and gold deposits in the Canadian Shield.

Collection and compilation of data on iron and manganese deposits and the geochemistry of iron formations and maintenance of reference files on subsea resources of manganese and other minerals continued throughout the year. The program leader resumed an active role in it in October, on completion of a two year assignment as Commonwealth Geological Liaison Officer in London, England.

Geomathematics Section

The Section carries out a program of research in order to develop mathematical methods for the quantification, statistical analysis and integration of geoscience data. Patterns of occurrence of various types of mineral deposits are correlated with parameters systematically quantified for the geological framework.

Emphasis during the year was on evaluation and analysis of coded information contained in two comprehensive computer-based data files for (a) regional geology and (b) mineral deposits of the Canadian Appalachian region. This activity is part of Project Appalachia which is an intradivisional co-operative effort to combine regional geological, metallogenic and geomathematical concepts in the development and application of computer-based methods of regional mineral resource appraisal. A series of meetings were held during the year with members of the Mineral Deposit Geology and Appalachian Sections to evaluate patterns consisting of numbers calculated using the multiple regression method for correlations between data from the two files.

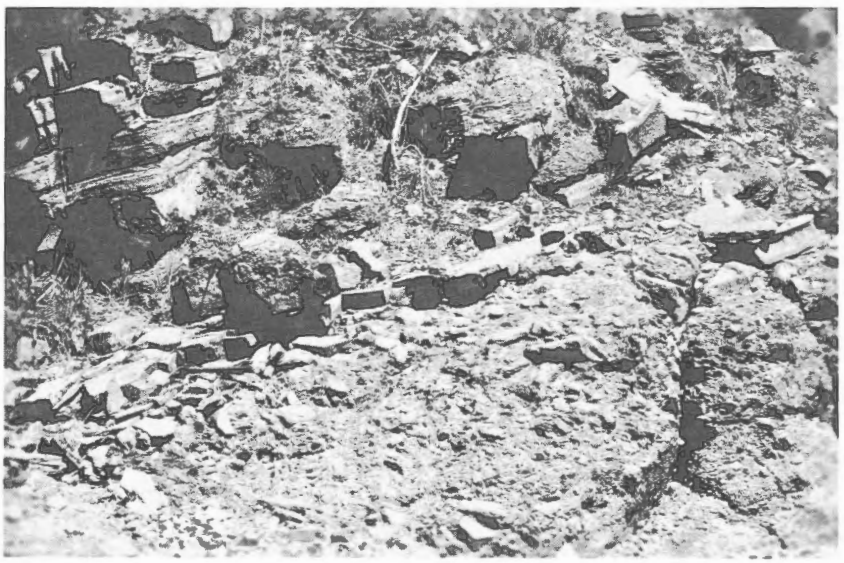
These reviews were useful for the further planning of the geomathematics program on regional resource appraisal which now consists mainly of the following four types of activity: (1) development of new methods for the estimation of probabilities of occurrence for various types of mineral deposits and provision of a mathematical background to the concept of mineral potential expressed in numbers of tons of metal per unit of area; (2) evaluation of other statistical methods used for resource evaluation including those applied in other countries; (3) application of a wider group of methods of multivariate statistical analysis, specifically cluster analysis, classification analysis and canonical correlation in order to attempt to statistically classify mineral deposits and the environments that contain them; and (4) updating and improvement of the plotting, computing and contouring program packages acquired for processing Project Appalachia data.

Mineral Deposits Geology Section

Charged with the responsibility of attaining a broad knowledge of all major types of Canadian mineral deposits, this Section comprises 16 geologists and one precision worker. Studies are currently underway on the geology of 17 elements (metallic and non-metallic) and the rare earths; in addition, two projects have been concerned with detailed mineralogical aspects of certain types of mineral deposits, chiefly nickel and porphyry copper.

The section program comprises the following activities: (1) comprehensive geological studies of all aspects of selected mineral commodities and the manner in which these are concentrated in the Earth's crust; (2) metallogenic studies of large geological segments of Canada to relate the distribution and nature of mineral deposits within the geological framework of these segments; (3) a geologically oriented merging of the foregoing activities as the basis for estimations of the mineral potential of selected regions or the nation as a whole; and (4) provision of advice and geological information on Canada's mineral deposits for mineral policy, socio-economic assessments, land-use studies and related matters.

Significant accomplishments during 1974-75 included: participation in three conferences on the methodology of quantitative resource evaluation and the exchange of data on mineral deposits pertinent to this objective (two of these conferences were initiated by the United States Geological Survey, the other by the Department of Energy, Mines and Resources and attended by provincial representatives); establishment of a computer-based file to handle data on reserves of certain Canadian mineral commodities; establishment of the key parameters to be used in a computer-based index of Canadian mineral deposits; continuing development of the



Dark grey, fine-grained, stromatolitic, laminated basal Windsor (Carboniferous) limestone overlying green-grey conglomerate at East Bay, Nova Scotia. Copper minerals occur in the conglomerate and lowest limestone beds. (GSC 202516-B)

geological specifications for a computer-based file of the geology of Canadian mineral deposits; participation with other Branches of the Department and the Manitoba Department of Mines, Resources and Environmental Management in planning projects to be carried out in the coming fiscal year under the Non-renewable Resources Evaluation Program.

Members of the Mineral Deposits Geology Section also published numerous scientific papers and reports in Geological Survey and outside journals. Included in these were major reports on the geology of Canadian tin and niobium-tantalum deposits.

In a typically active field season, section members examined mineral deposits in virtually every geological province of Canada. They examined also the geological features and settings of selected types of deposits outside the country that are not well known in Canada but which, in view of Canadian geology, may eventually be identified here.

Mineral Data Bank

The Mineral Data Bank is the repository for, and secondary source of geological data on mineral deposits in the Geological Survey of Canada. For the principal mineral commodities it co-operates with the Mineral Deposits Section in the collection and circulation of published data and in the standardization and computerization of files. For the rest it maintains files and watching briefs, ready to supply data on request.

The review of currently active mineral deposits, UPDATE, was discontinued at the beginning of the year. It proved too time consuming for the benefits derived. Material (location and geological background) formerly circulated in UPDATE is now accumulated in an UPDATE file which can be consulted by those interested.

Computerization of geological and other data on mineral deposits remains a prime concern of the unit. A TEST FILE (OPSEP) of 100 deposits, selected from the 700 considered in the mineral potential study Operation September, was created at the beginning of the year using the data management system GEODAM (GDMS). GEODAM, although conceptually very promising for the management of mineral deposit data, is only partially developed. The TEST FILE was, therefore, converted into a form manageable by MARS VI and tested, with promising results.

Specifications for an index file, CANMINDEX, were agreed upon at the year end by the geologists concerned and through co-operation with the Mineral Development Sector it may be merged with the MEPI file to produce a single shallow index file applicable to essentially all the mineral deposits in the country, estimated at from 50,000 to 100,000. The balance of the content of the TEST FILE will be incorporated in a deeper geological file (M-2), specifications for which are still being developed at the year end.

Correlation and Standards Subdivision

The Subdivision provides support to regional and economic geological programs of the Geological Survey of Canada through several scientific approaches: petrological, biostratigraphical, geochronological and geological. The criteria and

geological models developed lead to improved understanding of igneous and metamorphic processes of rock genesis and transformation, of correlation and paleoecology of strata, of the age and sequence of volcanic, plutonic and metamorphic events, and of the mineral and hydrocarbon potential of selected sequences.

Petrological studies are underway on selected rock types. Alkaline rocks of Canada have been examined and the associated base-metal sulphide occurrences documented. Anorthositic rocks are derived from a deep crustal level on the mantle; those near Harp Lake, Labrador, contain copper-nickel sulphide deposits being actively explored. Granite is a very common rock type, and in the Canadian Appalachian Region is often associated with economic minerals. Some ultrabasic plutons in the Cordillera Region appear to be genetically related to Triassic volcanism. Studies of them in co-operation with regional geologists of the Cordilleran and Pacific Margin Subdivision will aid in the understanding of the physical volcanic paleogeography and thence to the evaluation of the sulphide potential of the volcanics. Regional metamorphism is a complex process that has affected vast tracts of the Canadian Shield and bordering Phanerozoic fold-belts. The mineral assemblages are keys to the environment of formation mainly in terms of pressure and temperature. Computer data banks and programs are being developed to yield these parameters for particular assemblages, and a metamorphic map of the Canadian Shield in part of Manitoba is being compiled. Support is also provided to the Branch Data System Group undertaking the task of co-ordinating the use of electronic data processing and designing major data management systems.

Four scientists pursue biostratigraphic and paleontologic studies of particular fossil groups: Early Paleozoic trilobites and ostracodes and later Paleozoic spores. Their work is complementary to that of paleontologists of the Institute of Sedimentary and Petroleum Geology in Calgary, Alberta and Atlantic Geoscience Centre in Dartmouth, Nova Scotia. Successions of Ordovician trilobite faunas have led to improved dating of strata in Newfoundland and refinement in the understanding of faunal realms as related to once-separated continental and oceanic plates. Careful biostratigraphic studies viewed in relation to various rock facies are contributing to the evaluation of lead and zinc sulphide potential of Cambrian strata in Yukon Territory and Northwest Territories. Microscopic spores have permitted dating and correlation of some otherwise unfossiliferous, undated strata in the Hudson Bay region. Ostracodes in Paleozoic strata of Anticosti Island, Quebec and Northwest Territories have been zoned and may prove useful for correlation in wells drilled for oil and gas exploration.

Age determination by isotopic analysis has proven itself manifold as a necessary tool in the Canadian Shield, as well as in the bordering Phanerozoic belts. The three systems—K-Ar, Rb-Sr and U-Pb—are studied and used in our laboratory. Each system is applied optimally under different geological conditions and each complements the other. The U-Pb system uses mainly zircons, a very minor constituent of many rocks, and under most geological conditions seems to yield the most useful information, particularly in Precambrian rocks and those commonly with the most complex history of development. The zircon system this year yielded the oldest reliable age, about 3000 m.y., from the Slave Province in Northwest Territories, another step in unravelling the geological evolution of the Canadian Shield.

In the Appalachian Region, current study of a selected area of volcanic rocks in Newfoundland is expected to result in a reconstruction of a former island arc and an interpretation of the original place and environment of deposition of small base-metal sulphide deposits. This is a difficult and demanding task and if even only partly successful will be valuable to sulphide deposit prediction there and elsewhere in similar island arc deposits.

Petrology Section

The Petrology Section studies the processes and conditions of formation of igneous and metamorphic rocks by integrating results obtained by field observation, experiment, and theory.

Investigation of anorthosite massifs has contributed to an understanding of their origin, emplacement, and subsequent history. The discovery of high-pressure pyroxenes in some anorthosites suggests a derivation of the magma from mantle material. Various alkaline complexes were studied. It was demonstrated that omphacitic pyroxene is stable in alkaline rocks subjected to medium-grade metamorphism.

Laboratory studies on the mineralogy of the Axelgold ultrabasic pluton in the Cordillera Region are underway. The pluton and others like it appear to be genetically related to Triassic volcanism. These studies will aid in the evaluation of the potential of volcanogenic sulphide deposits by helping to reconstruct the physical volcanism of the volcanic rocks.

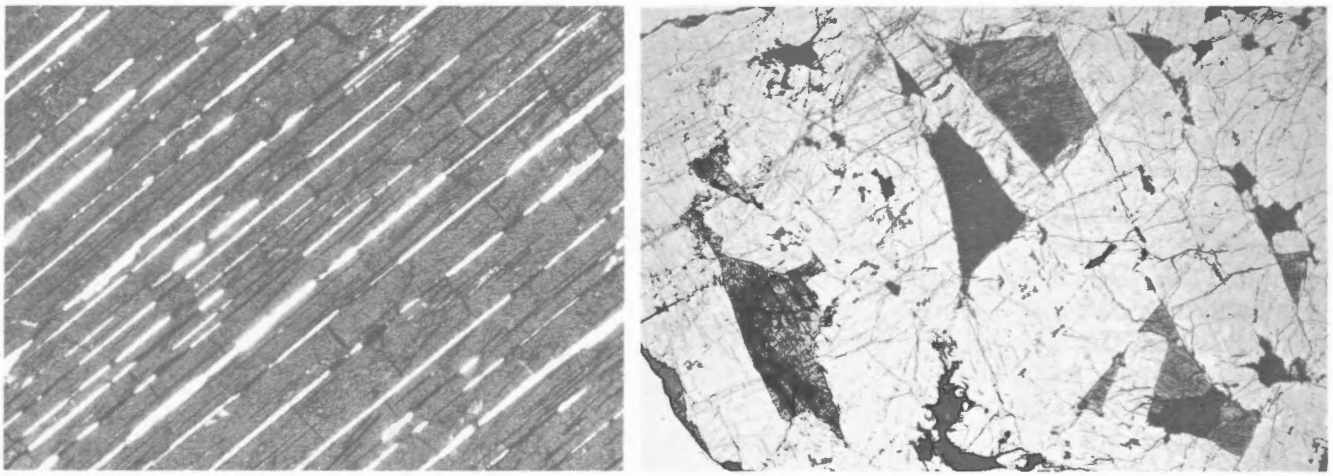
Work was begun on a metamorphic map of part of Manitoba as a contribution to a proposed metamorphic map of the Canadian Shield.

There has been continued study directed toward applying computing techniques to phase equilibria in the study of metamorphic rocks in order to use mineral assemblages as indicators of metamorphic conditions.

Support is being provided to the Branch Data System Group which is concerned with electronic processing of geological data.

Eastern Paleontology Section

The work of the section's four research scientists is to refine biostratigraphic methods of correlating and determining



Left. Photomicrograph of part of a large hypersthene crystal from the Lac St. Jean anorthosite, Quebec. Regular lamellae of plagioclase (white) are contained in hypersthene (dark grey). Black lamellae and blebs are titaniferous magnetite. The originally homogeneous hypersthene exsolved plagioclase and magnetite during decompression and cooling after being brought up by magma from depths of 40 to 50 km. (Long dimension of photograph is 4.2 mm — GSC 202623-N).
Right. Photomicrograph (x3) of anorthosite, Harp Lake Complex, Labrador, presently being explored by Kennco Exploration. Chalcopyrite and pyrrhotite (black) fill spaces between plagioclase (light grey) and pyroxene (medium grey). (GSC 202772-M)

the age of Paleozoic rocks of the Appalachian Region and other parts of Canada by studying, describing and evaluating the faunas and palynofloras they contain.

During the year, the staff completed 51 scientific reports on 324 lots of fossils for the Geological Survey of Canada and other organizations in North America and Europe. Zonal standards were developed for correlation of Silurian rocks of Anticosti Island, Quebec and Ordovician rocks of the Hudson-Foxe Basin and southwestern District of Mackenzie based on ostracodes. Descriptions were prepared of trilobites from Newfoundland, Quebec and British Columbia that will provide a basis for their use in correlation of Ordovician rocks of these regions. A concept was proposed that three grand cycles (shale-carbonate pairs) in Lower Cambrian rocks extend from Mexico to Yukon Territory, and that they will be useful for correlation and for predicting the occurrence of stratiform mineral deposits.

Ultimately, the refinement of biostratigraphy capability for Canadian rocks depends upon establishment of world-wide biostratigraphic standards to which zones in Canada can be correlated. During the year the staff of the Eastern Paleontology Section contributed toward this goal by membership on the International Subcommissions of Cambrian, Ordovician, and Devonian Stratigraphy of the International Union of Geological Sciences, and by collaboration with scientists from other countries in study of biostratigraphically critical fossils from western Europe, Turkey, and North Africa.

Geochronology Section

The Geochronology Section is responsible for the co-ordination of the radiometric age determination program of the Geological Survey of Canada and undertakes isotopic analyses of rocks and/or minerals required to support detailed geochronological studies. Age determinations are based on the K-Ar, Rb-Sr and U-Pb isotopic systems. Stable isotope analyses of sulphur, carbon and lead are also provided.

During the past year increased emphasis has been placed on the application of U-Pb dating techniques to zircons selected from key rock units. Laboratory facilities have been expanded with the objective of processing 100 zircon samples per year. The development of the capability to process very small quantities of zircon facilitates comparison of the response of the K-Ar, Rb-Sr and U-Pb isotopic systems within a

single rock unit to the tectonic and metamorphic events that have affected the rocks. By undertaking such research it is often possible to distinguish between the original age of intrusion or deposition and the time of subsequent metamorphic events.

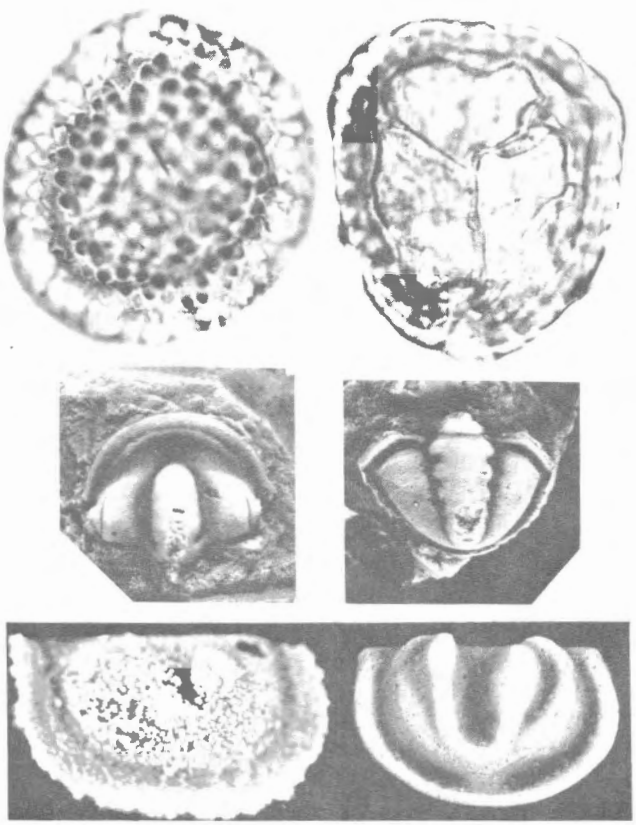
Zircon is a minor constituent of rocks and consequently large samples are required in order to obtain sufficient for precise age measurement. A field testing kit has been used to identify favourable rocks before samples are selected. Fourteen field sampling kits were provided for field officers in 1974 and in addition, members of the section visited 11 field parties to assist with the collection of specific key samples. During the 1974 field operation, 138 zircon-bearing samples were shipped to Ottawa for age study; concentrates have now been prepared from many and preliminary age results reported.

This year completed zircon age measurements have spanned the range from 60 m.y. to over 3000 m.y. The oldest age was obtained for rocks representing the Archean basement in the Slave Structural Province and is the first rock of this antiquity to be dated in our laboratory. In addition, recent results obtained for acid volcanic units in the Slave Province proved to be identical to ages previously obtained for similar rocks in the Ennadai-Rankin Inlet area and the Noranda area. The geochronological results thus indicate that acid volcanism occurred simultaneously about 2650 m.y. ago in widely separated regions of the Canadian Shield.

The hardware required to interface the laboratory minicomputer to all mass spectrometers was designed and assembled. Five of the six mass spectrometers are now equipped with an operator panel that permits the analyst to initiate transfer of isotopic data to the computer and to control the flow of data during the analysis. A software package for mass spectrometer sample data acquisition operating under the real-time disc operating system has been developed (by personnel of Computer Science Centre) and successfully tested. This system permits the simultaneous transfer of information from all mass spectrometers and the calculation of all isotopic parameters and age results. Use of this facility greatly accelerates the flow of data in the laboratory and makes it possible for the analyst to critically assess the analytical output before terminating the instrumental analysis.

Appalachian Section

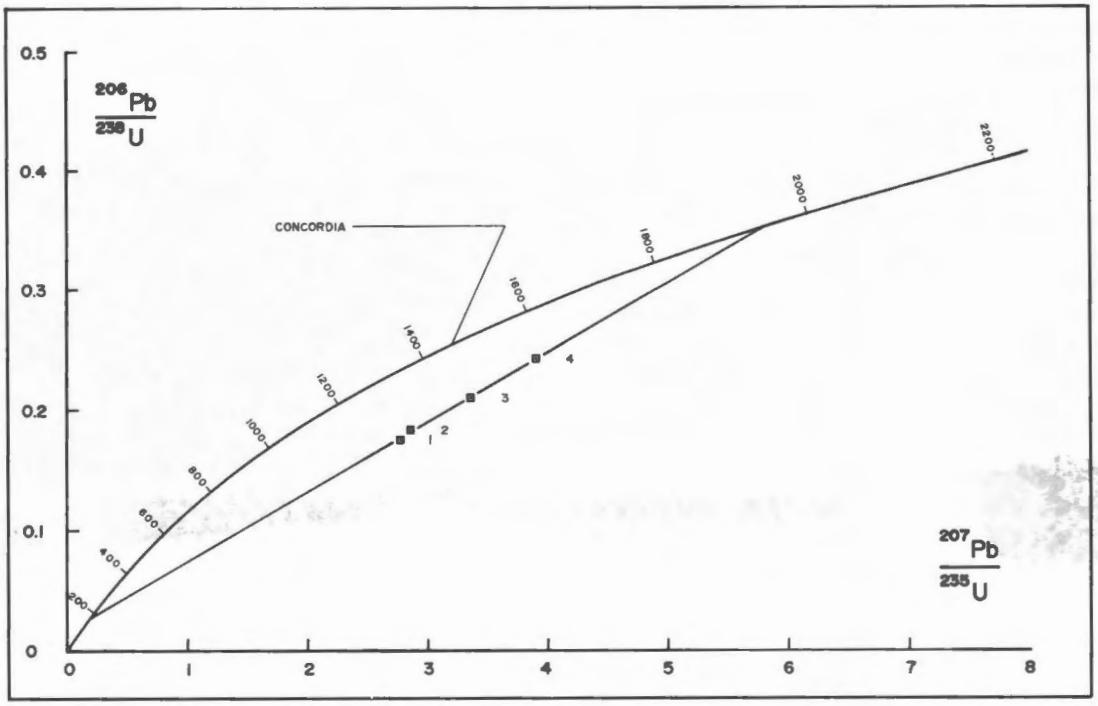
The objectives of the Appalachian Section are to define the composition, stratigraphy and structure of the rocks of the Appalachian geosyncline and eastern Canadian platformal regions; thus to determine their mode of origin and evolution and to provide information for the evaluation of the potential for mineral and hydrocarbon resources. This information is made available to the public in the form of published maps, reports and scientific papers.



***Cymbosporites* cf. *C. yorkensis* McGregor, x1000, GSC 41717 (1) *Chelinospora Vermiculata* Chaloner and Streel, x 1000, GSC 41704 (r)**
Spores are used in determining the age and correlation of strata. These came from sedimentary rocks that lacked other fossils.

***Ekwipagetia plicofimbria* Fritz, x8, GSC 33215, 33221**
Trilobites aid in dating and correlation of Cambrian strata of Mackenzie Mts. where lead and zinc sulphide deposits are being actively explored.

***Eurychilina prairiensis* Copeland, x20, GSC 35255 (1)**
***Zygobolba anticostiensis* Ulrich and Bassler, x15, GSC 43344 (r)**
Early Paleozoic ostracodes from Mackenzie Mts. and Anticosti Island are used in the search for oil and gas.



Concordia plot of U-Pb analyses of zircons indicates Precambrian age (1960 m.y.) of orthogneiss in Shuswap Complex, British Columbia. The K-Ar method records only the much more recent thermal events (50-110 m.y.).

Investigations during the year were mainly of stratigraphical and structural nature. A study of the regional geology of southern Avalon Peninsula in eastern Newfoundland marked the final phase of reconnaissance mapping in the Canadian Appalachian Province. This project, to be completed in 1975, is being carried out under a contract let to Memorial University of Newfoundland. The results of recently completed studies of the geology of the northern extremity of Great Northern Peninsula is in the process of preparation for publication. The report, when completed, will be of considerable value to current engineering feasibility studies relating to a proposed tunnel to be constructed beneath Strait of Belle Isle to carry electric power to insular Newfoundland from the Gull Island hydroelectric power dam under construction in Labrador. The report will also assist exploration companies in locating the more favourable areas for zinc deposits such as those near Daniel's Harbour in western Newfoundland, where mining will begin in 1975. In northeastern Newfoundland, a detailed study of volcanic rocks was initiated. The objective of this program is to reconstruct the environments of volcanism and the formation of associated (sub-economic) sulphide deposits.

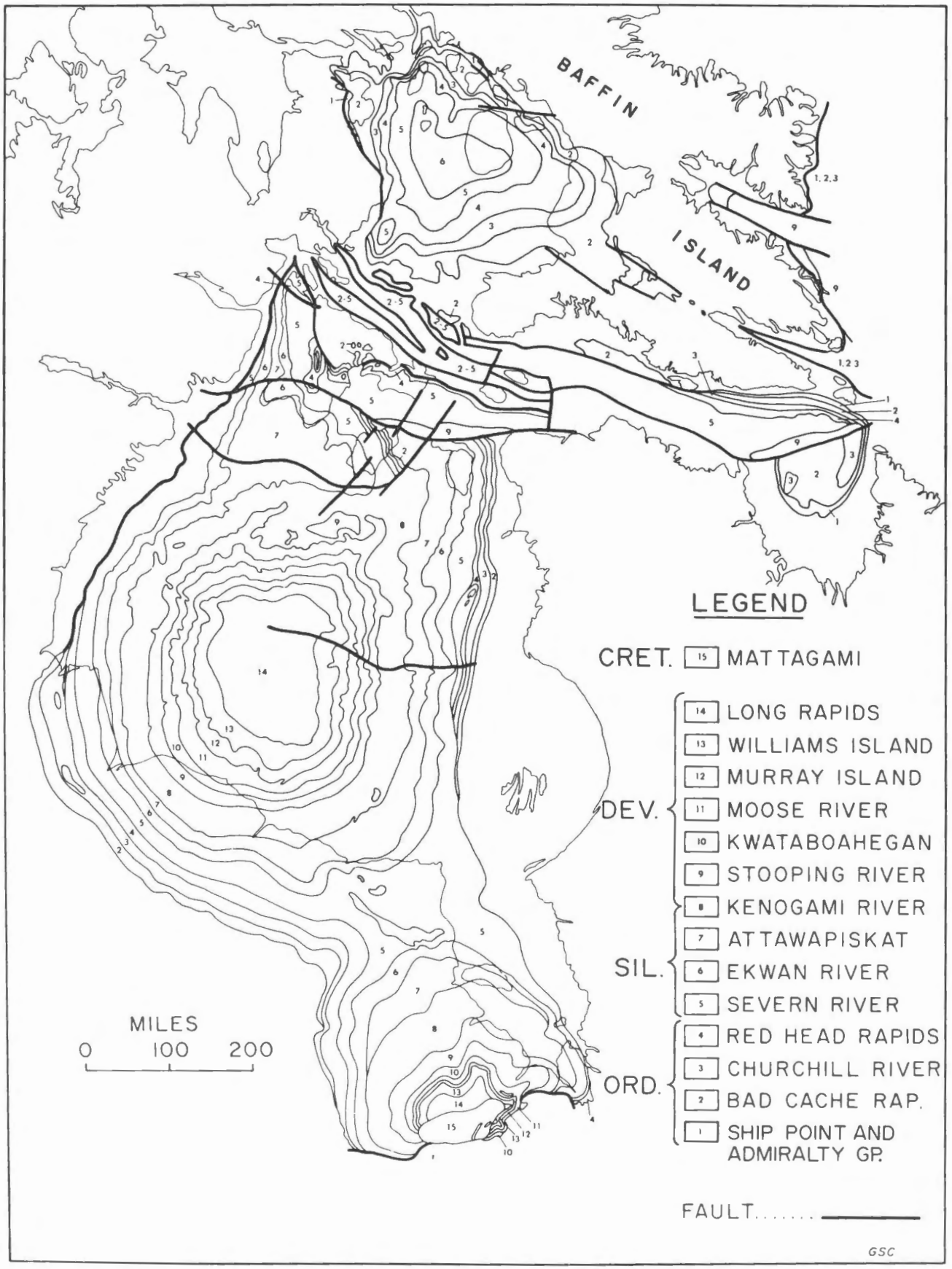
The L'Anse aux Meadows National Historic Park, the viking site occupied about 1000 A.D. at the northern end of Great Northern Peninsula, was briefly studied for Parks Canada, and information supplied that will aid in the development of the park for tourists.

Compilation maps at 1:2 million scale initiated and largely compiled at Atlantic Geoscience Centre were completed of the geology, physiography and basin structure of the onshore-offshore regions of eastern Canada. The three maps focus on the sedimentary basins of eastern Canada that are believed to have hydrocarbon potential. A regional study of the evaporite basins of Canada was begun with one objective being to investigate the feasibility of utilizing salt deposits for the storage of radioactive wastes.

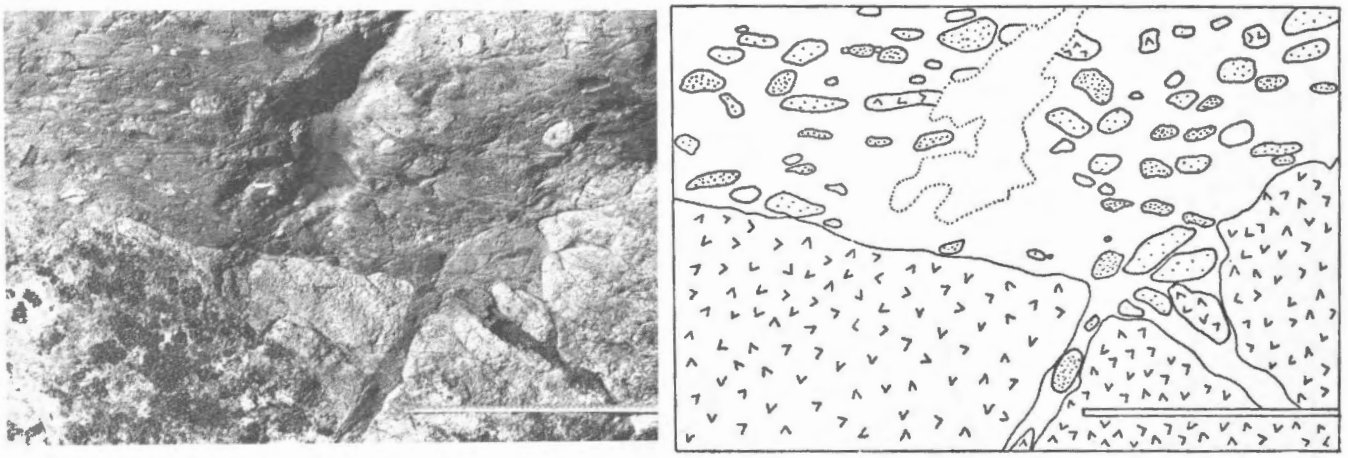
Advice and project evaluation were provided to mineral development programs in the Atlantic Provinces, funded mostly by Department of Regional Economic Expansion.

Precambrian Subdivision

This unit comprises 25 officers and two physical scientist support staff engaged in Precambrian studies, three officers and two support staff engaged in paleomagnetic studies and a draftsman. Since compilation of the reconnaissance mapping of the Canadian Shield in 1973, the Subdivision has engaged in more detailed geology and special studies in areas of most economic potential, mainly north of 60 degrees north latitude. Field work in Northwest Territories was confined largely to the Bear-Slave Structural Province where six parties operated and the Foxe Fold Belt where three parties were engaged. Four parties mapped elsewhere in Canada; in northern Saskatchewan, on the Manitoba-Ontario boundary, in the Kirkland Lake area, Ontario and on the north coast of Labrador, Newfoundland.



Geological map of Hudson Bay region. Such maps help guide exploration for oil, gas and minerals in northern Canada.



An ancient unconformity between granitic basement and sediments of Archean age is exposed on Point Lake, District of Mackenzie. A preliminary determination of the age of the basement granite is 3.0 billion years. Cobbles of volcanic and granitic rock that have fallen into fractures in the granitic basement surface were deposited over 2.6 billion years ago. (Scale extended 17 in. or 43 cm — GSC 163013)

Within the Bear-Slave Province, P.F. Hoffman and J.C. McGlynn continued the work in two adjacent map-areas (Sloan River and Calder River) with emphasis on regional volcanic stratigraphy and its relationship to mineral deposits, R.A. Frith studied gneiss domes within Indin Lake map-area, W.R.A. Baragar investigated volcanic belts at Yellowknife, Wolverine Lake and James River, and J.B. Henderson made sedimentological studies of the Yellowknife Supergroup in the upper Back River area and in High Lake, Point Lake, Beechy Lake and Hearne Lake map-areas. F.H.A. Campbell commenced a stratigraphic and sedimentological study of the Goulburn Group of early Proterozoic (Aphebian) age in the Kilohigok Basin, Bathurst Inlet.

Within the Foxe Fold Belt, W.C. Morgan commenced a four-year project to study the Piling Group and its relationship to basement in central Baffin Island and T. Frisch and M. Schau completed studies of gneissic and volcanogenic rocks of the Prince Albert Group, Melville Peninsula. Elsewhere, F.W. Chandler studied the Daly Lake Group of the Wollaston Lake Fold Belt in northeastern Saskatchewan. This group comprises migmatized sandstone and limestone and is of economic significance because it is host to base metal and uranium deposits. I. Ermanovics (with G. Park, Keele University, England) began study of the Island Lake map-area on the Manitoba-Ontario boundary. Three greenstone belts were mapped in detail and studies were carried out on their contained sulphide concentrations. R.H. Ridler began a regional metallogenic and volcanic stratigraphic investigation of the Superior Province in the area west of Kirkland Lake and extended known stratigraphy of the Kirkland Lake area westward 35 miles to Matachewan, Ontario. D. Bridgwater, an exchange geologist with the Geological Survey of Greenland, studied the early Precambrian rocks in the Saglek area, coast of Labrador, Newfoundland.

The Precambrian Subdivision has been divided into four sections, three of which deal with the regional geology of the Canadian Shield, and a fourth section that carries out investigations largely to apply paleomagnetic techniques to the solution of Precambrian geological problems. The Bear-Slave Section under J.C. McGlynn will investigate the geology of the Bear and Slave Provinces, the Northern Churchill Section under K.E. Eade will deal with the geology of the Churchill Province, excluding those parts that lie in northern Saskatchewan and Manitoba, and the Superior-Grenville Section under R.H. Ridler will study the geology of the Superior and Grenville Provinces and parts of the Churchill Province that lie in northern Manitoba and Saskatchewan. The Paleomagnetic Section will be the responsibility of E.J. Schwarz. The three Precambrian sections were organized late in 1974; separate reports on their activities have not been prepared for the present publication.

Under the title "Nice Canada" the Subdivision held a series of eleven seminars between December 20, 1974 and March 14, 1975. These well attended Friday afternoon sessions, co-ordinated by M. Schau, discussed and debated the composition, morphology, methodology of mapping and distribution of gneissic rocks of Canada.

Paleomagnetism Section

The program of the Section is aimed at obtaining information of geological significance by using magnetic properties of rocks and single minerals. Most of the work is

done in co-operation with other staff members of the Geological Survey of Canada.

Progress was made in the following programs:

1. More precise determination of the polar wandering curve based on new results from the Grenville Province in Quebec (Mealy Mountains, Lac St. Jean, Sept-Îles anorthosites and associated rocks). Study of the Circum-Ungava geosyncline initiated last year with sampling of the Smith Island basalts was expanded into the Richmond Gulf area. Good results were also obtained for the Kaminak (Northwest Territories) and Hopedale (Labrador, Newfoundland) dykes. The study of early Archean rocks from Greenland is continuing.
2. Magnetic stratigraphy of Paleozoic and Precambrian sedimentary rocks in the St. Lawrence valley and the Abitibi greenstone belt is being investigated. Work on the Trenton limestone (Ordovician) has been partially successful as well as work on relatively weakly metamorphosed Archean volcanics.
3. Study of the intrinsic magnetic properties of pyrrhotite has been completed. The results may be used for the identification of pyrrhotite phases in natural pyrrhotite associated with orebodies. A preliminary theoretical study of the effect of cation vacancy ordering has also been completed. A pilot study on ore deposits in well-defined mining areas suggests good possibilities for applied work in providing means of selecting magnetic anomalies in prospecting for sulphide base-metal deposits.
4. The tectonic evolution of the Cordillera Region is being evaluated by paleomagnetic techniques. Studies on the Mt. Barr, Hope, East Sooke and Copper Mountain intrusions have been completed.
5. Upper Proterozoic sedimentary and basic intrusive rocks on both sides of the Boothia Arch, Northwest Territories, have been sampled. Paleomagnetic measurements on this material are nearly complete. The Mistastin mangerite pluton east of Schefferville, Quebec was sampled for paleomagnetic study.

CORDILLERAN AND PACIFIC MARGIN SUBDIVISION

The Cordilleran and Pacific Margin Subdivision is based in the Sun Tower Building, Vancouver, British Columbia. It includes a Geological Research Unit comprising 16 officers and 7 support personnel and an Information Services Unit comprising 4 staff members. During the year the Information Services Unit was completely reorganized with the intent of increasing self service facilities for customers and more closely integrating library and sales functions.

GEOLOGICAL RESEARCH UNIT

This Unit conducts geological research in the Cordilleran Orogen. It prepares maps, reports and scientific papers that describe the general composition, structure, origin and geological development of the Cordillera Region and relates these to mineral deposits to help in assessing the mineral potential, to guide mineral exploration and to provide aid for planning of the orderly development of land utilization in the region. The Marine Geology Group is conducting a long range program of geological and geophysical studies of the Pacific Continental Shelf and Slope to provide information on hydrocarbon and other resource potential. Ultimately, the objectives of the subdivision are concerned with providing a comprehensive geological data base which will lead to a better understanding of the geology of the Cordillera Orogen and of the geological processes involved in its tectonic evolution. The investigations are supplemented by, or supplement, related co-operative activities by other subdivisions and divisions of the Geological Survey of Canada and the Geological Branch of the British Columbia Department of Mines and Petroleum Resources. In addition, the subdivision supports research carried on by graduate students from various universities. Current activities of the subdivision are directed toward two interrelated objectives: the completion of the reconnaissance phase of regional investigations to provide a broad geological and tectonic framework for the Cordillera Region, and detailed studies of specific problems to further the understanding of the nature and sequence of geological processes, with particular reference to the formation and localization of mineral deposits. Reconnaissance studies were carried out in southwestern Yukon Territory, north-central British Columbia, southern Coast Mountains and southern Vancouver Island. Detailed investigations were concerned with the relationships of mineral deposits to stratigraphy and structure in southeastern Yukon Territory, Tertiary volcanic rocks, Upper Paleozoic and Mesozoic sedimentary and volcanic rocks in southwestern Yukon Territory, Mesozoic strata in north-central British Columbia, low to high grade metamorphic rocks bordering and lying within the Shuswap Metamorphic Complex, and studies of hot springs and recent volcanic rocks to determine geothermal energy potential. The Marine Geology Group carried out a restricted program of geophysical surveys off the west coast of Vancouver Island.

Three projects of the subdivision are directly concerned with energy resources of the Cordillera Region. Studies of the Pacific Continental Shelf and Slope and of successor basins are designed to provide information for assessment of hydrocarbon and uranium energy potential. The geothermal program, in conjunction with a project carried out by the Earth Physics Branch provides data relating to possible geothermal energy sources. Projects in north-central British Columbia and particularly in southeastern Yukon Territory are in areas of intense mineral exploration. In these areas, stratigraphic data gathered by the Geological Survey of Canada is critical for exploration for strata-bound mineral deposits.

Operation Saint Elias, Yukon Territory. View southeast up the valley of St. Clare Creek showing folded Wrangell strata in the intensely deformed central part of the St. Clare Province. Nearly flat-lying lavas and interlayered clastic rocks on the high peaks at left form the upper limb of an overturned anticline.

RESOURCE GEOPHYSICS AND GEOCHEMISTRY DIVISION

A.G. DARNLEY, Director

The responsibilities of the Division are to act as a national centre for research and development into geophysical and geochemical methods for application to mineral resource evaluation and exploration, terrain investigations, and the better definition of bedrock geology; also, to advise upon and provide systematic geophysical and geochemical surveys as required for various purposes.

The objectives of the Division are to obtain in progressive steps systematic geophysical and geochemical data for all areas of the country, to serve as a quantitative base for mineral resource discovery and evaluation at both the regional and local level; to establish the most appropriate methods and standards for these quantitative surveys; to use suitable geophysical methods in support of terrain studies; to use the best available methods of interpreting, presenting and integrating geophysical and geochemical data in conjunction with geological information.

The activities of the Division have been traditionally organized around scientific specializations. This has led to strength in method development, and in the execution of particular methods, but less satisfactory performance in providing solutions to problems which are broader than individual

methods can satisfy. Steps have been taken toward remedying this situation with the Division by identifying three main program areas and assigning co-ordinator roles to individuals.

The longest established group of activities in the Division fall within the Magnetic Survey Program, for which Dr. P.J. Hood is co-ordinator. This Program combines the output of the Magnetic Methods, Contract Surveys, Digital Compilation and part of the Experimental Airborne Surveys Sections.

Mr. L.S. Collett is co-ordinator of the Engineering and Environmental Geophysics Program, which is currently the chief concern of the Electrical Methods and Seismic Methods Sections.

The Uranium Reconnaissance Program, co-ordinated by the Division Chief, absorbs the bulk of the effort of the Geochemistry, Radiation Methods and part of the Experimental Airborne Operations Section. This program is the newest, but is already the most extensively funded, and sets new standards of technical and administrative complexity.

Goals have been met in every major aspect of the work. The distance flown in aeromagnetic surveys was higher in 1974/75 than in 1973/74, both in Canada and for CIDA Projects overseas. A gradiometer for measuring small differences in the vertical gradient of the Earth's magnetic field has been constructed and installed on one of GSC's two experimental survey aircraft. Initial flights of this unique system have been extremely encouraging. Good progress has been made in the development and testing of methods for detecting and mapping the distribution of permafrost, both on land and below the sea-bed. A significant new development has been made, in co-operation with the Communications Research Centre, with the construction of a practicable radar device for soil moisture measurement. High sensitivity airborne gamma-ray spectrometer test surveys were undertaken in 5 provinces (Saskatchewan, Ontario, Quebec, Prince Edward Island and Newfoundland) and compiled during the year. Extensive arrangements were made for the start of the Uranium Reconnaissance Program in 1975. A major (20,000 sq. mile) lake sediment geochemical survey was undertaken in Saskatchewan at the request of the provincial government and DREE, and this contracted operation is the precursor of larger operations under URP. A useful start has been made in the co-operative development project with industry relating to borehole exploration methods.

Further advances have been made in the use of minicomputers for process control, and for on-line analysis. The automated atomic absorption unit, reported last year as complete and operational, is now linked via cassette tape recorder and a telephone coupler with the main EMR computer, allowing immediate manipulation of the data by any program available there. The Division's high sensitivity airborne gamma-ray spectrometer, besides having had extensive circuit renovations, is now equipped to provide full spectral recording.

During the year members of the Division submitted 74 manuscripts for publication, internal and external.

The ensuing pages deal in turn with the three principal missions with which the Division is concerned, and section reports are appended to the most relevant missions. Special projects not included elsewhere are dealt with at the end.

Magnetic Survey Program

This program entails developing new magnetic survey instrumentation and techniques, conducting experimental aeromagnetic surveys over land and sea, devising new techniques for the digital treatment, presentation and interpretation of resultant data, preparing specifications for surveys carried out under contract, monitoring their execution, and supervising the publication of results. Geological interpretations of the results are provided to the fullest extent possible.

Aeromagnetic survey techniques have been under active development in the Geological Survey of Canada since the first airborne magnetometer was introduced shortly after World War II by modification of submarine detection equipment. This development work and its subsequent utilization in aeromagnetic surveys by Survey staff eventually led to an aeromagnetic survey program for the whole of the Canadian Precambrian Shield, which was contracted out to the airborne geophysical survey industry. Up to the end of 1974 approximately 4.5 million line miles has been flown (164,000 line miles in 1974/75 alone) and the program has been completed for Nova Scotia, Prince Edward Island, New Brunswick, Ontario, Manitoba, Saskatchewan and Alberta in co-operation with the relevant provincial agencies. In addition, aeromagnetic survey coverage has been obtained for the island of Newfoundland. Thus the aeromagnetic survey program has resulted in some 6900 one-mile and 400 four-mile aeromagnetic maps being issued and these form a substantial bank of data for mineral resource endeavours in Canada.

As part of the development work of the program, the year saw the completion of an inboard vertical gradiometer system on the GSC Queenair experimental survey aircraft. The digital recording twin-boom system is designed to delineate the vertical contacts between large near-surface rock formations having a relatively low magnetization contrast; the somewhat troublesome time-variable diurnal variations of the Earth's magnetic field are also eliminated in the difference readings between the two sensors. The results obtained to date demonstrate conclusively the superior resolution of the gradiometer compared to the total field results, and it is clear that a first vertical derivative map reflects the underlying geology much better than does the classical total field map.

The data processing system for the compilation of high resolution aeromagnetic survey data was further improved to permit the production of two-dimensional filtered aeromagnetic maps. These derived maps enhance the higher frequency components of the data and better delineate near-surface rock

formations whose magnetic expression is often masked by the presence of large amplitude, longer wavelength anomalies produced by more strongly magnetized deep-seated crustal features.

Digital Compilation Section

The Digital Compilation Section is responsible for compiling digitally recorded aeromagnetic total field and gradiometric data and providing Systems Analysis and Programming Services to other sections with regard to bulk digital geophysical-geochemical data compilation. It also carried out analysis and programming work in fields less directly related to aerogeophysics.

This year saw the continued application and improvement of the ADAM (Aeromagnetic Data Automatic Mapping) System. Work began to extend the system to allow compilation of aeromagnetic gradiometer data.

The Geochemical Data Compilation System commenced the previous year was completely redesigned to allow usage via interactive remote terminals and should be completed this year.

Programs were written for the compilation of radiometric flight path data produced by automatic digitization and recommendations made for the further improvement of the Radiometric Compilation Programs.

M.T. Holroyd designed and wrote the digital acquisition and processing section of the specifications for the coming GOIAS project in Brazil.

To simplify the work necessary for the coming Branch accommodations redistribution, the IBAM (Interactive Building Accommodation Management) System was designed, written and implemented. It provides automatic "Housekeeping" of names, addresses and numbers of people per room, etc. while allowing On-Paper redistribution of personnel by interactive terminal commands. As it incorporates a feature to select, re-order and print out sub-sets of the data at any time, and add, delete or change entries, it is an ideal basis for a digital telephone directory.

Contract Surveys Section

This Section is responsible for the acquisition and publication of conventional aeromagnetic data over the Canadian Shield, Arctic Islands and Cordillera. Included in this responsibility is planning, specification-writing and monitoring of regional aeromagnetic survey contracts which are executed by geophysical survey companies either for EMR alone, or for EMR jointly with the provincial Departments of Mines. Similar surveys, including total count radiometric data, funded by the Canadian International Development Agency, are carried out in developing countries. Storage and retrieval of archival survey records, geophysical map manuscripts and reproduction material is an additional service provided to potential users. Also, the section participates in the compilation, monitoring and publication of high sensitivity aeromagnetic data.

337 aeromagnetic maps were published during the year.

Engineering and Environmental Geophysics Program

The Electrical and Seismic Sections are responsible for programs directed toward research in both land and marine geophysical methods for engineering and geological mapping problems. The methods used are DC resistivity, VLF Radiohm, electromagnetic induction, radar, conventional and shallow seismic techniques. The aim of the program is to investigate the use of these techniques for determining the lateral distribution and thickness of permafrost on land and offshore and gain a knowledge of the physical properties of frozen materials. These Sections take a leading role in assessing and developing new techniques and publish progress reports on their research.

The main thrust of the program has continued during 1974/75 in the permafrost environment. DC resistivity, VLF Radiohm and shallow seismic surveys were conducted over the Heart Lake (near Norman Wells) and Involuted Hill test sites in the Mackenzie Valley. Further radar experiments were conducted in spring of 1974 in the Tuktoyaktuk area. A number of companies and universities have used these test sites for experimentation and it is expected that more will do so as the sites become better known. Resistivity and seismic surveys in co-operation with Terrain Sciences Division have been conducted on Banks, Melville and Ellesmere Islands and Boothia Peninsula. DC resistivity surveys were also done at Malcolm River to establish the thickness of gravel deposits in the area.

On the offshore work in the Arctic, a map is being compiled for the southern part of the Beaufort Sea of the top of the sub-seabottom permafrost layer. Approximately 8,000 line miles of company seismic records are being utilized in this compilation. A marine seismic survey at Kay Pt., Yukon Territories, was completed to map the top of the permafrost in the Babbage River Delta as part of the study of Arctic coastal processes. DC resistivity and seismic surveys were conducted over the ice in Kugmallit Bay and the interpretations were confirmed by drilling. Similar soundings were initiated through the ice at Consett Head, Melville Island, over the interisland pipeline route. Seismic and resistivity specifications were prepared for a contract survey along the Mackenzie Highway route at Martin River and Willowlake River crossings north of Fort Simpson.

Borehole Logging Program

A co-operative program with four companies (Cominco, Noranda, Inco and Canex Placer) was undertaken by the Geological Survey of Canada to determine the state-of-the-art

in borehole surveying for mining purposes and to make a comparison of induced polarization, electromagnetic and magnetic methods. The program consists of three phases, the first of which is a survey of the literature of all geophysical methods (already submitted as a GSC publication). The second phase consists of a field program that was commenced in 1974 and will continue in 1975. The third phase will hopefully result in improvement of borehole survey methods for mining purposes.

Electrical Methods

This Section investigates and develops passive and active electrical techniques and instrumentation and adapts them to the needs of the Canadian government. Airborne electromagnetic systems are assessed for mapping thickness and conductivity of overburden. The Scintrex Tridem System is a 3-frequency EM system and is presently being evaluated. Flying has been completed over test sites at Hawkesbury and Timmins, Ontario. Theoretical feasibility studies involve dipole-dipole soundings in permafrost, induction methods for sea-ice thickness and plane wave behaviour of VLF (very low frequency) and higher frequencies with altitude. Soil moisture measurements of ground are being measured using time domain reflectometer (TDR) techniques at radar frequencies. These measurements are being correlated with absorption phenomena of gamma rays. An electrical rock property laboratory is continuing the study of electrical parameters of rocks and their modification due to the inclusion of conducting minerals, such as sulphides, and the variation of temperature as in the case of frozen ground and ice inclusions. Knowledge of these electrical parameters is necessary for theoretical studies and data interpretation.

Seismic Methods

This Section is responsible for seismic programs directed toward research and uses conventional refraction and reflection methods applied to geological problems throughout Canada.

In the Sverdrup Basin refraction work, a north-south line was run on the ice during 1974 from the edge of the permanent polar pack south between Ellef Ringnes and Amund Ringnes Islands to the southeast. This is a continuation of the east-west refraction line that was started in 1972 as a co-operative industry-government project in which six companies participated.

For urban geological purposes, a shallow seismic survey was conducted in the Hamilton Metropolitan area for a depth-to-bedrock map. Shallow reflection seismic surveys were conducted over a salt dome occurrence in Magdalen Islands in co-operation with SOQUEM. Good reflections were observed in some locations but were not recorded in others.

A good start has been made on determining the physical properties and hence the identification of bottom sediments along the Arctic coast. Not only does this seismic technique look promising but it can be done through the ice. Theoretical model studies for reflections from the lower permafrost boundary were continued in co-operation with the University of Western Ontario. The amplitudes of various frequency wavelets was completed for velocity gradient boundaries typical of the Mackenzie Delta.

Uranium Reconnaissance Program

The objective of this program is to provide high-quality systematic reconnaissance data relating to the distribution of uranium in Canada, to serve as a guide and incentive in exploration for new deposits, and to provide a basis for national uranium resource appraisal. GSC will undertake preliminary reconnaissance and feasibility studies as required, but the principal operations will be contracted, and entail airborne radioactivity and ground geochemical surveys. GSC will maintain ongoing R & D activities relating to methods of uranium exploration, in parallel with this program.

The main activities during 1974/75 have involved extended discussions with technical representatives of all the provinces as a preliminary to making detailed plans. The program will be cost-shared with the provinces. Specifications have been drawn up and negotiations commenced for the initial phase of contract work in 1975. As part of the need to provide public information on uranium exploration, a successful morning session consisting of 5 papers was held at the Prospectors and Developers Association Meeting in Toronto in March.

Geochemistry Section

This Section is responsible for research on geochemical processes; for obtaining data to assist in mineral resource appraisal and exploration; and for providing geochemical support to various government programs, including external aid, regional development, and environmental studies.

During this year the major part of the Section's effort was diverted from its previously mainly research role, to the establishment of procedures for large-scale contracted surveys. A National Geochemical Reconnaissance has been instituted in support of the Uranium Reconnaissance Program and federal-provincial mineral development agreements. Over the longer term, this program will provide a consistent group of methodologies for all federal and federal-provincial geochemical surveys; for storing and presenting the data; and for disseminating the information in suitable form for such requirements as resource evaluations, mineral exploration, environmental studies, agriculture etc.

The change to contracted surveys was more difficult and time consuming than anticipated. In particular, establishing control procedures has required a great deal of effort. The first survey carried out under contract involved lake sediments collected over a 20,000 square mile area of Saskatchewan.

This was part of the federal-Saskatchewan mineral development agreement. E.H.W. Hornbrook, R.G. Garrett and J.J. Lynch were mainly responsible for this work, but many others contributed. For such surveys it was determined that the most appropriate division of effort was for the sampling, sample preparation and analytical components to be carried out under contract, with orientation surveys, contract specification, analytical control, data merging, presentation and interpretation by the GSC. This results in a ratio of approximately two thirds of the expenditures by contractors, to one third by GSC.

The other major effort of the Section was to host a multidisciplinary study of methods of resource appraisal in an area of the northern Shield. Our recent work on lake sediment reconnaissance has shown those methods to be promising for rapidly assessing the mineral resource potential of large areas of the Canadian Shield. However, the best results will come when these data are integrated with geological and geophysical information. This field investigation of lake sediment anomalies included geological work, sulphide mineral studies, VLF-resistivity, gravity, magnetometry, aerial colour photography, as well as rock, soil and water geochemical investigations. Co-operating with E.M. Cameron, C.C. Durham, W. Dyck, I.R. Jonasson and an analytical group from this section were: W.J. Scott, L.J. Kornik and V.R. Slaney (all R.G.G.); J.B. Boyd, R.A. Gibb and M.D. Thomas (Earth Physics Branch); J.D. Williams (D.O.E.) and T. Pearce and D. Lefebvre (Queen's University).

Other important work included studies of sulphide minerals (I.R. Jonasson); the use of helium and other gases in mineral exploration (W. Dyck); and development of a computer-controlled atomic absorption spectrometer (Q. Bristow). R.G. Garrett contributed to the Branch's development of autocartographic methods.

Radiation Methods Section

This Section is responsible for the development, testing and evaluation of nuclear geophysical methods, and remote sensing methods for geological mapping and exploration. Activities of the Section include investigation of airborne, ground and borehole methods.

The major activity in 1974/75 was in collection of airborne gamma-ray spectrometry data. Surveys were carried out in Saskatchewan under the Canada-Saskatchewan Agreement on Mineral Exploration and Development in Northern Saskatchewan, in Ontario to investigate uranium distribution in possible source rocks for the Elliot Lake deposits and to examine a Paleozoic uranium occurrence west of Ottawa, in Quebec to obtain data on the Johan Beetz type of uranium occurrence, and in Prince Edward Island and Newfoundland to test the feasibility of using airborne spectrometry for the Uranium Reconnaissance Program in these Atlantic Provinces.

Some ground work was done in the Elliot Lake area to verify that the airborne radioelement distribution pattern reflected the bedrock composition rather than the percentage of outcrop. Ground radiometric investigations were made in conjunction with geochemical work on the Palaeozoic uranium mineralization west of Ottawa.

Upgrading of the GSC high sensitivity airborne gamma-ray spectrometer began in 1974 which will result in some electronics improvements in the system to be flown in 1975, and computer-based multi-channel spectrometer to be test flown in 1976. Theoretical studies on optimizing detector sizes, increasing the accuracy of airborne measurements by improving the determination of correction coefficients, and developing filtering techniques were carried out.

The gamma-ray spectrometry laboratory provided over 500 sample analyses for thorium, uranium and potassium, the spectrometer calibration was improved, and equipment was installed to enable research into the possibility of measuring disequilibrium in the uranium decay series.

Investigation of nuclear techniques in borehole logging began in 1974 with a literature review of the current state-of-the-art prepared for publication.

In the field of remote sensing, 2,200 line miles of colour aerial photography were acquired in the Beechey Lake area, N.W.T. as part of an integrated geophysical and geochemical investigation of a multi-element geochemical anomaly located in 1973. The colour photography showed gossan distribution, gave structural information that directed further work in the area, and was used to produce a detailed topographic map of the area.

An evaluation of side look radar imagery for the Hearne Lake map-sheet N.W.T. showed this to be a relatively rapid and inexpensive method for producing a mosaic, but with some limitations on the quality of the mosaic, compared to conventional air photo mosaics.

Finally, the GSC library of satellite imagery, maintained by the section, continued to expand, and includes over 200 colour LANDSAT images, and all of the SKYLAB photographs of Canada.

Experimental Airborne Operations

This Section is responsible for (a) the design, construction and testing of airborne geophysical survey equipment and the evaluation of electronic navigation systems used to position survey lines, (b) experimental airborne geophysical survey operations in any part of Canada in which the two GSC aircraft (Beechcraft B80 Queenair and Short Bros. Skyvan) are used.

A vertical gradiometer aeromagnetic system has been completed for the Queenair aircraft and much effort has been expended in the compensation of the dual-sensor inboard system. The combined figure of merit has been reduced to an

acceptable level and experimental surveys have commenced. Three ground stations to monitor the diurnal variation of the Earth's magnetic field have also been completed and these will be used in the flying of the control line network for the Magnetic Anomaly Map of Canada. Work is also proceeding in the evaluation of video camera systems for track recovery and in the use of VLF navigation systems for the digital recording of latitude and longitude information directly in survey operations together with the other pertinent data. If successful, the system will make redundant the conventional technique of track recovery using 35 mm cameras with the attendant processing of the resultant negative film, which is a troublesome procedure in field operations.

Analytical and Nuclear Instrumentation

The automated analysis of geochemical samples by a computer controlled atomic absorption spectrophotometer has been refined to the point that it is now possible to transmit the data, recorded on cassette tape, via a telephone coupler directly to the EMR computer at 588 Booth Street for processing. A program written by M.T. Holroyd of the Digital Methods Section, combines these "wet chemistry" analyses with other data from the same samples for use in the final contoured maps showing element distribution. This represents an illustration of the philosophy that minicomputers should be used for process control and data acquisition only, while sophisticated processing of that data should wherever possible be left to a larger and more powerful machine geared for the purpose.

The development of a trace gas analyzer, which was started at the University of Toronto Institute for Aerospace Studies in 1970 under very modest funding, has now been placed on a firm footing by DSS bridge financing. Under the new arrangements, Sciex Ltd., a firm started by members of the Aerospace Institute staff, have a contract to build two units, one of which will be delivered to the GSC by about March 1976. A second part of the arrangement provides the Aerospace Institute itself with substantial funds for the necessary research to develop algorithms for the unambiguous identification of various classes of trace gases. It is intended to conduct experimental airborne surveys using the device in order to see if gases can be detected which emanate from buried ore deposits. If this proves to be the case, then the trace gas analyzer could be a revolutionary new tool in resource exploration.

The first phase of a two phase project to update the high sensitivity airborne gamma-ray spectrometry system is now complete. This involved replacing the all important signal conditioning electronics with units designed in terms of the newer and more sophisticated linear integrated circuits which are now available. The result has been a dramatic improvement in the ability of the system to resolve the peaks which occur in the natural radioactivity spectrum, and this in turn should result in a corresponding improvement in field performance.

During the course of this work a program was written to allow a minicomputer to be used as a gamma-ray spectrometer, with the capability for recording and displaying complete spectra and for performing in seconds some of the tedious calculations which are necessary in checking the performance of scintillation detectors. This has proved invaluable in checking the new signal conditioning electronics for the airborne system. It has already enabled us to respond quickly to a request by one of the airborne survey companies for a detailed test of a new scintillation detector which they had acquired, and it will be used to monitor the performance of commercial airborne gamma-ray spectrometry systems to be used in contract surveys under the Uranium Reconnaissance Program.

TERRAIN SCIENCES DIVISION

J.S. SCOTT, Director

Responsibilities of the Division are focused upon all aspects of surficial geology and geomorphic processes of the Canadian landmass including the coastal and adjacent offshore regions exclusive of the coastal and offshore regional responsibilities of the Atlantic Geoscience Centre. These responsibilities are met by scientific, technical, and support staff based in Ottawa and small operational units located at Canada Centre for Inland Waters, Burlington, Ontario, Institute of Sedimentary and Petroleum Geology, Calgary, and the Vancouver offices of the Geological Survey.

The objectives of the Division are: to provide a systematic coverage of surficial geology of the Canadian landmass consistent with the information requirements for effective use of the terrain and for the interpretation of Quaternary and Holocene geological events; to identify and assess the occurrence and magnitude of natural terrain hazards; to provide geoscience information to assist in the maintenance and restoration of the physical environment; and to provide standards, controls, and reference materials to ensure consistency of correlation between geological events of the Pleistocene and Holocene Epochs and to develop and maintain standards of mapping of surficial geology appropriate to national needs.

Although major features of the glacial geology of Canada have been portrayed at a scale of 1:5,000,000 (Geological Survey of Canada, Map 1253A, 1968) systematic surficial geology maps exist for only a small part of Canada. At present approximately only 15 per cent of the surficial geology of Canada has been mapped at a scale of 1:250,000 and less than 5 per cent of the country at a scale of 1:50,000. Thus systematic surficial geology mapping at scales of 1:250,000 in northern regions and 1:50,000 in the southern populous regions of Canada constitutes a major activity of the Division.

In view of the extensive unmapped area of the country, priority of work within a program year is assigned on the basis

of response to government imperatives such as Environmental-Social Program, Northern Pipelines, provincial requirements in relation to economic development, and on the significance of a specific area to the understanding of the regional surficial geology.

Surficial geology mapping at a field scale of 1:125,000, supported by Environmental-Social Program, Northern Pipelines, was completed for the Mackenzie Valley Transportation Corridor and the major emphasis in northern mapping was redirected to the Arctic Islands in anticipation of terrain information requirements for potential gas pipeline routes from the Arctic Islands to southern Canada. A pilot project of landscape mapping involving geomorphologists, geologists, botanists, and wildlife zoologists was completed for eastern Melville Island and terrain mapping was completed for the Boothia Peninsula between 68° and 72°N. Field work in Boothia Peninsula also was utilized in the evaluation of ERTS-1 satellite data for small scale mapping in the Canadian North. Terrain mapping of Banks Island, in response to information required for administration of the Territorial Land Use Regulations, was begun as part of a three-year project required to cover the entire island.

Terrain mapping activities were continued in the eastern District of Keewatin, an area in which the Division is also evaluating the potential use of glacial drift as a prospecting medium. Mapping in eastern Keewatin will be extended north to Boothia Peninsula and south to adjoin the recently completed mapping in the Churchill-Nelson drainage basins. In this developing region of Canada, terrain information thus is directly applicable to both mineral exploration and engineering evaluation of potential gas pipeline routes.

In southern Canada terrain mapping of Cape Breton Island was completed and continued work in Newfoundland has brought the level of surficial geological map coverage to approximately 80 per cent of completion.

Surficial geology mapping at a scale of 1:50,000 was continued in the lower Fraser River valley and in support of urban geology studies in Hamilton, Ottawa-Hull, and Montreal.

Systematic mapping of surficial geology in offshore regions and the study of coastal processes constitute significant activities of the Division. These studies are in progress in Straits of Georgia and Juan de Fuca and in the Beaufort Sea as part of the industry-sponsored Beaufort Sea Project. Although very heavy ice conditions in the Beaufort Sea during the summer of 1974 limited the extent of shipborne surveys, side-scan sonar data obtained by the Division in Mackenzie Bay and Beaufort Sea contributed to the understanding of the origin of bottom scour in these critical areas of petroleum exploration.

Studies of coastal processes in Barrow Strait and elsewhere in the Arctic Islands region were undertaken to provide information pertinent to proposed pipeline crossings of interisland channels. The use of SCUBA diving techniques beneath the arctic ice was a novel approach employed in some of these studies to complement, by direct observation, information normally acquired by remote sensing or by widely spaced bottom sampling.

Environmental impact assessment of major engineering projects is an increasing activity of the Division as a direct outgrowth of Divisional expertise in terrain mapping and studies of geomorphic processes. Assessment of design packages covering segments of the Mackenzie Highway, evaluation of geotechnical data obtained along the route of the highway, and assessment of granular material resources for construction of the highway were major activities.

Previous work by the Division in mapping the distribution of Champlain Sea clays in the Ottawa-St. Lawrence Lowlands has been utilized as the basis for a study of the occurrence and mechanism of landslides within these sensitive clays. An investigation into the behaviour of the clays under dynamic loading and the influence of regional hydrogeology on slope stability are salient aspects of the study.

Correlation of geological events and evaluation of environmental changes within the Quaternary and Holocene Epochs are dependent upon measurement of time and upon an understanding of the character and distribution of past and present biological assemblages. Accordingly, the Division operates a quality-controlled radiocarbon laboratory and complements its stratigraphic studies through the work of specialists in palynology, paleontology, paleoentomology, and paleobryology.

Special Projects

Senior scientific staff of the Division assigned to this unit are involved in regional compilations of surficial geology, studies of unique Quaternary geological features, and the provision of scientific and technical advice to the Division and other government agencies. Work is continuing on compilations of Quaternary geology of the Prairie region and Lower Fraser River valley. New studies have begun on the occurrence and origin of glacially displaced massive blocks of bedrock in the Prairies and on the distribution and origin of Cochrane till in northern Ontario and Quebec. Staff of the unit provided scientific and technical advice to the Mackenzie Valley Pipeline Application Assessment Group and to the Department of Indian and Northern Affairs on matters pertaining to the application of the Territorial Land Use Regulations.

Geotechnical Subdivision

The program of the Geotechnical Subdivision is directed primarily toward analysis of those dynamic and geotechnical attributes of surface and near-surface materials that influence

land use decisions. Information is provided on stream, lake, and mass wasting processes as they affect terrain stability, and on engineering and thermal properties of materials as they bear on the performance of the terrain under a variety of natural and man-induced conditions.

The accelerated program of work in the Mackenzie Valley Transportation Corridor was completed and similar work was commenced in the Arctic Islands Archipelago. Application of the urban geoscience data bank to the problems of selected cities across Canada was continued. Preparation of a prototype urban geoscience atlas of the National Capital Region is nearing completion and is being complemented by a comprehensive study of terrain stability problems associated with marine clays in the region.

The program of using surface sediments as an aid to mineral prospecting is being expanded and has led to a number of reports that improve our ability to apply this technique to the search for new mineral resources.

Sedimentology and Mineral Tracing

This Section undertakes research to define and elucidate geomorphological processes (particularly in areas of permafrost), physical and chemical aspects of fresh water (fluvial and lacustrine) sedimentation, physical and chemical aspects of fresh and weathered glacial sediments (particularly till), and mineral prospecting techniques that use glacial drift as a prospecting medium. Laboratory functions that support these and other analytical requirements of the Division also are administered through this Section.

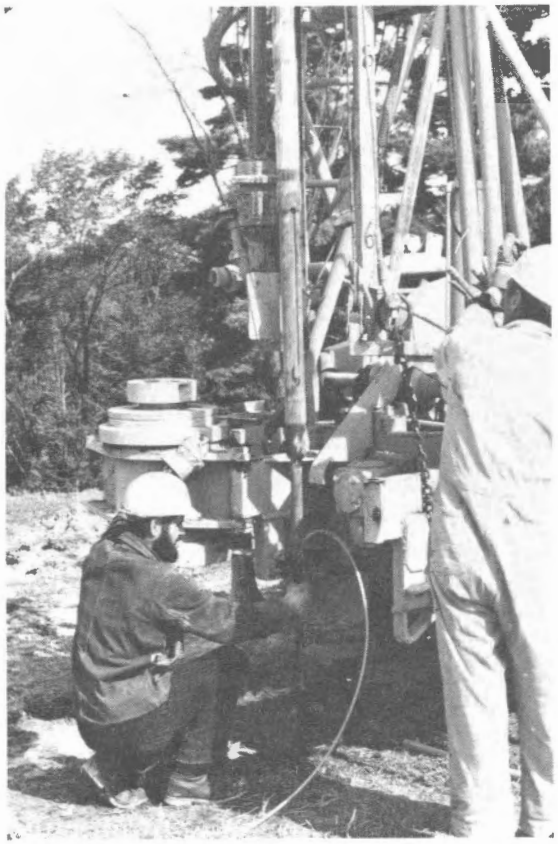
Limited field work on drift prospecting was carried out in southeastern Quebec where models were developed to describe local mechanisms of glacial dispersal of trace elements in eskers and till. Laboratory work continued to define the chemical and physical properties of glacial sediments collected in the District of Keewatin, particularly in regard to their potential value as a geochemical prospecting medium.

A reconnaissance survey of fluvial processes on Banks Island, N.W.T. was completed and forms the basis for a detailed study of fluvial dispersion and sedimentation to be carried out on that island in 1975-76.

Analyses and tests in support of sedimentological and engineering activities are undertaken at the Spencer Street Laboratory in Ottawa. Processing and analyses of samples for chemical and mineralogical studies, primarily within the mineral-tracing program, are carried out at another Ottawa laboratory at Booth Street.

Engineering and Environmental Geology

This Section undertakes studies of the physical and engineering properties of soil and rock materials in order to evaluate the geological processes that are hazardous to man and to the terrain, and to recommend the best environmental use of the terrain.



Installing a Geonor piezometer in the sensitive clay of the Champlain Sea deposits. GSC 202875-B

In northern Canada part of the activities of this Section are concerned with the highway and proposed pipeline of the Mackenzie Valley, and the gas pipeline from the Arctic Islands. A mile by mile assessment of the alignment and the engineering design of the highway is being made in order to ensure that minimum terrain disturbance will result from construction. A geotechnical data bank for the Mackenzie Valley is being compiled from the logs of more than 10,000 boreholes; this information will permit the relationships between various geological and geotechnical parameters to be studied. A listing of thermal readings from more than 300 thermistors in shallow boreholes situated in permafrost zones is being prepared for publication.

A preliminary reconnaissance was made in the Arctic Islands of the terrain response to such man-made disturbances as airfields and oil well sites. This study should provide background data and insight that will be useful in the environmental evaluation of the proposed Arctic Gas Pipeline.

In the east Kootenay area of British Columbia, a three-year project to examine the environmental impact of coal mining in mountainous terrain is in its final stages. The portion of the study concerned with coal waste dump stability has been completed, and final reports and maps on the geological and geotechnical aspects of land use problems await the completion of laboratory analysis.

Soil sampling, Central Banks Island, N.W.T., using helicopter portable drill. GSC 202655-K

Another major activity of the Section is the study of landslide hazards in the sensitive clays of eastern Canada. A compilation of the areal extent of all silts and clays of the Champlain Sea and an inventory of their associated landslides is being made in the Ottawa Valley. It is hoped that this compilation will provide a regional overview, which will be useful to planners and geotechnical consultants.

The Urban Geology Unit is completing preparations to make available to the public the subsurface data which has been gathered for 28 urban centres in Canada. This information, presently stored on magnetic tape, will be made available on microfiche. Computer drawn location maps are being produced to allow access to the microfiche file.

Both compilation and computer drawn maps have been prepared for inclusion in a report being prepared on the environmental geology of the Ottawa-Hull area. Maps in final manuscript form include bedrock geology, rock units defined by geotechnical properties, surficial geology, drift thickness, and bedrock contours. A similar set of maps is being prepared for the Hamilton area from available geotechnical information that has been compiled.

The Section recently has become involved in a new activity—the nuclear waste storage program of Atomic Energy of Canada Limited. This program will involve studying the feasibility of underground containment in hard rock of solid nuclear wastes.

Quaternary Subdivision

Regional Projects

The activities of this Section are largely directed toward providing a Canada-wide inventory of the unconsolidated deposits and landforms and establishing their stratigraphic and environmental history. Mapping projects are undertaken at various scales chosen on the basis of the present state of knowledge and potential use. This information is of value to forestry, agriculture, engineering, construction, and the mineral industry and is used in land use and environmental impact studies.

The Regional Projects Section continued its accelerated terrain mapping program in the Arctic Islands and adjacent mainland areas. This area was given priority in order to provide surficial geology and terrain sensitivity information to aid in the implementation of the Territorial Land Use Regulation and to provide data for assessment of the environmental impact on areas that might be affected by pipeline construction. As part of this program inventory mapping was started on Banks Island. This four-year project will provide surficial geology maps for the entire island and will include some characterization of vegetation cover in addition to descriptions of surficial materials and of their geotechnical properties. Field mapping of southern and central Ellesmere Island was completed. The results of this work will be released as they are compiled, and the first maps should be available May 1975. Inventory mapping of terrain conditions on Boothia Peninsula was conducted. Data resulting from this work should be available in June 1975 and will include information on soils and vegetation that has been supplied by Soils Research Institute, Agriculture Canada through the participation of C. Tarnocai. Late in the year the main results of integrated, terrain-vegetation-wildlife studies carried out in eastern Melville Island were released.

Testing and development of shallow drilling and sampling equipment continued as part of sampling programs for the northern field parties. This year it was possible to adapt a new, light, hydraulic drill to the permafrost coring program.

Terrain inventory and surficial geology studies were conducted in Kluane Park in conjunction with bedrock mapping of the Regional and Economic Geology Division. Parks Canada has requested the information for inclusion in their biophysical survey of the park, as an aid in preparation of interpretative information and to assist in park planning.

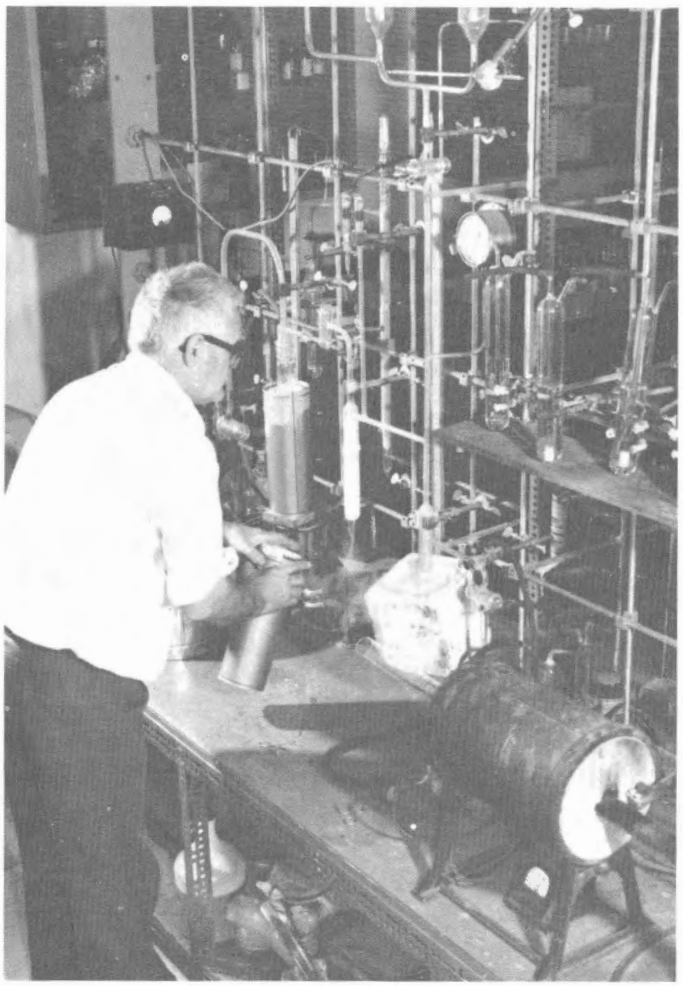
Field work continued in the Maritime provinces. This past summer, mapping of Cape Breton Island was completed and work on Newfoundland was brought to the point where it can be completed in two further field seasons.

Systematic mapping of the Ottawa Valley Lowland was continued; the Ontario part of the area that lies between Ottawa and the St. Lawrence River has now been completed.

Paleoecology and Geochronology

Work is mainly of a laboratory nature providing analyses of fossil materials (e.g., pollen, mosses, wood, insects, seeds, cones, and diatoms) and radiocarbon dates as a service to other units and individuals; a particular effort is made to identify all materials dated by the radiocarbon laboratory. The unit also determines variations in radiocarbon content of modern materials as background for other research, and investigates the chronology of fossil-bearing deposits. Research on changes in environment and in the distribution of plants, insects, and marine invertebrates during the Quaternary is being conducted. Field work during 1974 was carried out in the Arctic Islands, Yukon Territory, Alaska, Ontario, Quebec, and Greenland.

The Radiocarbon Dating Laboratory has at its disposal three proportional counters, any two of which may be used at the same time. In addition to the continuing program of monitoring atmospheric fluctuations of radiocarbon at Ottawa, another research project involves testing the validity of dates obtained on various fractions of bones, shells, and peat. Reference samples for cross-checking purposes continue to be prepared for distribution to new laboratories which are starting up. The program of interlaboratory cross-check age determinations also has been maintained, and samples previously dated by Brock University and by the Radiological Dating Laboratory, Trondheim, Norway were processed during the year. In order to make the best use of the production capacity of the laboratory, samples for age determination in the Radiocarbon Dating Laboratory are selected by an informal committee, in consultation with other members of the staff as appropriate to the samples under consideration. Most of the samples analyzed were selected to provide data for current research projects in the field of Quaternary chronology and related glacial events, to shed light on crustal movement, and to provide information on the rates of geological processes



RADIOCARBON DATING LABORATORY: Sample Preparation Line GSC 202598-R

such as sedimentation and solifluction. A few samples were dated in support of archeological research projects across the country.

Marine and Coastal

Activities of the Geological Survey concerning the seafloor and coasts of the Pacific region, Great Lakes region, and Arctic Island channels and liaison activities with other groups and agencies undertaking related work are the responsibility of this Section. Projects are designed to contribute inventory information about the seafloor and coast, their stratigraphic sequence, and environmental history and to develop regional understanding of geodynamic, geomorphic, sedimentary, and geochemical processes and the engineering attributes that control the stability and character of coastline, seafloor, and sediments. Such information will be utilized in offshore and coastal engineering planning for pipeline and cable routes, anchoring and wellhead completion problems, environmental

and ecological studies, dredging and waste disposal management, mineral resource estimates including aggregate sources, fishery management, and in defence considerations.

In the Pacific region the program of environmental marine geology, operated from the Vancouver office of the Geological Survey, was continued with studies of sedimentation in the Fraser River Delta and Quaternary geology of northern Strait of Georgia.

Studies of Great Lakes sediments were continued by palynological investigations of sediment sequences and buried marsh zones, stratigraphic coring, core description, and X-radiography. Much of this work was done at Burlington, Ontario, co-operatively with staff and facilities of Canada Centre for Inland Waters.

Staff of the Section participated in the industry-funded Beaufort Sea Environmental Studies Program which is operated under the project management of the Department of the Environment. Logistics support provided by *MV Pandora, MV Pressure Ridge,* and submersible *Pisces* was employed in studies of the distribution of offshore permafrost and the occurrence of bottom scour by sea ice in the Beaufort Sea. Studies also were made of the susceptibility of the Beaufort Sea coast to oil spills.

Studies in the eastern Arctic were co-ordinated with Atlantic Geoscience Centre operations aboard *CSS Hudson* to provide information on bottom sediments and bathymetry in northern Baffin Bay, Nares Strait, Parry Channel, Lancaster Sound, and Barrow Strait. Palynological analysis of bottom cores from Maxwell Bay, southwestern Devon Island suggests the presence of Tertiary-Cretaceous sediments previously unknown in this area.

Novel approaches to the study of arctic marine geology were employed in Cunningham Inlet, northern Somerset Island through the use of a 31-foot landing craft transported to the area aboard *CSS Hudson,* and by SCUBA diving to observe and sample bottom sediments off Melville Island. These studies provided information on coastal processes, permafrost, drift ice phenomena, and coastal stability of significance to potential gas pipeline construction.

CSS Hudson Barge collecting bottom sediment cores and grab samples, offshore of Cunningham Inlet, Somerset Island, N.W.T. GSC 202299-I

GSC Activities in International Development

Through the medium of a Memorandum of Understanding reached between the Department of Energy, Mines and Resources and the Canadian International Development Agency (CIDA), the GSC has continued to supply technical advice and services to CIDA during the past year.

Requests from CIDA have generally fallen into one of four categories. In the first category, individual officers have been asked to visit developing countries to evaluate proposals for earth science projects. Visits were made to Brazil (Dr. A.G. Darnley, Mr. B.E. Manistre, Dr. E.M. Cameron, Mr. L.S. Collett); Pakistan (Mr. B.E. Manistre); Algeria (Dr. L.P. Tremblay and Dr. A. Larochelle); Guyana (Dr. P.J. Hood); Ivory Coast, Mali (Dr. A. Larochelle).

All-Terrain Vehicle equipped with echo sounding and sub-bottom profiling gear. The vehicle is capable of driving from a beach or an ice flow into open water. GSC 202653-N

Field crew preparing to board the two vessels used in the collection of nearshore marine geological information at Cunningham Inlet, Somerset Island, N.W.T. GSC 202728-C

In the second category, officers have been seconded to CIDA for periods of one or more years. This included a continuing project in Ethiopia (Dr. T. Davidson) and a secondment to the CIDA engineering division (Dr. A. Larochelle).

In the third category, GSC has interviewed Canadians for service abroad under CIDA contract (Nigeria) and agreed to accept trainees for practical attachment to GSC projects from Brazil, Pakistan, Uganda, Ethiopia and Yugoslavia and Indonesia under various sponsoring agencies.

The fourth category includes those CIDA projects in which GSC has a continuing responsibility. This normally involves the preparation of technical specifications, advice on the proposals or tenders received from Canadian companies, inspection and monitoring of contracts and acceptance of the work on behalf of CIDA.

In Brazil, the GSC is acting as technical advisers to the Departamento Nacional da Producao Mineral (DNPM) of the Ministry of Mines and Energy for a comprehensive mineral exploration project in the Goias state. This is a joint Canada-Brazil project partly financed by a Canadian loan from CIDA, administered by the Inter American Development Bank in Washington ($4.4 million) and partly by Brazil ($6.5 million). The project will extend over the next 4-5 years.

An initial airborne magnetic/radioactive survey will be flown over the project area (375,000 km^2) by a consortium of Canadian companies under contract to DNPM. Concurrently, pilot studies will be undertaken in five small areas of known mineral occurrences utilizing a variety of geochemical and geophysical methods in order to determine which techniques are liable to be most effective under Brazilian conditions. This work will be carried out by Canadian companies under four separate contracts.

In 1974, GSC prepared specifications for all contracts and work will begin in 1975. Inspection and technical supervision of the work will be undertaken by GSC officers.

In Pakistan, GSC is preparing specifications for an airborne magnetic survey in two areas of Baluchistan, primarily designed to define and analyze known mineralized belts partly covered by extensive alluvium. Advice on contract award, inspection and acceptance will be undertaken for CIDA.

In the Ivory Coast, specifications for a photo geological mapping project were approved in 1974 and contract supervision will be provided in 1975.

Advice was given on the selection of a consultant for the interpretation of the airborne magnetic maps resulting from an earlier CIDA project in Cameroun. This work will also be monitored for CIDA.

The GSC also participated actively in the International Workshop in Earth Science Aid to developing countries held at St. John's, Newfoundland, in May 1974. The proceedings of this workshop were published as GSC Paper 74-57.

LIST OF PUBLICATIONS

In compiling this list of branch publications, papers contained in the Survey's Reports of Activities are cited individually but collectively as they represent over 900 pages of scientific information.

Other branch publications comprise Memoirs, Bulletins, Papers, Open File items, Economic Geology Reports, Miscellaneous Reports and Maps.

Survey officers often publish articles in scientific journals and these publications are listed under other scientific publications as they too are a measure of the total scientific output of the branch. The names of the Survey's officers are underlined in this section.

OFFICE OF THE DIRECTOR GENERAL

Branch Publications

Bolton, Thomas E. Catalogue of type invertebrate fossils of the Geological Survey of Canada—Volume V; Geol. Surv. Can., Cat. no. M41-415, 1974.

Bolton, Thomas E. National Advisory Committee on Research in the Geological Sciences—Current research in the geological sciences in Canada 1973-74; Geol. Surv. Can., Paper 74-5, 1974.

Gordon, Terry and Hutchison, W.W. (editors) Computer use in projects of the Geological Survey of Canada; Geol. Surv. Can., Paper 74-60, 1974.

Hutchison, W.W. Computer-based systems for geological field data; Geol. Surv. Can., Paper 74-63, 1975.

ATLANTIC GEOSCIENCE CENTRE

Branch Publications

The following papers were published in *Report of Activities, Part B, Geol. Surv. Can., Paper 74-1 pt.B, 1974.*

O.P. Ascoli: Biostratigraphic zonation (foraminifera and ostracoda) of the Mesozoic and Cenozoic rocks of the Atlantic Shelf p. 132-135

D.L. Barrett: Elastic properties of Bermuda basalts p. 152-153

M.S. Barss: Palynological zonation of Carboniferous and Permian rocks of the Atlantic Provinces p. 135-136

Dale E. Buckley: Environmental marine geology of a coastal inlet p. 115

R.E. Cranston: Geochemical interaction between natural waters and particulate solids in the marine environment p. 119

C.A. Godden: A self-contained underwater television system p. 161-162

A.C. Grant and R.F. Macnab: Bedrock geology, northeast Newfoundland p. 153

Iris A. Hardy: Depositional history and facies distribution of the Tertiary System on the Scotian Shelf p. 137-138

D. Heffler: Marine seismic reflection data processing p. 154-155

R.D. Howie: Compilation of geoscientific data in the Paleozoic basins of Eastern Canada p. 139-140

L.F. Jansa: Stratigraphy and sedimentology of the Mesozoic and Tertiary rocks of the Atlantic Shelf p. 141-143

J.D. Leonard and M.A. Rashid: Geochemical analysis of hydrocarbons of samples from Eastern Offshore oil wells—gaseous hydrocarbons as a measure of oil and gas potential p. 119

R.F. Macnab: Natural resource maps east of Newfoundland p. 156

E.H. Owens: An investigation of ice in the littoral zone at Richibucto, northeast New Brunswick p. 120-121

M.A. Rashid and J. Brown: Influence of marine organic matter on the engineering properties of sediments and underwater structures p. 122

M.A. Rashid and J.D. Leonard: Geochemical analysis of hydrocarbons of Eastern Offshore oil well samples—heavy hydrocarbons as source and maturity indicators p. 122

C.T. Schafer and F.E. Frape: Environmental marine geology of Chaleur Bay p. 123-126

K.G. Shih, I.A. Hardy and A.G. Sherin: A feasibility study of computer-based subsurface data systems p. 163-164

Bruce D. Vardy: Specifications for a marine seismic reflection array p. 165

W.J.M. van der Linden: The surficial geology of Hamilton Bank and periphery p. 157-160

Gustavs Vilks: Foraminiferal, molluscan and lithologic study of sediment cores from the Beaufort Sea and Northwest Passage p. 127-128

Gustavs Vilks: Micropaleontology of unconsolidated sediments on the Labrador Continental Shelf p. 128-130

John A. Wade: Regional geology of the Mesozoic-Cenozoic sediments off Nova Scotia and Newfoundland p. 147-149

F.J.E. Wagner: Benthonic foraminiferida and mollusca in the Beaufort Sea p.130

D.A. Walker: Test surface ultrastructure of benthonic foraminifera and applications of scanning electron microscopy p. 131

D.A. Walker and C.T. Schafer: Sudan Black B: a stain for quantitative determination of living foraminifera p. 131

G.L. Williams: Biostratigraphy and paleoecology of the Mesozoic and Cenozoic rocks of the Atlantic Shelf p. 150-152

The following papers were published in *Report of Activities, Part A, Geol. Surv. Can., Paper 75-1A, 1975.*

R.H. Fillon: Geomorphology and glacial history of the Hamilton Bank, Labrador Shelf p. 167-169

I.M. Harris: Sedimentological study of the Goldenville Formation, Nova Scotia p. 171-174

R.F. Macnab and S.P. Srivastava: A regional geophysical survey of the Labrador Sea p. 177-179

R.F. Macnab: Geomorphology of Flemish Cap, Flemish Pass, and the northeastern Grand Banks of Newfoundland p. 175-176

E.H. Owens: Littoral processes and sediment dynamics, Magdalen Islands, Quebec: July-August, 1974 p. 157-160

G.D. Patton: Estuarine geodynamics in an area of high tidal range p. 161-162

D.I. Ross and R.K.H. Falconer: Geological studies of Baffin Bay, Davis Strait, and adjacent continental margins p. 181-183

M.A. Rashid, G. Vilks and J.D. Leonard: Geological environment of a methane-rich Recent sedimentary basin in the Gulf of St. Lawrence p. 163

B.V. Sanford: Paleozoic geology of Hudson Bay region p. 144

C.T. Schafer: Marine geology of the nearshore and estuaries of Chaleur Bay p. 163

S.P. Srivastava: An assessment of the methods used in applying diurnal correction to marine magnetic data p. 186

S.P. Srivastava: Sea floor spreading history of the Labrador Sea p. 185-186

Frances J.E. Wagner: Mollusca and foraminiferida of Pleistocene and Holocene sediments in Eastern Canada p. 164

Willam J.M. van der Linden and S.P. Srivastava: Crustal study of the Labrador Continental Margin p. 187

David A. Walker: Ingestion of benthonic foraminifera by larger invertebrates: Field sampling p. 165

Branch Publications

Haworth, R.T. Gravity and magnetic natural resource map (1972) Offshore Eastern Canada: Philosophy and technique in preparation by computer; Geol. Surv. Can., Paper 74-22, 1974.

Jansa, L.F. Evolution of a Middle and Upper Devonian sequence from a clastic coastal plain—deltaic complex into overlying carbonate reef complexes and banks, Sturgeon-Mitsue area, Alberta; Geol. Suv. Can., Bull. 234, 1974.

Jenkins, W.A.M., Ascoli, P., Gradstein, F.M., Jansa, L.F., and Williams, G.L. Stratigraphy of the Amoco IOE A-1 Puffin B-90 well, Grand Banks of Newfoundland; Geol. Surv. Can., Paper 74-61, 1974.

Macnab, R.F. and Grant, A.C. Shallow seismic data from Cruise Minna 73-019; Geol. Surv. Can., Open File 228, 1974.

Parrott, D.R. Magnetic and bathymetry data from the Gulf of Maine; Geol. Surv. Can., Open File 238, 1974.

Pelletier, B.R. (editor) Offshore geology of Eastern Canada, Volume 1—Concepts and applications of environmental marine geology; Geol. Surv. Can., Paper 74-30, Vol. 1, 1974.

Ross, David I. Free air and simple Bouguer gravity maps of Baffin Bay and adjacent continental margins; Geol. Surv. Can., Paper 73-37, 1973.

Watts, A.B. and Haworth, R.T. Gravity and magnetic data from the Gulf of Maine; Geol. Surv. Can., Open File 218, 1974.

Watts, A.B. and Haworth, R.T. Geological interpretation of Bouger anomaly and magnetic anomaly maps east of the Magdalen Islands, southern Gulf of St. Lawrence; Geol. Surv. Can., Paper 74-55, 1974.

Williams, G.L., Jansa, L.F., Clark, D.F., and Ascoli, P. Stratigraphy of the Shell Naskapi N-30 well, Scotian Shelf, Eastern Canada; Geol. Surv. Can., Paper 74-50, 1974.

Other Scientific Publications

Anderson, R.W. The chestnut pollen decline as a time horizon in lake sediments in Eastern North America; Can. J. Earth Sci., v. 11, p. 678-685, 1974.

Barrett, D.L. and Keen, C.E. Lineations in the magnetic quiet zone of the Northwest Atlantic; Nature, v. 253, p. 423-425, 1974.

Cochrane, N.A. and Srivastava, S.P. Tidal influence on electric and magnetic fields recorded at coastal sites in Nova Scotia, Canada; J. Atmos. Terrestrial Physics, v. 36, p. 49-59, 1974.

Cranston, R.E. Geochemical interaction in the recently industrialized Strait of Canso; *in* Proc. Int. Conf. Transport of Persistent chemicals in Aquatic Ecosystems: Ottawa, 1974.

Fillon, Richard H. Deglaciation of the Labrador continental shelf: Nature, v. 253, February 1975.

Haworth, R.T. Gravity and magnetic natural resource maps (1972), Offshore Eastern Canada; Philosopy and technique in preparation by computer; Int. Hydro. Rev., v. LI, No. 1, January 1974.

Haworth, R.T. and Loncarevic, B.D. Inverse filter applied to the output of an Askania Gss-2 Sea Gravimeter; Geophysics, v. 39, no. 6, p. 852-861, 1974.
Heffler, D.E. A timing correction for real time seismic signal processing. IEEE Publication 74 Ch. 873-0 OCC' IEEE International Conference on Ocean 74, Engineering in the Ocean Environment, v. II, p. 212-217, 1974.
Jansa, L.F. Trace fossils from the Cambro-Ordovician Cow Head Group, Newfoundland, and their paleobathymetric implication; Palaeogeog., Palaeoclimatol., Palaeoecol., v. 15, p. 233-244, 1974.
Keen, C.E., Keen, M.J., Ross, D.I. and Lack, M. Baffin Bay: Small ocean basin formed by sea-floor spreading; Am. Assoc. Petrol. Geol., Bull, v. 58, no. 6, Part II of II, p. 1089-1108, 1974.
Keen, C.E. and Keen, M.J. The continental margins of Eastern Canada and Baffin Bay; *in* Geology of Continental Margins; ed. C.A. Burke and C.L. Drake, Springer-Verlag.
Keen, C.E. Some geophysical measurements on the northern shelf of Baffin Bay; Prog. 1973, Nat. Conv., Can. Soc. Exp. Geol., 1974.
King, L.H., Hyndman, Roy D. and Keen, C.E. Geological development of the Continental Margin of Atlantic Canada; *in* Geoscience Can., v. 2, no. 1, 1975.
McKeown, D.L. and Grant, A.C. The Ocean '74 Conference; Geoscience Can., v. 2, no. 1, February 1975.
Pelletier, B.R. Beaufort Sea project interim report; Project F-4-sediment dispersal in the southern Beaufort Sea; publ. by Beaufort Sea Project, 512 Federal Building, 1230 Government St., Victoria, B.C.
Monahan, David and Macnab, R.F. Meso-morph map. The mapping of medium scale morphology from echograms; Proc. Thirteenth Annual Canadian Hydrographic Conference, 1974.
Rashid, M.A. Absorption of metals on sedimentary and peat humic acids: Chem. Geol., v. 13, p. 115-123, 1974.
Rashid, M.A. Degradation of bunker C oil under different coastal environments of Chedabucto Bay, Nova Scotia; Estuarine Coastal Marine Sci., v. 2, p. 137-144, 1974.
Riding, Robert and Jansa, L.F. *Uraloporella* korde in the Devonian of Alberta; Can. J. Sci., v. 11, p. 1414-1426, 1974.
Srivastava, S.P. and Folinsbee, R.A. Measurement of variations in the total geomagnetic field at sea off Nova Scotia; Can. J. Earth Sci., v. 12, p. 227-236, 1975.
van der Linden, Willem J.M. Mesozoic and Cainozoic opening of the Labrador Sea, the North Atlantic and the Bay of Biscay; Nature, v. 253, January 31, 1975.
van der Linden, Willem J.M. and Norris, R.R. Structure and Quaternary history of Karamea Bight, South Island, New Zealand; New Zealand J. Geol. Geophys., v. 17, no. 2, 1974.
Vilks, Gustavs, Rashid, M.A. and van der Linden, Willem J.M. Methane in recent sediments of the Labrador Shelf; Can. J. Earth Sci., v. 11, p. 1427-1434, 1974.
Walker, D.A., Linton, A.E. and Schafer, C.T. Sudan black B: A superior stain to rose bengal for distinguishing living from non-living foraminifera; J. Foram. Res., v. 4, no. 4, p. 205-215, 1974.

CENTRAL LABORATORIES AND ADMINISTRATIVE SERVICES

Branch Publications

The following papers were published in *Report of Activities, Part B, Geol. Surv. Can., Paper 74-1 pt.B, 1974.*

The following paper was published in *Report of Activities, Part A, Geol. Surv. Can., Paper 75-1A, 1975.*

Branch Publications

Sabina, Ann P. Rocks and minerals for the collector: Kirkland Lake-Noranda-Val d'Or, Ontario and Quebec; Geol. Surv. Can., Paper 73-30, 1974.
Sabina, Ann P. Rocks and minerals for the collector: Cobalt-Belleterre-Timmins; Ontario and Quebec; Geol. Surv. Can., Paper 74-13, 1974.

Other Scientific Publications

Dence, M.R., von Engelhardt, W., Plant, A.G. and Walter, L.S. Indications of fluid immiscibility in glass from west Clearwater Lake impact crater, Quebec, Canada; Contrib. Mineral. Petrol., v. 46, p. 81-97, 1974.
Grieve, R.A.F., Plant, A.G. and Dence, M.R. Lunar impact melts and terrestrial analogs: Their characteristics, formation and implications for lunar crustal evolution; Proc. Fifth Lunar Conf.; Supp. 5, Geochim. Cosmochim. Acta, v. 1, p. 261-273, 1974.
Hogarth, D.D., Chao, G.Y., Plant, A.G. and Steacy, H.R. Caysichite, a new silico-carbonate of yttrium and calcium; Can. Mineral., v. 12, p. 293-298, 1974.
Steacy, H.R., Plant, A.G. and Boyle, R.W. Brannerite associated with native gold at the Richardson Mines, Ontario; Can. Mineral., v. 12, p. 360-363, 1974.
Steacy, H.R. Our beautiful, little known gemstones; Can. Geog. J., v. 89, no. 6 p. 4-13, 1974.
Steacy, H.R. and Grant, D.R. Tidal muds reveal mineral curiosity; Can. Geogr. J., v. 88, no. 1, p. 36-38, 1974.

GEOLOGICAL INFORMATION PROCESSING DIVISION

Branch Publications

Christensen, C.J. List of translations in the library of the Geological Survey of Canada: no. 3; Geol. Surv. Can., Paper 74-58, 1974.
Griffin, P.J. Index of publications of the Geological Survey of Canada; Geol. Surv. Can., Paper 74-3, 1974.

Other Scientific Publications.

Sutherland, Doreen M. and LaHam, Mary T. Geoscience document distribution in Canada; Geosci. Inform., v. 4, p. 75-83, 1974.

INSTITUTE OF SEDIMENTARY AND PETROLEUM GEOLOGY

Branch Publications

The following papers were published in *Report of Activities, Part B, Geol. Surv. Can., Paper 74-1 pt.B, 1974.*

The following papers were published in *Report of Activities, Part A, Geol. Surv. Can., Paper 75-1A, 1975.*

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Other Branch Publications

Aitken, J.D. and Cook, D.G. Geological maps showing bedrock geology of the northern parts of Mount Eduni and Bonnet Plume Lake map-areas, District of Mackenzie, N.W.T., scale 1:125,000; Geol. Surv. Can., Open File 221, 1974.
Aitken, J.E. and Cook, D.G. Geology of upper Ramparts River and Sans Sault Rapids map-areas, District of Mackenzie, N.W.T.; Geol. Surv. Can., Open File 272, 1975.
Brideaux, W.W. and Fisher, M.J. Upper Jurassic-Lower Cretaceous dinolagellate assemblages from Arctic Canada; Geol. Surv. Can., Open File 253, 1975.
Brideaux, W.W. and McIntyre, D.J. Spores, pollen, dinoflagellates and acritarchs from Lower Cretaceous rocks on Horton River, District of Mackenzie; Geol. Surv. Can., Open File 233, 1974.
Cook, D.G. and Aitken, J.D. Surface and subsurface geology of the Ontaratue River, Travaillant Lake and Canot Lake map-areas, District of Mackenzie, Northwest Territories; Geol. Surv. Can., Open File 234, 1974.
Douglas, R.J.W. Geology, Dahadinni River, District of Mackenzie, scale 1:250 000; Geol. Surv. Can., Map 1374A, 1974.
Douglas, R.J.W. and Norris, D.K. Geology, Wrigley, District of Mackenzie, scale 1:250,000; Geol. Surv. Can., Map 1373A, 1974.
Findlay, C.E. Index to publications on the geology of the interior plains of Canada north of 60° latitude by the Geological Survey of Canada; Geol. Surv. Can., Paper 74-5, 1974.
Frebold, Hans. The Jurassic faunas of the Canadian Arctic—Lower Jurassic ammonites, biostratigraphy and correlation; Geol. Surv. Can., Bull. 243, 1975.
Gibson, D.W. Triassic rocks of the southern Canadian Rocky Mountains; Geol. Surv. Can., Bull. 230, 1974.
Hopkins, W.S., Jr. Palynological study of Shell Anglo Harlequin D-86 well, offshore British Columbia; Geol. Surv. Can., Open File 268, 1975.
Jeletzky, J.A. Contribution to the Jurassic and Cretaceous geology of northern Yukon Territory and District of Mackenzie, Northwest Territories; Geol. Surv. Can., Paper 74-10, 1974.
Jeletzky, J.A. Porcupine plateau and adjacent areas, northern Yukon and District of Mackenzie, Northwest Territories; Geol. Surv. Can., Open File 203, 1974.
Jeletzky, J.A. Jurassic and Lower Cretaceous paleogeography and depositional tectonics of Porcupine Plateau, adjacent areas of northern Yukon and District of Mackenzie; Geol. Surv. Can., Paper 74-16, 1975.
Kerr, J. Wm. Geology of Bathurst Island Group and Byam Martin Island, Arctic Canada (Operation Bathurst Island); Geol. Surv. Can., Mem. 378, Map 1350A, 1974.
Kerr, J. Wm. Tips on organizing Arctic geological field work: Geol. Surv. Can., Paper 74-12, 1974.
McIntyre, D.J. Palynology of an Upper Cretaceous section, Horton River, District of Mackenzie, N.W.T.; Geol. Surv. Can., Paper 74-14, 1974.
Meijer-Drees, N.C. Stratigraphical and lithological aspects and an evaluation of the gas potential of the Upper Cretaceous Milk River Formation in the Suffield and Medicine Hat areas, Alberta; Geol. Surv. Can., Open File 250, 1975.
Miall, Andrew D. Subsurface Proterozoic and Paleozoic stratigraphy of Banks Island, Arctic Canada, N.W.T.; Geol. Surv. Can., Open File 260, 1975.
Morrow, D.W. and Kerr, J. Wm. Stratigraphy and sedimentology of the Paleozoic formations of part of Devon Island in the vicinity of Prince Alfred Bay, N.W.T.; Geol. Surv. Can., Open File 255, 1975.
Nassichuk, W.W. Carboniferous ammonoids and stratigraphy in the Canadian Arctic Archipelago; Geol. Surv. Can., Bull. 237, 1975.
Norford, B.S. and Macqueen, R.W. Type sections of the Lower Paleozoic Franklin Mountain and Mount Kindle formations, Franklin Mountains and northern Mackenzie Mountains; Geol. Surv. Can., Open File 235, 1974.
Ollerenshaw, N.C. Geology, Fallentimber Creek (west half), Alberta, scale 1:50,000; Geol. Surv. Can., Map 1387A, 1975.
Ollerenshaw, N.C. Geology of part of Kananaskis map-area, Alberta, scale 1:250,000; Geol. Surv. Can., Open File 263, 1975.
Pedder, A.E.H. A revised megafossil zonation of lower and middle Upper Devonian strata of the central and lower Mackenzie Valley, District of Mackenzie, N.W.T.; Geol. Surv. Can., Open File 220, 1974.
Thorsteinsson, R. Carboniferous and Permian stratigraphy of Axel Heiberg Island and western Ellesmere Island, Canadian Arctic Archipelago; Geol. Surv. Can., Bull. 224, 1974.
Trettin, H.P. Stratigraphic sections and reconnaissance studies of the geological structure in widely separated areas of Foxe Basin, Melville Peninsula and Baffin Island; Geol. Surv. Can., Open File 236, 1974.
Uyeno, T.T. Conodonts of the Waterways Formation (Upper Devonian) of northeastern and central Alberta; Geol. Surv. Can., Bull. 232, 1974.
Yorath, C.J., Myhr, D.W. and Young, F.G. Geology of the Beaufort-Mackenzie Basin; Geol. Surv. Can., Open File 251, 1975.

Other Scientific Publications

Balkwill, H.R., Roy, K.J., Hopkins, W.S., and Sliter, W.V. Glacial features and pingos, Amund Ringnes Island, Arctic Archipelago; Can. J. Earth Sci., v. 11, p. 1319-1325, 1974.
Deroo, G., Tissot, B., McCrossan, R.G., and Der, F. Geochemistry of the heavy oils of Alberta; *in* Oil Sands Fuel of the Future, Can. Soc. Pet. Geol., Mem. 3, 1974.
Foscolos, A.E. and Kodama, H. Diagenesis of clay minerals from Lower Cretaceous shales of northeastern British Columbia; Clays Clay Miner., v. 22, p. 319-335, 1974.
Hacquebard, P.A. and Donaldson, J.R. Rank studies of coals in the Rocky Mountains and Inner Foothills Belt, Canada; Geol. Soc. Am., Spec. Paper 153, p. 74-94, 1974.
Hills, L.V., Chi, B.I. and Sweet, A.R. The genus *Ocksisporites* Chaloner; Rev. Palaebot. Palyn., v. 19(2), p. 101-115, 1975.
Irish, E.J. W. Rock fragments on file; Geos. Winter 1974, p. 18-20
Jeletzky, J.A. Jurassic-Cretaceous transition beds in Canada; Colloque du Jurassique, Luxembourg, 1967. Mèm. B.R.G.M., Fr., n°75, 1971. Publié avec le concours de l'Institut grand-ducal sect. sci. nat. phys. math., p. 701.
Miall, A.D. Manganese spherulites at an intra-cretaceous disconformity, Banks Island, Northwest Territories; Can. J. Earth Sci., v. 11, p. 1704-1816, 1974.
Miall, A.D. Paleocurrent analysis of alluvial sediments: A discussion of directional variance and vector magnitude; J. Sed. Petrol., v. 44, no. 4, p. 1174-1185, 1974.
Norris, D.K. Structural geometry and geological history of the northern Canadian Cordillera; Proc. 1973 Nat. Conv, Can. Soc. Exp. Geophys., 1974.
Porter, J.W. and McCrossan, R.G. Basin consanguinity in petroleum resource estimations; *in* Methods of Estimating the Volume of Undiscovered Oil and Gas Resources; Alta. Assoc. Pet. Geol., Res. Symp., 1974.
Stott, D.F. Lower Cretaceous coal measures of the foothills of west-central Alberta and northeastern British Columbia; Can. Min. Met., Bull., v. 67, no. 749, 1974.
Strimple, H.L. and Nassichuk, W.W. Pennsylvanian crinoids from Ellesmere Island, Arctic Canada; J. Paleontol., v. 48, no. 6, p. 1149-1155, 1974.
Sweet, A.R. and Hills, L.V. A detailed study of the genus *Azollopsis;* Can. J. Botany, v. 52, p. 1625-1542, 1974.

REGIONAL AND ECONOMIC GEOLOGY DIVISION

Branch Publications

The following papers were published in *Report of Activities, Part B, Geol. Surv. Can., Paper 74-1 pt. B, 1974.*

J.D. Aitken and D.G. Cook: Effect of antecedent faults on "Laramide" structure, Mackenzie Arc p. 259-264
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The following papers were published in *Report of Activities, Part A, Geol. Surv. Can., Paper 75-1A, 1975.*

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W.P. Binney and R.V. Kirkham: A study of copper mineralization in Mississippian rocks of the Atlantic Provinces p. 245-248
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A.C. Brown: A study of stratiform copper deposits in carboniferous strata of New Brunswick and Nova Scotia p. 598-600
B.E.B. Cameron: Geology of the Tertiary rocks north of latitude 49° West Coast of Vancouver Island p. 17-20
F.H.A. Campbell and M.P. Cecile: Report on the Geology of the Kilohigok Basin, Goulburn Group, Bathurst Inlet, N.W.T. p. 297-306
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Ingo Ermanovics, Graham Park, John Hill and Peter Goetz: Geology of Island Lake map-area, Manitoba and Ontario p. 311-316
W.H. Fritz: Broad correlations of some Lower and Middle Cambrian strata in the North American Cordillera p. 533-540
John B. Henderson: Sedimentological studies of the Yellowknife Supergroup in the Slave Structural Province p. 325-330
P.F. Hoffman and I. Bell: Volcanism and plutonism, Sloan River map-area, Great Bear Lake, District of Mackenzie p. 331-338
J.L. Jambor: Secondary minerals in an ultramafic intrusion, Amos area, Quebec p. 261-264
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J.C. McGlynn: Geology of the Calder River map-area, District of Mackenzie p. 339-342
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Other Branch Publications

Annells, R.N., Keweenawan volcanic rocks of Michipicoten Island, Lake Superior, Ontario—An eruptive centre of Proterozoic age; Geol. Surv. Can., Bull. 218, Map 1353A, 1974.

Benson, D.G. Geology of the Antigonish Highlands, Nova Scotia; Geol. Surv. Can., Mem. 376, Maps 1360A and 1361A, 1974.

Blusson, S.L. Five geological maps of Operation Stewart (northern Selwyn Basin), Yukon and District of Mackenzie, scale 1:250,000; Geol. Surv. Can., Open File 205, 1974.

Blusson, S.L. Six geological maps of part of Nadaleen River map-area, Yukon and District of Mackenzie, scale 1:50,000; Geol. Surv. Can., Open File 206, 1974.

Boucot, A.J., Cumming, L.M. et Jaeger, H. La datation des grès et du calcaire de Gaspé; Geol. Surv. Can., Etude 67-25, 1972.

Coates, J.A. Geology of the Manning Park area, British Columbia; Geol. Surv. Can., Bull. 238, 1974.

Copeland, M.J. Middle Ordovician ostracoda from southwestern District of Mackenzie; Geol. Surv. Can., Bull. 244, 1974.

Copeland, M.J. Silurian ostracoda from Anticosti Island, Quebec; Geol. Surv. Can., Bull. 241, 1974

Dawson, K.R. Niobium (columbium) and tantalum in Canada; Geol. Surv. Can., Econ. Geol. Rep. 29, Map 1354A, 1974.

Eade, K.E. Geology of Kognak River area, District of Keewatin, Northwest Territories; Geol. Surv. Can., Mem. 377, Map 1364A, 1974.

Eisbacher, Gerhard H. Sedimentary history and tectonic evolution of the Sustut and Sifton basins, north-central British Columbia; Geol. Surv. Can., Paper 73-31, Map 14-1973, 1974.

Fraser, J.A. The Epworth Group Rocknest Lake area, District of Mackenzie, Geol. Surv. Can., Paper 73-39, Map 1384A, 1974.

Frisch, Thomas. Metamorphic and plutonic rocks of northernmost Ellesmere Island, Canadian Arctic Archipelago; Geol. Surv. Can., Bull. 229, 1974.

Gabrielse, H., Blusson, S.L., and Okulitch, A.V. Geological map of MacMillan River sheet, Yukon and Northwest Territories, scale 1:1,000,000; Geol. Surv. Can., Open File 209, 1974.

Mathews, W.H., Gabrielse, H., and Rutter, N.W. Glacial map of Beatton River map-area, British Columbia; scale 1:1,000,000; Geol. Surv. Can., Open File 274, 1975.

Henderson, John B. Archean mafic volcanics and sediments and associated mineral deposits in part of Point Lake area; Geol. Surv. Can., Open File 232, 1974.

Jambor, J.L. Trace element variations in porphyry copper deposits, Babine Lake area, British Columbia; Geol. Surv. Can., Paper 74-9, 1974.

Lambert, M.B. The Bennett Lake cauldron subsidence complex, British Columbia and Yukon Territory; Geol. Surv. Can., Bull. 227, 1974.

Mulligan, R. Geology of Canadian tin occurrences; Geol. Surv. Can., Econ. Geol. Rept. 28, Map 1352A, 1975.

Muller, J.E., Northcote, K.E., and Carlisle, D. Geology and mineral deposits Alert Bay-Cape Scott map-area, Vancouver Island, British Columbia; Geol. Surv. Can., Paper 74-8, Map 4-1974, 1974.

Richards, T. Geological map of Hazelton map-area, British Columbia, scale 1:125,000; Geol. Surv. Can., Open File 215, 1974

Ridler, R.H. and Shilts, W.W. Exploration for Archean polymetallic sulphide deposits in permafrost terrain: An integrated geological/geochemical technique, Kaminak Lake area, District of Keewatin; Geol. Surv. Can., Paper 73-34, 1974.

Skinner, Ralph·Geology of Tetagouche Lakes, Bathurst, and Nepisiguit Falls map-areas, New Brunswick (with emphasis on the Tetagouche Group); Geol. Surv. Can., Mem. 371, Maps 1330A, 1331A and 1332A, 1974.

Souther, J.G., Brew, D.A., and Okulitch, A.V. Geological map of Iskut River, British Columbia, scale 1:1,000,000; Geol. Surv. Can., Open File 214, 1974.

Souther, J.G. and Symms, D.J.A. Stratigraphy and paleomagnetism of Mount Edziza volcanic complex, northwestern British Columbia; Geol. Surv. Can., Paper 73-32, 1974.

Tempelman-Kluit, D.J. Reconnaissance geology of Aishihik Lake, Snag and part of Stewart River map-areas, west-central Yukon; Geol. Surv. Can., Paper 73-41, Maps 16-1973, 17-1973 and 17-1973, 1974.

Tempelman-Kluit, D.J. Reconnaissance geology of Quiet Lake, Finlayson Lake, Sheldon Lake and Tay River map-areas, Yukon Territory; Geol. Surv. Can., Open File 212, 1974.

Tipper, H.W., Taylor, G.C., Stott, D.F., and Campbell, R.B. Geology of Parsnip River map-area, British Columbia, scale 1:1,000,000; Geol. Surv. Can., Open File 261, 1975.

Other Scientific Publications

Agterberg, F.P. Automatic contouring of geological maps to detect target areas for mineral exploration; Math. Geol., v. 6, No. 4, 1974.

Agterberg, F.P. Geomathematics mathematical background and geo-science applications; 596p., Elsevier Scientific Publishing Company, 1974.

Chandler, F.W. Lower Huronian sandstones; correlation problems and uranium; Morin Township area, Ontario; Can. J. Earth Sci., v. 12, p. 237-251, 1975.

Chase, R.L., Tiffin, D.L. and Murray, J.W. The Western Canadian continental margin; Can. Soc. Pet. Geol.; Spec. Mem. No. 1, 1974.

Copeland, M.J. Biostratigraphic zonation of Devonian and Mississippian ostracoda from Canada: A summary account; *in* International Symposium on Micropaleontological Limits, Namur, Belgium, Sept. 1-10, 1974.

Copeland, M.J. Late Ordovician to Middle Silurian Palaeocope faunas from Anticosti Island, Quebec, Canada; *in* Symposium on the Palaeocope ostracodes, Visby, Sweden, Aug. 26-30, 1975.

Copeland, M.J. and Bolton, T.E. Memorial to John Fletcher Caley 1903-1971; Geol. Soc. Am. Memorials, v. 3, p. 53-56, 1974.

Cumming, L.M. and Romaniuk, A.S. The 1st and 76th Meetings of the Canadian Institute of Mining and Metallurgy; Can. Inst. Min. Met., Bull., v. 44, no. 744, p. 31-32, 1974.

Currie, K.L. A note on the calibration of the garnet-cordierite geothermometer and geobarometer; Contrib. Mineral. Petrol., v. 44, no. 1, p. 35-44, 1974.

Dawson, K.M. and Sinclair, A.J. Factor analysis of minor element data for pyrites, Endako Molybdenum Mine, British Columbia, Canada; Econ. Geol., v. 69, no. 3, p. 404-411, 1974.

Eckstrand, O.R. The Dumont Serpentinite: A model for control of nickeliferous opaque mineral assemblages by alteration reactions in ultramafic rocks; Econ. Geol., v. 70, p. 183-201, 1975.

Eisbacher, G.H. Evolution of successor basins in the Canadian Cordillera; Soc. Econ. Palaeontol. Mineral., Spec. Publ. no. 19, p. 274-291, 1974.

Emslie, R.F. The Harp Lake Complex, Labrador, and the Morin Complex, Quebec: Examples of igneous and meta-igneous anorthositic complexes in the eastern Canadian Shield; *in* Centenaire de la Société Géologique de Belgique Géologie des Domaines Cristallins, Liége, 1974.

Frebold, Hans and Tipper, H.W. Upper Callovian and Lower Oxfordian ammonites from southeastern Bowser Basin, British Columbia; Can. J. Earth Sci., v. 12, p. 145-157, 1975.

Fritz, W.H. and Mountjoy, E.W. Lower and early Middle Cambrian formations near Mount Robson, British Columbia and Alberta; Can. J. Earth Sci., v. 12, p. 119-131, 1975.

Gabrielse, H. and Reesor, J.E. The nature and setting of granitic plutons in the central and eastern parts of the Canadian Cordillera; Pacific Geol., v. 8, p. 109-138, 1975.

Hoffman, Paul. Shallow and deepwater stromatolites in Lower Proterozoic platform-to-basin facies change, Great Slave Lake, Canada; Am. Assoc. Pet. Geol., Bull., v. 58, no. 5, p. 856-867, 1974.

Irving, E., Park, J.K., Emslie, R.F. Paleomagnetism of the Morin Complex; J. Geophys. Res., v. 70, no. 35, p. 5482-5490, 1974.

Irving, E., Emslie, R.F. and Ueno, H. Upper Proterozoic paleomagnetic poles from Laurentia and the history of the Grenville Structural Province; J. Geophys. Res., v. 79, no. 35, p. 5491-5502, 1974.

Lambert, M.B. Evidence of volcanism in Canada and prospects for geothermal energy; Can. Geogr. J., v. 89, no. 1, p. 12-13, 1974.

Lambert, M.B. The mighty volcanic drama in Iceland; Can. Geogr. J., v. 89, no. 1, p. 5-11, 1974.

Leech, G.B. Metallogeny of Canada—The geologic setting; Min. Eng.; v. 26, no. 12, p. 75, 1974.

McGlynn, J.C. and Irving, E. Paleomagnetism of Early Aphebian Diabase dykes from the Slave Structural Province, Canada; Tectonophysics, v. 26, p. 23-38, 1975.

Muller, J.E., Wanless, R.K., and Loveridge, W.D. A paleozoic zircon age of the Westcoast Crystalline Complex of Vancouver Island, British Columbia; Can. J. Earth Sci., v. 11, p. 1919-1922, 1974.

Murray, J.W. and Tiffin, D.L. Patterns of deformation sedimentation and tectonism, Southwestern Canadian Continental Margin; Annales Soc. Geol. Belgique, T. 96, 12 p., 1974.

Picklyk, D.D. and Ridler, R.H. Computer graphics—an interactive approach to volcanic geochemistry and stratigraphy: Illustrated by data from the Kirkland Lake area; Can. Min. Met., Bull., v. 68, February p. 1-8, 1975.

Ridler, R.H. The gold metallogeny of Archean exhalites; Min. Eng.; v. 26, no. 12, p. 75, 1974.

Ridler, R.H. and Shilts, W.W. Mineral potential of the Rankin Inlet; Can. Min. J., v. 95, no. 7, p. 32-36, 38-40, 42, 1974.

Rimsaite, J. Effect of Rb-metasomatism Rb/Sr and $^{87}Sr/^{86}Sr$ ratios in pegmatitic minerals and host rocks; Abstracts, II Cong. Latinoamericano de Geologica, p. 77-78, 1973.

Rimsaite, J. Mineral assemblages and low-grade metamorphic-metasomatic alterations in an Archean Greenstone belt, Malartic, Quebec; Can. Mineral, v. 12, p. 520-526, 1974.

Roddick, J.A. and Hutchison, W.W. Setting of the Coast Plutonic Complex, British Columbia; Pacific Geol., v. 8, p. 91-108, 1974.

Sangster, D.F. Canadian stratabound lead-zinc deposits in sedimentary environments; Min. Eng., v. 26, no. 12, p. 75, 1974.

Schwartz, E.J. Magnetic fabric in massive sulfide deposits; Can. J. Earth Sci., v. 11, p. 1669-1675, 1974.

Shina, A.K. and Frisch, Thomas. Whole-rock Rb/Sr ages of metamorphic rocks from northern Ellesmere Island, Canadian Arctic Archipelago. I. The gneiss terrain between Ayles Fiord and Yelverton Inlet; Can. J. Earth Sci., v. 12, p. 90-94, 1975.

Soregaroli, A.E. Geology and genesis of the Boss Mountain Molybdenum Deposit, British Columbia; Econ. Geol., v. 70, p. 4-14, 1975.

Wanless, R.K. and Eade, K.E. Geochronology of Archean and Proterozoic rocks in the southern District of Keewatin; Can. J. Earth Sci., v. 12, p. 95-114, 1975.

Wanless, R.K. and Reesor, J.E. Precambrian zircon age of orthogneiss in the Shuswap Metamorphic Complex, British Columbia; Can. J. Earth Sci., v. 12, p. 326-332, 1975.

RESOURCE GEOPHYSICS AND GEOCHEMISTRY DIVISION

Branch Publications

The following papers were published in *Report of Activities, Part B, Geol. Surv. Can., Paper 74-1 pt.B, 1974.*

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The following papers were published in *Report of Activities, Part A, Geol. Surv. Can., Paper 75-1A, 1975.*

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P. Sawatzky and Peter J. Hood: Fabrication of an inboard digital-recording vertical gradiometer system for aeromagnetic surveying, a progress report p. 139-140
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Branch Publications

Boyle, R.W. Elemental associations in mineral deposits and indicator elements of interest in geochemical prospecting; Geol. Surv. Can., Paper 74-45, 1974.
Cameron, E.M. and Durham, C.C. Geochemical studies in the eastern part of the Slave Structural Province, 1973; Geol. Surv. Can., Paper 74-27, 1974.
Charbonneau, B.W., Jonasson, I.R., Holman, P.B., and Ford, K.L. Ground and airborne gamma-ray spectrometry, stream sediment and soil geochemistry investigations of Paleozoic uranium-copper mineralization in the Ottawa-Arnprior area, Ontario; Geol. Surv. Can., Open File 264, 1975.
Dyck, Willy. Geochemical studies in the surficial environment of the Beaverlodge area, Saskatchewan, Part A. The geochemistry of U, Ra, Zn, Cu, Pb and Ni. Part B. A comparison of geochemical exploration methods—lake versus stream sampling; Geol. Surv. Can., Paper 74-32, 1974.
Garrett, R.G. Field data acquisition methods for applied geochemical surveys at the Geological Survey of Canada; Geol. Surv. Can., Paper 74-52, 1974.
Killeen, P.G. and Hobson, G.D. Project EGMA seismic survey—Timmins, Ontario to Val d'Or, Quebec; Geol. Surv. Can., Paper 74-44, 1974.
Lalonde, J.P. Research in geochemical prospecting methods for fluorite deposits, Madoc area, Ontario; Geol. Surv. Can., Paper 73-38, 1974.
MacLatchy, J.E. and Jonasson, I.R. The relationship between mercury occurrence and mining activity in the Nottaway and Rupert River basins of northwestern Quebec; Geol. Surv. Can., Paper 74-56, 1974.

Other Scientific Publications.

Boyle, R.W. The geochemistry of gold and its deposits ; Can. Inst. Min. Met., Bull., v. 67, p. 61, 1974.
Boyle, R.W. The use of major elemental ratios in detailed geochemical prospecting utilizing primary halos; J. Geochem. Explor., v. 3, no. 4, p. 345-369, 1974.
Collett, L.S. Geophysical parameters of permafrost; Nat. Res. Council, Can., Tech. Memo. no. 113, p. 1-16, 1974.
Collett, L.S. and Brown, R.J.E. Proceedings of a symposium on permafrost geophysics, 27 and 28 February 1974; Nat. Res. Council, Can., Tech. Memo. no. 113, 105 p. plus appendix, 1974.
Dyck, A.V., Becker, A. and Collett, L.S. Surficial conductivity mapping with the airborne input system; Can. Inst. Min. Met., Bull., v. 67, no. 744, p. 104-109, 1974.
Garrett, R.G. Mercury in some granitoid rocks of the Yukon and its relation to gold-tungsten mineralization; J. Geochem. Explor., v. 3, no. 3, p. 277-289, 1974.
Hood, Peter J. Mineral exploration: Trends and developments in 1974; Can. Min. J., v. 96, no. 2, p. 191-229, 1975.
Killeen, P.G., Carson, J.M. and Hunter, J.A. Optimizing some parameters for airborne gamma-ray spectrometric surveying; Geoexploration, v. 13, p. 1-12, 1975.
Killeen, P.G., and Heier, K.S. Radioelement variation in the Levang granitegneiss, Bamble Region, South Norway; Contrib. Mineral. Petrol., v. 48, p. 171-177, 1974.
Scott, W.J., Campbell, K.J. and Orange, A.S. EM pulse survey method in permafrost; Nat. Res. Council, Can., Tech. Memo. no. 113, p. 92-96, 1974.
Scott, W.J. and Hunter, J.A. Seismic and electrical methods in permafrost detection; Nat. Res. Council, Can., Tech. Memo., no. 113, p. 48-49, 1974.
Sellmann, P.V., McNeill, J.D. and Scott, W.J. Airborne E-phase resistivity surveys of permafrost; Nat. Res. Council, Can., Tech. Memo. no. 113, p. 67-69, 1974.
Scott, W.J. and Collett, L.S. Symposium on permafrost geophysics; Geoscience Can., v. 2, no. 1, p. 51-54, 1975.
Slaney, V.R. Satellite imagery applied to earth science in Canada; Proc. Comm. VII, Int. Soc. Photogrammetry, Banff, 1974.

TERRAIN SCIENCES DIVISION

Branch Publications

The following papers were published in *Report of Activities, Part B, Geol. Surv. Can., Paper 74-1 pt.B, 1974.*

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The following papers were published in *Report of Activities, Part A, Geol. Surv. Can., Paper 75-1A, 1975.*

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Other Branch Publications

Barnett, D.M., Edlund, S.A., and Dredge, L.A. Eleven classification and evaluation photomosaic maps and text (1318P) of eastern Melville Island, Northwest Territories, scale 1:125,000; Geol. Surv. Can., Open File 225, 1974.

Bird, C.D. Botanical studies near the Mackenzie River, Northwest Territories; Geol. Surv. Can., Open File 225, 1974.

Bird, C.D. Botanical studies in the Yukon and Northwest Territories; Geol. Surv. Can., Open File 227, 1974.

Brookes, I.A. Late-Wisconsin glaciation of southwestern Newfoundland (with special reference to the Stephenville map-area); Geol. Surv. Can., Paper 73-40, Map 15-1973, 1974.

Fulton, R.J., Hodgson, D.A., Minning, G.V., and Thomas, R.D. Ten surficial geology photomosaic maps of part of southern Labrador, scale 1:50,000; Geol. Surv. Can. Open File 216, 1974.

Grant, D.R. Five surficial geology maps of parts of Newfoundland, scale 1:50,000; Geol. Surv. Can.; Open File 244, 1974.

Henderson, E.P. Surficial geology of Avalon Peninsula; Geol. Surv. Can., Memoir 368, Map 1320A, 1972.

Henderson, E.P. Surficial geology of Kingston map-area, Ontario; Maps 7-1972; 8-1972; Geol. Surv. Can., Paper 72-48, 1973.

Hodgson, D.A. and Hazelton, G.M. Reconnaissance glacial geology, northeastern Baffin Island; Geol. Surv. Can., Paper 74-20, Map 1395A, 1974.

Hodgson, D.A. and Edlund, S.A. Two surficial material and two biophysical region maps of Baumann Fiord and Graham Island, eastern Queen Elizabeth Islands, scale 1:125,000; Geol. Surv. Can. Open File 265, 1975.

Klassen, R.W. Quaternary geology and geomorphology of Assiniboine and Qu'Appelle Valleys of Manitoba and Saskatchewan; Geol. Surv. Can. Bull. 228, 1975.

Klassen, R.W. and Netterville, J.A. Preliminary drafts of nine surficial geology photomosaic maps of part of northern Manitoba, comprising Grand Rapids; Cross Lake; Wekusko Lake map areas at a scale of 1 inch to 2 miles; Geol. Surv. Can., Open File 217, 1974.

Kuc, M. *Calliergon aftonianum* Steere in Late Tertiary and Pleistocene deposits of Canada; Geol. Surv. Can., Paper 74-24, 1974.

Lichti-Federovich, Sigrid. Palynology of two sections of Late Quaternary sediments from the Porcupine River, Yukon Territory; Geol. Surv. Can., Paper 74-23, 1974.

Lowdon, J.A., Wilmett, R., and Blake, W., Jr. Geological Survey of Canada radio-carbon dates XIV; Geol. Surv. Can., Paper 74-7, 1974.

Mackay, J. Ross. The Mackenzie Delta area, Northwest Territories; Geol. Surv. Can., Mis. Rep. 23, 1974; First published as Can. Geogr. Br., Mem. 8, 1963.

Monroe, R.L. Three terrain classification and sensitivity maps of part of the northern Yukon Territory, at a scale of 1:250,000; Geol. Surv. Can., Open File 210, 1974.

Klassen, R.W. and Netterville, J.A. Four surficial geology photomosaic maps of part of northern Manitoba, at a scale of one inch to two miles; Geol. Surv. Can., Open File 241, 1974.

Proudfoot, D.A., Skinner, R.G., and Shilts, W.W. Contamination in overburden samples obtained by the rotary dualtube drilling technique; Geol. Surv. Can., Open File 277, 1975.

Richard, S.H. Surficial geology map of part of the Winchester area, Ontario, scale 1:50,000; Geol. Surv. Can., Open File 213, 1974.

Ricker, K.E. Airphoto-interpretation surficial geology map (scale 1:125,000) and report of Nadaleen River map-area, Yukon; Geol. Surv. Can., Open File 207, 1974.

Rutter, N.W. Surficial geology and landforms, Williston Lake area, British Columbia, scale 1:125,000; Geol. Surv. Can., Maps 1381A, 1382A, 1383A, 1974.

St.-Onge, D.A. and Lengellé, J. Two erosion susceptibility maps of part of the Swan Hills region of Alberta, scale 1:50,000; Geol. Surv. Can. Open File 240, 1974.

St.-Onge, D.A. The geomorphology of the Swan Hills area, Alberta; Geol. Surv. Can., Paper 74-26, Map 1206A, 1974.

Shilts, W.W. Two maps showing Cu, Zn and Ni concentrations in till samples from the Henninga, Kaminak, Quartzite lakes area; Geol. Surv. Can. Open File 211, 1974.

Skinner, R.G. Report on terrain studies in the James Bay Development Area; Geol. Surv. Can., Open File 219, 1974.

Stalker, A. MacS. Surficial geology of the Kananaskis Research Forest and Marmot Creek Basin region of Alberta; Geol. Surv. Can., Map 1365A, 1973.

Stewart, J. McG. Hamilton Bank, Labrador, Part 1, surficial sediments; Geol. Surv. Can., Open File 230, 1974.

Vincent, J.S. Quatres cartes de geologie du quaternaire à l'est de la baie James, échelle, 1:50,000; Geol. Surv. Can., Open File 267, 1975.

Other Scientific Publications

Anderson, T.W. and Lewis, C.F.M. Chronology and paleoecology of an Holocene buried plant detritus bed in Lake Huron; Abstracts, 17th Conference on Great Lakes Research, August 12-14, Hamilton, Ontario, 1974.

Barnett, D.M., Edlund, S.A. and Hodgson, D.A. Sensitivity of surface materials and vegetation to disturbance in the Queen Elizabeth Islands: an approach and commentary; Arctic, v. 28, no. 1, March 1975.

Blake, W., Jr. Studies of glacial history in Arctic Canada. II. Interglacial peat deposits on Bathurst Island; Can. J. Earth Sci., v. 11, no. 8, p. 1025-1042, 1974.

Clague, John J. The St. Eugene Formation and the development of the Southern Rocky Mountain Trench; Can. J. Earth Sci., v. 11, p. 916-938, 1974.

French, H.M. Man-induced thermokarst, Sachs Harbour Airstrip, Banks Island, Northwest Territories; Can. J. Earth Sci., v. 12, p. 132-144, 1975.

Grant, D.R. and Prest, V.K. The contrasting styles of Late-Wisconsinan Laurentide and Appalachian glaciation: New England and the Atlantic Provinces; Geol. Soc. Am., Abstr., v. 7, no. 1, p. 66, 1975.

Thomas, Martin L.H., Grant, D.R., and de Grace, Marius. A late Pleistocene marine shell deposit at Shippegan, New Brunswick; Can. J. Earth Sci., v. 10, p. 1329, 1973.

Grant, D.R. Late-Wisconsin Ice Caps on the continental shelf, Eastern Canada; Geol. Soc. Am., Abstr., November 1974.

Lutenauer, John L. Geology; in the Fraser River Estuary—Status of environmental knowledge to 1974; eds. L.M. Hoos and G.A. Packman, Environment Canada, Sp. Estuary ser. no. 1, 1974.

Mackay, J. Ross. Ice-wedge cracks, Garry Island, Northwest Territories; Can. J. Earth Sci., v. 11, p. 1366-1383, 1974.

Mackay, J. Ross. Reticulate ice veins in permafrost, Northern Canada; Can. Geotech. J., v. 11, p. 230-237, 1974.

Mackay, J. Ross and MacKay, D.K. Snow cover and ground temperatures, Garry Island, N.W.T.; Arctic, v. 27, no. 4, p. 287-296, 1974.

Mackay, J. Ross and Mathews, W.H. Movement of sorted stripes, The Cinder Cone, Garibaldi Park, B.C., Canada; Arct. Alp. Res., v. 6, no. 4, p. 347-359, 1974.

Matthews, J.V., Jr. Quaternary environments at Cape Deceit (Seward Peninsula, Alaska): Evolution of a tundra ecosystem; Geol. Soc. Am., Bull., v. 85 p. 1353-1384, 1974.

Matthews, J.V., Jr. Wisconsin environment of interior Alaska: pollen and macrofossil analysis of a 27 meter core from the Isabella Basin (Fairbanks, Alaska); Can. J. Earth Sci., v. 11, p. 828-841, 1974.

Mott, R.J. Palynological studies of lake sediment profiles from southwestern New Brunswick; Can. J. Earth Sci., v. 12, p. 273-288, 1975.

Shilts, W.W. Glacial dispersal of rocks, minerals, and trace elements in Wisconsinan till, southeastern Quebec, Canada; Geol. Soc. Am., Mem. 136, p. 189-219, 1974.

Shilts, W.W. The wealth the glaciers left behind; Geos, Fall 1974, p. 8-9.

canada centre for mineral and energy technology (CANMET)

D.F. COATES, Director General
V.A. HAW, Deputy Director General

Fiscal year 1974-75 saw the organization formerly known as Mines Branch renamed Canada Centre for Mineral and Energy Technology (CANMET). The new name was chosen to indicate that the diverse activities of the Centre covers disciplines other than mining, and to reflect the fact that the R & D work is now co-ordinated through two main programs—the Minerals Research Program and the Energy Research Program.

Within the context of EMR's Mineral and Energy Resources Program (MERP), CANMET's mission has been redefined as follows: To ensure the effective extraction and utilization of Canada's mineral and energy resources by:

performing, contracting and co-ordinating research on extraction, upgrading, utilization, conservation and environmental problems.

providing a technical knowledge base for developing federal government policies and plans.

providing the public, industry and governments with information on advanced technology.

This summary states CANMET responsibility for determining R & D priorities in the minerals and energy areas, for co-ordinating technological efforts of government and private research institutions, for performing and contracting required R & D not being performed elsewhere, and for maintaining an up-to-date knowledge base. There is no implication that CANMET is charged with funding all the work required either in-house or on contract.

The name-change to CANMET is but one detail in the wide-ranging reorganization of the former Mines Branch to improve CANMET effectiveness. The new management structure, which was in an advanced stage of implementation by the beginning of 1975, introduced a matrix system of managerial control in which activities will be planned and implemented through three programs—the Energy Research Program, the Mineral Research Program and the Minerals and Energy Information Program, all operating across revised discipline-oriented units. The former Mines Branch divisions and research centres have been reorganized into four main laboratory groups known as Energy Research Laboratories, Mineral Sciences Laboratories, Mining Research Laboratories and the Physical Metallurgy Research Laboratories.

Under this system the program directors are responsible for determining priorities and objectives and for issuing the detailed work element structure and related statements, budgets and schedules which specify what effort will be accomplished when it will be performed and which functional unit will be accountable. The functional units are under the management of laboratories chiefs, who in response to program demands, are responsible for determining who will perform detailed work elements, where they will be done and how they will be accomplished. In addition, functional management is responsible for ensuring that the disciplines, skills and equipment needed to meet program objectives are available when required. It is intended that both the program and functional management will co-operate closely in meeting their respective responsibilities. As of January 1975 the new CANMET structure was under the direction of the following officers:

Energy Research Program	- D.S. Montgomery
Mineral Research Program	- W.A. Gow
Energy Research Laboratories	- F.L. Booth
Mineral Sciences Laboratories	- R.L. Cunningham
Mining Research Laboratories	- T.S. Cochrane
Physical Metallurgy Research Laboratories	- S.L. Gertsman
Library Services	- G. Peckham
Mining Information	- A.S. Romaniuk
Editorial and Publications	- C. Mamen
Technical Services	- E.K. Swimmings

MINERALS RESEARCH PROGRAM

The Minerals Research Program has three component projects—Mining, Processing and Utilization.

Mining Project

Work elements in the Mining Project currently managed by CANMET either in-house or on contract are mainly concerned with the mechanical and physical problems associated with extracting efficiently as much of a mineral deposit from the earth as possible and delivering it to a processing plant. Underground and open-pit mining methods, rock mechanics, ground support, equipment development, working environment and waste and tailings management are some of the more important elements. Mining technology is not constrained by the particular mineral being mined and thus, broadly, mining may be characterized as a process or operations-oriented industry.

Most of the research activities of the Mining Project are located in the Mining Research Laboratories, but the Energy Research Laboratories and the Mineral Sciences Laboratories also participate.

Pit Slope Project—Year Three

The third year of the 5-year Pit Slope Project, directed toward improved control over stability of rock slopes, was completed. Research continued in the following task areas: groundwater, perimeter blasting, structural geology, mechanical properties, monitoring, design, artificial support, environmental planning and waste embankment.

The project, due for completion in 1977, will result in a comprehensive engineering manual for use by staff engineers at mining properties. The first phase of the project included the collection of information on each task, the performance of field studies and the writing of the first draft chapter of the manual. This phase was completed for all tasks except environmental planning, where more information is being gathered, and artificial support, where field trials are being continued.

The conversion of an open-pit mine to an underground operation is being used to investigate new open-pit monitoring techniques and finite-element procedures. For the past two years the movement of the hangingwall pit slope has been measured with laser-theodolite and glass prism targets in a zone where underground stopes are being broken through into the bottom of the open pit. Movements of up to 1¼ inches have been measured, mainly in a direction into the pit and slightly downwards. There is no obvious deterioration of the pit wall as a result of this movement. Physical testing of rock specimens has been carried out with samples of up to 9.65 in. in diameter. It has been found that the ore is stronger than either the hangingwall or footwall rock and the footwall shear zone possesses about 50% of the strength of the hangingwall shear zone. A survey of joints and tests on frictional properties of geological fractures indicates that rotational or toppling failure of the hangingwall pit slope is unlikely, but critical rock-mass wedges could be formed by intersecting joints, faults and shear zones. The mine co-operating in this research program is utilizing the information provided in planning the extraction of stopes near the pit floor.

Laser theodolite in position to observe targets on opposite pit wall.

Mining Methods Hold Promise

At the Elliot Lake Laboratory, research was continued on the undercut-and-fill mining method. In one mine the conventional technique was modified by suspending the wooden mat on rock bolts anchored in the crown pillar, rather than supporting it on wooden posts. The loads on two rows of bolts on the first cut were monitored as the next cut undermined the mat. The measurements clarified the extent to which load is transferred from the bolts to the surrounding fill.

In another mine, stresses, pillar deformation and fill pressures were measured in a 'post'-pillar mining operation. Results show that the pillars near the centre are supporting very little load and those at the edge of the workings considerably more load. This is the reverse of what is encountered in normal room-and-pillar mining.

Preparation of a design guide for fill distribution systems and preparation plants has progressed and a review of capacity requirements, flow velocities, pipe size and wear for vertical and horizontal distribution systems has been completed. A comprehensive questionnaire has been prepared to gather information from industry on existing preparation plants and distributions systems. Tests have been done on determining friction factor for vertical boreholes and measuring in-situ percolation rates for fill. In co-operation with an exchange engineer from the USSR, a laboratory study on the properties of cemented mill tailings has been completed. The reinforcement effects of mesh embedded in the fill and of cement plugs has been evaluated as part of this study.

Stress in the rock strata is an important parameter affecting all mining methods. In co-operation with a mining company and the Federal Geological Survey of West Germany, measurements of ground stress were taken at various depths down to 7,000 ft during 1974. The stress measurements are the deepest made to date in Canada. The horizontal stresses were found to be much higher than the vertical stress; they are also much higher than those measured at comparable depth in South African gold mines.

Equipment Improvements

Research on automation of a laboratory diamond drill was completed with the application of a control strategy using an analog computer. Research is continuing on the development of a control strategy and control devices for the automatic control of a raise borer. In co-operation with a mining company, data logging of the variables in pilot-hole drilling and reaming operations on raise borers has continued. A number of control devices have been developed and tested successfully. The inter-dependent variables, hydraulic pressure and motor current, can now be controlled to adjust to ground conditions and reduce the number of breakdowns of the raise borer.

A device has been built to detect the position of the drill bit in a borehole that fails to intersect an underground opening as intended. This device has been tested successfully in mines in the Sudbury area.

Prototype diamond drill developed under contract.

CANMET contracts worth $50,000 per year are being used to encourage research and development in diamond drilling. As a result of this program the prototype of a light-weight mobile drilling machine has been constructed and is ready for testing.

Toward Environmental Control

Research started at a uranium mine by personnel of the Elliot Lake Laboratory to measure the respirable dust produced by various mining operations was extended to other hardrock mines and mills in Ontario, Quebec and Northwest Territories. At each mine, measurements have been taken on operations such as: drilling in stopes and headings, slushing, loading and dumping by scooptrams, backfilling and underground crushing. The measuring technique used is long period size-selective sampling with gravimetric and X-ray assessment to determine total respirable dust, combustible dust, and quartz content. These measurements form part of a research effort to provide the technical base to establish uniform gravimetric sampling in Canada in the three dust categories. Further development work has been done on a personal dust sampler (CAMPEDS) mounted on the top of a cap-lamp battery; the purpose is to develop an instrument for routine use in Canadian mines. The Elliot Lake Laboratory's X-ray diffraction equipment has been used to carry out quartz

analyses on 1,000 samples submitted by government agencies, mining companies and consultants.

Because of the toxicity of quartz-bearing mine and quarry dusts, an extensive investigation of the detection of α-quartz in such dusts was made by Mineral Sciences Laboratories using quantitative infrared absorption spectroscopy. Calibration curves relating sample concentration to absorbance were established for samples deposited on polycarbonate filters. Forty-one potentially interfering silicate minerals were examined, the greatest appearing to come from some clay minerals. The sensitivity of the method makes it a promising alternative to other techniques for analysis of quartz in dusts.

A survey was completed on radon gas produced from various mining operations in a uranium mine. It was established that material handling operations (ore passes, crushing and slushing) produce the greatest amount of radon gas. It is thought that the values measured in this study could be used to define the quantity of ventilating air required at each operation to dilute the radon gas and radon daughters to acceptable levels. Progress has been made on improving the measurement techniques for radon and radon daughters, by developing a scaler unit which automatically accumulates the number of electrical impulses over a set period of time. This eliminates manual timing and visual estimate of impulse rate on a count rate meter.

The survey of noise produced by mining equipment, started in a uranium mine, has been continued in a base-metal room-and-pillar mine with very large rooms, and in the adjoining smelter complex. The purpose of the research is the identification of noise sources in mining and the development of noise survey procedures. The performances of commercially available noise dosimeters and noise exposure monitors are being compared. A study has been initiated on the attenuation characteristics of various ear muffs and the effect of external factors such as the wearing of safety glasses.

Toxic fumes generated underground by explosives have long been recognized by the mining community as a health hazard. Research has been started in the Canadian Explosives Research Laboratory with the objective of minimizing the hazard through a better knowledge of the mechanism of fume production. Theoretical and experimental studies are being made to improve the methods for calculating the fume production of any explosive formulation under conditions of actual use in blasting and to improve the experimental methods of testing.

New procedures are being devised to evaluate the hazards involved in the transportation of the new types of explosives and blasting agents becoming available to the mining industry. Large scale critical diameter and critical booster tests carried out at Suffield, Alberta, in co-operation with the Department of National Defence, have been evaluated. The results were considered at a meeting of the Ammonium Nitrate subcommittee of the International Group on Unstable Substances, held at the Canadian Explosives Research Laboratory.

Diesel exhaust emission studies

The Canadian Explosive Atmospheres Laboratory (CEAL) tested and certified a number of diesel machines and electrical assemblies for use in coal mines where an explosion hazard exists in the form of methane. Certification for a diesel machine for non-gaseous mines is also in progress. In the latter case, the investigation is concerned only with the effect of the exhaust emissions on the mine atmosphere. Explosion-proof mine lighting systems and fire-resistant conveyor belts and cables have also been certified.

Concern over the use of higher voltages (1,100V) in coal mines resulted in the investigation of the possibility of electric arcing developing during gas/air explosions in flameproof electrical apparatus. This showed that the proposed 1,100 volt equipment would probably be safe from this phenomenon but that 2,000 volts would require greater electrical spacings than conventional equipment.

A co-operative research program has been started by CEAL with the participation of the Ontario Mining Association, The International Nickel Company of Canada Ltd., and Deutz Diesel (Canada) Ltd., into the problem of diesel exhaust emissions in underground mines. A major portion of this research effort has been to assess the hazard associated with the particulates in diesel exhaust (diesel "smoke"). It has been found that close to 100% of these particulates are respirable and therefore they rival nitric oxide as the largest toxic component of diesel exhaust. It has been established that the use of catalytic purifiers does not reduce the output of carbon particulates, but the purifiers do have a "storage effect", releasing the "stored" carbon particles during the high load, high speed portions of the duty cycle. This phenomenon could be used to advantage if the ventilation in the mine were increased in the locations where the machines operate at their maximum speed and load.

An evaluation is also being made into the change in diesel emissions as a result of rebuilding the engines. As the load cycle also has a bearing on diesel emissions, a field load-cycle recording package has been developed to determine typical load data for various mining cycles.

The participation of CEAL staff on Canadian and International Committees for standards for electrical equipment in explosive atmospheres has been supplemented by various research projects such as "Ignition of Explosive Mixtures by Smouldering Coal Dust on Electronic Components," "The Dangers of Induced Spark-Over Currents to Ground from Steel Frames of Mining Machines," "Impact Tests on Transparent Parts of Flameproof Enclosures" etc. This combination of participation in standards writing reinforced by research projects is useful in establishing safe and practical standards and providing more meaningful certification services.

Revegetation—Returning the Land to Nature

During the year the first contracts on revegetation, part of the Pit Slope Project, were defined and awarded. These contracts are for the collection of data on physical, chemical and biological properties, including growth limiting factors, for asbestos, iron, coal and sulphide wastes at locations across the country.

Research on revegetation of uranium tailings continued; field plots established in previous years have been maintained. Some types of grass have shown vigorous growth and have expanded. Species of legumes have survived but are not spreading. An assortment of tree seedlings was planted in the treated and untreated areas of the tailings. Survival has been high after the first year. Soil profiles are being taken in the vegetated and untreated areas to follow the development of the soil and the accumulation of iron precipitates over the years. A study was done on the habitat requirements of soil micro-organisms in tailings at Elliot Lake. These micro-organisms are essential in promoting self-sustaining vegetation without the continuous application of fertilizers.

Field investigations on the contamination of water by tailings from ore processing mills were undertaken on ten tailings areas in northwestern Quebec during the summer of 1974. It was found that the effects of lime additions in lowering the acidity of the water decrease rapidly. The acidity of the drainage water appears to increase after it has seeped out of the tailings, but the extent of the pollution seemed limited due to the low concentration of solutes in the water. Mixtures of pyrite and calcite were studied using laboratory percolators, and these studies have demonstrated the importance of the ratio of pyrite to calcite in the mixtures and of the relative grain sizes of these minerals in affecting the acidity of water during the oxidation of pyrite.

Processing Project

The Processing Project is concerned with exploiting differences in the chemical and physical properties of minerals to develop processes for producing marketable products from both metallic and non-metallic ores. Consequently, it involves all processes from beneficiation through to final product such as metals, aggregates, refractories and sulphur. Currently the major concerns are the development of an economic process to increase recovery from complex copper-lead-zinc ores; the study of problems in processing of Canadian iron ores, the analysis of methods for removing cyanide from gold mine wastes; the determination of costs of producing alumina from domestic raw materials; and the development of non-metallic mineral-based materials for use in both construction under Canadian conditions, and for specific inorganic ceramics for high technology applications. Since process technology is a function of the mineral involved, it is commodity-oriented.

Selected problems in all stages of mineral processing are being investigated by the Mineral Sciences Laboratories.

Mineral Investigations Aid Ore Processing

Studies of complex lead-zinc-copper sulphide ores were directed mainly at determining the liberation characteristics of the sulphide ore minerals from deposits in northeastern New Brunswick, northern Ontario and Cuba. A Quantimet image analyzing microscope was used in these investigations to define the properties of importance in the ore dressing process. The accuracy of the mineral analysis was established to be within 3% absolute, but is generally ±5% of the amount present. Investigation of size-distribution analysis of minerals of economic value show that the optimum grind to liberate these minerals can be evaluated, and that the extent of liberation after certain degrees of grinding can be predicted.

Photomicrograph of Peace River iron ore showing rounded oolites in ferruginous opal

The mineralogy of the Peace River iron ore deposits was studied in connection with mineral dressing tests. The deposit contains 37 wt% iron and consists of oolites in a matrix of amorphous nontronite and ferruginous opal. The oolites are up to 1 mm in diameter and account for about 75% of the iron. They are composed of goethite (about 45%) interlayered with amorphous nontronite, and an average oolite contains 44 wt% iron. The results indicate that it may be possible to produce an oolite concentrate containing 42 wt% iron by gravitational methods, or a goethite—amorphous nontronite concentrate of the same grade by flotation.

Mineralogical studies of the platinum group minerals have continued and a new system of nomenclature has been developed for platinum-iron alloy minerals. The work on the mineralogy of the Tulameen River area placers in British Columbia has resulted in the recognition of some magnetic platinum minerals and the application of this information to obtain higher recoveries in beneficiation tests. The importance of understanding and defining the nature and distribution of the platinum-group elements in low-grade copper-nickel deposits has been demonstrated in a study of the Kanichee deposit near Temagami, Ontario. Several new or unusual palladium arsenide and antimonide minerals were studied, including the new mineral stillwaterite (Pd_8As_3) and an unnamed Pd_8Sb_3 mineral from Sudbury, Ontario.

An extensive study of the magnetic properties of pyrrhotites ($Fe_{1-x}S$) has been made by Mõssbauer spectroscopy and magnetic susceptibility measurements, using oriented synthetic crystals. The magnetic spin-flip transition at about 170°C and the structural α-transition at about 145°C in near-stoichiometric FeS were investigated and the related transitions were followed in compositions with lower iron contents.

The crystal structures of the stannite group of minerals are being determined. These minerals are found in a complex copper-lead-zinc-tin deposit in New Brunswick. Stannite, $Cu_2(Fe>Zn)SnS_4$, and the related mineral kesterite, $Cu_2(Zn>Fe)SnS_4$ have been investigated and work is proceeding on other members of this group. The mineralogy and phase relationships of these minerals are being studied concurrently with the crystallographic work.

Mineral Concentration of Problem Ores

Standard and innovative techniques for the separation and concentration of valuable minerals from complex and fine grained ores were investigated in the Ore Processing Laboratory.

Two investigations were done on complex copper-lead-zinc ores finely disseminated in pyrite matrix. One of these, a sample of ore from Santa Lucia, Cuba was studied as part of a technical aid program done at the request of CIDA. Despite the extremely fine-grained nature of the ore—much finer than any known Canadian ore—it was possible, by employing selective flotation, at a grind of 86% minus 500 mesh to produce lead and zinc concentrates assaying 29% lead and 46% zinc. Mineralogical examination confirmed that the sphalerite was essentially liberated from the pyrite at about 13 microns and that sphalerite particles down to one micron in diameter were being recovered. This technical aid program is to be continued with efforts directed toward the recovery of the zinc. The second investigation was on ore from the Caribou Mine near Bathurst, New Brunswick. The object of this work was to determine if a less selective flotation technique, which would give higher metal recoveries, could be utilized to produce lower grade concentrate, suitable for recovery by hydrometallurgy. A flowsheet was developed and confirmed in continuous pilot-plant studies. In all, 140 tons were treated to produce sufficient copper-lead and zinc concentrate for further hydrometallurgical studies.

An investigation was begun on methods of upgrading Peace River iron ore. This material is from a huge deposit of low-grade iron-bearing material in northern Alberta. The material is oolitic in texture, and ores of this type are usually difficult to treat by standard beneficiation methods. It is hoped that the silica content of the material can be reduced to an economical level. Five methods of treatment are being investigated; flotation of silica, selective flocculation of iron slimes followed by removal of silica slimes by decantation, gravity concentration, high-intensity magnetic concentration, and reduction roasting followed by magnetic concentration.

Preliminary results show that the insoluble content can be lowered from 23% to about 16% by gravity concentration or high-intensity magnetic separation, but recoveries are in the 50% range. A relatively inexpensive process incorporating flotation and selective flocculation has been developed to yield concentrates containing less than 15% silica with iron recoveries of about 70%.

A study has begun on the selective flocculation of sulphide minerals using high molecular weight polyacrylamides. Using a series of polyacrylamides of different molecular weights and ionic characteristics, it has been shown that sphalerite slimes can be selectively flocculated and separated from galena slimes by controlling the quantity of reagent used. The effect of polyacrylamides on pyrite have been investigated, and it has been found that pyrite behaves much like sphalerite. The use of modifiers will be investigated for separating pyrite and sphalerite.

A study was conducted to determine the gold and platinum content in the alluvial sand and gravel along the Tulameen River in British Columbia. This alluvial deposit extends for hundreds of miles along the river and supposedly contains sufficient precious metals for economic placer mining. Because of the free nature of the precious metals and their sparse dissemination in the gravel, no accurate estimate of commercial potential of this deposit has been possible. A 100-ton sample of the gravel was taken from various locations along the river and processed continuously in the mineral processing division pilot plant. A carefully controlled gravity concentration flowsheet was employed to concentrate and recover all of the precious metals from the sample. The concentrates produced were further upgraded in the unit processing laboratory and the native metal recovered and assayed. By means of controlled samples of the gravity tailing and accurate analysis of the recovered gold and platinum metals, calculated feed assay of the whole shipment was obtained. Although some native gold and platinum were recovered by the process, the amount was small and the head assay revealed the deposit to be of no economic significance.

During the year projects related to marl from Saskatchewan and talc from Ontario and Quebec, showed some of the problems that would be encountered relating to their processing industrially. Floatability studies on industrial minerals were continued and a Technical Bulletin was issued on the results. Further work on electronic sorting was continued and a chapter related to electronic sorting was prepared for a new AIME Handbook.

An industry-sponsored project was successfully completed by the staff of ERL on the application of a 2-stage compound water Cyclone system (CWC) for recovery of fine gold lost in the sluice boxes of a placer operation in the Yukon.

Leaching Processes for Metal Extraction

Studies continued on the application of hydrometallurgical methods for recovering values from Canadian low grade and difficult-to-process ores.

Using column apparatus, a series of percolation tests were made on pyrite zinc-lead-copper ore from Bathurst, New Brunswick. The development of a leaching process for such ores would provide a bulk concentrate of intermediate grade but high metal recoveries. Currently, high grade concentrates are being produced, but the overall recoveries are poor because of the need to maintain the high concentrate grades. A leaching process could also remove much zinc and copper from the stockpiled tailings. Not only are these metals currently being lost to the tailings, they also constitute a serious pollution problem.

Under proper conditions, percolation leach experiments with ferric chloride solution revealed metal extractions from crushed mine ore of nearly 100% in Zn, 75% in Pb, but very little in Cu. There appears to be a galvanic effect operative during the leach action; the zinc dissolves first, then the lead, and lastly, the copper. The dissolution rates for both lead and zinc increase directly with increasing flow rates used in commercial percolation leaching practice and with increasing ferric ion concentrations.

Work on the percolation leaching of chalcopyrite ores with ammonium hydroxide-ammonium carbonate solutions yielded encouraging results. The use of ammoniacal solutions for leaching low-grade copper ores shows promise for both mixed oxide-sulphide ores and for ores containing large amounts of acid-consuming gangue. Since such solutions do not dissolve iron, they could also be utilized for leaching ores high in acid soluble iron without presenting a serious solution treatment problem. In fact, the high purity of the pregnant solution obtained in recent tests should greatly facilitate subsequent copper recovery.

A project to study the application of electrochemical methods to the dissolution of copper sulphides has the objective of obtaining metallic copper and elemental sulphur directly from flotation concentrates in one step, thereby eliminating smelting and converting processes. An important implication of this direct formation of elemental sulphur is that it avoids pollution by SO_2 produced by the conventional pyrometallurgical techniques. The anodic dissolution and polarization behaviour of synthetic chalcocite (Cu_2S) and covellite (CuS) using both compacted or pellet anodes and fluid-bed anodes in several types of electrolytes are currently being investigated.

Anodic dissolution of copper sulphides was found to proceed smoothly in a non-aqueous medium that dissolves the sulphur deposit on the anode and thereby reduces the overpotential encountered in the final stages of electrolytic dissolution. A new method of processing chalcopyrite by cathodic dissolution was found, whereby iron goes into solution, sulphur comes out in elemental form, and covellite remains in the solid phase for further processing.

Solution Purification by Solvent Extraction

Solution treatment studies were continued for the purpose of obtaining better separation and higher recoveries of the valuable metals in leach solutions, and also to produce environmentally acceptable effluents.

Previous investigations revealed that Kelex 100, a quinoline derivative, was a suitable solvent for extracting various metals from acidic solutions. Recent work proved this reagent to be effective in extracting and separating copper, cobalt, nickel and zinc from ammoniacal solutions of carbonates or sulphates. The metals were readily recovered by stripping the loaded solvent with sulphuric acid, except for cobalt if it was in the cobaltic state.

To understand and predict the extraction of metals in solvent extraction processes, investigations were carried out on commercially available chelating extractants, so-called metal-specific extractants. Isolation of the pure isomers of the primary 2-hydroxybenzophenone oxime (LIX Reagent) has been completed, together with determinations of their proton-ligand stability constants. Studies on the structures of these isomers have revealed how they are hydrogen-bonded, which explain many of the properties of the reagents and which go a long way toward determining the mechanisms involved in metal-extraction processes. More mechanistic studies are planned in the near future, together with the determination of metal-ligand stability constants.

In designing a process for solvent extraction, proper selection of the diluent and modifier can be almost as important as selecting the extractant, and, because of the effects on phase disengagement the diluent and modifier can exhibit, the economics of a process can be seriously affected. Investigators have found that not only are diluents and modifiers not "inert" to the solvent extraction process, but that they can play a very substantial role in determining the success of an operation.

Work was directed toward attempting to evaluate diluents and modifiers by investigating various chemical and physical parameters in real extraction systems. The results showed that one may select the best diluent or modifier for a particular process, by considering the chemical components of the diluent, or its physical characteristics such as the dielectric constant, polar nature, and solubility parameter. The effect of the modifier and diluent in the extraction process can differ greatly from that found in the scrubbing and stripping operations, both from the standpoint of mass transfer and kinetics, and also from the aspect of phase disengagement and solvent entrainment tendency. The rate of phase disengagement may, in the final analysis, be the determining factor in the selection of the diluent and modifier for a particular system. Their proper selection can affect the size and type of contactor as well as the overall efficiency for a solvent extraction system.

One of the aspects of solvent extraction investigation at CANMET is the study of extraction equipment, and how the extraction system can play a major part in determining the best contactor for that particular process. The object of the work in progress is to compare the various parameters of flow capacity, mass transfer, separation efficiency, and coalescence, of several different contactors, and to attempt to relate these comparisons with the economics of plant operations. The system chosen for the comparison study is copper, zinc, and nickel, using Kelex 100.

For designing mixer-settlers, work was initiated, in co-operation with the University of Bradford, U.K., based on tests for exploring the behaviour of both mixer and settler using two commercial copper extractants, to obtain equipment design data with a minimum of experimental work. The program consisted of attempting to correlate degree of agitation, time of agitation, and phase ratio, with droplet size, rate of mass transfer and coalescence rate in various solvent extraction systems. A proper understanding of these parameters would facilitate the design of solvent extraction plants.

For designing a column extractor, processing plants are faced with a multitude of choices for proper equipment to effect the desired mass transfer. Because each contactor has its particular advantages and disadvantages the selection is often based on economics, other things being equal. One type of contactor is the sieve-plate pulse column. Many types of devices have been suggested and used in the past to supply the energy to such extractors, but in all cases the capital expense was high. Diaphragm pumps have been the most common of the devices used to supply the energy to the sieve-plate pulse column. The use of compressed air to pulse a column was suggested as an alternative to the expensive diaphragm pump. Following an initial design and construction, the air pulsing device was evaluated on a 2-in. diameter pulse column. The parameters of air pressure, volume, orifice diameter and position, and water pressure were studied for their effect on pulse frequencies and thus on mass transfer.

Hydrometallurgical treatment of ores or concentrates frequently produces leach liquors containing significant concentrations of iron, which usually must be removed prior to recovery of the metal values. To accomplish this the iron is often removed as a jarosite-type compound. A general program was therefore undertaken to characterize jarosite compounds and relate their conditions of preparation with their physical and chemical properties and their applicability to iron removal from acid leach liquors.

Nickel carbonate recovered from leach solutions by precipitation usually contains commercially unacceptable concentrations of magnesium due to co-precipitation. This co-precipitation mechanism has been satisfactorily established, and conditions have been defined for producing nickel carbonate containing >0.1% Mg, which is commercially acceptable.

Investigational work continued on the electrowinning of zinc from commercial electrolyte supplied by Cominco. The objectives of this work are to improve current efficiency, product purity and cathode stripping characteristics.

Developments in analytical chemistry included atomic absorption methods for silicon and for metals dissolved in organic solvents, and the application of ion exchange for rare earth separation and concentration. Extended use was made of computer programs for analysis, research, and statistical studies on minerals.

Environmental Protection Integral Part of Hydrometallurgy

The area of environmental pollution most pertinent to hydrometallurgical extraction processing is that of water pollution, and consequently the toxicity of solvent extraction reagents to aquatic life becomes important. Thus, the primary consideration in the development of water quality standards with respect to these reagents is to determine their toxicity toward fish, and their biodegradability.

In co-operation with the Ministry of Environment of Ontario, a joint program was undertaken to assess the relative toxicity that the various solvent extraction reagents had on aquatic life. Preliminary results indicate that most diluents are non-toxic up to at least 100 ppm concentration, although there were some exceptions among the diluents tested.

Because organic losses from solvent extraction processing constitute an economic as well as an environmental problem, investigations were undertaken to study methods for their removal from aqueous effluents by adsorption with activated carbon. Preliminary results showed that carbon possessed the necessary properties for reducing these reagents down to trace levels of 1 ppm or less.

Electrolytic and precipitation techniques are often considered as methods of separating soluble metals from solution. Separation by selective sorption techniques are seldom considered in hydrometallurgical processing. For this reason, the feasibility of separating metallic cations as chloro-complexes on an anion exchanger was examined.

At present, the toxic heavy metals, nickel, copper and zinc, in waste streams may be concentrated 10 to 20 times on a cation exchanger, then desorbed to precipitate a bulk product by neutralization. Alternatively, the metals may be selectively separated as chloro-complexes and recovered by neutralization of the effluents. Using this system, a series of experiments yielded (1) products containing 95% NiO and 95% ZnO from the separation of nickel and zinc, and (2) products containing 73% CuO and 97% ZnO from the separation of copper and zinc.

Corrosion and Wear in the Mineral Industry

Corrosion research is aimed at reducing the costs of corrosion and wear and conserving materials. This is accomplished by identifying and classifying these problems and by developing and promoting more effective methods for reducing their effect.

Investigations were continued in wet grinding media to evaluate the effectiveness of various inhibitors for reducing the corrosion-erosion rate of commercial grinding balls. Tests were carried out using both sulphide ores and iron ores (hematite), and a corrosion mechanism in the latter was proposed. Cathodic and anodic protection were also investigated and found to be ineffective. Sodium metasilicate, borate, carbonate, phosphate and acetate were shown to act as inhibitors of corrosive wear in the grinding of iron ores; percentage reductions in ball wear were in the range of 15 to 36%. Sodium nitrite, chromate and metasilicate were the most effective corrosion inhibitors in the milling of sulphide ores.

A study on the effect of inhibitors on the corrosion of steel by acid mine waters was also carried out. Evaluation of the results indicated potassium oxalate afforded excellent protection and functioned at 93% efficiency.

A laboratory investigation has shown that hexamine is an efficient accelerator for the formation of phosphate conversion coatings on mild steel and so promotes improved corrosion protection.

In electroplating research, a process for producing crack-free chromium platings has been developed and the results published. A new process for plating bismuth on copper for electronic application was also developed. Work on a chromium-nickel alloy plating process has been started with investigations of cathode potentials during the separate plating of nickel and of chromium.

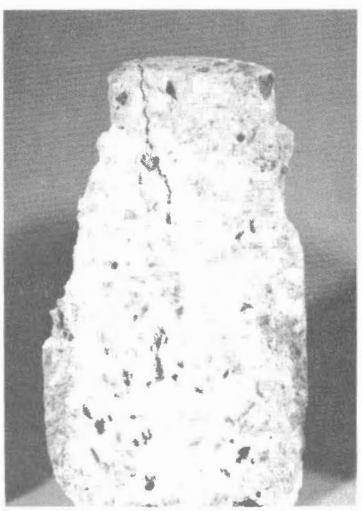
Certified Reference Materials Invaluable to Analysts

In commercial transactions involving mineral and metallurgical products, both the purchaser and vendor must be able to make reliable determinations of the valuable metal contents of the consignment. This implies that there must be reliable and accepted methods of analysis available, and that there should be certified reference materials against which an analyst may test a method of analysis.

The objective of the Canadian Certified Reference Materials Project is to provide homogeneous, carefully analyzed samples of ores, concentrates, mattes and alloys suitable for use in testing analytical methods. Carefully homogenized samples are tested by a number of laboratories experienced in mineral and metallurgical analysis. Results are evaluated by statistical procedures to arrive at a best value for certification and at confidence limits for this value. Although part of the analytical work is done in CANMET laboratories, the excellent co-operation of industrial and commercial laboratories has been vital to the success of the project. Conversely, participation in the project can be of benefit to the co-operating laboratories, as difficulties in their analytical procedures, which previously had not been evident, may be revealed in the course of the careful analytical work required for certification and by the comparison of the results with results from other laboratories.

During 1974-75 the certification of the following reference materials was completed: a zinc-lead-tin-silver ore (KC-1) certified for the four metal values, a gold ore (MA-1) certified for gold only, and six radioactive ores certified for uranium and thorium. In addition, seventeen materials certified previously are also available for sale. Materials currently being processed include five ores, two rock samples, a blast furnace slag, and both ferrous and copper alloys for use as standards in emission spectroscopy.

In the development of standard methods of testing, active contributions are being made through participation in the Canadian Advisory Committees of the International Organization for Standardization. For example, significant contributions have been made to the development of standard sampling methods and methods of chemical analysis for iron ores. The existence of recognized methods for assessing the quality of mineral products facilitates international trade in which Canada has a vital interest.



Sulphur-infiltrated concrete. Compressive strength 14,500 psi at 56 hours

NEW DEVELOPMENTS IN NON-METALLIC MINERAL PRODUCTS

Research has been done for the purpose of producing concretes with high strength at early ages at a price competitive with conventional concrete or cheaper. Expensive monomers that require high pressure to impregnate the concrete were ruled out. Instead, simple and effective procedures for using cheaper materials such as sulphur were sought. The research work has resulted in the development of sulphur infiltrated concrete. Briefly, the method consists of moist curing lean concrete specimens for 24 hours, drying them at 120°C for 24 hours, immersing them in molten sulphur under vacuum for two hours, releasing the vacuum and soaking them for an additional half hour, then removing them from the sulphur to cool. They are tested one to two hours later.

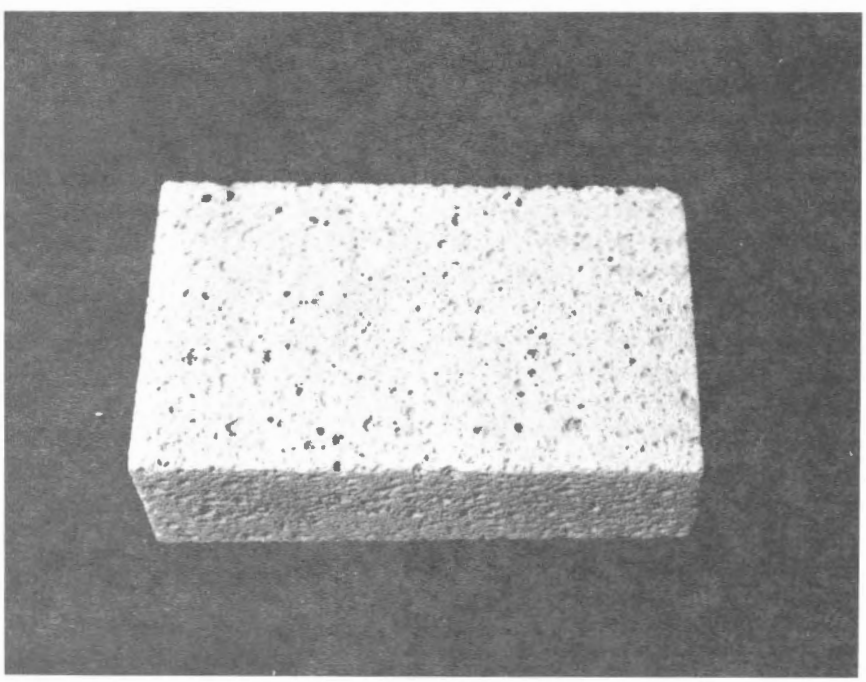
Phenomenal increases have been obtained in the mechanical and elastic properties of sulphur-infiltrated specimens. The compressive strengths increased up to fifteenfold over those of reference moist-cured specimens, which were about 7MN/M² (1000 psi).

A corresponding increase was observed in the flexural strength of the infiltrated test specimens. The infiltrated specimens perform excellently under freeze-thaw conditions. This new type of concrete should find wide application in the precast concrete industry for the manufacture of curbs, staves for farm silos, patio slabs, precast sidewalks, concrete poles, and railway ties.

The Ceramic, Non-Metallic and Waste Minerals, and Construction Materials Sections carried out work on energy conservation through research on minerals and their products. This work has involved development of materials suitable for insulation, study of processes involving high temperatures, and initiation of studies related to development of minerals having insulating properties. For example, it has been successfully shown how waste glass can be used as a raw material for lighweight aggregate manufacture and foamed insulation materials. A very comprehensive monograph on the production, properties and applications of lightweight aggregates is under preparation.

Theoretical studies showed a potential possible energy saving of (a) 36% for a rotary calcining operation for lightweight aggregate through utilization of waste heat to preheat both feed and combustion air and (b) 5.5% in production of fibre glass through substitution of diopside for equivalent individual raw materials.

In addition to utilization of waste glass for possible production of insulating products, other uses of mineral wastes were studied because of the possible need for development of processing industries in depressed areas, improvement of the environment, and for conservation of our natural resources. Twenty mineral waste samples were examined during the period; some of them potential raw materials for fertilizer, aggregate in concrete, and other applications. Research conducted in co-operation with Agriculture Canada showed



Rigid insulating material made with foamed waste glass

pelletized cement kiln dust that contained excessive amounts of soluble potassium and calcium to be a potential soil additive of particular interest as a liming material for acid soils. Similarly, high lime tailings from a mine at Oka, Quebec, were found to be of potential value as a soil additive for the acid soils of the Eastern Townships of Quebec.

Waste sludge from a fine paper plant at Thorold, Ontario, consisting of a mixture of wood fibre and filler clay, was separated into two products, one primarily wood fibre (80%), the other primarily filler clay (80%), by a differential flocculation technique. These products have considerable re-use potential in paper manufacture.

Instrumentation and techniques for determining the magnetite content of milled asbestos fibre were successfully developed and tested in a joint research program with the Geological Survey of Canada. Samples of fibre from various locations in several asbestos mills were evaluated. Results indicate that this technique is of value for quality control purposes in operating mills.

Security of Supply of Alumina

A joint, co-operative program with the U.S. Bureau of Mines was initiated in which studies were started to determine the feasibility of producing alumina (aluminum) from Canadian indigenous, non-bauxite sources, e.g., anorthosite and underclays (coal shales). Arrangements have been made to ship samples of anorthosite and limestone from the Arvida area of Quebec to a mini-pilot plant at Boulder City, Nevada, for preliminary trials and evaluation.

Utilization Project

The Utilization Project has two prime concerns. The first is improving processes by which metals are fabricated and processed into useful products. The second is developing the optimum properties and performance of metals and alloys required to solve Canadian materials problems. Current specific concerns under the Utilization Project include excessive wear of rail steel; corrosion of grinding steel; low-temperature fracture toughness of castings; welding of high strength, low alloy steels; increased emphasis on metal-working processes, particularly rolling; developing techniques for continuously casting small sections; and developing economic processes for recycling scrap and utilizing waste materials. It is apparent that the Utilization Project is in part operations-oriented and in part properties-oriented.

There is no environmental project as such in the Minerals Research Program because environmental problems are integral components of mining, processing and utilization systems and should not be considered in isolation. Consequently, activities in each of the projects include R & D on environmental and other social problems where their impact on the total system warrants it.

Investigating Vacuum Loading

A film test simulating the industrial process was devised by CANMET'S—Physical Metallurgy Research Laboratories to assess plastic films for the vacuum moulding process (V Process). In this test the films are heated under a gas-fired infrared heater and then drawn down onto a pattern of cups of equal depth but different diameters. Heating times are varied and the thickness of the films at the bottom of the cups where maximum deformation occurs are measured. The required film thickness appears to be dependent on the casting size as well as on grain fineness of the sand.

The possibility of casting magnesium in V-process moulds was investigated. If, when silica sand is employed, the plastic film lining the casting cavity is sprayed with teflon, it was found that this would inhibit the reaction between the silica sand and the magnesium. If zircon sand is employed, no inhibitor is necessary, and thin section magnesium castings can be readily poured in the V process.

Injecting Magnesium Wire

Work on the nodularization of cast iron and the desulphurization of pig iron by the injection of magnesium wire into the molten metal has been continued. The wire is fed through a horizontal plug at the base of the treatment ladle which contains 550 lb (259 kg) of iron. The technique developed is very reliable and the injection operation has become routine. Within the ranges available, metal temperature and speed of injection have little effect on the magnesium recovery. Nitrogen gas pressure at the nozzle, necessary to prevent blockage, has an adverse effect. The feasibility of one-step desulphurization and nodularization to produce ductile iron directly from a high sulphur melt has been demonstrated.

Effluent Abatement

A packed-bed unit capable of handling 600 lb coal/hr (272 kg/hr) has been constructed at the Corkstown Road Laboratories. This was designed to dry and preheat experimental blends of coal to be charged into the movable-wall coking oven at this site, as well as for the evaluation of a commercial coal dryer and preheater. The unit is now operational and has fulfilled all the requirements expected of it. A commercial size unit capable of handling 7,500 cfm (212 m^3/min) of hot gases is currently under construction. The new commercial unit should be adaptable to any cupola melting up to about 8 tons/hr.

Recycling of Tin Cans

One means industry has available to it of conserving materials and energy is to recycle and utilize materials reclaimed from waste. A Physical Metallurgy task group has been examining the problem of recycling cans from municipal waste. The metal in these cans is seriously contaminated with

undesirable impurities such as tin, aluminum, copper and lead. The steel industry is particularly concerned for the possible long-term recycling of tin-containing scrap metal. Effective recycling of the iron fraction from Canadian municipal solid waste could be markedly influenced by such factors as mandatory refundable deposits on certain cans, increased use of tin-free steel, and the banning of easy-open cans. The removal of impurities from tin can scrap, however, presents complex technological difficulties.

Galvanizing Iron Single Crystals

Hydrogen-atmosphere galvanizing of single crystal and polycrystal samples of four different types of iron with various surface pretreatments has shown that enamalling iron, Ferrovac E, and Cleveland (Armco) iron galvanize normally, independent of crystallographic orientation.

Silicon in steel promotes acclerated galvanizing reactivity. A means of controlling this undesirable effect is being sought. Preliminary exploratory work has indicated the possibility of developing a technique capable of producing conventional coating structures on silicon-containing low-alloy high-strength steels.

Welding and Lamellar Tearing

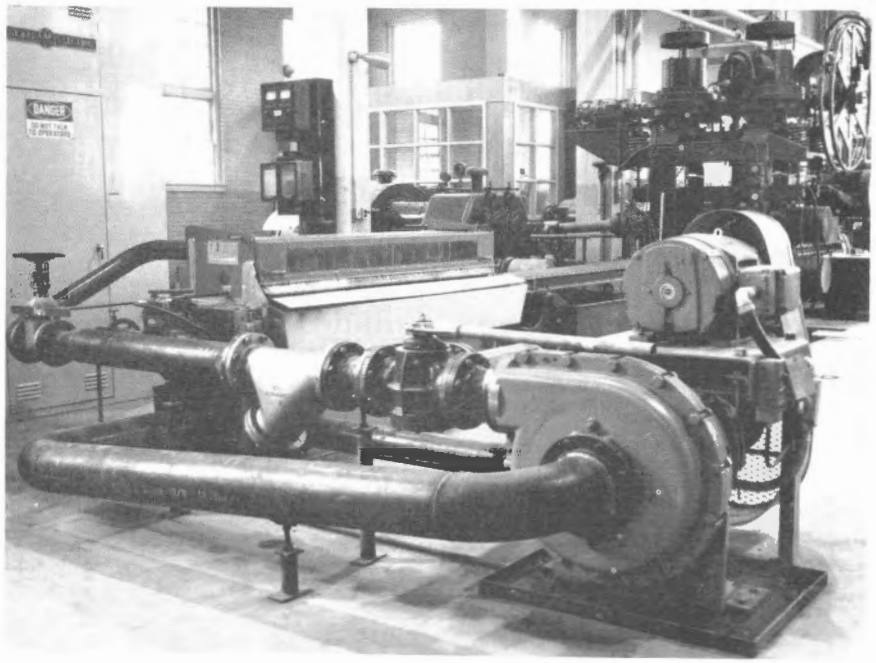
Various welded structures provide conditions for the occurrence of lamellar tearing. This phenomenon is the failure of steel in the through-thickness direction, i.e., in the rolling plane. The ability to test mechanical properties in the through-thickness direction is normally limited by plate thickness. There is a critical thickness below which such testing becomes practically impossible.

A simple method has been developed for testing steels at the shop level with minimum demands on skill, equipment and the amount of material required. This test has the ability to discriminate between different materials in terms of their susceptibility to lamellar tearing.

Metal Forming—Hot and Warm Working

The hot-working tests on C-Mn steels conducted on the Cam Plastometer show that the carbon level does not effect the hot-working stress in the austenite range; it does, however, have a marked effect in the ferrite-carbide range by increasing the flow stress with increasing carbon content. These C-Mn steels also show a flow stress independent of temperature in the austenite-ferrite temperature region. This can possibly allow lower working temperatures without subsequent raising of the working loads.

The HSLA steels were tested using a Cam Plastometer technique that allowed two deformation cycles with controlled cooling between each to simulate thermo mechanical treatments. Initial testing has shown some effect due to the Nb on the hot working of the austenite. The main effect of the Nb is to retard recrystallization.



Overall view of the spray quench and hot-rolling mill

Alloys for the Arctic

The research program on the environmental cracking (EC) of 18% Ni (200) maraging steel was completed by PMRL. The result indicated that this alloy was not suitable for marine use as it is susceptible to environmental cracking under conditions likely to be encountered. The chief emphasis of the work has now shifted to HY-130 steel, regarded as the most promising material for the foils system of a future hydrofoil craft. The results on preliminary EC evaluation have been promising and low-cycle corrosion fatigue tests are now underway.

In checking on the corrosion behaviour of metals in the Arctic, specimens of three structural steels were retrieved after exposure to atmospheric corrosion for one year at a site near the Arctic Ocean at Tuktoyaktuk, N.W.T. These specimens showed equivalent corrosion rates of 0.61 to 0.64 x 10^{-4}in./yr (0.015 to 0.016 mm/yr). Additional specimens are still on test that can be retrieved at planned intervals, to get a more complete picture of corrosion behaviour at this site.

Attempts to study corrosion of specimens immersed in deep water in Jones Sound in the Arctic Islands have so far been unsuccessful due to failure to retrieve. Two attempts were made and another will be made in 1975. The Department of National Defence is co-operating in this experiment. Experience to date points up extreme difficulty of planning and executing aqueous corrosion tests in Arctic sea-water and the low success ratio which can be expected. Considerable expenditure of time and effort have so far led to minimal results.

Corrosion Resistance of Austenitic Stainless Steels

Research is continuing in co-operation with the Endako Division of Placer Development Ltd., in British Columbia, on the evaluation of the localized corrosion resistance of Cr-Ni-Mo and Cr-Ni-Mn-Mo austenitic stainless steels. Recent results have indicated the superiority of the manganese-bearing alloys. In the composition ranges study, both molybdenum and chromium additions are effective in increasing the pitting and crevice corrosion resistance, whereas variations in nickel and manganese have little effect.

Work on the properties of low-carbon martensitic stainless maraging steel has now been completed. It has confirmed that the use of beryllium alone as a hardening element rather than in combination with titanium, is preferable in these stainless maraging steels. Titanium appears to reduce the annealed hardness and hence the strength attainable by ageing. For similar strength levels, the presence of titanium appears to result in lower tensile ductility and lower impact properties, particularly at sub-zero temperatures.

Non-Ferrous Alloy Investigations

The very low ductility of titanium alloys containing Ti_3Al has been investigated by examining ternary alloys containing titanium, aluminum and gallium. An alloy composition of Ti-12 at .% Al and 12 at .% Ga shows good ductility on quenching from the single-phase β field, but this ductility is lost on ageing at 300°C (572°F) and above. It is concluded that the low diffusion rate of gallium results in suppressing the formation of Ti_3Al on quenching. However, this embrittling phase does form during subsequent ageing. This investigation has now been completed.

The family of cobalt-nickel alloys, termed multiphase alloys, utilizes the allotropic phase transformation in cobalt to achieve high strength through deformation while retaining excellent ductility. Because TRIP steels, which are similarly strengthened, have been found to possess poor fatigue resistance, the fatigue properties of the Multiphase Alloy MP35N (35% Co-35%Ni-20%Cr-10%Mo) are being determined for conditions of alternating axial tension and compression. Fatigue tests of work-strengthened materials indicated a fatigue strength at a life of 10^7 cycles of only ~25% of the ultimate tensile strength. Work-strengthened and aged material showed about the same relationship of fatigue strength to ultimate tensile strength.

The Bureau of Medical Devices, Department of National Health and Welfare, has advised of the need for a critical evaluation of stainless steels corresponding to AISI 316 or 316L for metallic implants in the human body. These steels are commonly used for this purpose although their resistance to crevice and pitting corrosion is marginal. Advice is being given on the minimum acceptable specifications in preparation of a draft CSA Standard for surgical stainless steel.

ENERGY RESEARCH PROGRAM

CANMET energy research which also involves development and technology is chiefly concerned with assessing quality of the energy resources—gas, oil, coal and radioactive metals, with the improvement of processing technology, and with solutions to pollution problems arising out of the beneficiation and use of fuels. Endeavours are made to ensure that Canada's resources of energy minerals are developed, processed and used in the best interests of present and future generations of Canadians.

The energy program has three major activities—Supply, Processing, and Utilization which are briefly summarized as follows:

Supply of Fuels

The general objectives are to augment the supply of energy from fossil fuels to alleviate the shortfall of domestic oil and gas supplies projected for the 1980's; and to augment

the uranium supply necessary to satisfy the Canadian needs and export requirements from 1980 onward.

Specific objectives are:

To assess coal resources and to develop sufficient reserves to support a tenfold increase in Canadian production to 150 million tons per year within 15 years; and to develop the new and improved technology which will be necessary to mine the required volume of coal economically, with minimum waste and damage to the ecology and environment.

To assess quality of the oil contained in heavy oil and bituminous sand resources with the aim of accelerating their development to supplement declining supplies of conventional oil and gas; to improve mining technology in the Athabasca area and in-situ technology at Peace River within a decade; and to develop in-situ technology to reduce the cost of recovering heavy oils from the Lloydminster field.

To reappraise uranium reserves with respect to mineability criteria; and to develop mining technology for recovering ore from existing pillars and to minimize future losses, thereby increasing reserves and production accordingly to help meet 1980 requirements.

Oil

The oil embargo imposed by the Middle East oil producing countries has emphasized the necessity of developing Canada's low-grade oil resources and bituminous sands. The Energy Research Laboratories has increased research efforts to study the chemical composition of these oils in their natural state, as well as after thermal treatment and hydrocracking. This information is needed for the process design associated with the production and refining of this class of crude oil.

The refining of Canada's low-grade crude oils is complicated by the presence of large amounts of chemically bound vanadium nickel and iron, 1% mineral matter, and 5% sulphur which must be removed. CANMET has developed a high pressure thermal hydrocracking process which removes essentially all of the metals and mineral matter with the pitch and produces a low viscosity distillate oil for subsequent catalytic desulphurization treatment. The advantages of this process are first, that production of waste coke is eliminated; second, the amount of pitch produced, which is easily gasified, can be varied as energy requirements dictate, and third, the yield and quality of distillate oil produced is high. The operating conditions, product yields and process balances have been sufficiently well worked out on a pilot scale that government and industry are considering construction of a small commercial hydrocracking unit to evaluate the process on an industrial scale.

The distillate oils produced by thermal hydrocracking require further refining to remove the sulphur and nitrogen and to reduce the aromatic content. Investigations were therefore made to determine the optimum catalyst arrangement and formulation for the production of low-sulphur fuel oils suitable for commerce. For this purpose, gas-oils produced by delayed coking as well as thermal and catalytic cracking were studied. It was found that the concentrations of active metals on the catalysts required for the removal of the sulphur and those required to eliminate the nitrogen and to convert the aromatics were quite different. Whereas active catalyst loadings of 3 wt% of cobalt molybdate were quite effective for desulphurization, 13% to 15% were required to remove the nitrogen to acceptable levels.

The production of synthetic natural gas from coal has attracted considerable attention, particularly in regions of Canada that are short of natural gas but where coal resources exist. An engineering cost estimate was therefore made to determine the lowest cost at which natural gas could be made from coal using existing technology on the scale of 690,000 cu m (250 million cu ft)/day. This will provide a convenient means of estimating the influence of the cost of coal, water and electric power on the cost of natural gas produced via this process.

The increased exploration activity in the Arctic in search for oil has stimulated the search for better methods of characterizing oils and hydrocarbon residues found in drill chips, to determine the extent of thermal maturation of the oil. This is intimately connected with the need to develop a better understanding of the generation of oil in western and northern Canada as an aid to exploration. In this connection the research on the chemical composition of Athabasca bitumen has resulted in the development of improved analytical techniques which have already proved their value in oil spill detection, and the characterization or fingerprinting of crude oils. This capability has already revealed interesting differences in the Canadian Cretaceous oils of the tar belt which can only be due to differences in the organic source material. It is also possible to gain an insight into the extent of thermal maturation to which the crude oil has been subjected throughout geological time. The changes in composition of the mononuclear aromatic class of compounds appears to offer a much superior indicator of the past thermal history of crude oils than compounds in the saturated class that are used at present. This promises to be an interesting and useful tool for oil exploration in the Arctic and offshore on the east coast.

Coal Resource Evaluation

Since 1972 Canada and the Province of Saskatchewan have been co-operating in a jointly financed program to evaluate the lignite resources in the Ravenscrag Formation of southern Saskatchewan.

In 1972 and 1973 a two-phased drilling program was conducted in the four major areas, Estevan, Willow Bunch, Wood Mountain and Shaunavon. During this program more than 700 bore holes were drilled and more than 6,000 coal samples were obtained.

Drilling for lignite in Saskatchewan. Dr. D. S. Montgomery Energy Research Program Director observing operations

This is the first assessment of the lignite resources of the Ravenscrag Formation that includes a detailed study of the quality of the lignite. The analyses of almost 5,000 coal samples were completed at an overall cost to CANMET of more than $350,000. Detailed description of the quality of the lignite as evaluated by the sample analyses are available to the governments and will be published.

A system of electronically recording and manipulating the analytical data has been developed by CANMET and the Saskatchewan Research Council. All analytical data has been stored on computer tape and presently programs are being developed to permit a "marriage" of the coal chemistry and the coal geology of the Ravenscrag Formation to form a complete qualitative and quantitative assessment of the lignite resources of Saskatchewan.

In addition to the assessment of samples directly associated with resource inventory, bulk samples of lignite were acquired from selected sites in the Estevan and Willow Bunch areas where the lignite had been determined to be very high in mineral matter content. These samples were studied to determine the potential for beneficiation and combustion. Appropriate tests indicate the problems associated with burning the raw coal and the relative ease of reducing the ash content by mechanical cleaning processes.

Coal samples being dried for further processing in the analytical laboratory

A co-operative program to evaluate the coal resources of Nova Scotia was initiated with the Nova Scotia government. This program started in June 1974 and is to be completed in the next three years. The diamond drilling and core recovery is carried out by the Province of Nova Scotia and CANMET is the designated laboratory responsible for performing all analytical work on all coal samples obtained from the program. The CANMET facilities at Point Edward Park, Sydney, Nova Scotia are being used to their fullest extent.

The program involves plans for drilling in several districts of Nova Scotia. In 1974-75 drilling was concentrated in the Albion and Westville Districts including the Foord and several other coal seams. Almost 600 samples, including one-foot intervals and composites, were analyzed and initial steps were taken to allow electronic data recording and processing compatible with anticipated national coal data bank.

Ground control studies avoid productional loss

The western office of the Mining Research Laboratories in Calgary, contributes to the Coal Project through research activities in ground control, environmental control and mineability.

Room and pillar mining with subsequent extraction of pillars is a major mining method in the coal mines of western Canada. Strata-control and geological problems encountered during the pillar extraction phase often result in the abandonment of blocks of coal, which leads to shortfalls in production and eventually to early closure of mines. Research is being conducted with the objective of providing new information on which solutions for these problems can be based.

During the year, instrumentation was installed by MRL staff to monitor the deformation of pillars and roadways at seven sites in a mine where mining by retreating pillar extraction was initiated in 1973. Preliminary analysis of the data indicates that a zone 400 feet wide behind the break line is affected by depillaring. The extraction ratio within the

affected zone directly influences the degree of floor heave and pillar deformation.

In another area a two-mile beltway is being driven about 400 feet above a producing mine and interaction between these two operations is of concern. Borehole instrumentation which detects strata movement through the movement of brass rings grouted into a borehole has been tested.

Point Edward Park laboratory

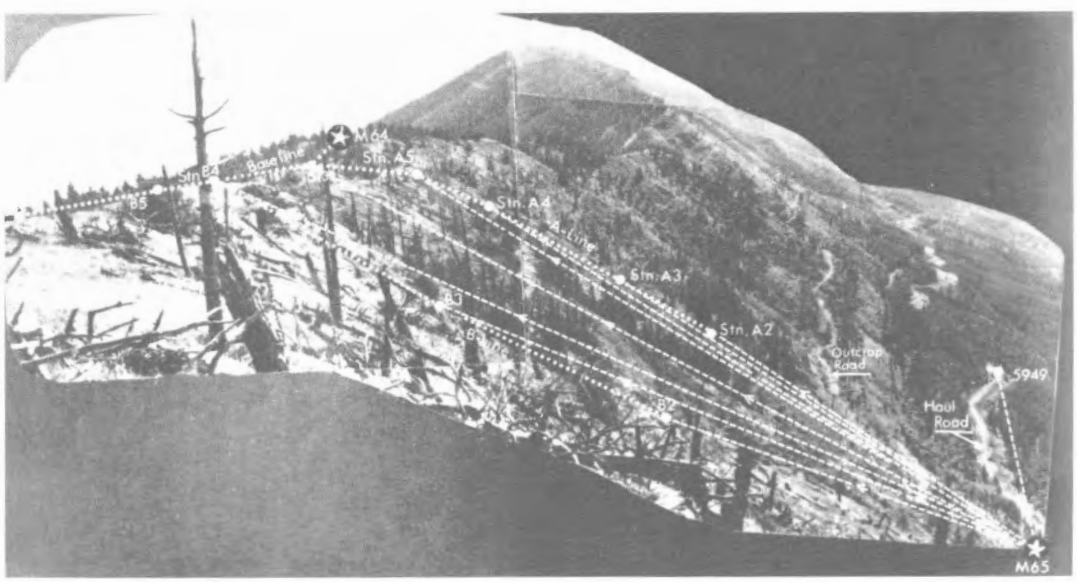
A knowledge of coal strength is fundamental to ground control. The coals of western Canada, however, are too friable for sampling and laboratory testing and large-scale in-situ tests are prohibitively expensive. A small-scale in-situ plate load test, has been investigated as a means of determining the uniaxial compressive strength of these coals. The results of two field trials have been analyzed with promising results.

Under certain conditions of loading and methane content, some western coals are prone to outbursts that seriously hamper ground control. Methods have been developed for measuring the pressure of methane in coal and the permeability of coal to methane. Measurements were made successfully in one mine having a history of outburst problems.

Assessing spontaneous combustion liability in mine

Research in this area is focused on spontaneous combustion for the purpose of minimizing its effects on the miners' health and safety. Laboratory analysis of mine gases is carried out at the Canadian Explosives Research Laboratory in Ottawa using a gas chromatograph, a paramagnetic oxygen analyzer and an infrared analyzer for CO. Preliminary work on oxygen adsorption shows that inherent oxygen in the bituminous coals is very low and that there is no correlation between oxygen adsorption and the spontaneous combustion liability as determined by the ignition method.

Field research was carried out by personnel of the Western Office in a mine where there have been two occurrences of spontaneous combustion. It was found that spot sampling could not give an indication of incipient heating and



Surface topography and subsidence stations over an hydraulic mine.

arrangements were made for the installation of a continuous gas-monitoring system. Studies were made of the effect of the mine environment on spontaneous combustion. Because the roof strata had fractured extensively and wooden stoppings allowed air to leak into the goaf, heating of coal was possible even though spontaneous combusion was unlikely.

A look at foreign technology

A study was initiated on new technology needed for mining the thick and inclined coal seams of western Canada by assessing mining methods used elsewhere in the world. During the year, studies of a number of French mining operations were completed and reported. A brief study of Australian experience with shortwall mining operations was carried out.

In co-operation with the project of the Geological Survey of Canada to delineate the in-place lignite resources of Saskatchewan, slope design and dragline selection procedures were quantified and made ready for computer programming.

Processing of Fuels

General objectives for fossil fuels are to extend both the quality and the versatility of coal by beneficiation and further processing and to supplement oil reserves by production of "synthetic" crude from bitumen, and production of synthetic natural gas from coal. For the Canadian uranium industry objectives are to improve existing processes and to develop new ones for treating uranium ore with the aim of alleviating environmental damage and producing up-graded nuclear uranium and uranium by-products.

Specific objectives are:

To develop improved methods of separating mineral matter from coal thereby reducing the volume of material moved and lowering transportation costs as well as enlarging reserves of coal suitable for use in the metallurgical industry; to develop methods of making high-strength coke for the steel industry from western Canadian coals; to develop technology for converting coal to pipeline-quality gas and low-Btu gas for industrial use; to utilize coal rather than natural gas as a source of hydrogen for processing tar sand bitumen and heavy oils.

To assist industry with the development of more efficient tar sand separation techniques which will reduce energy requirements and minimize flocculation of fine clays which threaten the environment; to develop methods of refining bitumen and heavy oil by thermal and catalytic hydrocracking which will yield a refineries feed stock that can be pumped to central refineries and which will eliminate waste coke produced by current coking of bitumen; to use coal as a source of process heat and to utilize residual pitch and tars more effectively as feedstock.

To improve uranium ore treatment processes to achieve reduced costs, improved recovery from refractory ores and pollution abatement; to improve control of metal-bearing acidic seepage from existing sulphide-containing tailings piles, through chemical and microbiological engineering; and to promote further processing of uranium ores in Canada by direct production of UF^4 from uranium leach solutions, recovery of nuclear-grade ThO_2 from effluent, and modification of the UF_6 to UO_2 conversion process to recover fluorine to reduce environmental damage.

Coal Beneficiation Assumes Growing Importance

The EMR/Devco field program for evaluation of sulphur removal in Lingan coal concluded in early 1974. The study showed that the EMR process was, at minimum capital and operating costs, eminently suited to the purpose and a proposal for a 750 tph plant was submitted to Devco.

The first commercial plant utilizing the EMR process went on-stream in mid-1974 at Stellarton, Nova Scotia for recovery of thermal coal in rejects from three dumps in the locality.

A major study sponsored by a Canadian steel company was initiated in the summer of 1974 to determine the feasibility of washing subbituminous coal for use in form-coke steel making. Specifications call for a fixed carbon to ash ratio of $\geq$10:1 and maximum alkali of 0.12% (coal basis). A solution is difficult using gravity separation processes alone because of the high inherent ash, narrow sp gr range of the material and low solubility of the alkali in water.

High-clay lignites from the Willowbunch and Estevan areas of Saskatchewan were easily cleaned to <25% ash by desliming at 48 mesh for clay removal. Washability studies indicated that 15% ash thermal grade products could be recovered at high efficiencies using a combination of desliming and gravity separation with water only cyclones.

Two industry-sponsored reclamation studies were begun in 1975, one for recovery of carbon and iron-rich fractions from blast-furnace flue dust and sludge, the other for recovery of coking coal from pond slimes.

Design of a modular plant essentially based on the EMR water-only cyclone coal cleaning process was in progress. In addition to low construction costs, the design features compactness, versatility and portability. Value of the concept lies in being able to provide, at minimum cost, washing capability covering a range of field and plant applications that may vary widely in size and process requirements. These include test washing units at exploration sites, treatment of low-grade coal at reclamation sites, hydraulic mining developments as well as normal washery operations.

Research continued on the cleaning of coal slimes (28 m x 0) in large diam ($\geq$20 cm) compound water cyclones (CWC).

Evidently a 2-stage CWC circuit can be made to clean coal slimes as effectively as small (≅5 cm diam) cyclones and promise the absence of plugging and less wear in their operation.

Development of a clarification process aimed at reducing the size of settling facilities for washery effluents was continuing by ERL staff. The process employs flocculation, cyclonic prethickening and a bottom-fed thickener and has been tested on effluents containing low and high proportions of bentonitic clays.

A circuit for the on-line analysis of mineral slurries has been designed, fabricated, and assembled by MSL to give simultaneous X-ray fluorescence measurements with a dual-isotope-excitation energy-analysis system and a conventional X-ray spectrometer equipped with an X-ray tube and an analyzing crystal. A density gauge is incorporated into the circuit to measure the solids content of the aqueous slurry.

Studies have been carried out on the on-line analysis of coal in an aqueous slurry. X-ray measurements taken for sulphur, iron and ash have not yet been fully evaluated, but a preliminary assessment indicates that both systems are capable of producing analytical data adequate for process control purposes. For example, sulphur was determined to within 2% relative and ash to with 5% relative.

The isotope used in the density gauge is gadolinium-153, which is more suitable than the conventional caesium-137 since it is more sensitive (because of its lower energy) for the determination of the solids content of aqueous slurries containing solids of low atomic number, such as coal.

New techniques for uranium extraction investigation

Canada will be expected to help supply the increasing world requirement for uranium as an energy source, and unless new high-grade ore bodies are found, the resources to be used will have to come from known lower grade and more complex ore deposits. Research is being directed toward improving the technology of the extraction processes by examining new techniques which, in effect, use less energy and thereby improve the economics of the process and which avoid serious pollution control problems associated with sulphuric acid leaching of uranium ores.

One technique presently being investigated for extracting uranium ores involves the use of nitric acid, considered to be more amenable to recovery and recycling than sulphuric acid. Using a double-stage leaching procedure, 98% extractions of uranium have been obtained to date at pulp densities of up to 65% solids and temperatures of 60°C and 75°C. The investigation also includes studies on (1) the distribution of iron, radium and thorium between leach liquor and residue (2) solvent extraction removal of uranyl nitrate from the leach liquor, and (3) the recovery of nitric fume evolved during the leaching process.

In many uranium mills, effluent discharges contain excessive amounts of sulphates, nitrates, and ammonia. Investigational work has shown that ion exchange can be used successfully to reduce the levels of these contaminants. Presently attention is being given to methods of recovering these reagents for recycling or other useful purposes.

Chemical analysis of uranium continued to play a prominent role in processing research activities. Development work was completed and reported on a method for analyzing low-grade ores by X-ray fluorescence spectroscopy. This relatively fast and accurate method of determining uranium could possibly be of value to uranium mills which already possess X-ray equipment. Also, work was resumed on a method for determining high concentrations of uranium in solutions by X-ray.

An amperometric and potentiometric method for determining uranium in ores volumetrically was developed. The procedure was successfully applied to uranium ores containing 0.1 to 5% uranium. Current uranium extraction processes do not meet proposed environmental criteria with respect to radioactive elements discharged to the environment. A project for the determination of radium in tailings and mill effluents has been undertaken to provide analytical methods to support investigations into waste treatment and new process development in this field. One established procedure for isolating Ra^{226} is being used and is providing acceptable values in the absence of thorium. Present studies using a multi-chemical analyzer and a solid state detector indicate that radium can be determined by measuring the disintegrations from only the element Ra^{226}.

Mineralogical investigation of radioactive ores and minerals is a most effective tool in helping to develop new and improved processes for extracting uranium. In one investigation, electron microprobe analysis of samples of brannerite from several mines in the Elliot Lake district of Ontario confirmed that this brannerite is indeed anomalous. Not only is the uranium content lower than that indicated by the ideal formula, UO_2 $2TiO_2$, but when compared with brannerites from deposits in other parts of the world the Elliot Lake mineral has a deficiency of uranium. Therefore, when considering the distribution of uranium in the main ore minerals, brannerite and uraninite, the amount of uranium present in brannerite is less than would be expected.

Utilization of Fuels

General objectives are to derive greater benefits from available processed fossil fuels by improving existing combustion systems, developing new systems of converting coal to electric power which will lessen reliance on oil and gas, developing coal/oil slurry transportation technology and developing new and improved materials for more efficient fuel systems.

Specific objectives are:

To develop design parameters for the more efficient combustion of fossil fuels to be used for stationary and mobile applications with minimum negative impact on the environment through research on turbulent diffusion flames, dispersion of smoke plumes and scrubbing of flue gases.

To develop new technology which will enable coal to play a larger role in the energy field: by developing fluidized-bed combustion of washery reject coal containing a high ash and sulphur content; by developing new techniques for using low-rank coal in the metallurgical industry and by converting coal into forms more suitable for transportation and utilization.

To develop materials suitable for Canadian conditions of service and manufacture for: recovery and transportation of Arctic and offshore fossil fuels, especially natural gas; special applications in fuel conversion technology and more efficient generation, storage and transmission of electricity; and to adapt available material and metallurgical by-products to the production of insulating and construction material for conservation of fuel.

Canmet Facilities Further Coking Technology

The Metallurgical Fuel Engineering Group in co-operation with the Canadian Carbonization Research Association (CCRA) continues to be active in the field of carbonization research using specialized pilot scale apparatus. (CCRA is an association of the major Canadian steel and coal-producing companies formed to conduct joint research projects with the former Mines Branch.) These facilities which include two industrial-scale moveable-wall coke ovens (0.31 and 0.46 m), three smaller ovens and related ancillary equipment in Ottawa, and one 0.31 m oven in Edmonton, are used to routinely test coke oven blends for the development of improved conventional industrial metallurgical coke. These facilities continue to give valuable assistance to western Canadian coal producers in developing export markets by characterizing the properties of their coals.

The new facility is now being operated on departmental coal evaluation projects and also co-operatively with the western Canada coal industry on resource development, on a cost-sharing basis.

Effort was continued in the development of a method for preheating coke oven charges. Preheating, an industrial technique of long-standing interest because of its potentially higher oven productivity (up to 40%), has only slowly begun to be put into use, largely because of operational difficulties and dangers resulting from the large amounts of coal dust involved. Under the combined demand for greater oven productivity and the stimulus of environmental constraints, preheating has become increasingly attractive.

The new oven at Clover Bar has been active in preheating investigation.

Development of a method of carbonizing small samples ($\simeq$1 Kg) in metal canisters placed in a 0.31 m test oven promises to eliminate many large-scale and expensive tests. Success of the method results from reliable correlations between small and large-scale tests.

Indicative of the scale of operations, during this past year 150 large oven (225-350 Kg charge) and many more smaller oven tests were completed on a shared-cost basis with CCRA and non-member coal companies.

Much of the current development work has been directed to modifying coal blends to reduce dependence of Canadian steel mills on the uncertain and increasingly costly sources of imported (U.S.) coking coals, for example by substituting coke fines and anthracite fines as antifissurants in lieu of imported low-volatile coals.

Formed coke, made by carbonizing preforms such as briquettes of coal, is being tested extensively as a substitute for conventional (slotoven) coke by the world-wide steel industry. In the past year, the CANMET laboratory and pilot plant facilities were expanded in a continuing program of applied research into formed coking to provide a capability for wide range testing of Canadian coals for various formed coke processes and for related research and development.

The laboratory formed coke facility, unique in Canada, is designed to make briquettes of non-caking coal or char, using a thermo-plastic (caking) coal for binder on a continuous basis. The same equipment is intended for the study of important parameters in hot briquetting and also for producing, under closely-controlled steady-state conditions, considerable quantities ($\cong$22.5 Kg/hr) of 25 mm diam briquettes for multiple tests of other uses. The facility comprises a continuous fluidized-solids unit and a briquetter. The fluidized solids unit mixes the two components (one at high temperature, the other at low temperature) and feeds the hot mixture to the briquetter, a custom-built, heated, automatic piston-type press. A larger scale facility with a double-roll press that will make 225 Kg briquettes/hr is also under construction.

Investigating Alternatives for Iron Ore Reduction

The growing desire for increased local steelmaking facilities in western Canada has stimulated reinvestigation in this Department, in co-operation with the Research Council of Alberta, into methods of processing the low-grade phosphatic iron deposit which occurs in the Peace River district of Alberta. It is essential that processes developed or applied for use in western Canada are appropriate to the scale required, to the flexibility of design to allow for growth and fluctuation in markets, to the energy sources and to the raw materials available. Western Canadian coals, especially those unsuitable for conventional coking and lignites, naturally come to mind as sources of energy.

Despite the present superior efficiency of integrated blast-furnace operations for large-scale production, alternative methods of iron ore reduction are being followed with keen interest in all parts of Canada particularly where specialized and relatively small-scale operations are sought. In this connection, investigations are continuing on the bench scale at CANMET on the reduction of composite pellets of iron ore and carbon. Several cases have been considered to take into account situations existing in western Canada (Peace River iron ore and western Canadian sub-bituminous coal) (and in eastern Canada using high-volatile coal from Cape Breton).

With the assistance of a consultant under contract, a program of iron ore-carbon composite pellet smelting was continued. A pilot-scale vertical shaft furnace for this work was nearing completion.

Use of a 4.6 m by 5.1 cm diam counter-current non-isothermal gas-solids reactor (Rist Apparatus) was used extensively to study iron ore under reaction conditions simulating the blast furnace, especially in investigating the effect of zinc on iron ore pellet strength.

A program of physical testing of iron ores supported by the Canadian Advisory Committee to ISO/TC 102 (Testing of Iron Ores) with membership drawn from the principal interested Canadian iron ore and steel industries, continued during the past year.

Testing of a variety of iron ores was done. CANMET personnel continued to be active in the past year in ISO (International Standards Association) establishing standard test methods.

As a development of the shaft electric reduction furnace (SERF) process developed at CANMET over several years, larger tests were made at a Canadian steel company under ERL supervision. Results supported those obtained on a smaller scale of CANMET. By using the sensible heat of the off-gases to preheat and prereduce inflowing iron ore, substantial lowering of electrical energy consumption resulted. With the growing cost of steel scrap, electric reduction of iron ore looks increasingly attractive.

Also confirmed in these trials was the low particulate emission of the furnace by the scrubbing action of the ore-filled shaft.

Fuel Efficiency and Energy Conservation Demand Attention

The prospect of increased coal use, coupled with the rapid depletion of oil and natural gas, has placed increased emphasis on the subjects of fuel efficiency, fuel substitution, energy conversion and energy conservation.

In the industrial and thermal power sectors, dwindling supplies of low-sulphur, low-ash fuels will necessitate the use of low-quality fuels that have previously been rejected because of inconvenience and cost. Pilot-scale combustion trials have demonstrated, as one example, that lignites containing over 35% ash can be burned successfully in pulverized form with minimal environmental impact. Similar trials with a number of coals and coal blends are planned on a continuing basis. Likewise, certain crude oil derivatives which cannot be utilized for refinery feedstock have proven to be viable substitutes for No. 2 fuel oil in heat processes. In other pilot-scale trials, coal-in-oil fuel has shown promise and is partly the basis of a large development program in the United States.

To aid in the more efficient use of home heating fuel oil, a research program conducted in collaboration with industry has shown that the performance of residential oil burners can be improved significantly by the incorporation of a flame retention head and a positive oil-shut-off device. This work is being complemented by field trials with continuously instrumented furnaces to study the effects of conservation measures such as thermostat cutback, increased operating time and heat reclaimers, in conjunction with basic weather parameters including temperature, wind and solar radiation. One experimental device which shows promise of a 10-17% fuel saving is a damper that automatically closes off the chimney when the burner is not operating.

Extracting Materials and Heat from Waste

The rising cost of fossil fuels has increased industrial interest in alternative energy sources. This has given the Energy Research Laboratories several opportunities to encourage the use of combustible wastes and waste heat from thermal power stations. There has, for example, been considerable EMR input to the Ottawa Master Plan Study, chaired by the Department of Public Works which is investigating means of using municipal garbage from the Capital region as fuel to heat government buildings. In addition, ERL staff are providing technical advice to a Canadian consortium which is proposing a plant, fueled in part by municipal refuse, to supply a paper mill with electricity and process steam.

Residential and commercial heating presently comprises nearly 30% of national annual fuel consumption, amounting to the equivalent of about one trillion cu ft of natural gas per year. Most of this energy requirement is presently met by premium fuels, but a large portion of it could be supplied by waste heat from thermal power stations via district heating systems, using well-proven technology. Canada presently makes very little use of district heating, but EMR is promoting the concept through participation in a number of Canadian and international committees, and keeps abreast of district heating technology.

Atmospheric Pollution Control Studies

Energy losses and ground-level pollution associated with industrial stack emissions can be effectively minimized by proper stack height selection. Current empirical methods developed overseas cannot be applied to Canadian conditions

with confidence and for this reason intensive studies on the behaviour of smoke plumes in different geographic regions of the country have been in progress for 5 years. During the past year ERL carried out plume dispersion studies at Pincher Creek, Alberta under chinook conditions and at Trail, British Columbia under channelling conditions in a deep valley. Dispersion computations based on actual plume measurements obtained by aerial probing have been incorporated into mathematical models to validate the origin of SO_2 emissions as measured by ambient air monitors and to predict the effect of potential emissions from new industrial plants on regional air quality.

Automobile performance factors responsible for the progressive deterioration in fuel economy under Canadian driving conditions are also being evaluated. It is evident from this research that automobiles with add-on pollution control devices designed for U.S. warm weather conditions can be modified to yield increased fuel economy with minimal pollution during the seasonal extremes of weather found in Canada. A Canadian automobile package has been proposed which will maintain emission levels below 1975 standards while recovering most of the fuel and drivability penalties due to increases in pollution controls, car weight and equipment deterioration in post-1970 cars.

The evaluation characteristics of two types of line pipe were completed by the Physical Metallurgy Research Laboratories and work is in progress on four additional types. This work is being done to provide reference data against which to compare the properties of pipe proposed or used for gas transmission lines in Canada's North and Arctic regions.

Experiments on the C-Mn-Nb steel (0.05 C-1.5 Mn-0.08 Nb) were completed and a report on the topic is being prepared.

Research on quenched and tempered steel for line-pipe applications showed that the required mechanical properties can be obtained in hot-rolled 0.5-in. (12.7 mm) thick plate by employing controlled rolling, a low finishing temperature and a direct water-spray quench, giving a cooling rate of about 70°C/sec. Heat treatment of the as-quenched plate produced very little age hardening and a decrease in impact toughness. Some effort was made to improve toughness in the aged condition by modifying a rolling schedule to retain more Nb solution, but the modified rolling schedules were too complex to be practical.

Data obtained on the properties of the seam welds of five commercial-quality line-pipe lengths, characteristic of production in the late 1960's showed toughness levels to be well below present requirements for Arctic applications. Recent data obtained from two samples of line pipe produced to CAGSL Specifications indicate that this problem has been overcome.

Welding Characteristics and Cold Cracking Susceptibility

Weldability tests using the control thermal severity test indicate that the low-carbon controlled-rolled molybdenum-bearing steels (micro-alloy steels) show a superior resistance to heat affected zone cracking and much less hardening in the heat affected zone than the more conventional higher-carbon steels. It was also observed that the conventional carbon equivalent formulae cannot be applied to the micro-alloy steels.

A systematic study of the factors contributing to the initiation of failure in line pipe is being pursued. The effect of energy and velocity of impact on the character of damage inflicted on flat specimens of X65 steel is being studied. The damage of such specimens indented in normal impact has established the relationship between the extent and type of damage and the impact energy. Two distinct and measurable layers, a transformed layer and a deformed layer are found between the indenting tool and the specimen material. The width of the transformed layer is linearly proportional to the impact energy, while the width of the deformed layer remains constant. The impact velocity does not affect the widths of the deformation layers.

Fatigue in Line-Pipe Steel

A strong environmental effect on fatigue crack growth rates in line-pipe steel is being investigated. A distinct pattern in the functional dependence of growth rates on ΔK and cyclic frequency has been found. The maximum environmental enhancement of the growth in a 3.5% NaCl solution occurred at the lowest frequency (0.01 Hz) and at relatively high values of ΔK.

Transmission Tower Studies

Progress is being made in evaluating factors affecting the integrity of fabrication processes for the manufacture of single-mast transmission towers. This is a co-operative effort between several industrial companies and a public utility under the aegis of the Canadian Galvanizing Research Association. A research report has been completed concerning the various properties of the materials, showing how they are affected by the fabrication and processing operations. Particular reference is made to the effects on fracture toughness. The fabrication, stress analyses and other test procedures are continuing on the octagon shaped monolithic tower poles. The program is being extended to include a twelve-sided pole design, and also a laboratory-model project

Materials for Energy

A survey of the main features of national energy needs and resources were completed, and a broad outline of a

materials research strategy to support energy activities was mapped out. Present indications are that work on materials for Arctic use and on hydrogen embrittlement is timely and as a consequence, work is proceeding on the factors controlling brittleness of materials.

Scientific and Technical Information

As mentioned earlier, the name change to CANMET is part of a significant reorganization of the former Mines Branch. This reorganization included the introduction of a matrix system of management, consolidation of research laboratories, and the establishment of three CANMET programs. Two of these, the Energy Research Program and the Mineral Research Program include all of CANMET's research and development work and are in an advanced state of implementation. The third, the Mineral and Energy Information Program is still being developed. It will be comprised of three projects which are identified by the public they serve, namely:

- the scientific and technical community cencerned with advancing mineral and energy technology in Canada,
- management within the Department of Energy, Mines and Resources
- CANMET staff.

CANMET's library continued to play an active information transfer role for both CANMET staff and those outside, including persons in the private industry and educational sectors. Loans of books, journals, conference proceedings etc. are as shown.

	Fiscal 1973-74	Fiscal 1974-75
To CANMET staff	14,535	14,838
To others	3,945	4,194
Total	18,480	19,032

In addition, the CANMET library arranged for full-text translation of foreign language reports covering a variety of technological subjects. This service is provided by the Multilingual Services Division of the Secretary of State and is of benefit to staff members in keeping abreast of new developments around the world. Translations made for CANMET are noted in a central registry at the National Research Council for the benefit of outside scientists. To meet the requirements of a national information transfer role, the library continued to strengthen its holdings of all pertinent publications.

The demand for literature searches by the Mining Information Centre continued to increase during fiscal 1974-75. Examples would include searches for papers on underground mine illumination for an inspector of mines, on measuring asbestos fibre length for a company technologist, and on hydraulic coal mining for a consulting engineer. The literature searches are based on a growing file of mining information selected from the world literature. This file is in two parts—the first, containing 8,300 references, is a manual system developed prior to April 1973 while the second, which is computer processable, held 3,300 references by the end of March 1975. Mining Information Centre staff also used indexes other than their own such as Engineering Index (New York), French language abstract cards from Centre d'Etudes et Recherches des Charbonnages de France, Geotechnical Abstracts (Germany) and Referativni Zhurnal: Gornoe Delo (U.S.S.R.).

The traditional information role of the Mines Branch in the mineral and energy fields was continued during the past year through published papers and reports, through presentations at association meetings and through direct communications by the scientific staff. Extensive changes in the publications policy were made in conjunction with the Branch reorganization and name change. These involved reclassification of reports, discontinuing the former categories and introducing new series. The following list of reports and papers prepared by CANMET staff during 1974-75 include both the former and new categories.

LIST OF PUBLICATIONS

Monographs

881 "Methods for the Analysis of Ores, Rocks and Related Materials" by E.M. Donaldson.

Research Reports

R 248 "Some Electrical Properties of Bubbles and Their Role in the Flotation of Quartz" by H.P. Dibbs, L.L. Sirois and R. Bredin.

R 266 "Sampling and Characterization of Cupola Emissions" by R.D. Warda and R.K. Buhr.

R 269 "Susceptibility of Temper Embrittled Materials to Strain Ageing" by R.F. Knight.

R 271 "Further Surface Treatment Aspects in Galvanizing Iron Single Crystals" by G.E. Ruddle and J.J. Sebisty.

R 273 "The Hydrocracking of Residual Oils and Tars, Part 6: Catalysis De-Activation by Coke and Metals Deposition" by E.C. McColgan and B.I. Parsons.

R 274 "Inhibitors for the Prevention of Mild Steel Corrosion in Synthetic Acid Mine Waters" by D.V. Subrahmanyam and G.R. Hoey.

R 275 "Dynamic Toughness—Its Relevance and Measurement" by L.P. Trudeau.

R 276 "Hydrocracking Athabasca Bitumen in the Presence of Coal, Part 1: A Preliminary Study of the Changes Occurring in the Coal" by M. Ternan, B.N. Nandi and B.I. Parsons.

R 278 "Comparison of Notch Ductility of Welds made by Various Processes in Structural Steels" by W.P. Campbell.

R 282 "Cam Plastometer Operation Manual Including Theory and Design" by M.J. Stewart.

Technical Bulletins

TB 183 "Experiments with Radiant Heat for Drying Mineral Commodities" by R.A. Wyman and T. Marshall.

TB 184 "Recovery of Waste Energy in the Production of Expanded Shale Aggregate" by V.V. Mirkovich.

TB 185 "Calibration of Pressure Measuring Systems of Movable-Wall Coke Oven" by D.A. Reeve and J.C. Botham.

TB 186 "The Floatability of Ten Non-Metallic Minerals (A Supplement to TB 108)" by R.A. Wyman and J.H. Colborne.

TB 187 "Catalysts for Hydrocracking and Refining Heavy Oils and Tars, Part 1: The Effect of Cobalt to Molybdenum on Desulphurization and Denitrogenation" by R.J. Williams, R.G. Draper and B.I. Parsons.

TB 188 "Mining Technology—Statistics 1972 and 1973 Developments" by A. Dubnie.

TB 189 "The Mining of Thick Flat Coal Seams by a Longwall Bottom Slice with Caving and Drawing" by K. Barron.

TB 190 "Plan Geometry and Other Factors Relating to Natural Rock Slope Stability Applied to Design of De Beers Mine" by D.F. Piteau.

TB 191 "Environmental Cracking Behaviour of Pd-Bearing Ti-721 Alloy" by G.J. Biefer and A.J. Williams.

TB 192 "Utilization of Diopside in the Manufacture of Glass" by V.V. Mirkovich.

TB 193 "Kidd Creek Ore KC-1: Its Characterization and Preparation for use as a Standard Reference Material" by G.H. Faye, R. Sutarno and W.S. Bowman.

TB 194 "Technical Manual for a Five Digit BCD Interface Designed for use with a Monroe 1666 Calculator" by G.E. Alexander.

TB 195 "Determination of Tin in Ores, Steel and Alloys with Gallein after Extraction as the Iodide" by E.M. Donaldson.

TB 198 "Relationships Between Dynamic and Static Low-Temperature Disintegration Tests" by J.T. Price and D.A. Reeve.

Information Circulars

IC 304 "Mechanical Boring of Tunnels and Raises" by M.D. Everell and A. Dubnie.

IC 312 "The Theory and Practice of Precipitation and Co-precipitation with Particular Reference to Hydrometallurgical Processing" by E. Rolia.

IC 313 "No-Fines Concrete—Its Properties and Applications" by V.M. Malhotra.

IC 314 "Evaluation of Canadian Commercial Coals: 1973 Saskatchewan, Alberta and British Columbia" by T.E. Tibbetts.

IC 315 "Scientific and Technical Papers Published by the Staff Mines Branch in 1974".

IC 316 "A Guide for Evaluating Coal Properties which Affect Combustion" by E.R. Mitchell, F.D. Friedrich and G.K. Lee.

Reprint Series

RS 127 "A Rock Mechanics Case History of Elliot Lake" by D.F. Coates, H.U. Bielenstien and D.G.F. Hedley.

RS 128 "Lost a Drill Hole Recently?" by R. Tervo and L. Tirrul.

RS 129 "Studies of Long-Hole Drilling" by A. Dubnie and M. Gyenge.

RS 130 "Development of an Anechoic Chamber" by M. Savich.

RS 131 "Rapid Estimation of Concrete Strength Potential for Hydro-Quebec Dams with Special Reference to Modified Boiling Method" by V.M. Malhotra and René Bauset.

RS 132 "Crack-Free Chromium from Conventional Plating Baths" by J.C. Saiddington and G.R. Hoey.

RS 133F "Sources Nouvelles des Combustibles" par A.C.S. Hayden.

Scientific Bulletins

CM 75-2 "Relationships Between Dynamic and Static Low-Temperature Disintegration Tests" by J.T. Price and D.A. Reeve.

CM 75-3 "The Determination of Lead in Ore Slurries by Gamma-Ray Attenuation" by T.R. Churchill, J.L. Dalton and H.P. Dibbs.

CM 75-4 "The Determination of Low Concentrations of Uranium in Ores and Solid Mill Products by X-Ray Fluorescence Spectrometry" by J.B Zimmerman and V. Reynolds.

CM 75-7 "Reverse Osmosis for the Treatment of Metal Waste Solutions" by V.S. Sastri

Available Investigation Reports

MINERAL SCIENCES LABORATORIES

IR 67-2 "Mineralogical Examination of a Lead-Zinc Ore from Fennix Mines Ltd., Yellowknife, North West Territories" by D.R. Owens.

IR 67-33 "Jigging Investigation of Upgraded Ore from Crest Exploration Limited, Yukon Territory" by G.W. Riley.

IR 67-64 "The Evaluation of Iron Oxides for 'Hard' Ferrite Manufacture on Behalf of the Northern Pigment Company Limited, New Toronto, Ontario" by N.F.H. Bright, J.F. Rowland and R.H. Lake.

IR 68-52 "Mineralogical Investigation of a Sample of Silver-Gold Ore from Mount Nansen Mines Limited, Yukon Territory" by D.R. Owens.

IR 68-82 "Determination of the Cause of Premature Discharge of a High-Voltage Sparking Device" by J.A. Soles.

IR 69-25 "Mineralogical Examination of a Complex Ore from the Red Lake District of Ontario, Submitted by Cochenour Willans Gold Mines Limited" by L.J. Cabri.

IR 69-33 "Lead Zirconate-Titanate Ceramics Prepared from Co-Precipitated Powders Modified with Strontium, Iron and Chromium Oxides" by V.M. McNamara, T.B. Weston and A.H. Webster.

IR 69-38 "The Preparation and Evaluation of Anisotropic Barium Ferric Ceramic Magnets, on Behalf of Northern Pigment Company Limited, New Toronto, Ontario" by W.S. Bowman, G.E. Alexander and R. Sutarno.

IR 69-48 "Mineralogical Investigation of a Sample of Silver-Lead-Zinc Ore from Causqua Creek, Smithers, B.C., on Behalf of Silver Standard Mines Limited" by D.R. Owens.

IR 69-58 "The Preparation and Evaluation of Additional Anisotropic Barium Ferrite Ceramic Magnets, on Behalf of Northern Pigment Company Limited, New Toronto, Ontario" by W.S. Bowman, G.E. Alexander and R. Sutarno.

IR 69-82 "Investigation of the Use of By-Product Iron Oxide in 'Hard' Ferrite Manufacture, on Behalf of the Steel Company of Canada, Limited, Hamilton, Ontario" by R. Sutarno, W.S. Bowman and G.E. Alexander.

IR 70-34 "Mineralogical Investigation of an Ore Sample from the Mount Pleasant Deposit in New Brunswick for Nigadoo Mines Limited" by W. Petruk.

IR 70-74 "Mineralogical Investigation of Nickel-Copper Ore from the McWatters Mine, Langmuir Township, Ontario" by E.H. Nickel.

IR 71-25 "Mineralogical Evaluation of Iron Concentrates from the Iron Ore Company of Canada, Schefferville, Quebec" by E.H. Nickel.

IR 72-15 "Petrography of Samples of Magnesite Rock from Northwest Gander River, Newfoundland" by J.A. Soles.

IR 72-20 "Mineralogical Investigation of a Gold-Silver Ore from Kleanza Mountain, Terrace Area, British Columbia" by A.E. Johnson.

IR 72-37 "Mineralogical Investigation of Cu-Ag Ore of Terra Mining and Exploration, Camsell River, Northwest Territories" by D.C. Harris.

IR 72-39 "Mineralogical Examination of a Coarse Tantalum Concentrate from Tantalum Mining Corporation (TANCO), Bernic Lake, Manitoba" by D.C. Harris.

IR 72-53 "Mineralogical Examination of a Low-Grade Ni-Cu-Bearing Peridotite from the Mattagami Lake Mine, Matagami, Quebec" by D.C. Harris.

IR 72-55 "Bacterial Leaching of Oxidized Copper Ore from Campbell Chibougamau Mines Ltd., Quebec" by H.W. Parsons.

IR 72-60 "Bacterial Leaching of Copper Ore from Manitou-Barvue Mines Limited, Val d'Or, Quebec" by H.W. Parsons.

IR 73-9 "An Investigation to Upgrade a Concentrate Produced from the Spiral-Plant Tailings of the Iron Ore Company of Canada, Labrador City, Newfoundland" by G.O. Hayslip.

IR 73-17 "Mineralogical Investigation of Hand Samples from the Strathcona Lead-Zinc Deposit, Baffin Island" by L.J. Cabri.

IR 73-26 "Mineralogical Investigation of a Lead-Zinc-Copper Ore from Burnt Basin Mines Ltd., British Columbia" by L.J. Cabri.

IR 73-27 "Mineralogical Investigation of a Cu-Ag-Bi Ore from Terra Mining and Exploration Limited, Camsell River, Northwest Territories" by D.C. Harris.

IR 73-29 "Mineralogical Investigation of a Placer Sand Sample from the Tulameen River Area, British Columbia" by L.J. Cabri.

IR 73-41 "Mineralogical Investigation of Sulphurous Coal from the Lingan Mine, Cape Breton Island, Nova Scotia" by A.E. Johnson.

IR 73-64 "Mineralogical Investigation of Copper Nickel Ore from the Thierry Deposit of Umex (Union Minière Explorations and Mining Corporation Limited)" by D.R. Owens.

IR 73-65 "Laboratory Support for Spodumene Pilot Plant Trials" by K.D. Atkinson.

IR 73-67 "A Method for Improving Bismuth Recovery at Terra Mining and Exploration Ltd., Hay River, N.W.T." by D. Raicevic.

IR 73-69 "Strength Development of Non-Reinforced Concrete Slabs Exposed to Ottawa Temperature Extremes" by V.M. Malhotra.

IR 73-72 "The Feasibility of Producing a Dry-Pressed Building Brick with Tailings from a Quebec Iron Mine" by R.K. Collings and G.A. Brown.

IR 74-2 "Mineralogical Investigation of Precious Metal-Rich Copper-Nickel Ore from the Kanichee Mining Incorporated Deposit, Strathy Township, Ontario" by L.J. Cabri and J.H.G. Laflamme.

IR 74-4 "Concentration and Recovery of Gold and Silver from a Telluride Ore, Submitted by Kleanza Mines Limited, Terrace Area, B.C." by A. Stemcrowicz and R.W. Bruce.

IR 74-6 "Investigation of A White Granite from the Stanstead Area, P.Q." by F.E. Hanes.

IR 74-7 "Evaluation of an Ontario Dolomite as a Refractory Raw Material" by M. Palfreyman.

IR 74-17 "Recovery of Barite from Tailings, Buchans, Newfoundland (Project MP-IM-7007)" by F.H. Hartman and R.A. Wyman.

IR 74-18 "Ceramic Properties of Seventeen Samples from Northern Ontario" by K.E. Bell and L.K. Zemgals.

IR 74-19 "Investigation to Determine Causes for the Variation in Flotation Behaviour of Iron Ore from Schefferville, Quebec" by I.B. Klymowsky.

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IR 74-32 "Suitability of a Quebec Group Shale for Vitrified Structural Clay Products" by K.E. Bell.

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IR 74-40 "A Spectral Examination of Serandite from Ste. Hilaire, Quebec, August 30, 1974" by G.H. Faye.

IR 74-41 "Preliminary Assessment of Clays from Winnipeg, Manitoba, for Lightweight Aggregate" by H.S. Wilson.

IR 74-44 "Beneficiation of Graphite from Mont Laurier, Quebec (Project MP-IM-7106)" by F.H. Hartman and R.A. Wyman.

IR 74-47 "Investigation to Determine Causes for the Poor Nickel Recoveries in Flotation of Old Asbestos Tailings of Carey-Canadian Mines Limited, East Broughton, Quebec" by I.B. Klymowsky.

IR 74-49 "Determination of Gold and Platinum Content in a Low-Grade Alluvial Gravel from the Tulameen River Area of British Columbia" by D. Raicevic and R.W. Bruce.

ENERGY RESEARCH LABORATORIES

IR 74-28 "An Investigation of the Abnormal Swelling Characteristics of High- and Low-Silica Iron Oxide Pellets" by D.A. Reeve and N.J. Ramey.

IR 74-29 "The Low-Temperature Disintegration Properties of Sinters with Varying Basicities" by J.T. Price and D.A. Reeve.

IR 74-45 "The Oil Heating Association of Canada Clean-Air Program, Phase V: Evaluation of Burners with High and Low Speed Motors in a Domestic Hot Water Heater" by T.D. Brown.

Laboratories Reports

MRP/MSL 75-12(IR) "Mechanical Properties and Freeze-Thaw Resistance of No-Fines Concrete" by V.M. Malhotra.

MRP/MSL 75-13(IR) "Flotation as a Method for Carbon Removal from Ontario Fly Ash" by A. Stemerowicz and R.W. Bruce.

MRP/MSL 75-14(IR) "The Treatment of a Carbonaceous Gold Ore from McIntyre Mines, Schumacher, Ontario" by D. Raicevic and R.W. Bruce.

MRP/MSL 75-15(J) "Ionic Conductivity of Thermal-Shock Resistant Zirconia" by T.A. Wheat.

MRP/MSL 75-16(J) "Microstructure of Thermal-Shock Resistant Zirconia" by T.A. Wheat.

MRP/MSL 75-21(IR) "Mineralogical Investigation of Ores from the Kidd Centre Deposit of Texas Gulf Sulphur" by W. Petruk and D.R. Owens.

MRP/MSL 75-25(LS) "Certified and Provisional reference materials available from the Canada Centre for Mineral and Energy Technology as of 1975" compiled by G.H. Faye.

MRP/MSL 75-28(IR) "Examination of Sulphur-Impregnated Concrete by Infrared Spectroscopy" by D.M. Farrell.

MRP/MSL 75-30(IR) "The Ceramic Properties of Two Samples of Rochester Shale from the Niagara, Ontario Region" by K.E. Bell.

MRP/MSL 75-43(J) "Contract Strength Requirements—Cores Versus In-Situ Evaluation" by V.M. Malhotra.

MRP/MSL 75-56(J) "An Improved Bismuth Plating Process" by W. Dingley, J.S. Bednar and G.R. Hoey.

Periodicals

MINING RESEARCH LABORATORIES

"Burning Trials of Blasting Agents", by J.A. Darling, Canadian Mining and Metallurgical Bulletin, Vol. 67, No. 747, July 1974.

"Development of an Anechoic Chamber", by M. Savich, published in Rudarsko Metalurski Zbornik, Leto 1973, St. 1-2, p. 65-81 (available from CANMET Ottawa, as Reprint No. RS 130).

"Low-Frequency Electromagnetic Bore Hole Finder", by R. Tervo, Canadian Mining Journal, March 1974.

"Full Shift Assessment of Respirable Dust Exposure", by G. Knight, T.E. Newkirk, and G.R. Yourt, Canadian Mining and Metallurgical Bulletin, Vol. 67, No. 744, p. 61-72, April 1974.

"Optimization of the Design and Use of a Triaxial Strain Cell for Stress Determination", by W.M. Gray and N.A. Toews, published in Field Testing and Instrumentation of Rock, Special Technical Publication, 554, American Society for Testing and Materials, Philadelphia, 1974.

"Etat actuel de l'automatisation des machines de forage", by M.D. Everell, G. Turcotte and J.M. Ducros, Revue de l'Industrie Minérale, November 1974.

"Automatic Control of a Laboratory Diamond Drilling Machine and Prospects for Field Applications", by M.D. Everell, G. Turcotte, M. Boisvert and G. Fortier, Industrial Diamond Review, November 1974.

"Mining Research Centre's Quebec Office", by M.D. Everell and G.E. Larocque, The Northern Miner, Annual Review, November 28, 1974.

"Production Characteristics and Abatement of Noise from Light and Medium Rock Drills", by M. Savich, Canadian Mining and Metallurgical Bulletin, Vol. 67, No. 751, November 1974.

"Ground Stress Determination in Canada", by G. Herget, Rock Mechanics, pp. 53-64, July 1974.

"Mechanical Properties of Rocks and Rock Masses", by M.D. Everell, G. Herget, R. Sage and D.F. Coates, published in Advances in Rock Mechanics, Proceedings of the 3rd Congress of the International Society of Rock Mechanics, Vol. 1, Part A, Themes 1-3, p. 101, 1974.

"Effect of Geological Factors on Stope-and-Pillar Layout in an Elliot Lake Uranium Mine", by D.G.F. Hedley, Canadian Mining and Metallurgical Bulletin, Vol. 68, No. 755, pp. 107-112, March 1975.

"Overlap Problems in Counting Fibres", by G. Knight, American Industrial Hygiene Association Journal, Vol. 26, No. 2, pp. 113-114, February 1975.

PHYSICAL METALLURGY RESEARCH LABORATORIES

"Preparation of Investment Shell Moulds by Electrophoresis", by E.I. Szabo, Modern Castings, pp. 50-51, August 1974, AFS Trans, V. 82, 1974.

"Pitting Resistance of 18% Cr Ferritic Stainless Steels Containing Molybdenum", by R.J. Brigham and E.W. Tozer, Journal of the Electrochemical Society: Electrochemical Science and Technology, Vol. 121, p. 1192, September 1974.

"The Measurement of Liquidus Temperatures by a Stationary Interface Technique", by K.G. Davis, Metallurgical Transactions, V. 5, pp. 1993-1998, September 1974.

"Constant True Strain Rate Deformation—The Cam Plastometer", by M.J. Stewart, Canadian Metallurgical Quarterly, V. 13, 1974.

"Relation Between Surface Slip Topography and Stress Corrosion Cracking in Ti-8 Wt % Al", by J.D. Boyd and R.G. Hoagland, Corrosion, V. 30, p. 102, 1974.

"Slow Fatigue Crack Propagation in Pearlitic Steels", by R.J. Cooke and C.J. Beevers, Mat. Sci. and Eng., Vol. 13, pp. 201-210, 1974.

"Tensile Failure of Directionally Solidified Al-Al_3Ni Eutectic", by E.E. Laufer and J.T. Jubb, Kovove Materialy, Vol. 12, p. 145, 1974.

"Removal of Magnesium from Aluminum by Fumeless Chlorine Treatment", by L.V. Whiting and J.O. Edwards, AFS Trans., V. 82, 1974.

"Precipitate Morphology and Orientation Relationships in an Aged Mg-9% Al 1% Zn-0.3% Mn Alloy", by A.F. Crawley and K.S. Milliken, Acta Met., V. 22, p. 557, 1974.

"Effect of Two Step Aging on the Precipitate Structure in Magnesium Alloy AZ91", A.F. Crawley and B. Lagowski, Met. Trans., V. 5, p. 949, 1974.

"Densities of Liquid Metals and Alloys", by A.F. Crawley, International Metallurgical Review, V. 19, p. 32, 1974.

"Ordering and Tensile Ductility in a Ti-Al-Ga Alloy", by W.N. Roberts and M.J. Godden, Scripta Metallurgica, V. 9, pp. 75-78, January 1975.

"Ultra-High-Vacuum Purification of Large Niobium Crystals", by D.C. Briggs and S. Saimoto, Japan J. Appl. Phys., V. 14, (1), pp. 113-121, January 1975.

"A Complex Bismuthian Palladium Telluride Inter-Growth from the Stillwater Complex, Montana", by L.J. Cabri and K.M. Pickwick, Economic Geology, V. 69, pp. 262-274, March/April 1974.

"Strain Fields of Cracks under Tension Including Thickness Effects, Part I—Experimental Results", by O. Vosikovsky, International Journal of Fracture, V. 10, No. 2, pp. 141-157, June 1974.

"Strain Fields of Cracks under Tension Including Thickness Effects, Part II—Correlations", by L.P. Trudeau and O. Vosikovsky, International Journal of Fracture, V. 10, No. 2, pp. 159-166, June 1974.

"A Comparison of the Mechanical Properties of ESR and Directionally Solidified AISI 4340 Steel", by A. Mitchell, R.K. Buhr and F. Weinberg, Metal Technology, July 1974.

ENERGY RESEARCH LABORATORIES

"Investigation of Oils in The Western Canada Tar Belt—Oil Sands of the Future", by A.E. George and H. Sawatzky, published in The Canadian Society of Petroleum Geologists, Proceedings, Calgary, Alberta, p. 168, September 1974.

"Sulphur Compounds in the Oils from The Western Canada Tar Belt", by A.E. George and H. Sawatsky, ACS Advances in Chemistry Series.

"Plume Dispersion from a Thermal Power Station on the Shore of a Large Lake", by H. Whaley, G.I.C. Lee, Journal of The Institute of Fuel, Vol. XLVII, December 1974.

"Oxidation Studies on Coking Coal Related to Weathering, Part 4: Oxygen Linkages Influencing the Dilatometric Properties and the Effect of Cleavage of Ether Linkages," by B.N. Nandi, Fuel, (London), Vol. 53, pp. 212-219, 1974.

"Microscopic Studies of Semicoke from Different Macerals After Treatment of the Coal in K/THF/Naphthalene, by B.N. Nandi, Fuel, (London), Vol. 53, pp. 226-228, 1974.

"Nature and Thermal Behaviour of Semifusinite in Cretaceous Coal from Western Canada", by B.N. Nandi, (FRC Divisional Report 74/88), submitted to Fuel, (London), for publication December 1974.

"The Certification of Electrical Equipment Conveyor Belting and Diesel Mining Equipment at the Department of Energy, Mines and Resources", by P. Mogan, D.B. Stewart, E.D. Dainty and G.K. Brown, Northern Miner, Vol. 60, No. 33, pp. 68-69, November 28, 1974.

"The Exhaust Emissions of a Simulated LHD Diesel Configuration", by P. Mogan, E.D. Dainty and D.B. Stewart, published in The Canadian Mining Journal, pp. 35, 36 and 60, September 1974.

"An X-Ray Photoelectron Spectroscopic Investigation of Coal", by D.C. Frost, W.R. Leeder, and R.L. Tapping, Fuel, (London), V. 53, pp. 206-211, 1974.

MINERAL SCIENCES LABORATORIES

"Mineral Waste Utilization Studies", by R.K. Collings, A.A. Winer, D.G. Feasby, and N.G. Zoldners, Proceedings of the Fourth Mineral Waste Utilization Symposium, Chicago, Illinois, May 7 and 8, 1974, pp. 2-12.

"Result of an Inter-Laboratory Program for the Determination of Tin in a Standard Reference Ore: A Caveat", by G.H. Faye, W.S. Bowman and R. Sutarno, Analytica Chimica Acta, V. 67, pp. 202-203, 1973.

"On the Weak Ferromagnetism of Orthorhombic $CuFe_2S_3$", by M.G. Townsend, J.L. Horwood and J.R. Gosselin, Can. J. Phys., V. 51, pp. 2162-2165, 1973.

"Mössbauer Investigation of Synthetic Single Crystal Monoclinic Fe_7S_8", by J.R. Gosselin, M.G. Townsend, R.J. Tremblay and A.H. Webster, Materials Research Bulletin, V. 10, pp. 41-50, 1975.

"Magnetic Susceptibility and Mössbauer Investigation of Single Crystal FeS", by J.R. Gosselin, J.L. Horwood, M.G. Townsend, R.J. Tremblay and A.H. Webster, American Institute of Physics Conference Proceeding, V. 6, pp. 55-56, 1975.

"The Optical Absorption Spectra of Tourmaline: Importance of Charge-Transfer Processes", by G.H. Faye, P.G. Manning, J.R. Gosselin and R.J. Tremblay, Can. Mineral., V. 12, pp. 370-380, 1974,

"A Measure for Assessing Certified Reference Ores and Related Materials", by R. Sutarno and G.H. Faye, Talanta, in press (1975).

"Electrochemical Properties of the Oxide-Solution Interface in Relation to Flotation", by S.M. Ahmed, Proceedings of AIChe Symposium on 'Application of Interfacial Phenomena in Flotation Research', in press (1975).

"Rubidium Jarosite and Thallium Jarosite—New Synthetic Jarosite-Type Compounds", by J.E. Dutrizac and S. Kaiman, Hydrometallurgy.

"Description of Ultramafic (Ore) Samples UM-1, UM-2, UM-4: A Discussion", by G.H. Faye, Chem. Geol.

"Limit of Detection in the Determination of Sulfur on the Combustion Method Using the Visual and Spectrophotometric Iodometry", by B. Nebesar, J. of Testing and Evaluation.

"Ionic Conductivity of Thermal-Shock Resistant Zirconia", by T.A. Wheat, Can. Cer. Soc.

"Microstructure of Thermal-Shock Resistant Zirconia", by T.A. Wheat, Can. Cer. Soc.

"Stannite and Kesterite: Distinct Minerals or Components of a Solid Solution?", by S.R. Hall, S.A. Kissin and J.M. Stewart.

"Chemical Phase Analysis of Ores and Rocks: A Review of Methods", by H.F. Steger, Talanta, (in press).

"Zoning in Os-Ir Alloys and the Relation of the Geological and Tectonic Environment of the Source Rocks to the Bulk Pt:Pt+Ir+Os Ratio for Placers", by L.J. Cabri and D.C. Harris, The Can. Mineral.

"Electron Microprobe Analyses of Monazite from the Mount Pleasant Deposit in New Brunswick", by D.R. Owens and W. Petruk, The Can. Mineral.

Haycockite, $Cu_4Fe_5S_8$: A Superstructure in the Chalcopyrite Series", by J.F. Rowland and S.R. Hall, Acta Crystallographica, in press (1974).

"The Crystal Structure of Costibite (CoSbS) and Paracostibite (CoSbS)", by J.F. Rowland, E.J. Gabe and S.R. Hall, The Canadian Mineralogist, in press (1974).

"Crystal Structures of the Chalcopyrite Series", by S.R. Hall, The Canadian Mineralogist, in press (1974).

"The Crystal Structure of High-Temperature $CuFe_2S_3$", by J.T. Szymanski, Sonderdruck aus: Zeitschrift fur Kristallographie, V. 140, pp. 240-248, 1974.

"A Refinement of the Structure of Cubanite, $CuFe_2S_3$", by J.T. Szymanski, Sonderdruck aus: Zeitschrift fur Kristallographie, V. 140, pp. 218-239, 1974.

"On the Mechanism of the Adsorption of Trace Copper by Bentonite", by H.F. Steger, Clay and Clay Minerals, V. 21, p. 429, 1973.

"Stability of Metal Oxinates", by H.F. Steger, J. Inorg. Nucl. Chem., V. 37, p. 39, 1975.

"Determination of Tin as Stannite-Kesterite and Cassiterite in Ores", by H.F. Steger, Talanta, V. 22, p. 543, 1975.

"The Crystal and Molecular Structure of 3α,6α-Dihydroxy-5β-cholan-24-oic acid, $Cu_{24}O_4H_{40}$", by S.R. Hall, Acta Crystalligraphica, B30 [6], pp. 1441-1447, 1974.

"Comments on 'Metamorphism at the Normetal Mine, Northwestern Quebec' ", by L.J. Cabri, W.H. MacLean and S.D. Scott, CIM Bulletin, V. 67, No. 746, pp. 158-159, 1974.

"Platiniridium-Confirmation as a Valid Mineral Species", by L.J. Cabri and M.H. Hey, Can. Mineral., V. 12, pp. 299-303, 1974.

"Some Observations on the Geochemistry of the Platinum-Group Elements", by L.J. Cabri, Trans. Geol. Soc. S.A., V. 77, pp. 65-67, 1974.

"Rhodium, Platinum, and Gold Alloys from the Stillwater Complex", by L.J. Cabri and J.H.G. Laflamme, Can. Mineral., V. 12, p. 399-403, 1974.

"Mineralogical Investigations of the Platinum-Group Elements in the Sudbury-Area Deposits—A Preliminary Report", by L.J. Cabri and J.H.G. Laflamme, Can. Mineral., V. 12, p. 429 (9bs), 1974.

"Platinum-Iron Alloys: A Nomenclature Based on a Study of Natural and Synthetic Alloys", by L.J. Cabri, Can. Mineral., V. 13.

"Laboratory Manual for the Analysis of Ores, Rocks and Related Minerals", by E.M. Donaldson, accepted for publication in the Northern Miner, 1974.

"Optical Absorption Spectrum of Ni^{2+} in Garnierite: A Discussion", by G.H. Faye, Can. Mineral., V. 12, pp. 389-393, 1974.

"Automatic Timing of the Spectrophotometric Iodometric Titration Using LECO Sulphur Determinator", by B. Nebesar and J.V. Krzyzewski, Anal. Chem., V. 46, p. 1148, 1974.

"New Data on Stannite and Related Sulphide Minerals", (Abstract), by S.A. Kissin and D.R. Owens, Program Abstracts, North-Central Section G.S.A., and G.A.C./M.A.C. Annual Meeting, 1975, Waterloo, Ontario, p. 798, 1975.

"'Blue Dragon' Basalt from Craters of the Moon National Monument, Idaho: Origin of Color", by G.H. Faye, Amer. Mineral., V. 58, pp. 1048-1051, 1973.

"Mineralogy and Geology of the Zgounder Silver Deposit in Morocco", by W. Petruk, Can. Mineral., V. 13, pp. 43-54, 1975.

"The Application of Quantitative Mineralogy to Ore Dressing", by W. Petruk, Northern Miner Annual Review, p. 103, November 28, 1974.

"Quantitative Mineralogical Analysis to Evaluate Theoretical Recoveries of Metals from Ores," by W. Petruk, Quantimet, Vol. 2, No. 2, 1974.

"Quantitative Mineralogical Analysis to Evaluate Theoretical Recoveries of Metals from Ores," by W. Petruk, Quantimet, V. 2, No. 2, 1974.

"Observations on Acanthite, Aguilarite and Naumannite", by W. Petruk, D.R. Owens, J.M. Stewart and E.J. Murray, Can. Mineral., V. 12, Part 6, pp. 365-369, 1974.

"Unnamed Palladium Antimonian Platinum Bismuthide", by L.J. Cabri, Amer. Mineral., accepted for publication.

"New Data for Pyrochlores from Oka, Quebec", by W. Petruk and D.R. Owens, Can. Mineral., in press.

"Some Mineralogical Characteristics of the Silver Deposits of the Guanajato Area, Mexico", by W. Petruk and D.R. Owens, Econ. Geol., V. 69, p. 1078, 1974.

"Maturity Concept and the Estimation of Concrete Strength—A Review, Part I", by V.M. Malhotra, The Indian Concrete Journal, Vol. 48, No. 4, pp. 122-126, April 1974.

"Maturity Concept and the Estimation of Concrete Strength—A Review, Part II", by V.M. Malhotra, The Indian Concrete Journal, Vol. 48, No. 5, pp. 155-159, May 1974.

"Further Studies on Acid Pressure Leaching a Chalcopyrite-Pentlandite-Pyrrhotite Concentrate", by J.A. Vezina, CIM Bulletin, Vol. 66, No. 733, pp. 57-60, 1973.

"A Review of the Use of Carboxylic Acids as Extractants for the Separation of Metals in Commercial Liquid-Liquid Extraction Operations", by A.W. Ashbrook, Minerals Science and Engineering, Vol. 5, No. 3, pp. 169-180, 1973.

"The Effect of Some Impurities on the Rate of Chalcopyrite Dissolution", by J.E. Dutrizac and R.J.C. MacDonald, Canadian Metallurgical Quarterly, Vol. 12, No. 4, pp. 409-420, 1973.

"Determination of X-Ray Fluorescence Spectrometry of the Metal Concentration in the Organic Phase from Solvent Extraction Processes", by J.B. Zimmerman, Canadian Journal of Spectroscopy, Vol. 18, No. 6, pp. 147-152, 1973.

"Preparation of Capillary Mounts in a Dry Box", by S. Kaiman, Journal of Applied Crystallography, Vol. 6, Part 6, p. 500, 1973.

"The Reaction of Tungsten with Selenium Vapour", by J.E. Dutrizac, Journal of the Less-Common Metals, Vol. 33, No. 3, pp. 341-353, 1973.

"Solution Purification Important to Metals Recovery Technology", by G.M. Ritcey, Northern Miner, Vol. 59, No. 42, pp. 12-13, 1974.

"Corrosive Wear and Its Control in Ball Mill Grinding—A Progress Report", by G.R. Hoey, Proceedings of the Sixth Annual Meeting of the Canadian Mineral Processors held at Mines Branch, Ottawa, pp. 236-259, 1974.

"The Role of Hydrometallurgy in Mineral Processing", by W.A. Gow, Proceedings of the Sixth Annual Meeting of the Canadian Mineral Processors, held at Mines Branch, Ottawa, pp. 284-309, 1974.

"Some Aspects of the Extraction of Metal from Acidic Solutions by Kelex 100", by G.M. Ritcey and B.H. Lucas, CIM Bulletin, Vol. 67, No. 742, pp. 87-92, 1974.

"Continuous Counter-Current Ion Exchange in the Mining Industry", by M.J. Slater, CIM Bulletin, Vol. 67, No. 742, pp. 93-98, 1974.

"Ferric Ion as a Leaching Medium", by J.E. Dutrizac and R.J.C. MacDonald, Minerals Science and Engineering, Vol. 6, No. 2, pp. 59-100, 1974.

"Kinetics of Acid-Catalysed Hydrolysis of the α and β Carbonato(4,7-dimethyltriethylenetetramine) cobalt(III) Ions", by D.J. Francis and G.H. Searle, Australian Journal of Chemistry, Vol. 27, No. 2, pp. 269-277, 1974.

"Percolation Leaching of Pentlandite Ore", by J.E. Dutrizac and R.J.C. MacDonald, CIM Bulletin, Vol. 67, No. 743, pp. 169-175, 1974.

"Nitric Oxide Formation at High Temperatures", by D.J. MacKinnon, Air Pollution Control Association Journal, Vol. 24, No. 3, pp. 237-239, 1974.

"Control of Solid Wastes from Metallurgical Plants", by H.H. McCreedy, Fifth Mines Branch Report on Environmental Improvement, E. M & R Report ADM 74-1, p. 48, 1974.

"Control of Effluent Quality from Metallurgical Plants by Ion Exchange", by A.J. Gilmore, Fifth Mines Branch Report on Environmental Improvement, E. M & R Report ADM 74-1, pp. 49-50, 1974.

"Recovery of Copper by Cementation on Nickel Powder", by D.J. MacKinnon, Canadian Metallurgical Quarterly, Vol. 13, No. 3, pp. 473-477, 1974.

"Determination of Base Metals in Multi-Element Organic Solutions by X-Ray Fluorescence Spectrometry without Destruction of the Organic Solvents", by J.B. Zimmerman, Canadian Journal of Spectroscopy, Vol. 19, No. 4, pp. 115-120, 1974.

"The Use of Flame Procedures in Metallurgical Analysis, Part 1: Determination of Silicon in Sulphide and Silicate Minerals", by R.J. Guest and D.R. MacPherson, Analytica Chimica Acta, Vol. 71, No. 2, pp. 233-253, 1974.

"Aspects of Copper Extraction in Mixer-Settlers", by M.J. Slater, G.M. Ritcey and R.F. Pilgrim, Proceedings of the International Solvent Extraction Conference held at Lyon, France, Vol. 1. pp. 107-140, 1974.

"Treatment of Solvent Extraction Raffinates for the Removal of Organic Reagents", by G.M. Ritcey, B.H. Lucas and A.W. Ashbrook, Proceedings of the International Solvent Extraction Conference, held at Lyon, France, Vol. 1, pp. 943-968, 1974.

"Air Pulsing Techniques for Extraction Columns", by M.H.I. Baird and G.M. Ritcey, Proceedings of the International Solvent Extraction Conference, held at Lyon, France, Vol. 2, pp. 1571-1589, 1974.

"Diluents and Modifiers—Their Effect on Mass Transfer and Separation", by G.M. Ritcey and B.H. Lucas. Proceedings of the International Solvent Extraction Conference, held at Lyon, France, Vol. 3, pp. 2437-2481, 1974.

"Some Comments on the Loss, and Environmental Effects of Solvent Extraction Reagents used in Metallurgical Processing", by G.M. Ritcey, B.H. Lucas and A.W. Ashbrook, Proceedings of the International Solvent Extraction Conference, held at Lyon, France, Vol. 3, pp. 2873-2884, 1974.

"Crack-Free Chromium from Conventional Plating Baths", by J.C. Saiddington and G.R. Hoey, Plating, Vol. 61, No. 10, pp. 923-930, 1974.

"Hydrolysis and Nitrosation of the $(NH_3)_5CoNCO^{2+}$ Ion. Evidence for $(NH_3)_5CoNHCOOH^{2+}$ and $(NH_3)_5Co^{3+}$ Intermediates", by D.A. Buckingham, D.J. Francis and A.M. Sargeson, Inorganic Chemistry, Vol. 13, No. 11, pp. 2630-2639, 1974.

"Strength Development of Concrete Exposed in Winter", by Carl Berwanger and V.M. Malhotra, published in the Engineering Mechanics Journal, American Society of Civil Engineers, April 1974.

"Study of Surface Chemical Characteristics in Gravity Separation", by S.R. Rao and L.L. Sirois. CIM Bulletin, pp. 78-83, June 1974.

"Mineral Wool Insulation from Asbestos Tailings", CIM Bulletin, pp. 97-104, December 1974.

"Sulphur-Infiltrated Concrete Promises High Strength at Early Ages", by V.M. Malhotra, published in Spanish in the Proceedings of the 2nd International Symposium on Concrete Technology, Monterrey, March 19-21, 1975, pp. 244-253.

"Sulphur-Infiltrated Concrete—An Alternative to the More Expensive Polymer Impregnated Concrete", by V.M. Malhotra, published in Concrete Construction, Chicago (in Spanish), Vol. 20, No. 3, March 1975, pp. 91-93.

"Reply to a Discussion by Henry E. Ahari of a Paper by V.M. Malhotra entitled 'Evaluation of Windsor Probe Test for Estimating Compressive Strength of Concrete' published in RILEM "Materials and Structures", No. 37, January-February 1974—by V.M. Malhotra, published in RILEM "Materials and Structures", No. 41, September-October 1974, Paris, France, p. 365.

"Evaluation of the Pull-Out Test to Determine Strength of In-Situ Concrete", by V.M. Malhotra, published in Materials and Structures, RILEM, Paris. France, Vol. 8, No. 43, January-February, 1975, pp. 19-31.

"Development of High-Strength Concrete at Early Ages Using a Sulphur-Infiltration Technique", by V.M. Malhotra, K.E. Painter and J.A. Soles, accepted for publication in the Proceeding of the International Congress on Polymer Concretes, London, U.K.

"A Discussion of a Paper Entitled 'Sulphur Impregnated Concrete, Sic' by Neils Thaulow, published in the Journal of Cement and Concrete Research, Vol. 4, No. 2, March 1974", by V.M. Malhotra, published in the Cement and Concrete Journal, Vol. 5, pp. 91-92, January 1975, Philadelphia, U.S.A.

"Thermal Conductivity of Mica as a Function of Temperature and Direction of Heat Flow", by V.V. Mirkovich, Proceedings of the 4th European Conference on Thermophysical Properties of Solids at High Temperatures, September 4-6, 1974, Orleans, France (paper now in print).

"Sulphur-Infiltrated Concrete—A New High-Strength Composite Material", by V.M. Malhotra, published in the Annual Review Number of the Northern Miner, Toronto, p. 106, November 1974.

"A Letter to the Editor of the Engineering Journal on 'Accelerated Strength Testing' ", published in The Engineering Journal, The Engineering Institute of Canada, Montreal, P.Q., Vol. 57/7, p. 82, 1974.

"Mineral Wastes—Ore Reserves for the Future?" by R.K. Collings, published in the Annual Review Number of the Northern Miner, Toronto, November 1974.

"Application of Polymers in Mineral Processing", by L.L. Sirois, published in the Proceedings of the Chemical Institute of Canada, Flocculation and Dispersion Symposium, Toronto, pp. 309-316, November 1974.

Patents Issued 1974-1975

Forming Oxalate Conversion Coatings on Iron or Steel	G.R. Hoey W. McLeod	U.S. Pat. No. 3,806,375 awarded April 1974
Co-extraction and Separate Recovery of Uranium and Thorium from Acid Solutions	G.M. Ritcey B.H. Lucas	U.S. Pat. No. 3,835,213 awarded September 1974
Methods of Forming Foundry Moulds	E.I. Szabo	U.S. Pat. No. 3,850,733 Can. Pat. No. 945,511

K. WHITHAM, Director-General

The objective of the Earth Physics Branch is to contribute to the description and understanding of the earth, its origin and evolution, physical configuration, structure and dynamic processes, as required for the management, development and use of Canada's physical domain for the present and future benefit of the Nation. To fulfill this objective, the Branch, organized in three scientific divisions, conducts seismological, gravity, geothermal, geodynamic and geomagnetic studies of the crust and interior of the earth.

An administration division provides central administrative and technical support services such as budgeting, accounting, record and property management, stores, drafting, photography, library, carpentry and machine shop facilities in support of the field operations and headquarters research programs of the scientific divisions.

The Branch operates throughout Canada a network of seismological observatories to monitor earthquakes and underground nuclear explosions, earth-motion observatories to monitor tilts, strains and polar motion and a network of magnetic observatories to monitor the magnetic field. As well, the Branch undertakes field work throughout Canada to improve and complete magnetic and gravity maps, to map the geothermal regime of Canada, to study permafrost and to undertake paleomagnetic and lithospheric studies in key formations and areas. Since many of the geophysical phenomena studied are global in character, the Branch participates in international projects and geoscience data exchanges in the relevant disciplines. Thus, it is the Canadian member of the International Seismological Centre.

The Branch provides advice, information and data to other government departments and agencies, to the mineral and petroleum exploration industry, to provincial government agencies, to universities and to the general public on technical problems within the Branch competence.

Some reorganization of the seismological activities of the Branch was completed during the year, and the first steps were taken in a complete overhaul of the technical information services provided by the Branch. Plans were made for Branch participation in the International Magnetospheric Project.

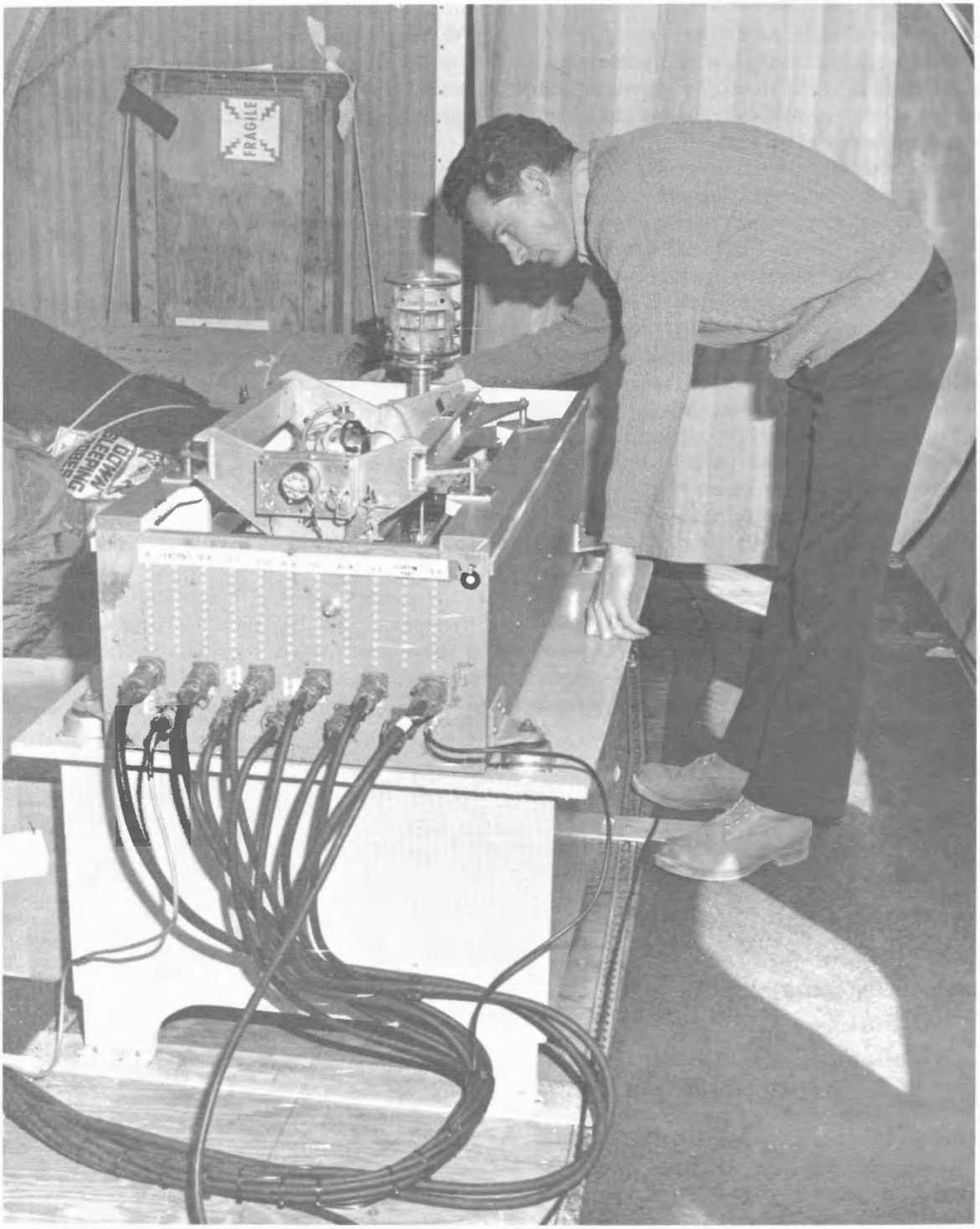
During the review period, a major three-component airborne magnetic survey of Central Canada was carried out, covering Manitoba, Ontario, Hudson Bay and the District of Keewatin. The third edition of the Bouguer anomaly map of Canada was published, providing regional gravity coverage for approximately two-thirds of Canadian terrain and waters. The Seismological Service completed its four-year project of theoretical and experimental studies to define the earthquake hazard along the proposed Mackenzie Valley transportation corridor. These and other activities of the Branch are discussed in the following pages.

DIVISION OF GEOMAGNETISM

P.H. SERSON, Director

The Division of Geomagnetism is responsible for the Geomagnetic Service of Canada, providing information on the magnetic field of the earth as required for navigation, telecommunications, and the control and interpretation of geophysical exploration surveys. In addition to publishing every five years up-to-date magnetic charts of Canada and the adjacent ocean areas, the Geomagnetic Service supplies geomagnetic data for over 2,000 map sheets published each year by other federal, provincial and international agencies. The Geomagnetic Service operates the Canadian Magnetic Observatory Network, consisting of 11 fixed magnetic observatories which record continuously the variations in the earth's magnetic field, ranging from the gentle year-to-year change known as the secular variation to the violent minute-to-minute changes occurring during magnetic storms.

The Division of Geomagnetism, besides providing industry, scientists and the general public with basic geomagnetic information, makes use of the geomagnetic field to study the structure, origin and history of the earth's crust. Large-scale magnetic anomalies mapped in airborne surveys give indications of the composition and structure of the crust at depth, as do electric currents induced in the earth by the natural variations of the geomagnetic field. The superimposed magnetizations in different directions acquired by rocks during their long lives can sometimes be disentangled in careful laboratory measurements, to yield both the history of the geomagnetic field and the history of various parts of the continents.



The Earth Physics Branch airborne magnetometer operating in a DC-6 aircraft during the 1974 survey over central Canada and Hudson's Bay. The photograph illustrates the three-component fluxgate sensor mounted on a gyro-stabilized platform.

Magnetic Surveys

A three-component airborne magnetic survey of central Canada was carried out in the fall of 1974. A total of 50,000 line-miles was flown along 30 survey lines extending from the United States border to the Arctic coast, and covering Manitoba, Ontario, Hudson Bay, and the District of Keewatin. The survey adjoins areas to the west and north which were covered by previous aeromagnetic flight lines spaced 20 to 40 miles apart. Improved navigational accuracy was achieved in the 1974 survey with the introduction of an inertial navigation system aboard the chartered DC-6 aircraft.

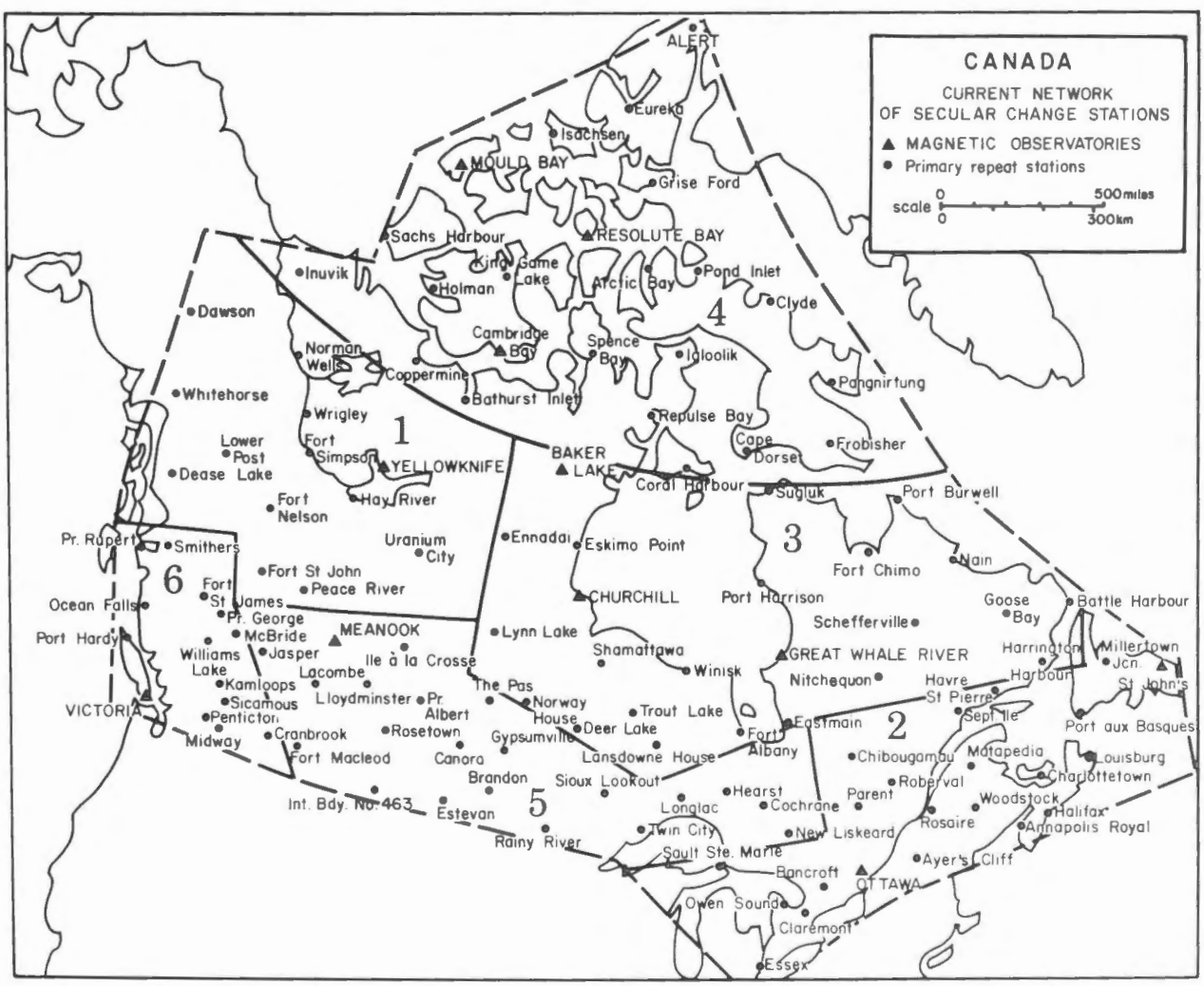
As part of a continuing study of secular variation in Canada, 23 repeat stations were occupied in Ontario, the Prairies, British Columbia and Northwest Territories. Portable recording variometers were operated for several days at each station to reduce uncertainties caused by diurnal variation and magnetic disturbances; absolute measurements in magnetic declination, inclination and total intensity provided base-line control.

Magnetic Charts

Magnetic charts of Canada for epoch 1975.0 showing declination, inclination, horizontal, vertical and total intensity at a scale of 1:10,000,000 are currently under preparation. Agreement has been reached with officials of the U.S. Geological Survey concerning values to be shown in common border areas. The printing of these charts should be underway in June, 1975.

The 1975 charts are based on a least-squares fit to over 20,000 magnetic observations made between years 1955 and 1974. The country was divided into four equal areas, with 10 per cent overlaps. The data, in the form of north, east and vertical components (X, Y, Z) for each area, were fitted with a 6th degree polynomial expressed as a function of latitude, longitude and time. The highest order time terms were cubic. The overall r.m.s. fit is 188γ.

Prior to the analysis, all data were screened using the International Geomagnetic Reference Field (IGRF) and an



arbitrary rejection criteria of 1000γ to eliminate erroneous or highly anomalous data. Only 92 of 20,490 observations were rejected. During the analysis, the following constraints were met; (1) curl H = 0, where H is the horizontal vector field; (2) X and Y cos θ were analyzed together, where θ is the geographic latitude and (3) data were weighted according to the type and date of the observation.

Magnetic data from the 1972 three-component aeromagnetic survey have been corrected for aircraft fields, and exist on digital magnetic tape as averages over 30 seconds of time (approximately 3.5 km of flight track). These data have been plotted as residual profiles, in D, H, Z, X, Y and F, relative to the International Geomagnetic Reference Field (IGRF). Lines of zero gradient have also been plotted. Three 3rd degree polynomials have been fitted to the data by least-squares, and vector residuals plotted relative to these polynomials. Differences between the polynomials and the IGRF are consistent with those of previous surveys, and again indicate biases in the IGRF of up to 300γ over about 2000 km.

A compilation map of anomalies in the vertical component of the magnetic field from high-level vector airborne surveys covers the northern and western Arctic Islands and western Canada. Major magnetic regions have been delineated. The vertical field is low in relief over the eastern parts of the Western Cordillera, with a broad embayment of subdued field over the Mackenzie Arc. Groups of high amplitude large-scale anomalies near the western edge of the buried shield are found in northeastern British Columbia, in the Northwest Territories and in the Yukon. The group of anomalies in the Northwest Territories and Yukon appears to extend at least to the Alaskan border, and suggests the presence of an ancient crystalline basement extending west from the known buried shield. The north to northeasterly magnetic trends common in most of the western Hudsonian crystalline basement appear to weaken or to be truncated south of 51°N. The relatively low relief anomalies in this latter southern region indicate major differences in magnetic character between this region and the region of high anomalies near the western edge of the buried shield, although both areas have considerable thicknesses of sedimentary cover.

Model interpretations have been made for a large-scale anomaly near Fort Nelson, northeastern B.C. Two-dimensional models showed that the anomaly could be explained by a body with base at 30 km depth and an irregular top of depth near 10 km, although shallower bodies could give equally good fits to the profile data used. Three-dimensional models, using an extended data set, showed that the bulk of the source body could lie within 7 and 24 km depth, although the exact shape was not well defined. The body could have a uniform magnetization in the ambient field direction of about 0.005 emu/cm^3. This body produces one of the largest high-amplitude anomalies in western Canada, and should have considerable significance for the tectonic history of northeastern British Columbia.

Magnetic Observatories

Magnetic observatories operated continuously through the year at Mould Bay, Resolute Bay, Cambridge Bay and Baker Lake in the Arctic; at Churchill and Great Whale River in the auroral zone; and at Victoria, Meanook, Ottawa and St. John's in southern Canada. A new Automatic Magnetic Observatory System (AMOS) at Yellowknife, Northwest Territories, began operation in July 1974, but reliable records were not obtained until October 1974. All the above observatories except Mould Bay record three components of the magnetic field plus total intensity in digital form on magnetic tape at one-minute intervals. Photographic records in standard magnetogram format are produced at all observatories except Yellowknife, Cambridge Bay and St. John's. Pen-and-ink fluxgate charts are available for the arctic station of Alert. Microfilm copies of all analogue records are deposited regularly at World Data Center A, Boulder, Colorado. Edited versions of the digital data are also deposited in the World Data Center. Telephone Verification Systems for checking the AMOS' performance by phone from Ottawa were installed at Yellowknife and Baker Lake Observatories in 1974.

In addition to the standard magnetic observatories, seven magnetic variation stations (without absolute control) were operated on a line from Winnipeg through Churchill to Rankin Inlet. Low-powered digital data loggers were installed at four of the stations in November 1974. These stations will play an important part in the International Magnetospheric Study (IMS), a three-year observing program due to start in 1976.

Paleomagnetism

A single coherent polar path (Track 5) has now been developed from the Laurentian Shield for the interval 2200-1800 m.y. in collaboration with workers from the GSC and Carleton University. The results are mainly from the Slave and Superior Structural Provinces, and hence they show that the Churchill Structural Province between them was not a product of plate-style orogenesis. The geosynclines of the Churchill Province appear to have been only narrow rifts and were not the sites of wide oceans.

A polar path (the Grenville Track) has been developed from observations from the Grenville Province. This is the first such track from metamorphic terrain, and it records the horizontal motions which the Grenville Province underwent during uplift following metamorphism. As previously suggested by Palmer and Carmichael and ourselves, these results indicate (but do not of course prove) that plate-style motions were involved during Grenville orogenies. A model has been developed based on the paleomagnetic evidence in which the Grenville orogenic cycle is thought to be an ocean opening and closing type orogenesis occurring between 1250 and 1000 m.y. ago. This idea is regarded as heretical by most geologists, but is nevertheless consistent with the existing geological evidence.

This appears to be the earliest plate-style rifting of the Canadian Shield.

An analysis of geomagnetic polarity has been completed for the Phanerozoic. Of especial interest are the periodicities in polarity bias of 300, 103, and 57 m.y., the former being the dominant long-term variation, presumably related to fundamental processes at the core-mantle interface.

Sampling in the 1974 season was carried out in Newfoundland (Holywood granite, Cambrian, Silurian and Carboniferous sediments), Ontario (Otto syenite, Huronian sediments, Nipissing diabase), and the Maritime Provinces (Ordovician, Silurian, Devonian and Carboniferous sediments).

Electromagnetic Induction and Crustal Structure

An investigation of electromagnetic induction in the crust over the continental shelf and slope west of Banks Island was carried out in April 1974, with unmanned magnetic recording stations set up on the sea ice. Six three-component fluxgate magnetometers were equally spaced along a northwest-southeast line from North Central Banks Island through Gore Island to 272 km offshore. Three offshore sites on this line straddled the continental shelf and slope. The extreme offshore station was over an estimated 3 km of ocean water. All data were recorded digitally with a 1 minute sampling rate. Polar Continental Shelf Project provided logistics and transportation in the area. More than 15 days of simultaneous data were obtained at 7 of these sites with only a few days at the remaining two. Visual examination of computer plotted magnetograms indicated that the North Central Banks Island site had the pronounced attenuation of short period events (10-20 minutes) in Z component as observed at Mould Bay and Castel Bay. All other land stations recorded sufficient short period energy to indicate that these sites were outside the anomalous zone. Records at the offshore stations gave a progressive attenuation of short period events in Z component with increasing depth of ocean. No reversals in direction of Z events were observed between the Gore Island station and the extreme ocean site.

An analysis was completed of short-period activity (15 to 120 minutes) recorded in 1972 with an array of 40 magnetometers in Saskatchewan, Manitoba, Montana, the Dakotas, Wyoming, and Nebraska, in a joint experiment with the University of Alberta. Source fields were from polar magnetic substorms and other events with more uniform external fields. The crustal conductor responsible for the North American Central Plains anomaly has been mapped northward from the Black Hills of South Dakota to within 100 km of the exposed Canadian Shield in north-central Saskatchewan. South of the Black Hills the conductor turns southwest and appears to plunge to link with the upper mantle conductor beneath the Southern Rockies. It is postulated that the linear crustal structure may be a major continental fracture zone with a total length of 1800 km, 300 km of which is exposed in the Shield.

A magnetotelluric experiment for study of crustal and upper mantle structure in and near the seismic zone at La Malbaie was conducted in October. Simultaneous observations were made at five locations using 3-component fluxgate magnetometers, telluric amplifiers, and digital cassette recorders. Recording at La Malbaie will continue for a period of 1-2 years in a combined Earth Physics Branch program to monitor seismic, gravity, tilt and geoelectrical effects in this active region.

A joint project with the Department of Physics, University of Victoria, to study the possible channelling of electrical currents through the straits separating Vancouver Island and the British Columbia mainland is continuing. Four field stations, two on Vancouver Island and two on the mainland, were occupied in 1974. Analysis of the data is proceeding and results are being compared to analogue and numerical models.

Rapid Geomagnetic Variations

Analysis of the data from the co-ordinated ground-based and rocket-borne observations during the January 15, 1972, event is completed except for the magnetic field data obtained along the rocket trajectory. The models indicate westward electrojets north of the arc and eastward currents inside the arc and upward within the arc. The field-aligned currents probably exceed the critical limit of flow possible along the magnetic field lines. A similar analysis is underway for the February 28, 1974, event.

The effect of the July 10, 1972, solar eclipse on the ionosphere currents is being investigated.

The longitudinal extent of a Pc5 geomagnetic pulsation was studied and found to be an odd-mode shear Alfven wave.

Plots of the data from all the magnetic stations along the Churchill meridian, which were prepared for co-ordinated studies with the ISIS II data, are available for the following dates: 17, 18, 19, 20 December 1971; 11, 15, 22 January 1972; 10 July 1972; 14, 21, 22, 28 February 1974.

Geomagnetic pulsations of the Pc5 class (periods 180 to 600 sec) were studied, using the 1967 standard observatory magnetograms of Victoria, Agincourt, Meanook, Great Whale River, Fort Churchill, Baker Lake and Resolute Bay. These data, at each station, were divided into the following groups: 1) Long period (300—600 sec) pulsations; 2) Short period (180 - 300 sec) pulsations; 3) Large amplitude ($\geq$ 40 nT) pulsations; and 4) pulsations which occurred during the same UT hour over a wide area of Canada. For each case the variations in the occurrence, amplitude and period with several geophysical variables were studied.

Large amplitude pulsations occurred in a belt from 60° to 74°N geomagnetic latitude. In case of simultaneous occurrences the periods of Pc5 increased with increasing latitude for low magnetic activity, but for the stronger magnetic agitation the periods were found to be smaller in the cleft region. Results show that under strong magnetic conditions the cleft

region moves equatorwards. In addition, the part of the magnetopause where pulsations are supposed to be generated seems to move to a lower altitude in that region.

For Great Whale River a strong correlation has been found between the Pc5 amplitude and the hourly values of the geomagnetic H-component at the diurnal, semi-diurnal and ter-diurnal frequencies. These results suggest that the ionosphere plasma exercises a stronger control on the amplitude of Pc5 than hitherto realized.

GRAVITY AND GEODYNAMICS DIVISION

J.G. TANNER, Director

The activities of the Gravity and Geodynamics Division are divided between the Gravity and Geodynamics Services of Canada. The Gravity Service carries out the collection, processing, and geodetic and geological interpretation of gravity data over the Canadian landmass and continental shelves. The Geodynamics Service is engaged in investigations of the dynamics of the earth through measurements and analyses of crustal strain and tilt, earth tides, and microgravimetry variations, and by studies of the earth's rotation and polar motion.

One of the main highlights of the division within the past year was the publication of the third edition of the Bouguer Anomaly Map of Canada which provides regional gravity coverage for approximately two-thirds of Canadian terrain and waters, and incorporates some 350,000 observations. Another significant event, in early 1975, was the first successful Canadian airborne gravimeter experiment using a North-Star aircraft on a flight from Ottawa to the Bruce Peninsula. Preliminary results from this endeavour are encouraging.

Gravity Service

The Gravity Service of Canada has as its principal objective the collection of gravity data for the Canadian landmass and continental shelves. These data provide the basis for geophysical studies concerning the composition and structure of the earth's crust and mantle, and for geodetic studies of the shape of the earth. These studies in turn provide, respectively, important geological frameworks for the exploration industry in its quest for non-renewable resources, and improved controls for Canada's map makers.

Gravity Surveys

In 1974 four major surveys and two small ones provided 4,700 new gravity observations over the Canadian landmass and sea ice, and 16,000 line kilometres of shipborne surface gravity meter data.

1. *British Columbia.* Some 650 gravity stations were observed using helicopter transport on Vancouver Island and in adjacent areas of the Coast Mountains. The work on Vancouver Island was directed to upgrading and densifying the existing coverage to conform with regional mapping specifications (12 km spacing). The Coast Mountains survey completed the regional mapping in this part of the Cordillera as far north as latitude 54°. During the survey a new positioning technique based on aerial photo mensuration was tested.
2. *Labrador Sea.* Between mid-June and mid-August, about 16,000 line kilometres of shipborne surface gravity measurements were made in the northern part of the Labrador Sea mainly between latitudes 56° and 62°. An average track spacing of 32 km was maintained during the survey.
3. *New Brunswick.* A field party supported by two vehicles and one helicopter occupied 2,200 gravity stations in New Brunswick. Combined with previous surveys, the new information will provide an average station spacing of 6 km throughout the province. Evaluation and upgrading of horizontal and vertical survey control used on previous surveys was also an important objective of this survey.
4. *Northwest Territories*

   (i) *Agricola Lake.* As part of a multidisciplinary study on mineral resource appraisal, co-ordinated by the Geological Survey of Canada, a detailed gravity survey was carried out over a prominent geochemical anomaly in the vicinity of Agricola Lake. Approximately 160 gravity observations were made on a locally surveyed grid of profiles 300 m apart, with station spacing varying from 10 to 50 m.

   (ii) *Amundsen Gulf.* Helicopter transportation was used to occupy 1,550 gravity stations on the frozen surface of Amundsen Gulf during March and April. This survey completes the coverage on the easterly and westerly approaches to the Gulf.

   (iii) *Sverdrup Basin.* In the Hassel Sound region, northeast of King Christian Island, 165 gravity observations were made at 1.5 km intervals along the line of a seismic experiment being carried out by the Geological Survey of Canada across the Sverdrup Basin.

Gravity Interpretation

The Precambrian Canadian Shield and the continental shelves and margins were the main areas of attention for regional gravity studies; a detailed gravity study of a Precambrian base metal deposit was also undertaken. In addition studies of subsidence patterns in the Sverdrup Basin, rock densities in the Interior Plains, and global plate motions were carried out.

1. *Labrador-Quebec.* In the eastern Grenville Province linear belts of steep gradients which delineate extensive regional anomalies are believed to coincide with major faults. One such belt coincides with the boundary between the Lake Melville graben and the Mealy Mountains horst. The faulting may be related to the development of the Lake Melville and St. Lawrence rift systems. In the same region prominent gravity highs (30-85 mgal) which are unique to

the area correlate with areas of anorthositic and gabbroic rocks. The anomalies are interpreted as large gabbroic bodies which may have formed in the lower levels of magma chambers from which rocks of the anorthositic suite were derived.

2. *Northwest Territories.* A detailed gravity survey near Agricola Lake outlined a small positive anomaly in a region where interesting Cu-Zn geochemical anomalies had been found by the Geological Survey of Canada. The anomaly coincides with a massive sulphide body detected through drilling by an exploration company. The residual anomaly derived from the gravity field has an amplitude of about 0.5 mgal. It correlates closely with a resistivity anomaly. In a regional study of the Western Churchill Province major negative anomalies in zones of high-level crust, characterized by abundant greenstones and greenschist to amphibolite facies metamorphism have been attributed to epizonal granitic plutons of Archean and Aphebian age. Gravity highs have been related to basic volcanic and intrusive rocks and to areas of deep-level crust, characterized by granulite or retrograded granulite facies metamorphism, roots of batholiths and an absence of greenstones.
3. *Continental Margins.* Belts of prominent elliptically-shaped free air gravity highs (peak values~100 mgal) occur over the continental break of several passive continental margins. Such anomalies over the Mackenzie Delta, Norwegian and Nova Scotian margins may be largely explained by pro-grading wedges of Quaternary and Tertiary sediments which have displaced sea-water and act as uncompensated loads on the crust. This effect combined with the edge effect for an Airy compensated model accounts for most of the gravity high along the break (~80 mgal). Basement or mantle ridges, high density belts in the basement, or carbonate banks may provide the source of the remainder of the anomaly.
4. *Scotian Shelf.* Studies of gravity and magnetic anomalies on the Nova Scotian continental shelf suggest that there is continuity of regional basement structure between southeastern Newfoundland and eastern Cape Breton Island. The continuity is terminated to the south by the Orpheus gravity anomaly which delineates structure separating magnetic basement on the north from essentially non-magnetic basement to the south. Modelling of magnetic anomalies and combined analysis of gravity and magnetic anomalies indicate that, in many cases, a significant amount of remanent magnetism is present in the basement rocks. An interesting problem is whether directions of total magnetization obtained from these analyses have any paleomagnetic significance.
5. *Subsidence Studies—Arctic.* Basin subsidence associated with the Sverdrup Basin is believed to be the product of two processes; formation of an initial depression at the earth's surface due to thermal contraction of the lithosphere and isostatic amplification of the depression by loading with sediments. Most of the observed subsidence, at least 70 per cent, results from lithospheric response to loading and it was determined that, to a first approximation, the pattern of observed basin subsidence and peripheral uplift is consistent with the loading response of a lithosphere modelled as a viscoelastic beam.
6. *Density Studies—Interior Plains.* An extensive density study based on gamma-gamma logs from 435 wells was completed in an area extending from the Rocky Mountains eastward to longitude 100°, and from the international boundary northward to latitude 56°. Large density variations have been outlined both horizontally and vertically. Generally, density above sea level increases towards the Rocky Mountains, whereas below sea level no general rule is apparent. The vertical density gradient appears to be higher at shallow depths than at greater depths.
7. *Global Plate Motions.* Preliminary studies of plate motions show that "hot spots" provide a frame of reference for plate motions and that this reference frame is one in which the net torque between the lithosphere and the mantle is nearly zero if the drag on oceanic plates is substantially less than it is on continental plates. Using poles and rates of rotation defined by hot spots, past positions of the paleomagnetic pole relative to each plate may be predicted. Although there is generally good agreement between predicted and observed Tertiary poles, there are significant discrepancies for earlier periods.

Physical Geodesy

Preliminary investigations using gravity data available for Canada and the northern part of the United States were carried out to obtain numerical estimates for the truncation error in the calculation of the "residual" geoidal height due to the variations of the "local" gravity field. Computations for 20 stations placed along two profiles indicate that the average truncation error amounts to -5.8m, -4.2m and -0.8m if the integration is carried out to angular distances of 8°, 10° and 20° respectively.

A method of predicting point and mean gravity anomalies using a local bivariate covariance function is being developed. The concept of bivariate character is introduced to take care of any possible directional variation of the covariance function. Another aspect of this method is that, instead of the gravity anomalies themselves, the covariance function corresponding to some suitable function of the anomalies has been derived which, in turn, makes it possible to obtain an analytical function for the prediction of mean gravity anomalies over blocks bounded by parallels and meridians.

In satellite geodesy a method for the determination of the position of a ground receiving station using the integrated doppler count of a single satellite pass has been developed.

Standards and Information

The Standards and Information Section is responsible for the National Gravity Data File which contains gravity data observed in Canada by government field parties or contributed by private industry and universities. At the present time some 500,000 observations including data outside Canada are on file. A computer retrieval system is used to provide gravity and related data in a variety of formats tailored to the needs of the user. Among these are digital tapes, plots and listings. Approximately 120 external and 480 internal requests, involving the retrieval of some 200 million characters of information were processed over the last year.

During the year several improvements were made to the retrieval software for the National Gravity Data File to permit the incorporation of dynamic gravimeter data. Data from some 270,000 observations obtained in offshore surveys by the Atlantic Geoscience Centre and the Department of the Environment were merged into the file.

The section also organizes an on-going program to improve and maintain the National Gravity Net, which is the absolute reference system for all gravity work in Canada. To this end two surveys were conducted in 1974. The first established 20 new control stations in the central and western Arctic Islands to provide a better gravity reference network for the oil exploration industry. The second survey updated 250 control stations in southeastern Quebec.

The expertise of the section was also directed to aiding the Ontario Ministry of Natural Resources with gravity surveys in the New Liskeard and Sturgeon Lake areas, and Ahmadu Bello University, Zaria, Nigeria, to establish a reference network and regional gravity map for Nigeria. The section also contributed to the international gravity standardization program through the compilation and adjustment of a gravity reference net spanning 17 Latin American countries.

EAI 430 plotter operating in Gravity Division's Data Centre.

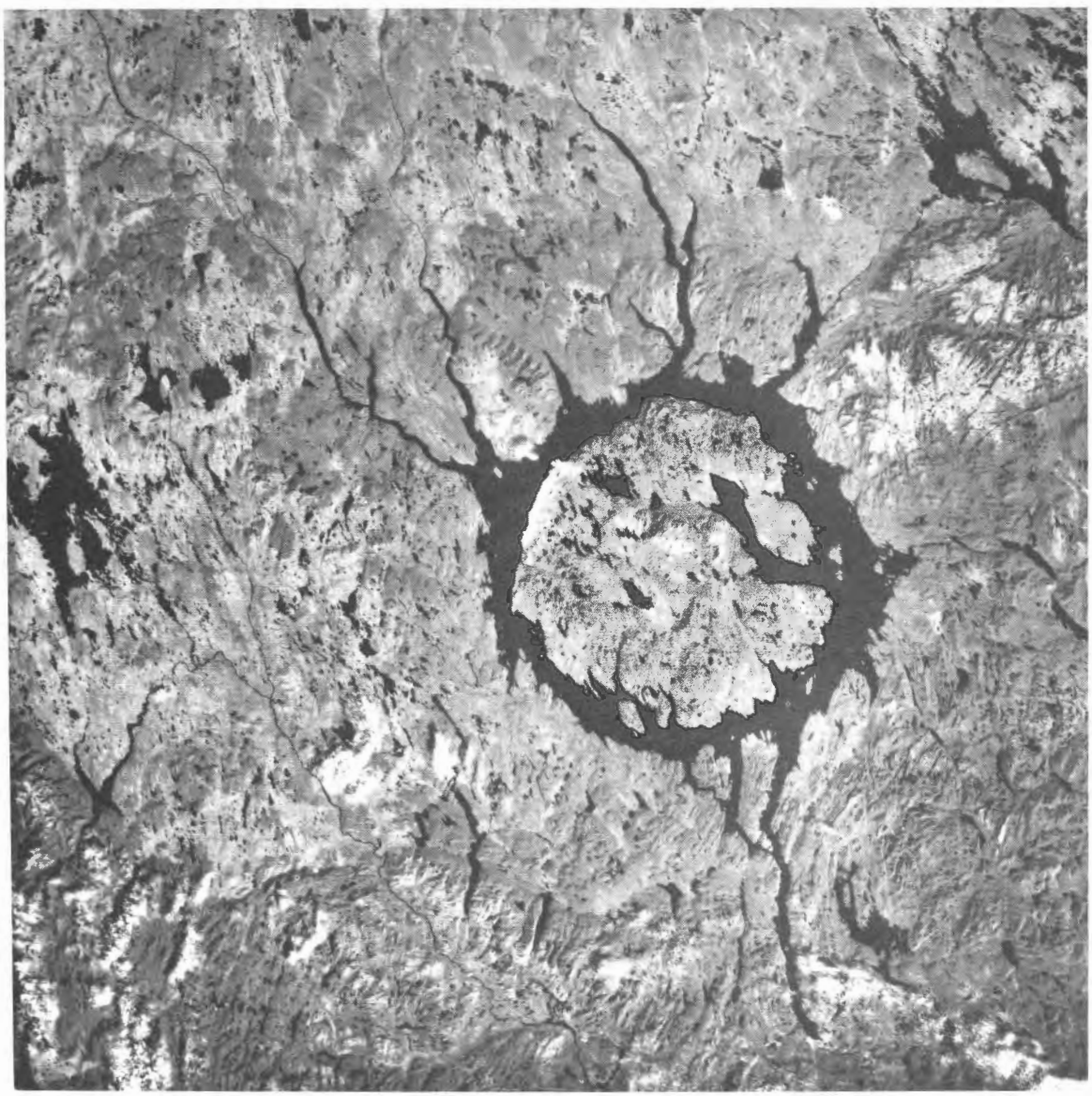
Rock Physics

The main interests of the Rock Physics Section are the role which meteorite impact may have played in the development of the earth, and a study of the structures and rocks produced by such impact.

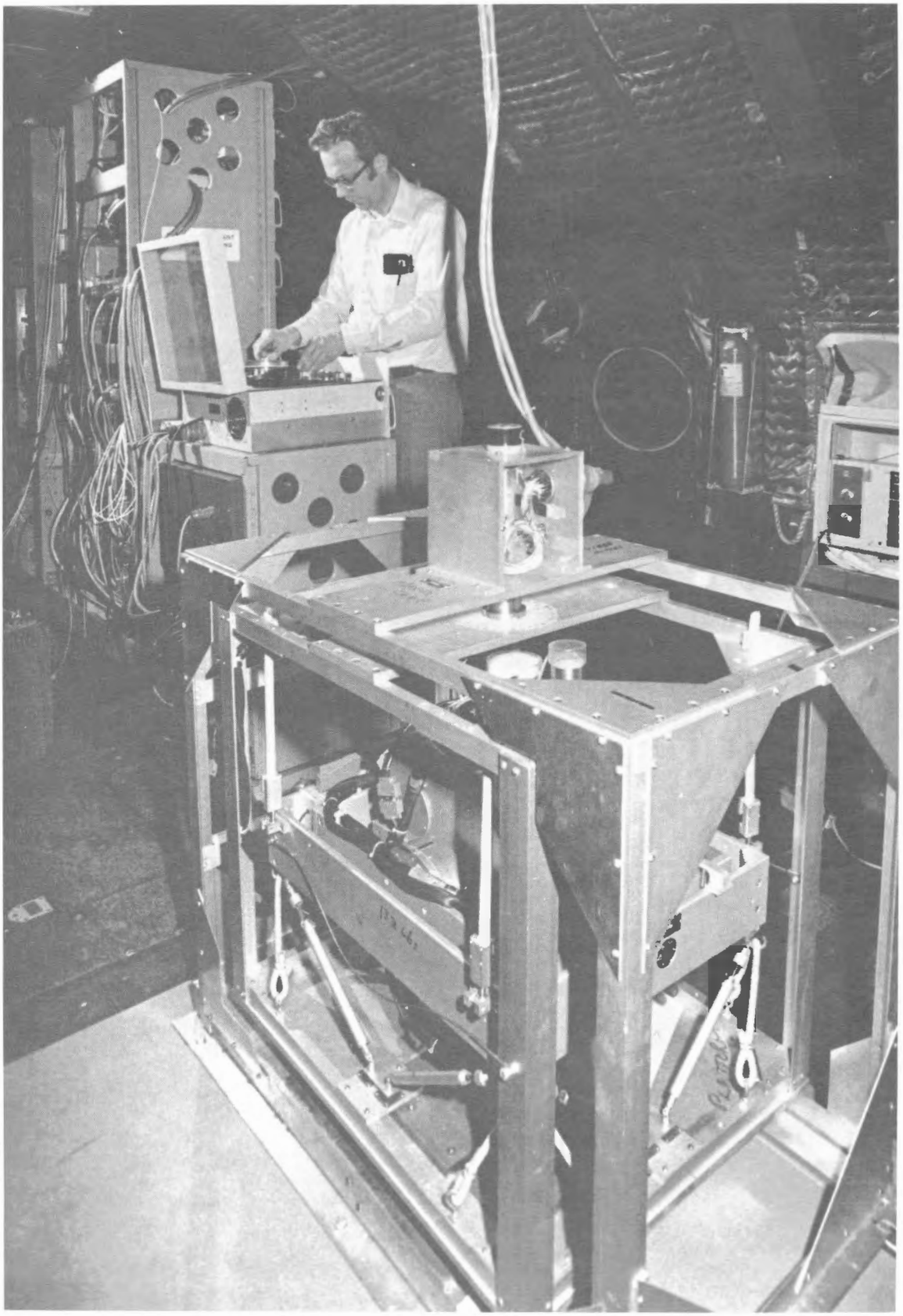
The Haughton Dome structure on Devon Island and the Slate Islands, Lake Superior, were added to the list of Canadian impact sites with the discovery of shock metamorphism phenomena at each. Using the size-frequency distribution of Canadian impact craters (22) it has been shown that the cratering rate on Earth has been equivalent to that on the lunar post-mare surfaces.

New studies were undertaken at the Manicouagan and Charlevoix craters. An aerial photograph interpretation of the Manicouagan crater was completed using imagery obtained by the Skylab astronauts. Scientists from NASA's Johnson Spacecraft Center, Houston, joined members of the Rock Physics Section in carrying out detailed sampling of the impact melt rocks at this crater. At Charlevoix the data from shock zoning studies were used to confirm the concepts of central uplift formation in complex meteorite craters.

Studies of lunar material continued with emphasis on determining sampling horizons in selected lunar craters as determined from characteristics of the surrounding ejecta.



Vertical satellite photograph of Manicouagan impact crater, Quebec, taken from Landsat A at a height of 925 Km. The outer diameter of the circular reservoir is 65 Km. Scientists from the Gravity Division and NASA carried out a joint field expedition to this feature in 1974.



Member of Gravity Division preparing a LaCoste and Romberg Model S-56 air/sea gravimeter for a test flight aboard a North Star aircraft.

Instrumentation

The Instrumentation Section provides invaluable support to both the Gravity and Geodynamics Services especially in the realm of gravity meter systems.

The increased participation over the last few years in shipborne gravity surveys has required research in the field of instrumentation of dynamic gravimetry. To this end the evaluation of a LaCoste and Romberg shipborne gravity meter complete with a 3-axis inertially stabilized platform for the direct measurement of the Eötvos correction was conducted with promising results.

An exciting step in dynamic gravimetry was taken early in 1975, when the same gravity meter was installed in a North-Star aircraft in the first Canadian attempt to measure gravity in an aircraft. Test data were obtained on a flight from Ottawa to the Bruce Peninsula. The experiment was conducted in conjunction with the National Aeronautical Establishment which provided expertise in avionics and aerodynamics. The preliminary results of the test are encouraging and it is envisaged that in the not too distant future airborne gravimetry will provide a rapid and economic method of obtaining regional gravity data over the remote and sometimes inhospitable Canadian terrain, as well as over Canadian waters.

Geodynamics Service

The role of the national geodynamics service is to increase the understanding of the dynamics of the earth by analyzing the motions of the whole earth and its crust and upper mantle, to provide basic information necessary to refine time standards, to improve the accuracy of geodetic networks and to support other national and international geodetic and geophysical research projects.

Earth Tides

The Earth Tides group is largely concerned with the collection and evaluation of data provided by tilt and strain meters operating at sites in eastern Canada. The design of such sites is a related study. A new site was established in the seismically-active La Malbaie region in order to investigate the possibility of detecting earthquake precursors based on the dilatancy fluid diffusion model. As an integral part of this investigation gravity observations were made using a LaCoste and Romberg Model D microgravimeter; 13 first-order monuments were established to permit regular reoccupation. Unusual ground water variations in Prince Edward Island have been studied by microgravimeter surveys in two different seasons, and a systematic gravity change has been detected. In theoretical work a technique has been developed for accurately predicting tilt-strain coupling effects due to topography near measuring sites. The section has recently commenced a project to use the latest American geodynamics satellite, GEOS-C, to investigate various earth tide/ocean tide properties.

Polar Motion

The Polar Motion group carries out studies of polar motion, earth rotation and crustal plate movements by continuous observations using astronomical and satellite techniques. Its program is closely related to the internationally co-ordinated studies of global geodynamics phenomena organized under the auspices of the I.A.U. and I.U.G.G.

This long term program includes the operation of the two Canadian photographic zenith tubes (PZT) located near Ottawa and Calgary which contribute data regularly to the international time (B.I.H.) and polar motion (I.P.M.S.) services. A close co-operation is maintained for the observing programs between the Calgary PZT and the Herstmonceux PZT of the Royal Greenwich Observatory.

In 1974 two satellite Doppler tracking stations were obtained on loan from the United States and installed near the PZT sites. The stations are included in the world-wide TRANET satellite tracking network and commenced regular data transmission to the Dahlgren Polar Monitoring Service. The main effort is presently concentrated on automation of the satellite data acquisition, verification, storage and communication using an on-line mini-computer distributed system.

SEISMOLOGY AND GEOTHERMAL STUDIES

M.J. BERRY, Director

The Division of Seismology and Geothermal Studies is responsible for the Seismological and Geothermal Services of Canada.

The Seismological Service monitors the seismic ground motion in Canada by operating a number of seismograph networks throughout the country. The scientists of the Service use the data from the stations to determine Canadian seismicity and with this knowledge make the best estimates possible of the seismic risk, with special emphasis on those areas around urban centres and regions of industrial development that lie in zones that are earthquake prone. Extensive theoretical studies are also undertaken to supplement the observational program.

Other scientists use the data base to determine the structure of the Canadian landmass and to study the nature of the mantle and core of the earth. These studies frequently require special field experiments involving controlled sources which may vary from a simple explosion to such complex devices as "Vibroseis" vibrating trucks.

The Service provides advice on a wide spectrum of subjects that involve seismology in one fashion or another. A continuing significant application is the problem of the detection and identification of underground nuclear explosions.

The Service was reorganized during the past year in order to respond more flexibly to the varying demands placed on it, and especially to be able to devote more effort to the study of Canadian seismicity and seismic risk. There are now four

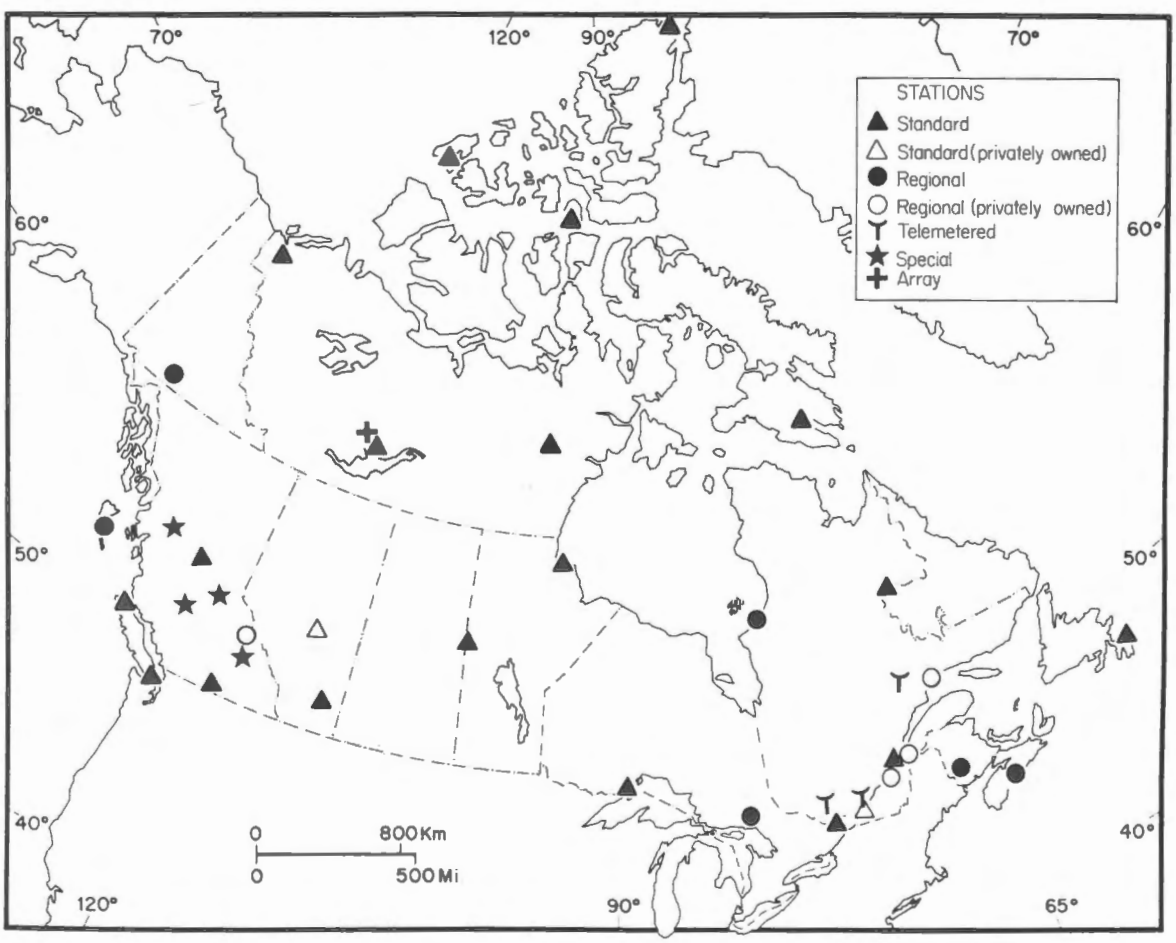
sections: Seismicity, Seismic Hazards and Applications; Seismotectonics and Seismic Hazards (based in Victoria); Seismological Studies of Earth Structure; and the Seismological Instrumentation Laboratory. The laboratory supports the research of both Services by developing systems necessary for data acquisition and by maintaining the extensive seismograph networks.

The Geothermal Service seeks to determine the geothermal regime throughout the country in order to understand deep-seated earth phenomena and to provide shallow and deep permafrost information appropriate to the needs of the resource industries and regulatory agencies. This experience is now being directed towards exploring the potential for geothermal power development in Canada.

Seismological Service

The Seismological Service operates a variety of seismograph stations throughout Canada and is responsible for instrument development and calibration, quality control, and data collection and dissemination. During the 1974-75 period, this seismograph network consisted of 22 standard stations, 11 regional stations, the short-period and long-period Yellowknife array, the Eastern Canadian Telemetered Network, temporary long-period digital stations in the Cordillera, and 97 strong-motion seismographs in western Canada. A two-month field survey using 20 specially deployed seismographs was undertaken in June and July, 1974, to monitor the low level seismicity along the St. Lawrence River centred on La Malbaie, Quebec.

Approximately 30,000 P phases were reported by the standard stations. These were relayed to international data centres for earthquake determinations. Original Canadian seismograms and data continued to be in constant demand by national and international research institutions. There was also a continuing demand for the loan of microfilm of Canadian seismograph records.



CANADIAN SEISMOGRAPH NETWORK - 1974

An on-line digital processing system was installed at the Yellowknife seismological array in early 1974. This system acts as an automatic event detector, data editor and array monitor. Telephone facilities have been installed to provide dialed access to the event detection log from Ottawa.

The Eastern Canadian Telemetered Network continued operation with 1200 baud telephone line transmission from three outstations to the Ottawa data laboratory. During 1974 the Hauterive, Quebec, outstation was moved to its intended location near the Manicouagan reservoir. In early 1975 a similar telemetered network is being deployed in the Vancouver Island-Georgia Strait region with data transmitted to Victoria.

Seismicity of Canada

The Service continued its study of Canadian earthquakes in 1974-75 in three general time frames: rapid determination, within about 48 hours, of earthquakes of interest or concern to the general public; preparation of preliminary monthly lists of earthquake activity for distribution to interested agencies; and preparation of definitive annual catalogues of earthquakes in Canada and adjacent areas. These investigations of Canadian earthquakes are based on recordings from the seismograph stations and are undertaken to delineate regions of significant earthquake activity, to assess earthquake hazards, and to contribute to general geophysical studies of the tectonic forces acting within the Canadian landmass.

Special investigations are undertaken for significant earthquakes and, during 1974-75, studies were completed for earthquakes at the north end of Vancouver Island, near Terrace, British Columbia, and on the Quebec-Maine border.

Earthquakes continue to be of general interest and, at times, some concern to the Canadian public and the Service responded to numerous requests for information throughout the year.

During 1974 a special 2-month study was made of the low level seismicity at the site of this century's most damaging eastern Canadian earthquake, the 1925 magnitude 7 earthquake in the St. Lawrence Valley near La Malbaie. Twenty-two special recording stations were deployed within a radius of 50 km and they detected an average of one microearthquake per day. The data are being studied intensively to gain further insight into the mechanisms of earthquakes in eastern Canada.

Studies of Earthquake Hazards

The history of Canadian earthquakes, to which additional information is added each year, continues to be evaluated for purposes of defining regions of the country subject to earthquake hazards and to assist in setting practical standards for earthquake-resistant construction. The Service responds to numerous requests for information on earthquake hazards from engineers, various government agencies and the general public.

In 1974, the Service completed its 4-year project of theoretical and experimental studies to define the earthquake hazard along the proposed Mackenzie Valley pipeline routes for the Task Force on Northern Oil Development, Environmental-Social Program, Northern Pipelines. As part of its national program, the Service will continue to monitor the seismicity of the Mackenzie Valley, and continue to evaluate new data with respect to conclusions already reached. During 1974, special studies began of the earthquake history of the Canadian Arctic archipelago. Emphasis, in this continuing project, will be placed on relationships between seismicity patterns and tectonic features, and on earthquake hazards in resource development areas and along proposed pipeline routes.

The Service has agreements with Hydro-Quebec, the James Bay Energy Corporation and, through a University of British Columbia research agreement, with B.C. Hydro to monitor seismic activity in the vicinity of the Manic 5, LG2 and Mica damsites, respectively. The Manicouagan seismograph records remotely in Ottawa as part of the Eastern Canadian Telemetered Network; the LG2 seismograph is planned for installation in the summer of 1975; the Mica seismograph system is a microearthquake array operated by the University of British Columbia. The purpose of these seismographs, in conjunction with others of the national network, is to monitor the seismicity in each region and to interpret, if it occurs, any seismicity related to reservoir loading.

In 1974, a subcommittee was established under the aegis of the Canadian Nuclear Association to draft a Canadian Standards Association Code on Seismic Design Requirements for CANDU Nuclear Power Plants. Service personnel are participating on those aspects of the draft code related to seismological and geological investigations and specification of design seismic ground motions for nuclear power plant siting and design.

Research on earthquake strong ground motions has continued during 1974-75. Ninety-seven strong motion seismographs in western Canada are now being maintained by the Service. Studies have continued on methods of reducing strong motion data and on deriving laws for the attenuation of strong ground motion with distance from the causative earthquake. Theoretical studies during 1974-75 have involved calculations of residual ground deformation for Pacific Coast earthquakes and comparisons of actual and theoretical strong ground motion spectra. These studies of earthquake strong ground motions provide essential information for the design of earthquake-resistant structures.

Studies of the Structure and Evolution of the Earth

The Service studies the dynamic processes, materials and structure of the earth beneath Canada by a wide variety of

techniques, all fundamentally based upon the arrival times and amplitudes of seismic waves propagating from distant earthquakes and nuclear events or from controlled seismic sources at shorter distances. Seismic waves provide one of the few direct probes available to earth scientists as they investigate the properties of the earth from its near surface crustal layers down to its inner core.

Slowness and azimuth measurements of a variety of seismic phases at the Yellowknife array have been interpreted in terms of core structure and lateral variations in the mantle. Special attention has been given to the deep mantle beneath the Caribbean and Pacific regions and the upper mantle to the east of the array. Ray tracing in laterally heterogeneous media is being used as an aid in interpreting the phases caused by scattering from small irregularities at the base of the mantle. The P'P' phase and its precursor have been shown to be influenced by lateral variations and possible scattering near the expected great circle reflection point, which gives the waves a strongly asymmetric character. An average mantle model has been determined from P phases recorded at the Canadian stations. It shows a low velocity zone below the crust and average station residuals which vary as a function of age and heat flow value. The remaining residuals show rapid variation with azimuth and distance and are considered to be due to dipping plates near the source or receiver regions.

A detailed study of the lithosphere in southwestern British Columbia is continuing, using the data from the long period digital network which is temporarily deployed in the area. The results to date suggest that upper mantle structure is more closely related to the recent tectonics of the region than to the older visible geological features.

In 1973, the Service conducted a trial experiment using the "Vibroseis" technique of the oil exploration industry as a means of delineating crustal structure by near-vertical reflection. This method proved quite successful and a further test in the Chatham, Ontario, area was carried out in 1974.

Geoscience of Nuclear Explosions

The Service is responsible for basic and applied research into the uses of seismology; in particular, it carries out research and provides advice to the Department of External Affairs on all matters pertaining to seismological verification of a ban on underground nuclear explosions.

During 1974-75, a complete evaluation has been made of the automatic detection capabilities of the on-line processing system at the Yellowknife array. Analyses of the event detection log and the array data have produced a definitive threshold of array detection capability and identified the influences of local noise sources on the seasonal variations in detection threshold. Technical facilities have been developed to provide daily transfer of the array event log to Ottawa for rapid access by the Ottawa research group and for further dissemination to the international community.

Studies of nuclear test detection and discrimination have continued. In collaboration with Swedish seismologists, a discrimination analysis has been completed for earthquakes and underground explosions in the United States in 1972. Scientists of the Service have also evaluated the feasibility of nuclear test evasion by multiple shooting of nuclear explosions to simulate earthquakes.

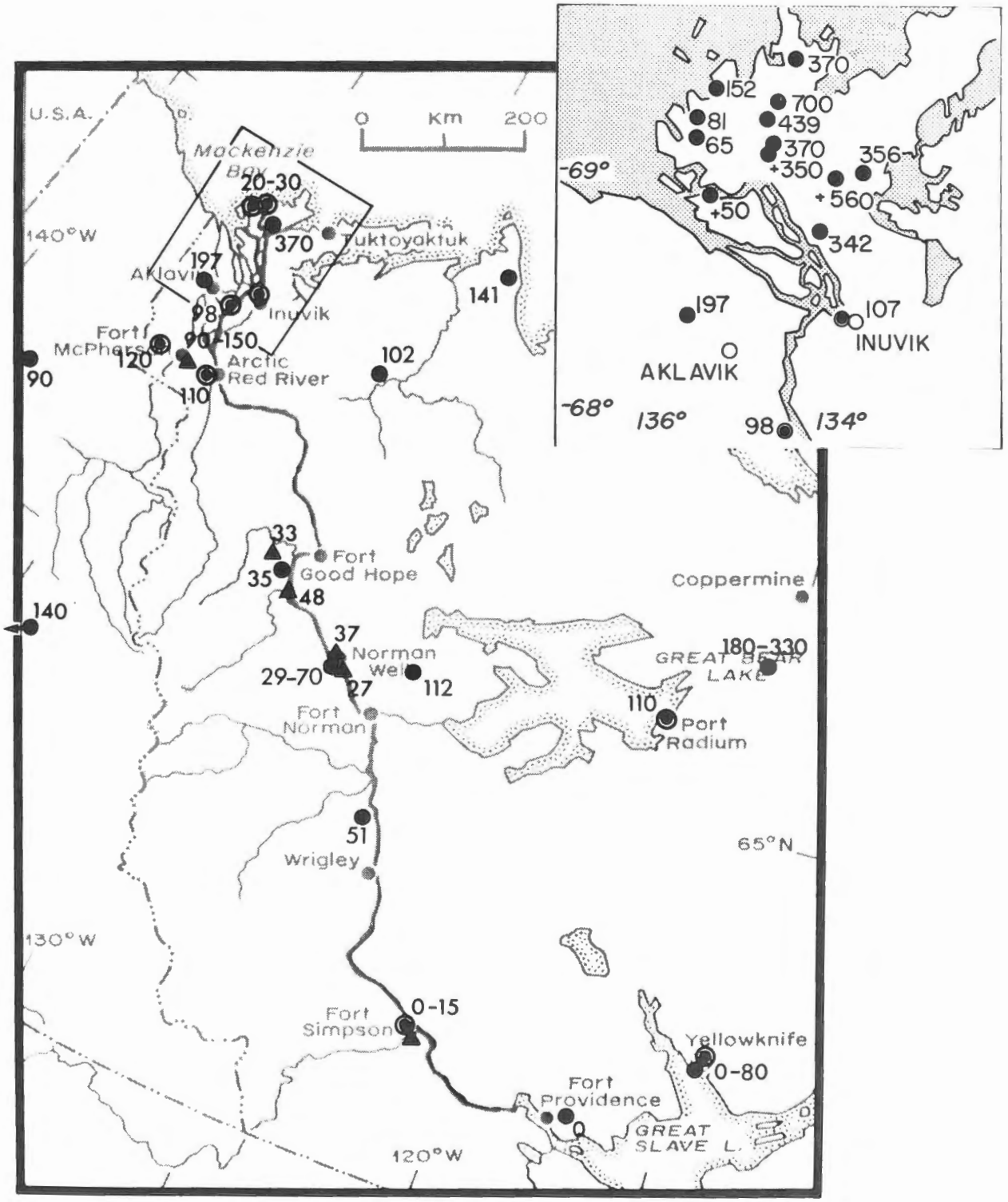
Scientists of the Service have participated in an interdepartmental study task force established to assess the practicability and economics of nuclear explosions for peaceful purposes.

Geothermal Service

Scientists of the Geothermal Service have made measurements of the geothermal heat flux in the Maritimes, the Cordillera and the high Arctic during the year. A major effort continues to be the study of permafrost, its distribution both laterally and with depth, and of the factors which affect it. The depth of the permafrost is being measured at about 50 locations in the Mackenzie Valley and the Arctic Islands by means of repeated temperature surveys in oil exploration wells. The 'Geothermal Series' of publications has been inaugurated with a volume of temperature data from these northern wells, and a second, updated volume will appear during 1975.

New emphasis has been placed on developing a thorough understanding of the complex system of thermal disturbance in the rock surrounding a well, by means of computer simulation, and by using the existing data as a limiting condition. It is now possible to use the accumulated data and experience to produce a predicted permafrost depth at any given location, based on estimates of terrestrial heat flow, thermal conductivities of the rocks involved and the past and present surface temperatures. During the past year, measurements have been extended to the Beaufort Sea in order to delineate the permafrost areas beneath the sea-floor and to study the special problems associated with the phenomenon.

The Geothermal Service has continued to play a leading and co-ordinating role in the investigation of geothermal energy resources. A program of research has been designed that will guide the Department toward a determination of the existence of useful geothermal resources in Canada. The first objective is an inventory of geothermal energy resources, with assessment of the amount of energy available and the best manner of use. In the early part of 1974 scientists of the Geothermal Service worked with colleagues of the Geological Survey to locate, drill, and obtain data from two shallow holes in the vicinity of a thermal spring in British Columbia. Toward the end of the year assistance was provided to B.C. Hydro in the acquisition of data from their borehole in the same area.



The depth in metres to the base of the permafrost in the Mackenzie Valley and delta

- Previously reported thicknesses
- Thicknesses from deep EPB site
- Thickness from shallow EPB site

} From ESP-NP Programme

Participation in the NATO/CCMS (Committee on Challenge to Modern Society) program has continued and has produced valuable interchange of information. The Geothermal Service represented the Department at meetings in Wairakei, New Zealand, and Los Alamos, United States.

Fundamental research in 'geothermics' is an essential background for the applied programs studying permafrost and geothermal energy. Thus, scientists of the Service have been instrumental in compiling an international data collection that brings together all known reliable values of the geothermal flux. This is to be used for broadly based studies of the thermal state of the earth. Measurements of heat flow and heat generation are basic input in the development of theories of crustal development and enable scientists to select those regions of Canada and particularly the Cordillera where geothermal resources are most likely to be found. Also directed toward the regional distribution of resources in the Cordillera is a program of studies of the radioactive trace-element content of intrusive rocks. A paper resulting from the work of a visiting Post-doctoral Fellow has been published, summarizing and intepreting the existing data from Precambrian Shields. This paper forms a background for current work on Precambrian areas within the Geothermal Service.

LIST OF PUBLICATIONS

Division of Geomagnetism

Andersen, Frede. An automatic magnetic observatory system, Pub. Earth Phys. Br., v. 44, no. 11, 1974.

Auld, D.R., and Walker, C.W. Record of observations at Victoria magnetic observatory 1972, Pub. Earth Phys. Br., v. 44, no. 13, 1974.

DeLaurier, J.M., Loomer, E.I., Jansen van Beek, G., and Nandi, A. Editing and evaluating digitally recorded magnetic components at Canadian observatories, Pub. Earth Phys. Br., v. 44, no. 9, 1974.

DeLaurier, Jon M., Law, L.K., Niblett, E.R., and Plet, F.C. Geomagnetic variation anomalies in the Canadian Arctic: Part II. Mould Bay Anomaly, J. Geomag. Geoelectr., 26, p. 223-245, 1974.

Gupta, J.C. Lunar ionospheric and oceanic dynamo variations, Berl. Beitr. zur Geophys., 83, p. 1-15, 1974.

Gupta, J.C. Amplitude variation of Pc5 pulsations at high latitudes, Radio Science, 9, nos. 8, 9, p. 757-768, 1974.

Gupta, J.C. Pc5 pulsations with period range 300-600 sec, in Vol. 2, Magnetosphere, International Symposium on Solar Terrestrial Physics, COSPAR, Sao Paulo, Brazil, p. 363-373, 1974.

Gupta, J.C. Period variation of Pc5 pulsations at high latitudes, Astrophys. and Space Sci., 31, p. 81-101, 1974.

Haines, G.V., and Hannaford, W. A three-component aeromagnetic survey of the Canadian Arctic, Pub. Earth Phys. Br., v. 44, no. 8, 1974.

Hannaford, W., and Haines, G.V. A three-component aeromagnetic survey of British Columbia and the adjacent Pacific Ocean, Pub. Earth Phys. Br., v. 44, no. 14, 1974.

Hruska, J. Record of observations at Ottawa magnetic observatory July 1968 to December 1969, Pub. Earth Phys. Br., v. 46, no. 1, 1974.

Irving, E. Latitude variation of the Canadian Arctic Islands during the Phanerozoic. Proceeding of the symposium on the Geology of the Canadian Arctic, Geol. Assoc. Can. 1973, Ed. Aitken, J.D., and Glaos, D.J., p. 1-3, 1974.

Irving, E. Dissent magnetic, Geotimes, 19, p. 14, 1974.

Irving, E., Emslie, R.F., and Ueno, H. Upper Proterozoic paleomagnetic poles from Laurentia and the history of the Grenville structural province, J. Geophys. Res., 79, p. 5491-5502, 1974.

Irving, E., and Lapointe, P.L. Paleomagnetism of Precambrian rocks of Laurentia, Geoscience Canada, 2, p. 90-98, 1975.

Irving, E., and Park, J.K. Paleomagnetism of metamorphic rocks: Errors owing to intrinsic anisotropy, Geophys. J. R. Astr. Soc., 34, p. 489-493, 1974.

Irving, E., Park, J.K., and Emslie, R.F. Paleomagnetism of the Morin Complex, J. Geophys. Res., 79, p. 5482-5490, 1974.

Lanzerotti, L.J., Maclennen, C.G., Fukunishi, H., Walker, J.K., and Williams, D.J. Latitude and longitude dependence of storm time Pc 5 type plasma wave, J. Geophys. Res., 80, p. 1014-1018, 1975.

Loomer, E.I., and Jansen van Beek, G. The development of current vortices in the polar cap preceding the large magnetic storms of August 4-5 and August 9, 1972, Report UAG-28 (III), WDC-A, NOAA, Boulder, Colorado, U.S.A., 1973.

McGlynn, J.C. and Irving, E. Paleomagnetism of early Aphebian diabase dykes from the Slave Structural Province, Canada, Tectonophysics, 26, p. 23-38, 1975.

Niblett, E.R. Electromagnetic induction in the earth. Geoscience Canada, 2, p. 47-51, 1975.

Niblett, E.R., DeLaurier, J.M., Law, L.K., and Plet, F.C. Geomagnetic variation anomalies in the Canadian Arctic: Part I. Ellesmere Island and Lincoln Sea, J. Geomag. Geoelectr., 26, p. 203-221, 1974.

Park, J.K. Paleomagnetism of miscellaneous Franklin and Mackenzie diabases of the Canadian Shield, and their adjacent country rocks, Can. J. Earth Sci., 11, p. 1012-1017, 1974.

Robertson, W.A. and Watkinson, David H. Paleomagnetism of the Spanish River alkalic rock—carbonatite complex, Twps. 107 and 108, Ontario, Can. J. Earth Sci., 11, p. 795-800, 1974.

Roy, J.L. and Park, J.K. The magnetization process of certain red beds: Vector analysis of chemical and thermal results, Can. J. Earth Sci., 11, p. 437-471, 1974.

Serson, P.H. Compact bias coil systems for geomagnetic measurements, Pub. Earth Phys. Br., v. 44, no. 10, 1974.

Stewart, A.D. and Irving, E. Paleomagnetism of Precambrian sedimentary rocks from N.W. Scotland and apparent polar wandering path of Laurentia. Geophys. J.R. Astr. Soc., 37, p. 51-72, 1974.

Ueno, H., Irving, E., and McNutt, R.H. Paleomagnetism of the Whitestone anorthosite and diorite, the Grenville Polar Track, and the relative motions of the Laurentian and Baltic Shields, Can. J. Earth Sci., 12, p. 209-226, 1975.

Gravity Division

Ajakaiye, D.E. and Sweeney, J.F. Three-dimensional gravity interpretation of the Dutsen-Wai complex, Nigerian Younger Granite Province, Tectonophysics, 24, p. 331-341, 1974.

Baer, A.J., Emslie, R.F., Irving, E. and Tanner, J.G. Grenville geology and plate tectonics, Geoscience Canada, 1, p. 54-61, 1974.

Beaumont, C. and Berger, J. Earthquake prediction; modification of the earth tide tilts and strains by dilatancy, Geophys. J.R. Astr. Soc., 39, p. 111-112, 1974.

Berger, J. and Beaumont, C. Precision tidal spectroscopy for earthquake prediction, Symposium volume on Earthquake Forerunners Searching, Tashkent, U.S.S.R., 1974.

Boyd, J.B., Gibb, R.A., and Thomas, M.D. A gravity investigation within the Agricola Lake Geochemical Anomaly, District of Mackenzie, Geol. Surv. Can., Paper 75-1, Part A., p. 193-198, 1975.

Dence, M.R., von Engelhardt, W., Plant, A.G., and Walter, L.S. Indications of fluid immiscibility in glass from West Clearwater Lake Impact Crater, Quebec, Canada, Contr. Min. and Petr., 46, p. 81-97, 1974.

Dence, M.R., Robertson, P.B., and Wirthlin, R.L. Coesite from the Lake Wanapitei Crater, Ontario, Earth & Planet. Sci. Letters, 22, p. 118-122, 1974.

Gibb, R.A. and Halliday, D.W. Gravity measurements in southern District of Keewatin and southeastern District of Mackenzie, N.W.T. Gravity Map Series, Earth Physics Br. Nos. 124-131, 1974.

Grieve, R.A.F., Plant, A.G., and Dence, M.R. Lunar impact melts and terrestrial analogs: their characteristics, formation and implications for lunar crustal evolution. Reprinted from Geochimica et Cosmochimica Acta Supplement 5, Proceedings of the Fifth Lunar Science Conference, 1, p. 261-273, 1974.

Lambert, A. Earth tide analysis and prediction by the response method, J. Geophys. Res., 79, p. 4952-4960, 1974.

Lambert, A. and Bower, D.R. The strange tides that move the earth we live on, GEOS, Energy, Mines and Resources, Canada, Spring edition, p. 10-12, 1974.

Lillestrand, R.L. and Weber, J.R. Plumb line deflection near the North Pole, J. Geophys. Res., 79, p. 3347-3352, 1974.

Maxant, J. Distribution and regional variation of density in the Western Canada Basin, Geophysics, 40, p. 56-78, 1975.

Morelli, C., Gantar, C., Honkasalo, T., McConnell, R.K., Szabo, B., Tanner, J.G., Uotila, U., and Whalen, C.T. The International Gravity Standardization Net 1971 (IGSN71), Special Pub. No. 4 of the International Association of Geodesy, Paris, France, 1974.

McConnell, R.K. and Tanner, J.G. Gravity standards in Canada, Proceedings of the 1973 National Convention of the Canadian Society of Exploration Geophysicists, Calgary, 1974.

Nagy, D. Gravity, geodesy and reference surfaces, The Canadian Surveyor, 28, p. 555-558, 1974.

Papezik, V.S., Hodych, J.P., and Goodacre, A.D. The Avalon magnetic lineament: A possible continuation of the Triassic dike system of New Brunswick and Nova Scotia, Can. J. Earth Sci., 12, p. 332-335, 1975.

Popelar, J., Sim, S.B., and Wheeler, M.O. PZT observations of time and latitude Ottawa and Calgary, 1973, Geodynamics Series of the Earth Physics Branch, Bull. No. 65, 1974.

Robertson, P.B. and Grieve, R.A.F. Impact structures in Canada: their recognition and characteristics, J. Roy, Astr. Soc. Can., 69, p. 1-21, 1975.

Sobczak, L.W. and Stephens, L.E. The gravity field of northeastern Ellesmere Island and part of northern Greenland and Lincoln Sea, Gravity Map Series Earth Physics Br. No. 114, 1974.

Sobczak, L.W. Gravity and deep structure of the continental margin of Banks Island and Mackenzie Delta, Can. J. Earth Sci., 12, p. 378-394, 1975.

Stacey, R.A. Plate tectonics, volcanism and the lithosphere in British Columbia, Nature, 250, p. 133-134, 1974.

Stoffler, D., Dence, M.R., Graup, G., and Abadian, M. Interpretation of ejecta formations at the Apollo 14 and 16 sites by a comparative analysis of experimental, terrestrial and lunar craters. Reprinted from Geochimica et Cosmochimica Acta Supplement 5, Proceedings of the Fifth Lunar Science Conference, 1, p. 137-150, 1974.

Sweeney, J.F. Subsurface density distributions east and northeast of Penobscot Bay, south-central Maine. Appendix to: Wones, D.R. Igneous petrology of some plutons in the northern part of the Penobscot Bay area, New England Intercollegiate Geol. Conf. Guidebook, Orno, Maine, 1974.

Thomas, M.D. The correlation of gravity and geology in southeastern Quebec and southern Labrador, Gravity Map Series Earth Physics Br. Nos. 64-67, and 96-98, 1974.

Valliant, H.D., MacNab, R.F., Stephens, L.E., Grant, S.T., and Cooper, R.V. Results of underwater and surface regional gravity surveys off the coast of Labrador, 1972, Gravity Map Series Earth Physics Br. No. 156, 1974.

Walcott, R.I. and Craig, B.G. Uplift studies, southeastern Hudson Bay, Geol. Surv. Can., Paper 75-1, Part A, p. 455-456, 1975.

Division of Seismology

Berry, M.J. and Forsyth, D.A. Structure of the Canadian Cordillera from seismic refraction and other data. Can. J. Earth Sci., 12, p. 182-208, 1975.

Clee, T.E., Barr, K.G., and Berry, M.J. Fine structure of the crust near Yellowknife. Can. J. Earth Sci., 11, p. 1534-1549, 1974.

Halliday, R.J., Shannon, W.E., Lombardo, F., and Compton, B. Seismological Bulletin, January-December, 1973. Seism. Series Earth Phys. Branch, No. 68, 1974.

Hasegawa, H.S. Theoretical synthesis and analysis of strong ground motion spectra of earthquakes. Can. Geotech. J., 11, p. 278-297, 1974.

Hasegawa, H.S. A theoretical evaluation of design ground seismic motions for pipelines in the Yukon Territory and Mackenzie Valley. Pub. Earth Phys. Br., V. 44, No. 21, 1974.

Hasegawa, H.S. Seismic ground motion and residual ground deformation near a vertical fault. Can. J. Earth Sci., 12, p. 523-538.

Hashizume, M. A P travel-time model for the Canadian Shield obtained by a joint epicentre method. Can. J. Earth Sci., 11, p. 611-618, 1974.

Hashizume, M. Surface wave study of earthquakes near Hudson Bay, Canada. J. Geophys. Res., 79, p. 5458-5468, 1974.

Horner, R.B., Milne, W.G., and McMechan, G.A. Canadian earthquakes—1969. Seism. Series Earth Phys. Branch, No. 67, 44 pp., 1974.

Jessop, A.M. and Judge, A.S. Temperature and heat flux measurements through permafrost as a geophysical tool. In: Symposium on Permafrost Geophysica, NRC Calgary, Feb. 1974. Assoc. Comm. Geotech. Res. Tech. Memo. 118, p. 17-27, 1975.

Judge, A.S. The occurrence of offshore permafrost in northern Canada. In: Beaufort Sea Symposium, Arctic Institute of North America, San Francisco, p. 427-437, 1974.

Leblanc, G. A l'écoute du Yukon. GEOS, Dept. Energy, Mines and Resources, Spring, p. 5-7, 1974.

Leblanc, G. and Wetmiller, R.J. An evaluation of seismological data available for the Yukon Territory and the Mackenzie Valley. Can. J. Earth Sci., 11, p. 1435-1454, 1974.

Leblanc, G. and Hasegawa, H.S. Earthquake data and design ground motions for the Yukon Territory and the Mackenzie Valley. Environmental-Social Committee, Northern Pipelines, Task Force on Northern Oil Development, Rept. 74-15, 25 pp., 1974.

McMechan, G.A. P-wave train synthetic seismograms calculated by quantized ray theory. Geophys. J., 37, p. 407-421, 1974.

McMechan, G.A. and Workman, W.G. P-wave amplitudes and magnitudes between 10 and 35 degrees. Bull. Seism. Soc. Am., 64, p. 1887-1900, 1974.

Rao, R.U.M. and Jessop, A.M. A comparison of the thermal characteristics of shields. Can. J. Earth Sci., 12, p. 347-360, 1975.

Stevens, A.E. Contemporary compressive stress and seismicity in eastern North America: an example of intra-plate tectonics: discussion. Geol. Soc. Am. Bull., 85, p. 839, 1974.

Stevens, A.E. The development of seismology in Canada. Phys. in Can., 30, p. 50-54, 1974.

Stevens, A.E. Seismicity in northern Canada. Bull. Can. Petrol. Geol., 22, No. 4, 1974.

Taylor, A.E. and Judge, A.S. Canadian geothermal data collection—northern wells 1955 to February 1974. Geothermal Series Earth Phys. Branch, No. 1, 171 pp., 1974.

Weichert, D.H. The role of medium aperture arrays: the Yellowknife system. In: Exploitation of Seismograph Networks, K.G. Beauchamp (ed.), NATO-ASI Series E, No. 11, 1975.

Weichert, D.H., Basham, P.W., and Anglin, F.M. Explosion identification and monitoring. In: Exploitation of Seismograph Networks, K.G. Beauchamp (Ed.), NATO-ASI Series E., No. 11, 1975.

Wickens, A.J., Hasegawa, H.S., and Bone, M.N. Pulse calibration and its application to the daily calibration of the Canadian standard seismograph network long-period seismometers. Can. J. Earth Sci., 11, p. 691-697, 1974.

Wright, C. Lateral variations in the upper mantle beneath the Yellowknife array and near the core-mantle boundary from observations of various P phases. In: Exploitation of Seismograph Networks, K.G. Beauchamp (Ed.), NATO-ASI Series E., No. 11, 1975.

Wright, C. and Lyons, J.A. Seismology, $dT/d\Delta$ and deep mantle convection. Geophys. J., 40, p. 115-138, 1975.

R.E. MOORE, Director

The Surveys and Mapping Branch is the federal agency responsible for surveying and mapping the nation. The mission of the Branch is divided into three major roles: cartographic activities in support of the inventory of present and potential resources; statutory responsibilities and services in cartography, legal, and boundary surveys; and technological developments related to this mission.

The task of surveying and mapping a country as vast as Canada must be a continuing enterprise for as long as specific exploration and economic expansion persist, and new resources are discovered. The surveying and mapping programs of the Branch are designed to meet the following objectives:

- To establish and maintain the basic national geodetic survey control upon which all other control surveys are structured.
- To administer the cadastral surveying of federal lands.
- To produce and maintain standard scales of topographic maps for administration, resource management, scientific research, engineering, defence and recreational purposes.
- To produce the National Atlas of Canada to depict the economic, human and physical geography of the country.
- To produce and provide a continuous updating of aeronautical charts to ensure the availability of vital flight information to the aviation industry.

There is close co-operation with provincial counterparts in co-ordinating activities and solving problems. The annual meeting of the Canadian Council on Surveying and Mapping includes the provincial Surveyors General and Directors of Survey, provides a means of co-ordinating federal and provincial surveying and mapping programs, and exchanging information of common interest. The National Advisory Committee on Control Surveys and Mapping includes representatives from federal and provincial departments, universities, and industry; advises the Minister of Energy, Mines and Resources on the co-ordination of federal surveying and mapping programs, and the promotion and co-ordination of research.

The Director of the Branch is also the Chairman of the Interdepartmental Committee on Air Surveys. The Branch provides the Secretariat for both the Canadian Council on Surveying and Mapping, and the Canadian Permanent Committee on Geographical Names.

The foreign aid program is administered by the Minister of Department of External Affairs and involves the Surveys and Mapping Branch in three fields: training, monitoring and consultant services related to mapping programs in other countries.

The Branch has a total staff of about 990 and an annual budget of about $22 million. There are five main directorates and divisions in the Branch: the Geodetic Survey Division, the International Boundary Commission (Canadian Section), the Topographical Surveys Directorate, Legal Surveys Division and the Map Production Directorate.

GEODETIC SURVEY DIVISION

Control Surveys

Control surveys of the Geodetic Survey Division establish basic reference systems of position and elevation for all purposes, including mapping. The objectives of the activity are to provide an adequate framework of such control covering Canadian territory and to determine the configuration of that territory with respect to the overall figure of the earth.

The objectives are approached by:

(a) Expanding and maintaining primary and secondary systems of monumented control established in accordance with internationally accepted standards of accuracy.

(b) Maintaining a national positional control data file linked to other similar files for the provision of survey data to government agencies, industry, and the general public as required. Survey data supports mapping, charting, cadastral and boundary surveys, national security, geoscience research, large-scale engineering, urban development, and similar activities.

(c) Promoting and conducting research and development to advance the knowledge and techniques of geodesy, and developing instrumentation and improved methods of operation.

Geodetic Survey promotes the effective management of the Canadian landmass, for the present and future benefit of the nation.

1974 Doppler Satellite Station at Grise Fiord, Canada's Most Northerly Eskimo Settlement

Doppler Satellite Field Computations Office in a Parcol Hut, Resolute Bay 1974.

Fly-in camp with observation tent in Coast Mountains near Stewart, B.C.

Astronomical set up at Mould Bay, during the 1974 Doppler Satellite Project.

Horizontal Control

The fundamental horizontal control framework now consists of about 5,800 stations in approximately 44,500 km of survey. Of these, 307 are astronomic Laplace stations and 889 are astronomic deflection stations.

First-order traversing was used in northern British Columbia to break down existing triangulation loops to complete a large project started in 1973. 1,300 km of this work was done in 1974. Other large parties worked on the densification of the existing horizontal control framework in Nova Scotia and in the Kitchener – Waterloo area of Ontario.

The program of strengthening existing networks was continued: one party worked exclusively on this type of work on the island of Newfoundland, and parties working in Ontario, Nova Scotia, Saskatchewan, British Columbia and Yukon Territory contributed to the program. Astronomic observing parties worked in Newfoundland, Nova Scotia, Quebec, Ontario, Alberta, British Columbia and NWT to establish 30 new Laplace stations and 33 deflection stations.

During 1974 a full scale doppler satellite positioning project was carried out throughout the Arctic Islands, Quebec, Nova Scotia and Newfoundland following the successful experimental 1973 season. Fifty-two stations were occupied including three on the western Greenland coast which were positioned in co-operation with the Danish Geodetic Institute. Also taking part in the project were five members of the Mapping and Charting Establishment of the Department of National Defence and a private surveying firm which supplied two receivers and crews under contract. The geographic scope of this project from Alaska to Greenland and from northern Ellesmere Island to the Atlantic Provinces—exceeded 3 million square kilometres.

Second-order traversing was carried out in the Northwest Territories, northern Quebec and the Arctic Islands. In all approximately 8,700 km of traversing was added to the lower order control fabric of the north and a further 3,200 km of existing traverses were strengthened. Mapping Control was established over an area of 600,000 sq. km.

Plans and studies which will culminate in the complete readjustment of the horizontal control system of Canada and North America have been continued in co-operation with the United States, Mexico and Denmark (for Greenland). Data preparation and assessment for the fundamental horizontal control framework is virtually complete and is being maintained up-to-date, and a start has been made on secondary networks. The assessment provides information for the improvement and strengthening of the horizontal control system prior to readjustment. The readjustment will combine the fundamental framework and satellite doppler positioning to produce dependable, precise basic control. Secondary networks will then be integrated with the basic control to form the horizontal control system. The continental readjustment is scheduled for completion in 1983; an interim Canadian readjustment is planned for 1978 to accommodate domestic needs.

Primary Vertical Control

The primary vertical control network was extended by another 2,692 km in 1974 and now consists of some 98,635 km of first-order levelling, plus 26,354 km of second-order levelling containing some 40,500 monumented bench marks. There was also 1,206 km of relevelling (upgrading) of old lines in 1974. The network was extended north along the roads in the Yukon and the shores of the Mackenzie River. Shared cost levelling in northern Manitoba was implemented during the winter months. Stability checks of the bench marks at 84 gauge sites between Sept Iles, Quebec and Thunder Bay, Ontario were made as part of a continuing yearly program. A new line of first-order levels was carried from La Grande to the LG 3 dam site in the James Bay area of Quebec.

Geodetic Data Services

Approximately 5,000 requests for control survey data were received during the year. Data issued included 8,600 vertical control quadrangle booklets and 450,000 individual pages of positional control data.

The program to automate the National Positional Control Survey Data File was continued with some 10% of the 200,000 stations having been entered. This computerized file will provide positional control data to government agencies, industry and the general public in the fields of geodesy, surveying and mapping.

Survey Systems

The division completed acceptance trials and took delivery of an Inertial Surveying System (ISS) early in 1975. An application of inertial space navigational systems, the ISS shows significant promise in initial field trials to provide accurate positions, elevations and gravity measurements.

TOPOGRAPHICAL SURVEY DIRECTORATE

Topographic Mapping

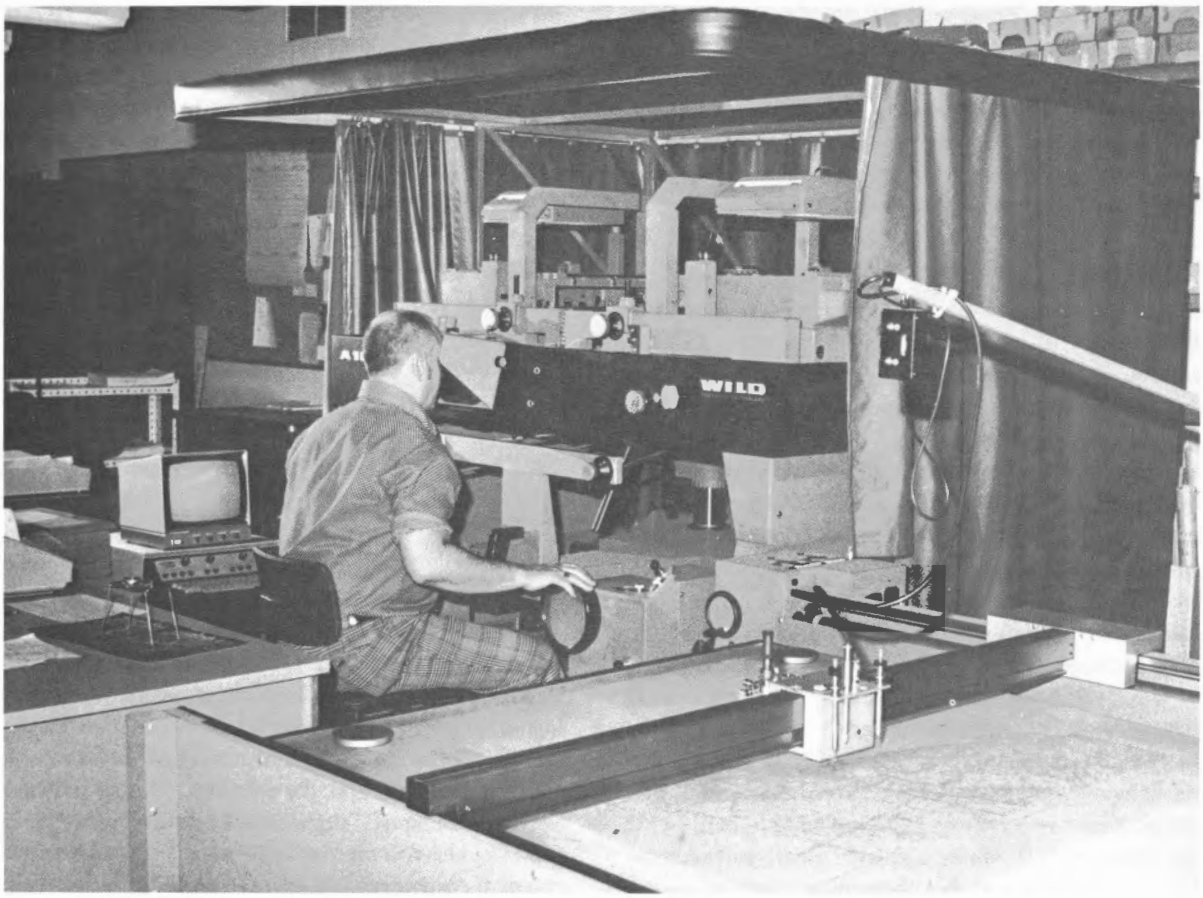
The chief responsibility of the Topographic Surveys Directorate is to compile the standard topographic map series of Canada (mainly at the scales of 1:25,000; 1:50,000; and 1:250,000) for such needs as resource development, urban and rural administration, national defence, scientific research, education and recreation by:

(a) Producing and maintaining, through a systematic program and to internationally accepted standards, national series maps at scales of 1:250,000 and larger;

(b) Providing, on request, to federal departments and agencies, photogrammetric and cartographic services including the provision of professional advice, the administration, monitoring and inspection of mapping contracts;

(c) Producing and maintaining a national photogrammetric control bank for the purpose of providing mapping data to government agencies, industry and the general public;

(d) Conducting and promoting research and development in photogrammetry and cartography to advance the knowledge and techniques of topographic mapping.



Wild A-10 Stereo Plotter engaged in compilation of a topographical map

During the past fiscal year the Topographical Survey Directorate produced 856 map manuscripts. These may be divided into the following categories:

1:25,000 new line maps	2
1:25,000 revision line maps	61
1:50,000 new line maps (coloured)	11
1:50,000 new line maps (monochrome)	329
1:50,000 revision line maps	307
1:50,000 photomaps	110
1:250,000 revision line maps	36
	856

The past year's work has been strongly influenced by the government's policy to encourage energy production. This has resulted in sheets being put into work covering areas in the Arctic Islands, the west shore (of Hudson Bay) pipeline corridor and a widening of the Mackenzie valley coverage. Hydro-electric development has generated a need for 1:50,000 sheets in Quebec, Labrador and British Columbia. The photomapping program is almost entirely geared to geological exploration, mainly in the Mackenzie River area, but to a lesser degree in northern Manitoba.

The Topographic Mapping Planning Section was responsible for the acquisition of all survey data and aerial photography for both new and revision mapping. Data for 1,700 sheets at 1:50,000 scale were prepared during the past fiscal year. In addition to this, arrangements were made for the acquisition of the requirements for a further 1,500 sheets during the present fiscal year.

The professional staff of the Section was employed on the assessment and testing of a radically new and very powerful survey tool, namely the Auto Surveyor. This device, working on the principle of the measurement of movement through the detection of the effect of inertia on pendulums, can give the relative elevations of ground points with great accuracy.

In the Airborne Altimetry Unit, contracts were let with two aerial survey companies for the flying of 19,700 kilometres of profiles. This unit also determined elevation data from previous work for the compilation of 1,475 sheets at 1:50,000 scale.

The Research and Development Section, Photogrammetric Engineering Division has completed development of a system for the automatic recording and centralized processing of aerial triangulation data. The system is installed and is now

in production use. Trials are underway on a system developed by the section for the digital compilation of map data from photogrammetric plotters. A trial has been conducted in co-operation with the Government of Manitoba to determine the feasibility of photogrammetric methods for the retracement of Legal Surveys. Results are now being evaluated and it has been demonstrated that an accuracy of 1 part in 10,000 over a distance of ½ mile can be achieved.

Interdepartmental Committee on Air Surveys

The Branch provides administrative and technical support to the ICAS by:

(a) Co-ordinating requests from various federal agencies for aerial photography, establishing program priorities and providing technical advice to users;

(b) Issuing technical instructions and specifications for aerial photography;

(c) Providing the professional advice, administration, monitoring and inspection necessary for federal aerial survey contracts;

(d) Promoting federal-provincial co-operation to maintain quality standards and to avoid duplication of effort.

In 1974-75 ICAS received requests from seven federal departments for aerial photography and Air Profile Recordings. Thirty-eight contracts were raised totalling 126,000 km of photography and 19,700 km of Air Profile Recording. The total value of these contracts was $1,483,406.81.

Approximately 78% of the airphoto program was completed and the entire Air Profile Recording program on the Northwest Territory Mainland, Victoria and Ellesmere Islands was completed. The photography flown amounted to approximately 98,800 km of black and white and 1,650 of colour. Some 159 separate areas were covered of which 37 required coverage at two scales or with two different types of film.

The high altitude photography flown by the Learjet produced approximately 58,000 km consisting of blocks of photography in Quebec, Ontario, Manitoba, Alberta, British Columbia, Northwest Territories and the Yukon Territory. Complete or partial coverage was obtained of some 18 separate areas. Included in this was complete coverage of the Athabasca Tar Sands area. In addition to the Jet Program, mapping photography flown for the Topographical Survey Directorate by conventional powered aircraft totalled approximately 22,700 km.

Other contracts included:

(a) Resource inventory photography of three of Canada's remote wilderness National Parks, Kluane, Nahanni and Baffin Island, as well as partial coverage of Wood Buffalo National Park.

(b) Photography for topographic purposes was continued along the Mackenzie Highway and the Canol Road was also covered at two scales for this purpose.

(c) Continuing crop studies for the Department of Agriculture of four research study areas in Ontario was flown with a 12" focal length camera using Kodak Aerochrome Infrared film.

(d) Photography for flood damage assessment was taken in the Gatineau and Montreal areas.

(e) Large scale photography for experimental and revision mapping and control retracement survey was taken in Ontario, British Columbia and Manitoba.

During the year a total of 316 rolls of film was inspected by the ICAS Inspection Section.

The major users of ICAS photography were:

(a) EMR—Topo Survey	64.2%
(b) INA	24.2%
(c) DND	4.5%
(d) DPW	2.1%
(e) Others	5.0%

National Air Photo Library

During 1974-75 NAPL received 14,093 requests for photo selection or information.

The microfilming of aerial photography and index maps, providing complete photo coverage of Canada in micro form was completed, together with the compilation of the "General Photo Coverage System" catalogues. Publication of the catalogues is expected to be completed by the fall of 1975.

The Institute of Sedimentary and Petroleum Geology, Calgary, Alberta, and the Maritime Resource Management Services, Amherst, Nova Scotia, have received preliminary copies of the coverage catalogues, and the microfilmed imagery of their respective provinces, and are acting as reference centres for the users of aerial imagery.

The NAPL also published a pamphlet "How to Order Aerial Photography" and a colour illustrated booklet "Canada Photographed from the Air".

With a growing inventory of 3,903,116 air photographs, and 9,152 index maps, NAPL remodelled its office, installing mobile shelving which provided an additional 44 per cent floor space, and created a colour co-ordinated open office concept, allowing for the installation of the microfilm stations.

NAPL Reproduction Centre

A total of 1,178,549 photographic items were produced in support of Departmental airborne and satellite programs. Production by program was:

Aerial Survey	823,893
Airborne Remote Sensing	20,201
LANDSAT (ERTS 1)	264,455

Average production turnaround for LANDSAT orders was reduced to 4.4 working days and for Airborne Remote Sensing orders, to nine working days.

A contract to move LANDSAT B&W reproduction to Prince Albert, Saskatchewan is in the negotiation and planning stages. The CCRS aim is to create a facility at the Prince Albert Satellite Station that will be capable of rapid production of all B&W imagery from satellite data, leaving

NAPL/RC responsible for the reproduction of precision, colour, special project and R&D imagery. The plan calls for the immediate acquisition of imagery reproduction equipment and the installation of a Lasar Beam Image Recorder by July, 1976.

The majority of research and development undertaken by NAPL/RC in the past year was internally generated with the exception of two projects from clients. NAPL/RC projects included:

Equipment	8
Chemistry	10
Papers	5
Films	11
Procedures	4
Total	38

NAPL/RC assumed complete responsibility for the microfilming and duplicating requirements of the NAPL program to microfilm aerial survey imagery. Photographic technicians were employed to produce a high quality information package and marketing tool. Total package consists of 631 master cassettes of approximately 2,200 images each which will be filed at NAPL/RC for duplication as required. To date, seven copies of each master has been duplicated and forwarded to NAPL for their use.

A new project of mosaicing Canada with LANDSAT (ERTS 1) imagery was started at the NAPL Reproduction Centre. The nation will be divided into 12 areas. Band six images are laid to a 1:1 million base map and a mosaic for each of these areas will be available at 1:2,500,000 or under the NTS system, as individual 1:1 million photomaps. The Arctic Islands, north of 72°, Manitoba, Yukon and Ontario sheets have been completed and work has started on southern Quebec and the Maritimes. It is estimated that LANDSAT mosaics and photomaps of the whole of Canada will be available in October, 1975.

Canada Map Office

During the fiscal year 1974-75, distribution of maps and charts through the Canada Map Office totalled approximately three and a half million items. The Canada Air Pilot and related publications distribution continued at a high level with 37,600 subscriptions. A new publication, Flight Planning Procedures GPH 204, was made available to the public. There are now 1,232 subscribers.

The number of orders for maps and charts handled through the Canada Map Office during 1974-75 totalled 107,994, compared to a total of 111,089 for the previous year. The Canada Map Office commenced to move its storage and distribution operations from 2487 Kaladar Avenue to 130 Bentley Avenue in January, 1975. The remaining phases of the moving operations are scheduled for midsummer 1975. No major curtailments of customer services are planned during the moving period.

Apart from sales and distribution through the Canada Map Office, the most important contact with the general public is through a network of 398 aeronautical publication dealers and 450 map dealers. In addition, there are 148 map depositories from which the public can obtain information pertaining to topographical map-sheets within their geographical area.

LEGAL SURVEYS

While provincial governments have jurisdiction over legal or land surveys in their territories, the federal government, through the Department's Legal Surveys Division, carries out and supervises such surveys in federal lands within provinces (i.e., National Parks and Indian Reserves) and in the Yukon and Northwest Territories. The Division fulfills the federal obligations regarding definition, survey and maintenance of provincial and territorial boundaries in Canada, ensures the competence of property surveys, land descriptions and plans made under the Canada Lands Surveys and other Acts and Regulations; manages such surveys on request by:

(a) Surveying and maintaining specified provincial boundaries jointly with the corresponding provincial agencies under commission of the Governor General in Council;

(b) Regulating the surveys of Indian Reserves and lands, National Parks, Territorial lands, lands under water in the offshore areas, and other Crown lands including the qualifying of Dominion Land Surveyors;

(c) Regulating the surveys of subsurface rights and of subdivisions of private lands in the Territories;

(d) Establishing Co-ordinated Surveys Areas;

(e) Establishing standards, issuing instructions, examining survey returns and inspecting field work;

(f) Providing, on request, to federal departments and agencies, and to Territorial governments a comprehensive professional surveying service including the provision of professional advice, the administration, monitoring and inspection of surveying contracts, and the execution of surveys;

(g) Ratifying, custody and maintenance of legal survey records;

(h) Preparing and ensuring the adequacy of legal descriptions of Crown Canada Lands, and also ensuring the adequacy of descriptions used to define federal electoral districts;

(i) Controlling oil and gas surveys made pursuant to the Canada Oil and Gas regulations both in the northern territories and on Canada's continental shelves.

Field Operations

Twenty-two field parties completed 120 separate survey projects in 1974-75. These assignments included 103 projects in Indian Reserves in all provinces except Newfoundland and Prince Edward Island, 4 projects in the Yukon Territory, and 8 projects in the Northwest Territories. In order to complete

Sue O'Neil term engineer Cobalt, Ont.

as many as possible of the projects required for federal government departments, 185 additional surveys were done under contract.

The nine regional offices have demonstrated their value, particularly in the area of liaison and consultation with the various Indian bands, with the Department of Indian Affairs and Northern Development, and with the governments of the Territories.

Technical instructions were issued for some 520 surveys in Crown Canada lands.

During 1974-75, of the 754 survey plans examined, 426 were for Federal Government departments and 328 were for outside organizations and individuals.

Two federally established commissions of which the Surveyor General of Canada Lands is a member were active. The Manitoba-Saskatchewan Boundary Commission continued to work on the returns of surveys and began the drafting of a boundary atlas. The British Columbia-Yukon-Northwest Territories Boundary Commission carried out maintenance on 133.5 km of this boundary.

The Division was also active in preparing for the establishment of the Alberta-British Columbia Boundary Commission. The Alberta-British Columbia Boundary Act received Royal assent on December 13, 1974.

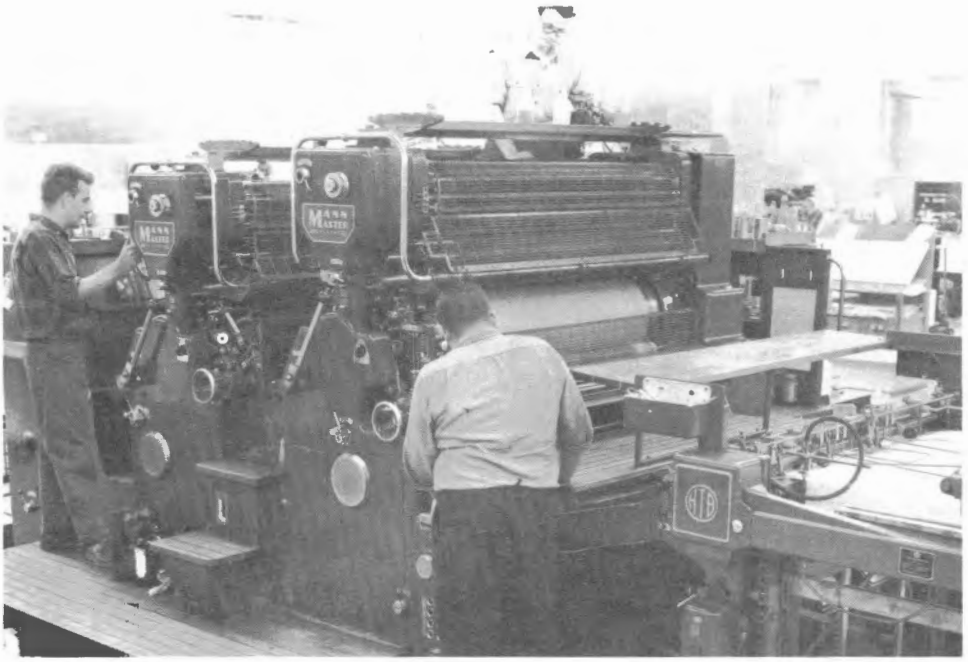
Board of Examiners for Dominion Land Surveyors

The Board of Examiners for Dominion Land Surveyors met seven times. A total of 17 candidates wrote the 1975 annual examination at Ottawa, Toronto, Winnipeg, Regina, Edmonton, Whitehorse and Yellowknife with the following results: one qualified for the preliminary and six for the final examination, the last examination qualifying for the Dominion Land Surveyor Commission. One candidate was successful in passing one schedule of the examinations for the Dominion Topographic Surveyor certificate.

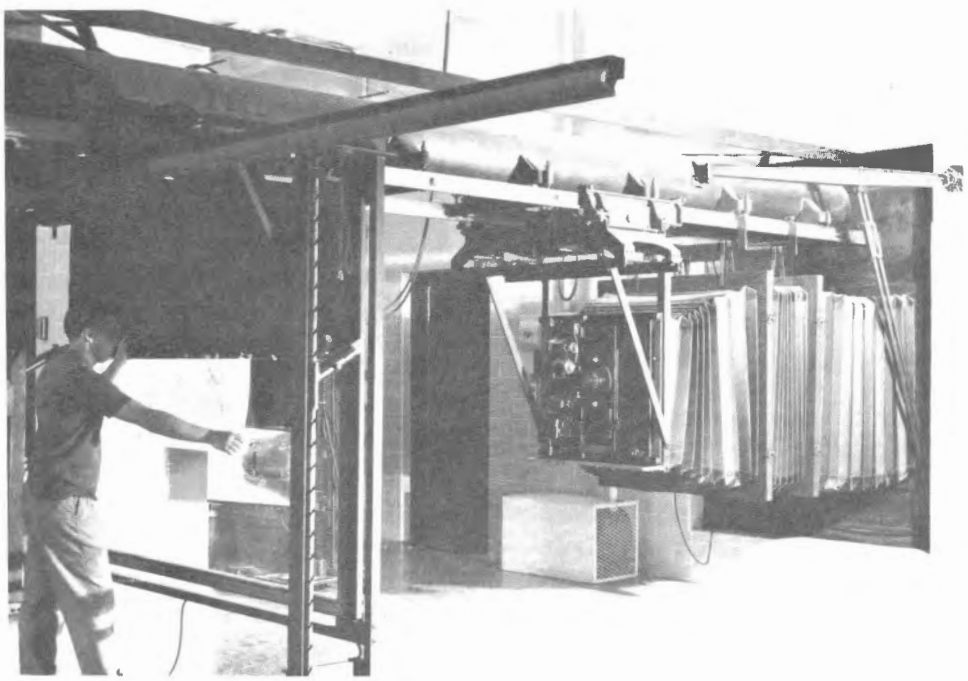
DIRECTORATE OF MAP PRODUCTION

Following the compilation of manuscripts by the Topographical Survey Directorate, the Directorate of Map Production is responsible for the drafting and printing of maps of the National Topographic Series. In addition, the Directorate has the responsibility for activities which include the design, production and maintenance of aeronautical charts and flight information publications; the National Atlas of Canada; the provision of cartographic services to other government departments; the provision of a Secretariat for the Canadian Permanent Committee on Geographical Names and Geographical Names Services to mapping agencies; and the provision of a departmental map library service.

Photo-Mechanical and lithographic services in support of all Branch mapping and charting activities are undertaken by the Map Reproduction Division. This Division is equipped with large modern overhead suspension cameras, film processing, contact and plate-making equipment. A computerized typesetting system is used to prepare cartographic textural matter and feature names for map and chart use. Automated trimming and folding machines are used to prepare maps and charts for distribution. In the lithographic plant two-colour and single colour rotary offset presses are working to full capacity, and an increasing percentage of printing work is



Two colour 48-inch press for printing maps and charts



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being contracted to private industry. During the year, a total of 3,777 maps and charts were printed for total of 9,525,953 copies. This figure includes 871 reprints to maintain stock inventory, primarily of maps of the National Topographic Series.

Topographic Map Drafting and Reproduction

Topographic map drafting is undertaken by the Cartography Division. During the year, drafting was completed for 594 new and revised topographic maps. This total includes 73 maps produced by the Automated Cartography System and 106 maps produced during April and May in the Federal Labour Intensive Project, undertaken January to May in Vancouver, British Columbia.

Topographic maps printed during the year were as follows:

New, multicolour	155
Revision, multicolour	453
New, monochrome	295
Photomaps	137
Total	1040

Aeronautical Charting

The Aeronautical Charts Division ensures the availability of aeronautical charts and flight information publications for the regulation and development of Canadian civil and military aviation by: (a) Maintaining up-to-date aeronautical chart coverage of Canada at scales of 1:500,000 and 1:1,000,000 according to internationally accepted schedules and standards;

(b) Producing and maintaining planning, enroute navigation and instrument procedure charts and related publications to internationally accepted schedules and standards;

(c) Producing and maintaining special aeronautical charts and related documents required for air traffic control, military flight operations, training and other air navigation requirements.

Total products include 2,009 charts of varying scales and sizes, and 1,003 pages of textual material. During the past year, revisions were completed for 184 charts. New products included:

Visual Flight Rule(VFR) Terminal Area Charts: This series at 1:250,000 scale was developed in support of aircraft operations at major aerodromes. To date, charts have been produced of Vancouver, Toronto and Winnipeg and a chart of Montreal is in the final production phase.

Tactical Air Navigation(TACAN) Facility Chart: Designed to provide enroute navigation data, this is the first of a two chart series developed and printed for the Department of National Defence.

Flight Planning and Procedures: The first joint civil / military edition of this publication was issued in November, on a semi-annual revision schedule.

The National Atlas of Canada

The major objective of the Geography Division is to document the development of the country through synoptic graphic presentations of its physical, human and economic geography, and the appropriate graphic aspects of Canada's history, by:

(a) Producing a National Atlas of Canada on a cycle phased to the decennial and quinquennial census;

(b) Publishing maps of selected subjects in various scales and formats.

First printing, in bound volume form, of the Fourth Edition was completed by Macmillan Co. of Canada in 15,000 copies. Favourable publicity has resulted from the marketing program in Canada and abroad, and from its use as gifts to Prime Minister Trudeau, President Ford and Prime Minister Wilson.

A newly created Advisory Committee on the National Atlas includes geographers and cartographers from universities and government agencies across Canada, as well as Surveys and Mapping Branch staff and will provide a broader geographical input to the preparation and publication of the Fifth Edition. The Committee met in Ottawa in October to discuss concepts, and details of content and production program are now being worked out.

In the selected map field, a thematic map depicting Electoral Districts and Results of the 30th Federal Election, July 1974 was prepared and published.

General and Small Scale Mapping

In the International Map of the World (IMW) series at 1:1,000,000 scale, a six year program of completing Canadian coverage is in hand, with the initial phases tied to Geological Survey of Canada's base map requirements. Publication of 13 new maps is scheduled for the current fiscal year.

In smaller scale maps, revisions included:

The World (English and French)	1:35,000,000
N.W.T. and Yukon Territory	1:4,000,000
Northwest Canada, Transportation Facilities 1:3,168,000	
Jasper National Park	1:250,000

Cartographic Services

The Directorate of Map Production has a federal obligation to provide cartographic services. These include:

(a) Producing and maintaining electoral maps for the Representation Commissioner according to the Representation Commissioner Act and the Electoral Boundaries Readjustment Act;

(b) Producing and maintaining bilingual district maps for the Secretary of State, in accordance with the Official Languages Act;

(c) Providing, as required, map compilation, drafting and reproduction services, and cartographic advice to federal departments and agencies, provincial governments, educational institutions, and industry.

In the field of electoral maps, uncertainty during the year on changes to be introduced in the number and boundaries of electoral districts, limited work in this activity to updating of base maps and to cartographic support to the Provincial Commissions. A recent amendment to the B.N.A. Act now provides for an increase in electoral districts from 264 to 282. Maps to support Provincial Commission studies, advertisement of proposals, and reports to Parliament will be required during the coming year.

Other major cartographic services included:

(a) 55 maps on various themes for the National Museum of Canada;

(b) 27 territorial electoral maps for the Councils of the Northwest Territories and Yukon Territory;

(c) a revision of the Highways of Canada map for the Canadian Government Office of Tourism;

(d) two special maps for the 25th Anniversary Presentation volume for the Province of Newfoundland;

(e) provision of 2,039 combined positives and negatives of topographic maps for use as bases by other government departments and provincial agencies;

(f) printing of 219 geological maps, 320 hydrographic charts and 332 miscellaneous other maps for other departments and agencies.

Geographic Names (Toponymic Services)

The Toponymy Division provides the Secretariat for the Canadian Permanent Committee on Geographical Names. Toponymic services provided include: field research on geographical names; research and reports on geographical names; production of gazetteers; and advice to mapping and publishing agencies on correct names and terminology

The Alberta volume of the Gazetteer of Canada series was revised and published during the year, and publication of the Ontario volume is scheduled for April 1975. Work is in hand for new editions of Gazetteers for Nova Scotia, Yukon Territory and Northwest Territories. A toponymic study on Geographical Names of New Brunswick, detailing the origins of over 4,000 names is scheduled for publication early in the coming year.

Departmental Map Library

The Map Library provides a map reference service to the Department and other agencies. An extensive collection of Canadian topographic maps, as well as large holdings of thematic maps, atlases and cartographic reference material is maintained for the use of Departmental scientists, cartographers and administrators. Close liaison is maintained with the National Map Collection of the Public Archives of Canada.

In 1974-75 the Map Library loaned 714 maps, atlases and gazetteers, and acquired 7,351 new maps and charts, 30 atlases and 14 gazetteers. Visitors to the Library numbered 2,798.

Automated Cartography

The Automated Cartography System now includes five digitizing stations in Cartography Division, primarily utilized for NTS mapping, and a hookup with a digitizing station in Geological Survey. Hardware enhancement during the year included acquisition of a second PDP 11 computer, two additional high speed disc drives for additional data storage, and a high speed PDP 10 to PDP 11 channel to handle increased volume of data transfer.

The hookup with Geological Survey was brought to operational status and a number of edit and final plots produced.

In topographic mapping, 73 maps were processed for final reproduction, along with 251 manuscript control plots. Experimental work was undertaken on the production of a 1:100,000 scale map using digitized data from maps at 1:50,000 scale.

Software developments were directed toward completion of the comprehensive cartographic monitor package, XCM, designed to accommodate a variety of users and to facilitate production processes such as digitizing, creating data files, merging data onto existing files, plotting, editing and data file management.

INTERNATIONAL BOUNDARY COMMISSION

The permanent Commission is empowered to continuously maintain an effective boundary line between Canada and the United States, under the terms defined by the Treaty of 1925, and other previous and future treaties. The primary task of the International Boundary Commission is to maintain the boundary and to determine the location of any point of the boundary line which may be required to settle any question that may arise between the two governments by:

(a) Inspecting the various sections of the international boundary when deemed necessary;

(b) Carrying out the surveys necessary to maintain the system of boundary monuments repairing, relocating and establishing new monuments where deemed necessary;

(c) Keeping the boundary vistas open;

(d) Regulating all work within 3 metres on either side of the international boundary;

(e) Reporting annually to the respective governments upon the work of the Commission including lists of the geodetic positions of all new or moved monuments and plans to revise the official boundary maps, certified by the Commissioner.

In addition, the Commission undertakes studies on boundary matters which could assist the formulation of Canadian policy respecting international boundaries by providing information and advice on the historic, technical and legal aspects of boundary development.

The Canadian Section of the Commission is, for operational purposes, incorporated in the Surveys and Mapping Branch.

Commission engineer establishing scale control for original boundary triangulation — Yukon-Alaska boundary

Raising the Lambert "Twin" Tower, a patented survey tower developed in Surveys and Mapping Branch

Canadian field parties operated in two areas during 1974-75.

On the Quebec 45th Parallel boundary 113 monuments were inspected, of these 27 monuments were dismantled and rebuilt on a firm base. Further monument reconstruction will be necessary to maintain the system of boundary monuments in good repair along this section. Six control stations were recovered during survey operations and one station remarked. Seventy-three boundary monuments and stations were occupied in extending the traverse from monument to monument along 34 km of boundary.

On the Yukon-Alaska boundary the program began last season, to recover and remark triangulation stations along the 141st Meridian boundary was continued. On a 250 km section of the line; 73 stations were recovered and remarked in a more permanent manner, six lost stations were replaced, and seven lines were remeasured to provide scale control for future readjustment.

BRANCH ADMINISTRATION

Book Library

The Branch Library has a book collection of approximately 18,000 volumes related to subject fields of Branch interest: geodesy, surveying, photogrammetry, aerial photography and its interpretation; Canadian history and geography; all aspects of map and atlas production, and other subjects pertinent to Branch responsibilities. A separate collection of books dealing with toponymy is maintained in the offices of the Canadian Permanent Committee on Geographic Names.

Some 350 current journals are received, and long runs of periodicals of particular Branch interest are maintained as a basis for a national collection of surveying and mapping materials.

Increasing use is being made of interlibrary loan facilities giving Branch personnel access to library materials anywhere in continental North America and, to a lesser extent, Great Britain and France.

An archives of Branch publications and photographs is in the process of being established.

Research and Development

The Research and Training Unit provides expertise in mathematics, electronics and computer sciences to the Directorates and Divisions of the Branch. In addition, the staff of the unit carries out research in the theory of map projections and designs of electronic equipment for use with survey instruments. Grants in support of research in surveying and mapping are administered by the Co-ordinator, Research and Training. Professional and technical training for the personnel of the Branch is organized by the Branch Training Officer.

System Control

The System Control office is responsible for the operations, administration, development and co-ordination of the Branch—oriented management information systems. These systems may be manual or computer-assisted, and are of a nature to supply senior management with information retrievals including the relationship of expended resources. The systems are used to identify effort to programs and activities,

supply the base for identifying organizational/activity costings, and the data available supplies a base for work measurement, inventory and production control.

Publications and Information Services Office

The Publications and Information Services Office maintains a publication program to document the Surveys and Mapping Branch activities, and provides an information service to answer telephone and letter enquiries on the various Branch services.

The documentation program is designed to report on the range of scientific and technical disciplines related to the surveying and mapping functions of the Branch: geodesy, surveying, geography, photogrammetry, aerial photography, topography, cartography, and toponymy.

Demands for scientific and technical communication increased by 50 per cent during the year; requests for Branch publications, and information enquiries came primarily from educational institutions and private industry.

All current publications published by the Surveys and Mapping Branch are available from the Canada Map Office, and include: 39 technical reports and specifications, 12 instruction manuals and text books, 12 gazetteers, 25 miscellaneous reports and brochures, 34 general information publications, and 35 reprints of articles written by branch staff and published in scientific journals.

Throughout the scientific and technical program of 1974-75, the Branch scientific staff continued to contribute to the communication program and to report on current projects and developments in the activities of the Surveys and Mapping Branch. These publications are listed on the following page.

LIST OF PUBLICATIONS

Maps and cartographic products form the bulk of the publications of the Surveys and Mapping Branch. A complete listing is given in the yearly "Catalogue of Published Maps", available, together with map indexes, from the Canada Map Office, Surveys and Mapping Branch, Ottawa (telephone 994-9663).

The following list indicates papers, reports and other publications by staff members which have been published recently by the Branch or elsewhere in scientific and technical literature.

Blackie, W.V., "Geodetic Needs in the Offshore". Proceedings of the Geodesy for Canada Conference, Appendix C, p. C1-C8.

Fleming, E.A., "Canada Sits for its Portrait". GEOS, Winter, 1975, p. 5-7.

Gale, L.A., "Applications of Statistical Characteristics of Geodetic Networks". The Canadian Surveyor, December, Vol. 28, No. 5, p. 702-708, 1974.

Gale, L.A., "Geodetic Needs in Surveying and Mapping". Proceedings of Geodesy for Canada Conference, B1-B13.

Gregerson, L.F., Frost, N.H., and Robertson, W.J. "The Gyroscope as a Tool for Azimuth Determinations". The Canadian Surveyor, March, Vol. 28, No. 1, p. 37-45, 1974.

Kouba, J. "Reduction of Doppler Satellite Data Observed in Canada". The Canadian Surveyor, December, Vol. 28, No. 5, p. 480-486, 1974.

McLellan, C.D. "Geodetic Networks in Canada". The Canadian Surveyor, December, Vol. 28, No. 5, p. 457-461, 1974.

Mitchell, J.C., "Regulation of Offshore Legal Surveys". Proceedings of 14th Annual Canadian Hydrographic Conference, Halifax, 1975, 4 pages.

Moore, R.E. "The Wide World of Surveying". The 1974 Annual Report of Association of Ontario Land Surveyors, p. 152-162, 1974.

Peterson, A.E. "Merging of the Canadian Triangulation Network with the 1973 Doppler Satellite Data". The Canadian Surveyor, December, Vol. 28, No. 5, p. 487-495, 1974.

Pinch, M.C. "A Test Adjustment of the Canadian Triangulation Network". The Canadian Surveyor, December, Vol. 28, No. 5, p. 474-479, 1974.

Porter, T.A. "Canadian National Positional Control Survey Data File". A Geodetic Data Bank for Canada. The Canadian Surveyor, December, Vol. 28, No. 5, p. 724-730, 1974.

Sauvé, P.I.R., "Metric Conversion and Its Effect on the Land Surveyor". Technical Papers of the 82nd Annual Meeting, Association of Ontario Land Surveyors, 1974.

Sebert, L.M. "1:50,000 Monochrome Series of the National Topographical System". The Canadian Cartographer, Vol. 11, No. 2, December 1974.

Smith, W.M. "The Assessment of Angular Measurements with the Lambert Instrument Tower". The Canadian Surveyor, June, Vol. 28, No. 3, p. 217-224, 1974.

Toponymy Division, "Gazetteer of Ontario", Surveys and Mapping Branch, 1974.

Wray, Thomas. "An Integrated Approach to Map Projections and Plane Coordinates". The Canadian Surveyor, December, Vol. 28, No. 5, p. 637-642, 1974.

Wray, Thomas, "The Seven Aspects of a General Map Projection". Supplement No. 2 to Canadian Cartographer - Monograph No. 11/1974.

Branch Publications

SMP 1092E	"Manual of Field Completion Survey", Topographical Survey Directorate, 18 pages, 1974.
SMP 1092F	"Manuel de complètement des cartes par levés sur le terrain", Topographical Survey Directorate, 25 pages, 1974.
SMP 1105	"Program Apicor", by Dr. M.M. Allam, 116 pages, 1974.
SMP 1106E	"Manual of Field Control Placement and Identification", Topographical Survey Directorate, 26 pages, 1974.
SMP 1108	"Proceedings of the Seminar on Control Photography, Photo Interpretation, and Mapping", Branch HQ, 105 pages, 1974.
SMP 1109	"Geodesy for Canada Conference", Branch HQ, 138 pages, 1974.
SMP 1110E	"Space M" (in English), Topographical Survey Directorate, 28 pages, 1974.
SMP 1110F	"Space M" (en Français), Topographical Survey Directorate, 28 pages, 1974.
SMP 1170E	"Topographic Mapping Manual of Compilation Specifications and Instruction", Topographical Survey Directorate, 118 pages, 1974.
SMP 1191F	"Specifications pour Levés de contrôle et conseils concernant la construction des repères", Geodetic Survey of Canada, 54 pages, 1974.

Inventions and Patents

Title	Inventor	Status of Invention
Light Weight Survey Tower for precise angular and distance measurements	A.F. Lambert	Can. Patent No. 960428 U.S. Patent No. 3815708

canada centre for remote sensing

L.W. MORLEY, Director

The Canada Centre for Remote Sensing is the nucleus of a national program in remote sensing, introducing this new technology into the established resource management and environmental monitoring agencies and organizations across Canada. Under the guidance of the Inter Agency Committee on Remote Sensing, made up of representatives of the concerned federal government departments, the Centre serves federal and provincial agencies, universities, regional association, industry, and the general public. It co-ordinates the national effort in conjunction with provincial remote sensing agencies and some 200 scientists and resource managers who make up the working groups of the Canadian Advisory Committee on Remote Sensing. There are 13 working groups covering the disciplines which support or use remote sensing techniques:

Agriculture	Atmospheric Sciences
Forestry, Wildlife and Wildlands	Ice Reconnaissance and Glaciology
Geosciences	Photogrammetry and Cartography
Geography	Photo Reproduction and Marketing
Limnology	Sensors
Oceanography	Hydrology
Data Handling and Satellite Engineering	

The Centre also fosters international co-operation in the peaceful use of space technology.

The activities of the Canada Centre for Remote Sensing are concentrated on the Earth Resources Satellite Program, the Airborne Remote Sensing Program and the Applications Program. The facilities include a satellite ground receiving station at Prince Albert, Saskatchewan, a fleet of four aircraft equipped with a variety of sensors and navigation equipment, a data processing system, sensor development laboratories, and advanced instrumentation for image processing and analysis. These facilities are available to scientific investigators and to users or potential users of remote sensing data.

DATA PROCESSING DIVISION

E. SHAW, Chief

During the past year the Division improved its ability to record and process data received from the Earth Resources Technology Satellite (LANDSAT formerly known as ERTSI) and began to receive data from the NOAA satellites. More LANDSAT film images and computer tapes were produced than last year and work to stabilize our electron beam recorders (EBR) will help increase production capability.

A basic facility for handling wide-band analog and narrow-band digital airborne data was built and plans have been made to develop an airborne data processing system.

The Centre has assisted development of systems for analysis of multispectral data on computer tape. Two interpretation systems are now operational, the MAD display system attached to the DEC-10 computer and the stand alone GE-100 system. Classified outputs from the systems can be reproduced on the EBRs and used to generate thematic colour images.

Prince Albert Satellite Station

During 1974, the Prince Albert station recorded 1,465 orbits of LANDSAT multispectral scanner (MSS) data and 554 orbits of NOAA very high resolution radiometric (VHRR) data. Bands 5 and 6 of the MSS and the thermal and visible band of the VHRR were recorded on the quick-look system to produce 51,378 LANDSAT and 2,300 NOAA master film images for rapid distribution to users.

Regular tracking of the NOAA orbits covering the Arctic, Hudson Bay and east coast areas began in June 1974. The recording of NOAA is done on a non-interference basis with the LANDSAT satellite. This operating mode was chosen to give first priority to LANDSAT followed by coverage of sea-ice areas with the NOAA Satellite.

Sea-Ice Fax

Last summer, LANDSAT and NOAA images were sent in near real time from Prince Albert to ships in the Arctic to demonstrate the use of satellite imagery for navigating in ice infested waters. The satellite imagery was sent by facsimile land line to ice forecast central in Ottawa, and by a U.S. geostationary UHF communication satellite from Ottawa directly to the ships in the Arctic. A high frequency radio transmission was also evaluated during this project but was not as reliable as the satellite link.

LANDSAT images were found to be more useful than NOAA images in the preparation of ice forecast maps. However, the NOAA images, although of lower resolution than the LANDSAT images, provided daily coverage and were useful in planning ship operations for geophysical exploration.

Quick Look System

In February 1974, the ERTSFICHE product was introduced; it is a set of three microfiche containing all of the band 6 MSS images received each day. Since the imagery is framed and annotated to correspond to the LANDSAT-1 index map, the ERTSFICHE is a low cost data base that can be used to select and order higher quality imagery.

In the summer of 1975, all black and white satellite products will be produced at the Prince Albert Satellite Station by ISIS Ltd. under a contractual arrangement with CCRS. Initially, the master imagery will be produced on the electron beam image recorders at Ottawa, but in early 1976, a high resolution recorder will be installed to produce the master images at Prince Albert.

East Coast Station

A Vancouver firm was awarded a contract by DSS to develop a portable satellite ground station for receiving and processing LANDSAT and NOAA data. When this station is completed in the spring of 1976, it will be moved to Shoe Cove, Newfoundland. It will have the capability of producing quick-look images and computer tapes from LANDSAT MSS, or NOAA VHRR data. An interface to land lines will be provided so that images can be sent directly from the computer to remote FAX receivers.

At first the station will be used for experimentation and testing but it is expected to be operational for LANDSAT and NOAA reception by the fall of 1976.

Satellite Image Production

Of the 1,465 orbits recorded at Prince Albert during 1974, 1,112 orbits were converted to imagery in Ottawa. To date a total of 2,522 orbits has been processed. The current image inventory consists of 32,500 scenes in black and white and 8,000 in colour. This year mosaics of LANDSAT images have become an important new product of the Surveys and Mapping Branch, EMR. This requirement for mosaics has necessitated the introduction of very stringent quality control procedures into the image production system.

Computer Compatible Tapes

In 1974, users requested and received 430 computer compatible tapes. This is an increase of 290% over 1973. A new tape format which was developed at a joint meeting between CCRS and NASA will be used after September 1, 1975.

Laser Beam Image Recorder

A colour laser beam image recorder was delivered to Ottawa mid-December 1974. The laser beam recorder, which was designed and built by the University of Toronto, has been undergoing development and testing by CAE Electronics Limited in Montreal. The recorder is undergoing integration and testing with its computer control system and is expected to be operational by early 1976. It will be used to produce

LANDSAT colour composites and also to produce infrared imagery from digital airborne scanner data.

Image Inventory and Catalogue Service

Summary information of the LANDSAT data base can now be produced on transparencies that overlay the picture centres on the LANDSAT index map. These overlays have proven useful in studies of imagery availability and seasonal variation of quality, cloud cover, etc. They are also useful as short form catalogue references and have been used in the CCRS Newsletter. A new service is the direct user search of the data base from remote sites via telephone modems. A user can now dial up and access the data base in an on-line search mode to obtain immediate information on image availability. Searches can be controlled with respect to time, quality and cloud cover, with a latitude/longitude defined search space or with a discrete picture centre location.

When black and white image production is transferred to Prince Albert next year, ordering will be done by sending orders for black and white products to a commercial firm in Prince Albert. Colour orders will be sent to CCRS in Ottawa. Facilities will be available for handling and splitting combination orders by telex between the two facilities.

Airborne Processing System

The Centre has now started recording digital tape data from many of their airborne sensors. The sensor data and navigation data is annotated and collected in flight by the Airborne Data Acquisition System (ADAS). In support of the ADAS, a ground data processing system has been built. This airborne data processing system is currently composed of a central processing unit, memory, an analog to digital convertor interface, and magnetic tape units for input and output. Software exists which allows the processing of scatterometer data, navigation data, camera firing times and other low data rate or analog functions. These data are extracted from the recorded data, processed and output on computer compatible tapes (CCT). High data rate digital input channels are being added to input digitized thermal scanner data. The system will be configured to handle four channels of digitized scanner type data during input, processing, and output so as to be compatible with the number of LANDSAT channels. As applications and requirements for more develop, then additional input and processing capabilities can be added.

During the next year the colour laser beam image recorder and a larger memory system will be added to the system to produce high resolution colour images.

Data Collection Platform (DCP) Support

During the past year CCRS has continued to receive DCP data from NASA, converting it to engineering units and providing it to users through a teletype or telex link. A study showed that the need for virtually instantaneous turnaround on this data was minimal and that most users were satisfied with a once-a-day provision of this data. Faster turnaround is available on a direct request to CCRS.

A study was performed on DCP reception at Prince Albert from the LANDSAT and GOES satellites. This study showed that these services could be made available for a capital investment of $70,000. Presently there are no plans to add this extension. NASA had indicated that data collected from the present Canadian platform will continue to be made available from LANDSAT-2 when LANDSAT-1 fails.

DATA ACQUISITION DIVISION

R.C. BAKER, Chief

Until very recently, airborne remote sensing has been limited to aerial photography, with a variety of camera and films, and thermal mapping. These techniques produced photographic products from which information could be obtained visually by trained photo-interpreters. While providing such services to users across Canada, the Centre is concentrating on developing new techniques for collecting data by means of integrated, multi-sensor systems producing data appropriate for automated interpretation. New electronic sensors are being developed and flight tested; the data is combined with navigation information and data from other sensors and recorded electronically in a form suitable for processing by the Centre's Ground Data Handling System.

Airborne Operations

The Centre's fleet of aircraft consists of a Falcon Fanjet for high altitude production flying, a Dakota for low altitude production work, and a second Dakota dedicated to the testing of new and experimental sensors and data recording systems. These aircraft are manned, serviced, and maintained by the Canadian Forces Airborne Sensing Unit under contract to the Centre. A Convair 580 turbo-prop aircraft has recently been purchased and is now awaiting configurating to fill both an operational and test-bed role.

Production sensors consist of Daedalus infra-red line-scanners, 9″ x 9″ metric cameras, multi-spectral four 70 mm Vinten camera packs and PRT5 radiometers. Sensor packages are fitted to meet the requirements of individual investigators and may be operated singly or simultaneously.

Missions flown last year were reduced to just less than half of those conducted in the previous year due to budget restriction and an increase in charges to users. A total of 22,026 sensor line miles were flown for all users including federal and provincial government agencies, universities, and industry. This was the first year of a $5.50 line mile charge plus full cost recovery for film, tape and reproductions.

Airborne Operations has this year taken over the full responsibility for film annotation, and indexing; invoicing for all functions including flight cost recovery and reproduction. Work is continuing on the expansion of the limited capability for the reduction of data from magnetic tape to provide

increased flexibility and the provision to users of a much wider variety of products in the form of special density slicing of scanner imagery and computer compatible tapes.

A "data bank" consisting of reports from investigators and applicable imagery has been established and is maintained and updated on a continuing basis. Using a computer based data retrieval system, pertinent information can be forwarded quickly to any agency on request. The system is also used by the operations staff to assist investigators in the selection of the most suitable sensor package and flight parameters to meet their requirements.

Airborne Systems

The Centre has a continuous program of improving aircraft facilities, installing, maintaining and upgrading navigation systems and integrating the sensors into co-ordinated data acquisition and track recovery systems.

The Airborne Data Acquisition System, installed on the experimental aircraft, has been used very successfully for a number of special projects. The system monitors status and data information from various sensors and navigation systems and records the information digitally on magnetic tape. Camera annotation is controlled and all operator comments and commands are recorded. Presently, the system is interfaced to the Intertial Navigation System, RC-10 camera, infrared line scanner, PRT-5 radiometer, four channel photometer and barometric altimeter. Other sensors and navigation systems will be interfaced to it in the near future. A "quick-look" ground playback and display system is used for display and preliminary analysis of data from the Airborne Data Acquisition System.

Sensors

New sensing capabilities are developed, both through work within the Centre and through the sensor development program which provides support in the development of new types of sensors in industry and universities. New sensors and sensing techniques are evaluated and flight tested in co-operation with users from the appropriate disciplines.

Some of the development work is highlighted as follows:

Airborne Bathymetry

The experimental laser bathymeter has demonstrated the capability to measure water depth profiles under the aircraft in moderately clear water at dusk and at night; the maximum depth measured to date has been 7.5 metres. A feasibility study in industry is formulating the design of an imaging laser bathymeter capable of daylight operation.

Identification of Oil Spills, Chlorophyll and Water Pollution

The experimental laser fluorosensor has overflown a number of areas, including a controlled oil spill, pulp mill effluent and water fluorescence. From the encouraging results and associate laboratory back-up work, the development program of a second generation laser fluorosensor is underway.

A number of new spectroscopic profiling sensors have been flown over water to investigate the remote measurement of chlorophyll concentration. This promising work is continuing in association with scientists and users in universities and government laboratories.

Sea Ice Type Identification

A major project was undertaken in the spring over the AIDJEX test site in the Beaufort Sea. Data was acquired

Convair 580 Turbo-Prop Aircraft

simultaneously with the microwave scatterometer, radiometer and infra-red scanner and is showing good correlation with the surface truth ice-type data.

Production Sensor Support

The production sensors undergo regular maintenance, calibration, improvement, and modification to fit the requirements of the users. This work is carried out in a calibration and testing laboratory set up to ensure that production sensors meet required specifications and tolerances.

A Look to the Future

The recently acquired Convair 580 aircraft is starting on its modification program aimed specifically at meeting those projects which cannot be done within the limitations of the present aircraft. Its long range and good payload capability make it ideally suited to work over the oceans, in the Arctic, and in co-operative programs with countries outside North America.

A number of holes, ports and attachments points will be provided which, in addition to accepting the present sensors, will allow it to carry the new sensors under development and a complement of microwave sensors specifically for all weather sensing in the Arctic and over the oceans. It will carry a full data acquisition system, and have sufficient equipment space and power to allow multi-sensor experiments to be performed.

Industrial Involvement Program

In line with its efforts to help Canadian industry develop a commercial capability in remote sensing, the Centre has let a three-year contract to Innotech Aviation Ltd. of Dorval, Quebec, for the operation and maintenance of the four CCRS sensor-equipped aircraft. Associated with Innotech are Intera Environmental Consultants Ltd., of Calgary; MacDonald Detwiler Associates of Vancouver and Lavalin Associates of Montreal.

During the course of this three-year period it is expected that the participation of Innotech and their associates will be broadened such that they will eventually be capable of providing a wide range of operational remote sensing services on a commercial basis, from the acquisition of raw data to the processing and application of the data to end user needs.

The Centre will continue to manage the airborne remote sensing program through this transition phase, with users "contracting" for and receiving data in the same manner as at present.

APPLICATIONS DIVISION

M.W. STROME, Chief

The Applications Division provides the Centre's main contact with the user community. During its early phases, the major efforts of the Division were expended in support of the satellite program in order to instruct the Canadian remote sensing user community, who were familiar with the existing airborne sensors and data products, on the application of satellite acquired data. In the past year, significant advances have been made in the development of automated analysis techniques for the satellite data. Also, because of a substantial increase in airborne systems development, the Division now expends about one half of its efforts on this program.

Applications Development Section

The Applications Development Section has the important role of maintaining the link between the research and technological aspects of the Centre and the practical and beneficial application of this work. In order to carry out this function, the applications development scientists interact with the user community and provide expertise in a wide range of scientific disciplines. During the past year a number of co-operative programs were undertaken. The general scope of studies included: land resource inventories;

specialty crop inventories;

monitoring of landslides;

the application of satellite data in the monitoring of man-made changes which were due to large hydroelectric developments such as the Churchill and Nelson Rivers diversion and the James Bay development;

vegetation mapping of the Hudson Bay lowlands;

land use classifications;

the use of airborne and satellite imagery in mapping suspended sediment in the Lake St. Clair ship channel;

investigation of spectral signatures for limnological studies;

multispectral scanner evaluation;

the use of satellite imagery in the identification of wheat and other crops;

forestry classifications using digital satellite data;

a specialty workshop on the remote sensing of snow cover.

In the case of high cash value crops such as potatoes, soybeans, grain corn and tomatoes, an increase in the accuracy of acreage and probable yield could amount to a potential value of several million dollars per year. Because of their high local concentration, these crops are uniquely suited to surveillance by remote sensing techniques. The Applications Development Section has carried out three evaluation projects on these types of crops and it is hoped that these projects will be carried to the operational phase in the near future.

Water is one of Canada's most important resources and remote sensing technology has a vital role to play in future operational surveillance systems. Remotely sensed data can provide detailed information, either by digital or visual interpretation, on sediment load, industrial and man-made effluents and environmental changes which have been caused by nature (floods) or by human activities (hydroelectric developments).

A number of the section's projects have been concerned with various aspects of land classification. For example, to

improve conventional resource development studies in remote northern regions and the mapping of large forest fires (greater than 100 acres) in the Northwest Territories.

Applications Development scientists have been active in working with various groups on the use of the Image-100 (See Figure 1) and Bendix Multispectral Analyser in the solving of specific problems. These digital interpretation systems are now in the operational phase and are available to users on request.

In addition to the major pieces of equipment which are mentioned above, stereoscopes, a multispectral photographic viewer, a density slicer and other standard photointerpretation equipment are also available at the Centre.

Methodology

The Methodology Section has developed two software based systems which are called MADUSE and MICA. These systems will interpret LANDSAT-1 and -2 digital multispectral scanner data as well as passive and active airborne imaging data. A General Electric Image 100 hardware classification system has also been acquired and is now being modified.

The MADUSE software system permits a user to interactively enhance any channel or combination of channels, or to carry out three-theme classification system has also been acquired and is now being modified.

The Modular Interactive Classification Analyser (MICA) system also uses the MAD. This system is composed of an extensive collection of methodology-developed programs which permit interactive selection of training areas, generation of image statistics, feature selection, classification and display of the results on the MAD, line printer or electron beam recorders. The availability of "HELP" files, each of which describes a particular program on the terminal, enables the user to master the MICA system. This system is used to research new algorithms of pattern recognition before developing production versions.

The Image 100 system was installed in April 1974 and is now capable of rapidly analyzing LANDSAT multispectral scanner imagery, airborne scanner data and SKYLAB digital scanner imagery. The results of classifications are displayed immediately on the colour video monitor. The classes also may be output onto a plotter or a electron beam recorder in geometrically correct form. Tabulations of class acreage within regional or other irregular boundaries may also be obtained. The Image 100 operates on three shifts over a twenty-four hour period and CCRS provides an experienced analyst to help use the digital imagery for terrain analysis.

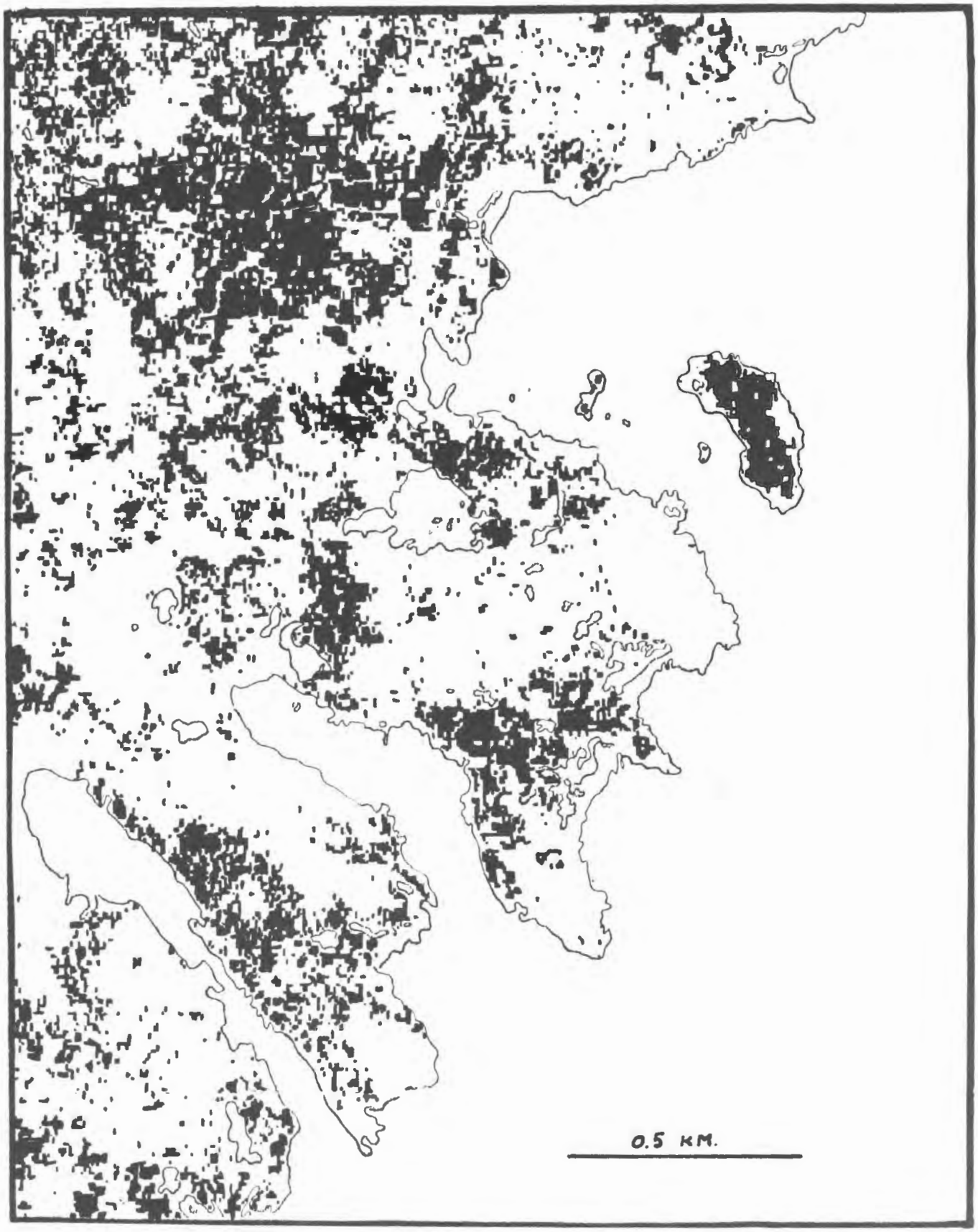
The Methodology Section has developed methods of processing imagery through coherent optical equipment so as to enhance features of geological interest. This work will be extended in the next year to cover the analysis of holographic data produced by imaging radar systems.

Research in reflectance spectroscopy in the visible and microwave regions has been initiated so that it will be possible to make better decisions concerning the choice of sensors, spectral channels and resolution which will be appropriate for various applications.

Methods of image classification may be divided into two main groups—supervised and unsupervised. In the supervised classification, the user trains the system (Image 100 or MICA) to recognize areas which are similar to a user selected sample. This sample has been identified previously from 'ground truth data', which may consist solely of low altitude aerial photography. When the user's ground truth information is not very accurate, one may use unsupervised classification in which the computer system displays the most separable classes. These classes are then identified by the user so as to correspond to the features of interest. Rapid methods of unsupervised classification or clustering have been added to our system this year.

As an example of the type of product available from the Image 100 system, Figure 2 shows an image from our plotter. The scene is an area near Port Mouton, Nova Scotia. A joint project with Lands Directorate, Department of the Environment, resulted in the classification of various environmental features of which one is shown here. The accuracy of the classification was greater than 85% and was produced in less than one hour of system interaction.

Image-100 Remote Sensing Image Analysis System



I-100 Classification of showing softwoods. March 15, 1973. Port Mouton, Nova Scotia.

PROGRAM PLANNING AND EVALUATION DIVISION

J.C. HENEIN, Chief

In this division benefits and potential benefits of remotely sensed data in resource management and development and environmental monitoring are evaluated. Considerable emphasis has been given in recent studies to applications in northern Canada including both land and offshore areas. One study has assessed benefits of remote sensing to renewable resource management and development in boreal and arctic regions. The accelerating search for petroleum in ice-infested waters has brought urgent requirement both for baseline data and for surveillance systems. Cost-benefit studies on remote sensing applications for sea-ice study and reconnaissance and a technology assessment of microwave remote sensing satellite systems potential for Canada have helped focus attention on the value of remote sensing methods, particularly those with all-weather surveillance capability. Such studies provide one indicator of where priorities should lie in remote sensing research and development programs. They can also help in planning national programs such as a national all-weather ocean surveillance program, and clarifying priority areas for co-operation with NASA, European Space Agency, and other foreign space agencies.

Constant re-evaluation of the remote sensing program is made in terms of program costs, benefits generated from operational programs, and potential benefits. Program planning is carried out based on this constant re-evaluation.

TECHNICAL INFORMATION SERVICE

As part of its function as a national centre for remote sensing, CCRS operates a library which maintains an up-to-date collection of literature and imagery on remote sensing and related topics, distributes the reports of the Centre, and operates an information exchange with remote sensing centres in Canada and abroad.

Documentation on remote sensing is made widely available through a machine-readable catalogue, called RESORS, Remote Sensing On-line Retrieval System. By entering a search strategy based upon a controlled keyword vocabulary, one is supplied with an immediate listing of bibliographic references, ranked by degree of correlation to the keywords used.

During the past year, printouts of over 26,000 references were requested in the course of 2,363 searches.

The image library maintains large files of LANDSAT imagery in various formats, as well as selected imagery from NOAA and SKYLAB, to assist users in selection and ordering of products. Special efforts are made to provide remote sensing centres with up-to-date information and image catalogues.

LIST OF PUBLICATIONS

Alfoldi, T.T., Landslide Analysis and Susceptibility Mapping, Symposium on Remote Sensing and Photointerpretation, Banff, Alberta, October 7-11, 1974 (ISP, Comm. VII.)

Alfoldi, T.T., Photo Enhancement by Electro/Optical Techniques for Remote Sensing Applications, Snow/Ice Workshop, Ottawa, January 13, 1975.

Alfoldi, T.T., Utility of Airborne Multispectral Scanner Data, Aerospace Electronics Symposium, Halifax, N.S., February 3-5, 1975.

Alfoldi, T.T., Prout, N.A., Geometric Adjustments of IMAGE-100 Outputs for Ground Truth Compatibility, Ottawa, Canada Centre for Remote Sensing, April 1975.

Clough, D.J., Henein, J.C., and McQuillan, A.K., Case Studies of Canadian Benefits of Remote Sensing, 2nd Canadian Symposium on Remote Sensing, Guelph, April 29-May 1, 1974.

Economy, R., Goodenough, D., Ryerson, R., and Towles, R., Classification Accuracy of the Image-100, 2nd Canadian Symposium on Remote Sensing, Guelph, April 29-May 1, 1974.

German, D.M. and Ryerson, R.A., Land Use Information for the Great Lakes Basin; Report to Technical Committee B, International Joint Commission, March 1975.

Godby, E.A., Acquisition and Use of ERTS-1 Data in Canada, Seminar on Space Applications of Direct Interest to Developing Countries, San José dos campos, Brazil, June 19-21, 1974.

Goodenough, D., and Shlien, S., Automatic Classification Methodology, Aerospace Electronics Symposium, Victoria, B.C., February 1974.

Goodenough, D. and Shlien, S., Results of Cover-type Classification by Maximum Liklihood and Parallelepiped Methods, 2nd Canadian Symposium on Remote Sensing, Guelph, April 29-May 1, 1974.

Goodenough, D., MacDowall, J. and Ryerson, R.A., Status Report on Automatic Classification of ERTS Imagery of Canada, Symposium on Remote Sensing and Photointerpretation, Banff, Alberta, October 7-11, 1974 (ISP Comm. VII.)

MacDowall, J., The Application of Remote Sensing to Crop Information Systems, UN/FAO Regional Seminar on Remote Sensing of Earth Resources and Environment, Cairo, September 4-15, 1974.

Morley, L.W., Report on the Canadian ERTS Program, Third ERTS Symposium, Vol. 2, Washington, D.C., December 10-14, 1973.

Ryerson, R.A., Economic Analysis of Ontario Farms from Aerial Photographs, Symposium on Remote Sensing and Photointerpretation, Banff, Alberta, October 7-11, 1974 (ISP Comm. VII.)

Ryerson, R.A. and Gierman, D.M., Land Use Mapping in the Great Lakes Basin: Report on the Canadian Sector of Task B1, Prepared for Land Drainage Reference Group, IJC, July 23, 1974.

Ryerson, R.A., Remote Sensing: A General Introduction, Canadian Association of Geographers Annual Meeting, Toronto, May 26-30, 1974.

Shaw, E., An Economical Approach to ERTS Data Reception and Dissemination, Ottawa, Canada Centre for Remote Sensing, March 1974.

Shlien, S. and Goodenough, D., Quantitative Methods of Processing the Information Content of ERTS Imagery for Terrain Classification, 2nd Canadian Symposium on Remote Sensing, Guelph, April 29-May 1, 1974.

Strome, W.M. and Vishnubhatla, S.S., Format Specifications for Canadian ERTS MSS System Corrected Computer Compatible Tape Format, Ottawa, Canada Centre for Remote Sensing, June 1974.

Tarnocai, C. and Thie, J., Application of Remote Sensing to Permafrost Studies, Workshop on Permafrost Hydrology and Geophysics, Calgary, February, 1974.

Thie, J., Distribution and Melting of Permafrost in a Part of the Southern Discontinuous Permafrost Zone in Manitoba, Arctic, V. 27, No. 3, September 1974.

Thie, J., Remote Sensing for Northern Inventories and Environmental Monitoring: A Discussion Paper, National Workshop to Develop an Integrated Approach to Northern Baseline Data Inventories, Toronto, April 1974.

Thomson, K.P.B. and Jerome J., Digital Level Slicing of IR Imagery for Thermal Plume Studies, Canada Centre for Inland Waters, January 1974.

Thomson, K.P.B. and McColl, W.D., Evaluation of the RS-14 Line Scanner Imagery from a User's Point of View, Canada Centre for Inland Waters, 1973.

Thomson, K.P.B., Ross, S.L., and Howard-Lock, H., Remote Sensing of Oil Spills, Environment Canada, Environmental Protection Service, Report No. EPS-3-EE-74-2, December 1974.

Thomson, K.P.B., Jerome, J. and MacPhail, H.W., A Simple Colour Meter for Limnological Studies, Scientific Series No. 49, Inland Waters Directorate, Environment Canada, 1974.

polar continental shelf project

G.D. HOBSON, Director

The Polar Continental Shelf Project undertakes research and field surveys in the continental shelf area of Arctic Canada and the adjacent islands and Arctic Ocean. Its purpose is four-fold:

1. To obtain fundamental information on the geological, geophysical and oceanographic characteristics of the Arctic areas of Canada and the Arctic Ocean, to serve as a basis for evaluation and management of mineral and other resources, and to provide knowledge of the problems to be encountered in development and exploitation of resources, establishment of transportation and communications facilities, or other economic, strategic, and social or administrative activities in Arctic Canada;

2. To obtain information on the Arctic environment and the manner in which this environment can or may affect or be affected by economic, sociological, or military activities in the polar regions of interest to Canada;

3. To devise equipment and techniques that will enable Departmental responsibilities to be fulfilled in the polar regions as efficiently and economically as possible;

4. To provide the factual information, and evidence of national activity and service to Canada, which can substantiate the national position with regard to utilization of Arctic Canada and the adjacent Arctic Ocean, and provide de facto evidence of occupation, administration, and authority.

The program of the Polar Continental Shelf Project comprised about 105 separate investigations during 1974. About 60 per cent of these, accounting for nine-tenths of the total expenditures, are studies in the earth sciences or technical surveys that are part of the normal program of the Department of Energy, Mines and Resources, co-ordinated for efficiency and adapted to Arctic conditions; the remainder are studies by other government agencies or universities that contribute to the national need for information about the Arctic and which can be undertaken at comparatively little cost because of the logistics facilities established for the EMR program.

REVIEW OF 1974 OPERATIONS

Field work was carried out from mid-February to mid-October, being co-ordinated from Tuktoyaktuk in the Mackenzie Delta and from Resolute Bay on Cornwallis Island.

The Beaufort Sea Project environmental studies taxed the capacity of TUK base camp on several occasions when unfavourable ice conditions in the Beaufort Sea kept scientific parties on shore. The 32 projects under the Beaufort Sea umbrella were all supported through the facilities at TUK and were over and above the normal PCSP program. Again, the major field program efforts were concentrated in the hydrographic survey of Eureka Sound and adjacent fiords and the gravity survey of southern and eastern Amundsen Gulf. Permafrost studies also received considerable support again both in the Beaufort Sea and Resolute areas. The biological sciences were very well supported in 1974. The Northwater Project, to study the polynia of northern Baffin Bay, was well supported by Canadian government agencies. A total of 73 diverse projects were supported by the Polar Continental Shelf Project in 1974; the Beaufort Sea Project is additional to this regular program.

In addition to the Department of Energy, Mines and Resources, the following agencies were involved in, or received assistance from, the 1974 program of the Polar Continental Shelf Project:

Arctic Institute of North America
Department of Indian and Northern Affairs
Department of Defence, D.R.E.P. and D.R.E.O.
Environment Canada, Environmental Management
Environment Canada, Fisheries and Marine Service
Environment Canada, Canada Wildlife Service
Environment Canada, Lands, Forests and Wildlife
Environment Canada, Inland Waters Directorate
Environment Canada, Marine Sciences Directorate
Environment Canada, Canada, Water Management
Institute of Low Temperature Science, Japan
McMaster University
McGill University
Memorial University of Newfoundland
National Museums of Canada
Quebec Wildlife Service
Scott Polar Research Institute
Swiss Federal Institute of Technology
University of Alberta
University of British Columbia
University of Ottawa
University of Toronto
University of Uppsala, Sweden
University of Washington
Michigan State University
University of Liège

Brock University
Hokkaido University
Laurentian University
Carleton University

The following is a summary of work done in 1974 by the Polar Continental Shelf Project or to which the Project contributed. In several cases, as noted, the Project provided logistical or field support to studies of other agencies; these studies are described in greater detail in the reports by the various agencies responsible for their scientific direction.

Archaeology

Field work was directed at clarifying the picture of occupation in the High Arctic and to discern whether the Port Refuge sequence is typical of the cultural history of the entire region. Results indicate that the Port Refuge area is singularly and uniquely rich in archaeological material.

Biology

The Polar Continental Shelf Project gave considerable logistical support to Environment Canada, Arctic Institute of North America, National Museum of Natural Sciences, and Quebec Wildlife Services, to undertake various biological surveys in the Archipelago. These studies included such as aquatic ecosystems in the Mackenzie Delta, soil bacteria on Devon Island, whales, caribou, and polar bears in various parts of the Arctic, musk-ox and grizzly bears in selected areas, and the continuation of the animal community study of Bathurst Island. Many projects are continuations of previous projects undertaken to establish a history and baselines for future requirements. There is considerable concern that animals such as the musk-ox and the caribou are decreasing in numbers while the harvesting of polar bears must be more closely regulated in some areas.

Climatology

Twice daily transmissions of aviation weather reports were made from Resolute Bay to the Edmonton Arctic Weather Control from over 50 field stations during the 1974 season. This contributed to a more efficient High Arctic surface weather network.

During 1974 the stations on Coburg Island, Carey Island, and Cape Herschel continued to record climatological observations every six hours, continuous measurement of radiation, maintenance of four automatic weather stations, mapping of air humidity for isotope analysis every 24 hours and weekly observations of sea ice. The next major phase of the North Water Project will be the analysis of data compiled over the past two years. PCSP provided logistical support of equipment and aircraft.

Geodesy

Eight Doppler satellite positioning receivers were used simultaneously to establish high precision geographical positions at stations throughout the Arctic Islands, Greenland, and the northern Arctic Coast. Co-operation with the Danish Geodetic Institute allowed the Greenland-Canada tie to be initiated. The Canadian contingent of 35 men used one helicopter and two fixed-wing aircraft with support from PCSP as well as numerous casual chartered aircraft.

Geology

Several geological projects were supported during 1974 by PCSP with considerable aircraft time being allocated to some projects. Support was allocated to such projects as the study of coastal sedimentation along the Yukon coast and Byam Martin Channel as conducted by the Geological Survey of Canada. Quaternary sediment studies on Banks Island by the Geological Survey of Canada received considerable helicopter and fixed-wing support from PCSP. Geomorphological studies on Banks Island by the Geological Survey and by the University of Liège, Belgium, received support in the form of camp equipment and aircraft support while other similar studies by University of British Columbia staff and Geological Survey staff in various areas of the Archipelago were supported. Stratigraphic studies on Banks Island by the Geological Survey of Canada and on Somerset Island by the University of Ottawa were supported. In all projects cited above, the principal agencies have been assisted in their studies through logistical support by the Polar Continental Shelf Project.

Geophysics

In a similar manner several geophysical projects were undertaken by various agencies and supported by the Polar Continental Shelf Project to varying degrees. This support consisted of a few hours of flying time to complete supply of equipment and logistics.

The intensive study of permafrost, being undertaken by several agencies, was well supported by PCSP. These studies consisted of geothermal measurements at several wells in the Arctic Islands, seismic studies at various onshore and offshore locations, both in the Mackenzie Delta and near Resolute, resistivity and VLF investigations to determine the electrical properties and thickness of permafrost; all were well supported by PCSP. It is believed that it is possible now to determine the depth to the top of the permafrost as well as an indication of the thickness of the permafrost. The presence and absence of permafrost in the Beaufort Sea is a major project being undertaken by the Geological Survey of Canada with considerable support from PCSP.

The National Gravity Net was updated and monumented in 1974 to provide an improved gravity-reference standard for the exploration industry. New stations were established at oil company campsites. Revised gravity values and base station descriptions are now available. The systematic regional coverage of Amundsen Gulf was also completed with gravity readings being taken from the surface of the ice.

Oriented samples were collected for paleomagnetic studies at 33 sites on Prince of Wales and Somerset Islands. The dykes of the Hunting River area are stably magnetized with a direction almost reversed to that of the Prince of Wales sills, while the kimberlite specimens from south-central Somerset Island are stably magnetized and indicate a very young age of intrusion. This work was undertaken by the Geological Survey of Canada with aircraft support from PCSP.

A weather satellite receiving capability was established at Tuktoyaktuk for the provision of weather data to the Beaufort Sea Project, particularly aircraft movements. This project of the Geological Survey of Canada has been particularly valuable in providing not only weather data but climatological data in the High Arctic.

Glacier Physics and Glaciology

Snow and ice samples were collected for every 100 metres change of elevation for O^{18}, electrolytic conductivity, water equivalent and density determinations by scientists of PCSP. Atop each ice cap traversed a core was taken to uncover the 1962 summer melt layer and the 1963-64 bomb-test horizon. At each site samples were also collected for snow chemistry, particulate analysis and for pollen studies.

In 1974 the mass balance of White and Baby Glaciers was measured by McGill University scientists. A study of the thermal regime of the White Glacier was commenced with a new drilling program using an open-system, hot-water drill for the first time in the High Arctic. PCSP provided aircraft support.

Mid-summer aerial photography covered parts of Ellesmere and Seymour Islands while late-summer aerial photography covered selected glaciers at other selected areas in the Archipelago. This photography will assist in the mass balance studies of the various base camps.

Hydrography

All helicopter and fixed-wing support and logistics for bathymetric sounding of Eureka Sound and adjacent fiords was provided by PCSP in 1974. Four thousand one hundred and eighty nine soundings were taken and were positioned over most of the area by Motorola RPS. New horizontal control was established to supplement the existing topographic control to facilitate positioning of the data. This project is one of the larger programs supported by PCSP.

Hydrology

Helicopter support was provided to Environment Canada to obtain continuous records of precipitation, water level, air temperature and humidity at a few locations in the Mackenzie River Basin.

At Truelove Inlet observations of the main water budget variables were made and correlated with meteorological records. Snow coarse measurements and studies of physical properties of melting snow were made. Soil types were sampled to measure water-holding capacities and range of moisture content.

Research at Vendom Fiord by McMaster University was directed to document and model the hydrologic regime of the two large rivers which join to flow into the head of the Fiord and to examine the sediment transport rates of the rivers and the resultant conditions in the Fiord. A second concern of this project was the investigation of the hydrologic properties of the active layers of permafrost. Aircraft support for this project has been through PCSP.

Sea Ice

The systematic airborne sea ice reconnaissance surveys conducted by PCSP from April to October 1974, marked the 14th consecutive year for this program. Good weather allowed favourable coverage and progress. Breakup was later than usual and resulted in a smaller amount of open water.

A project to study the dynamics of first-year ice was continued by PCSP supported scientists wherein two strain gauges were set up approximately two miles apart on sea ice northwest of Tuktoyaktuk. The elastic changes noted are in qualitative agreement with the measurements made by laser interferometer on the ice island T3.

During 1974 considerable progress was made in finalizing arrangements for the Arctic Ice Dynamics Joint Experiment (AIDJEX) to be undertaken during 1975-76. In association with AIDJEX scientists, an ice island was visited to deploy instrumentation and investigate the origin of the island. The morphology of the ice island is such that it would be suitable for a research station. Instrumentation was established on the island for a period of approximately two months.

LIST OF PUBLICATIONS

Hobson, G.D. Seismic refraction—Sverdrup Basin; *in* Report of Activities, Part A: April to October 1973, Geol. Surv. Can., Paper 74-1, Part A, p. 71

Hobson, George D. Digital seismic instruments, Pakistan; internal report to C.I.D.A., 82 p.

Hobson, George D. A review of some geophysical data in the Sverdrup Basin; *in* Proceedings of the 1973 National Convention, pub. C.S.E.G., Calgary, ed. A.E. Wren and R.B. Cruz, p. 106-114.

Hobson, G.D. and Mirynech, E. Seismic survey of the Wellington Bay-mouth bar, Prince Edward County, Ontario; *in* Report of Activities, Part B, November 1973 to March 1974, Geol. Surv. Can., Paper 74-1, Part B, p. 75-77

Hunter, J.A., Good, R.L., and Hobson, G.D. Mapping the occurrence of sub-seabottom permafrost in the Beaufort Sea by shallow refraction techniques; *in* Report of Activities, Part B, November 1973 to March 1974, Geol. Surv. Can., Paper 74-1, Part B, p. 91-94

Killeen, P.G. and Hobson, G.D. Project EGMA seismic survey—Timmins, Ontario to Val d'Or, Quebec; Geol. Surv. Can., Paper 74-44, 33 p.

Koerner, R.M. and Paterson, W.S.B. Analysis of a core through the Meighen Ice Cap, Arctic Canada, and its paleoclimatic implications; Quaternary Research, vol. 4, no. 3, p. 253-263.

Paterson, W.S.B., and Koerner, R.M. Radio echo sounding on four ice caps in Arctic Canada; Arctic, vol. 27, no. 3, p. 225-233.

Prantl, F.A., Koerner, R.M., and Robertson, E. Nuclear Techniques for snow and ice studies on Devon Island; Proceedings of Conference on Ice and Snow, Monterey, Cal., Advanced Concepts and Techniques in the study of snow and ice resources, U.S. Contribution to the International Hydrological Decade, compiled by Henry S. Santeford and James L. Smith, National Academy of Sciences, Washington, p. 632-641

explosives branch

E.J. FRASER, Director

The Explosives Branch is responsible for the administration of the Canada Explosives Act and related activities in the explosives field. One of the main responsibilities is control over all factories that produce commercial blasting explosives, military explosives, blasting accessories, sporting ammunition, fireworks and other pyrotechnics, and for the quality and safety of these products. Responsibility also extends to the road transportation of these items and to their storage, sale and importation. Control is exercised by a system of licencing supported by inspections by members of the Branch who are located in five Regions with offices in Ottawa(2), Halifax, Calgary and Vancouver. All licences and permits are issued by the Ottawa Headquarters office.

The number of factories licenced to manufacture explosives decreased from 66 to 64 in 1974; however, they produced some 231,000,000 kilograms of commercial blasting explosives as compared to 215,000,000 kilograms during the previous year. The production of fireworks, ammunition and blasting accessories also increased.

Courses to qualify candidates as "Fireworks Supervisors" were continued and on March 31, 1975, approximately 3,650 persons had received this form of training at various locations across Canada.

Bill S-17, a bill to amend the Explosives Act in order to provide more stringent guidelines on the sale, purchase, possession and security of explosives was introduced in the Senate in the fall of 1974 and subsequently passed to the House of Commons for clause-by-clause examination. The bill passed first reading in the House on November 25, 1974.

Members of the Branch participated in the following committee activities:

The UN Group of Experts on Explosives

The UN Group of Rapporteurs on the packing of dangerous goods

Technical Committee on Dangerous Goods set up by the Assistant Dominion Fire Commissioner

Committee on Tagging Explosives

MOT Executive Committee and the Policy Council on the Transport of Dangerous Goods

Various Working Groups in CTC Task Force on Dangerous Goods

Advisory Committee on Explosives Technicians Course, Humber College

Advisory Committee on Drilling and Blasting Technicians Course, Sir Sandford Fleming College

Inspectors of Explosives regularly meet with members of industry, federal and provincial government agencies, municipal authorities and other groups to provide assistance and advice in the handling and use of explosives.

The Branch has available for distribution safety literature on the storage, handling and transportation of explosives.

office of energy research and development

R.P. CHARBONNIER, Director.

B.D. COOK, Co-ordinator

The Office of Energy R and D has been, since January 1974, acting as Secretariat to the Interdepartmental Task Force on Energy R and D studying the improvement and co-ordination of federal Energy R and D. The Task Force (chaired by the Deputy Minister, EMR) and its interdepartmental Working Committee (chaired by the ADM, S and T, EMR) include representatives of all federal departments with involvement in energy R and D and also five task co-ordinators representing their departments as lead agencies for co-ordinating the development of 32 energy R and D programs within the following five specific tasks (See Table 1).

Task	Co-ordinating Agency
1.—R and D to Conserve Energy and Improve Efficiencies in Energy Consumption	EMR (Office of Energy Conservation)
2.—R and D to Increase Domestic Non-Renewable EnergyProduction	EMR
3.—R and D to Substitute Other Energy Sources for Oil and Gas	EMR
4.—R and D to Develop Nuclear Capability	AECL
5.—R and D to Exploit Renewable Energy Resources	NRC
6.—R and D to Improve Energy Transportation and Transmission Systems	MOT

These tasks and programs represent the final consolidation of a large number of detailed statements, solicited from the specialist level by the Working Committee, of current and proposed research and development, required to meet the general energy policy objective of self-reliance by the 1980's. Supporting programs on environment, materials, manpower and basic research are incorporated, where appropriate, in the tasks. All programs are being consolidated by responsible departments and will include suggested levels and mechanisms of funding. Many programs reflect on-going established activities, and all are constantly being updated as circumstances dictate. Suitable versions of these programs will be made public when available. The first of these, "Solar Energy", has already been issued in March 1975.

An internal report to the Minister/EMR: "Energy Research and Development for Canada" (March 31, 1975), has been prepared, which delineates the major issues and outlines the objectives of the R and D tasks and programs in the context of developing national energy policy. The report also summarised the results of a financial questionnaire on Federal Energy R and D expenditures (1973-5) and of a similar industrial energy R and D questionnaire. A further report is being prepared, recommending relative priorities (and their reasons) for the proposed energy R and D programs with proposed levels for federal funding.

The Office of Energy R and D has also prepared a public information document titled "Science and Technology for Canada's Energy Needs", to be tabled in the House of Commons as the Report of the Task Force on Energy R and D to the Minister, EMR, in July 1975. Thus it will be available for use in international fora and in federal/provincial discussions, as well as for general information.

In Table 1, the 32 programs on energy R and D recommended by the Task Force on Energy R and D have been listed, together with the Energy R and D projects selected by the International Energy Agency for international co-operation, which may be of great interest to Canada.

canadian centre for geoscience data

C.F. BURK, JR., National Co-ordinator

The major activities during the year were completion of a planning document for development of the Earth Resources Data System (ERDS) and the resulting initial steps for implementation. To carry out this task CCGD was transferred administratively from the Geological Survey of Canada to the Office of the Assistant Deputy Minister, Science and Technology, and physically re-located at 580 Booth Street, Ottawa.

The objectives for ERDS, as identified in the planning document, are:

1. Establishment of a national referral centre for landmass and earth resources data, 2. Operation of a departmental data-base management service for accessing computer-processable data, 3. Establishment of access facilities for computer-based data sources external to EMR, and 4. Provision of ERDS data and services on a cost-recoverable basis. The planning document laid stress on providing improved co-ordination of computer-processable data files and on providing more convenient access to them.

As a first step toward implementing ERDS, a contract was let to Williams Geological Consultants Ltd., Edmonton, to identify and evaluate EMR computer-processable files potentially available to ERDS, to assess computer facilities required by ERDS, and to demonstrate an approach to the ERDS data base using data on coal deposits in Alberta and Saskatchewan. Files were also examined by CCGD from a broader point of view to identify categories—40 were recognized—and data co-ordinators from within the sector were assigned to each category. The 40 co-ordinators effectively constitute nodes defining an ERDS referral network.

In CCGD's role as the national referral centre for geoscience data, good progress was made in development of the Canadian Index to Geoscience Data. Most significantly, five new agencies agreed to contribute the indexing of their publications and holdings (British Columbia Department of Mines and Petroleum Resources, Alberta Research Council, New Brunswick Department of Natural Resources, Nova Scotia Department of Mines, and Prince Edward Island Department of Industry and Commerce), bringing the total number of contributing agencies to 9 provincial, 5 federal and 1 industrial. With increasing coverage, use of the *Index* by contributing agencies as well as the public accelerated, and improved systems and software were developed by CCGD and the Computer Science Centre to improve customer service. The file itself grew to about 43,000 titles. Programs were completed to produce output in microfiche form (COM), in addition to standard printout, and specifications were written to permit input by optical character recognition (OCR) techniques.

The Geoscience Index Advisory Committee (re-named from Thesaurus Committee), established in 1970 by CCGD, provides a forum for agencies contributing to the Canadian Index, and advises CCGD on policy and practical operations. One meeting was held in Calgary in December 1974, attended by 11 representatives.

During the year CCGD provided financial and/or advisory support to various projects related to the development of better tools for the management of computer-processable data in the context of the proposed Earth Resources Data System. Three such projects were: GEODAM, a generalized file management system under development by CCGD, the Geological Survey and the University of Alberta; MINDEP, a mineral deposit system for British Columbia being developed by the Department of Geological Sciences, University of British Columbia, to which CCGD contributed in the form of a contract study to evaluate data base management systems; and FILEMATCH, a communications system under development by the Atlas Computer Laboratory, United Kingdom which will facilitate data exchange between different data and file management systems (e.g. G-EXEC, SAFRAS, SYSTEM 2000, MARS VI, etc.).

The Canada Centre for Geoscience Data continued to provide secretariat services to COGEODATA, a committee of the International Union of Geological Sciences. Services included editing and publishing a proceedings volume, preparation and distribution of a newsletter, answering individual inquiries for advice on information technology, overseeing committee budgeting and financing, and providing assistance to the Chairman in scheduling and organizing COGEODATA meetings and other activities. Other international activities of note included continued participation in the ICSU Abstracting Board/IUGS project to develop a multilingual thesaurus for geology, and co-ordinating the initial contributions from EMR to an international directory of energy research and development projects, being compiled in a computer-based system by the Smithsonian Science Information Exchange, Inc., under a National Science Foundation (U.S.A.) contract.

PUBLICATION BY CCGD STAFF, 1974-75

Burk, C.F., Jr., 1975, Data-base management for large data files:
CODATA Bull. 15, p. 20.

Title	*Inventors*	*Status of Invention*
Recovering Vanadium Ore	J.A. Vezina	Can. Patent No. 783,006
Electronic Ceramic Compositions	V. McNamara I.F. Wright	Can. Patent No. 805,071 U.S. Patent No. 1,112,187
Portable Rock Drill	A.G. Meilleur E.H. Gaucher	Can. Patent No. 747,779
Proton Precession Magnetometer	P.H. Serson	Patents in U.S.A., Canada, U.K., Australia, France, S. Africa, Sweden and Germany. Patent application pending in Mexico.
Method and Apparatus for Measuring Magnetic Intensity	S. Washkurak P. Sawatzky	Patents in U.S.A. and Canada
Deep Water Wave Recorder	R.L. Gilbert	U.S. Patent No. 3,383,915 Can. Patent No. 768,793
Rock Drill Assembly	E.G. Eeles	U.S. Patent No. 3,123,951 Can. Patent No. 738,863
Compound Water Cyclone	J. Visman	Patents in Canada, U.S.A., U.K., Australia, France, S. Africa, India, Germany, Holland and Mexico.
Method of Treating Coal	H.P. Hudson J.G. Walsh W.J. Riva	Can. Patent No. 697,251
Digital Recorder	H.D. Valliant J.W. Geuer	Can. Patent No. 799,317
Flotation Process for Upgrading Cassiterite Concentrates	R.W. Bruce L.L. Sirois C.M. Lapointe B. Yaksic	Can. Patent No. 770,660
Method and Apparatus for Producing Air-Fuel Flames of Sonic and Supersonic Velocities	L.B. Geller E.R. Mitchell	Patents in Canada and U.S.A.
Process for Utilizing Hydrocarbon Injection Into Hot Reducing Gases in Steelmaking	J.H. Walsh	U.S. Patent No. 3,356,488 Can. Patent No. 752,792
Treatment of Copper and Nickel and Their Alloys	J.O. Edwards R. Thomson	Patents in Canada and U.S.A.
Method of Orienting Fibres by Means of AC and DC Voltage	A. Winer H.M. Woodrooffe	U.S. Patent No. 3,497,419 Can. Patent No. 813,882
Prevention of Gas Absorption in Metals	N.S. Spence R.D. McDonald W.A. Morgan L. Badone	Patents in Canada and U.S.A.
Treatment of High Antimony Bearing Gold Ores	R.W. Bruce	U.S. Patent No. 3,174,848 Can. Patent No. 675,560
Method of Making Electromagnetic Measurement	P.H. Serson	U.S. Patent No. 3,114,103 Can. Patent No. 654,552
Ion Bombardment Camera for Crystal Orientation Determination	R.L. Cunningham A.V. Grant J. Ng-Yelim K.V. Gow	U.S. Patent No. 3,180,987 Can. Patent No. 763,034
Corrosion Inhibition in Fuel Fired Equipment	G.K. Lee E.R. Mitchell A.T. McCord	Can. Patent No. 804,536 U.S. Patent No. 3,490,926

Title	*Inventors*	*Status of Invention*
Type E Stoker Grate	E.R. Mitchell F.D. Friedrich	Can. Patent No. 609,355 U.S. Patent No. 2,967,496
Stoker for the Combustion of Coal	E.R. Mitchell F.D. Friedrich	Can. Patent No. 621,375 U.S. Patent No. 3,117,537
Process for the Preparation of an Inorganic Gel Having a Predetermined Pore Structure	D.S. Montgomery B.I. Parsons	U.S. Patent No. 3,417,028 Can. Patent No. 706,356
Corrosion, Pitting and Tarnish Resistant Stainless Steel	W.A. Morgan D.E. King R.J. McClure	U.S. Patent No. 3,252,792 Can. Patent No. 690,749
Stabilization of Chromium Nickel Stainless Steel	W.A. Morgan R.J. McClure D.E. King	U.S. Patent No. 3,203,789 Can. Patent No. 690,750
Recovery of High Purity Magnesium Oxide from Magnesite and Calcite Ores	G.A. Kent	U.S. Patent No. 3,411,880 Can. Patent No. 803,444
Beneficiation of Carbonate Rocks and Minerals	J.S. Ross	Can. Patent No. 811,652
Method of Removing Al Oxide from Aluminum-Killed Steels and Steels Produced by Such Method	G.P. Contractor R.K. Buhr	U.S. Patent No. 3,119,159 Can. Patent No. 680,706
Free Machining Steels of Improved Transverse Mechanical Properties and Method of Making Same	G.P. Contractor D.E. King R.J. McClure	U.S. Patent No. 3,203,788 Can. Patent No. 690,748
Method and Apparatus for Inductive Prospecting	L.W. Morley	U.S. Patent No. 2,919,397 Can. Patent No. 680,595
Propane Gas Heater for Water Wells	E.R. Mitchell	Can. Patent No. 633,674
Smoke Reducing Method and Apparatus for Stokers	E.R. Mitchell F.D. Friedrich	U.S. Patent No. 3,044,422 Can. Patent No. 663,319
Cyclone Fired Cupola	H.P. Hudson	Can. Patent No. 618,814
Reduction in Coke-Combustion in Slag-Iron Process	J.H. Walsh H.P. Hudson J.C. Botham J.E. Landon	Can. Patent No. 791,059 U.S. Patent No. 3,462,263
New Apparatus and Method for Automatic Ground Faults Clearing	E.K. Swimmings	U.S. Patent No. 3,341,741 Can. Patent No. 777,407
Method of Calibrating an Electro-magnetic Seismograph	P.L. Willmore	U.S. Patent No. 2,939,079 Can. Patent No. 609,852
Uranium Bearing Steels	W.A. Morgan R.D. McDonald G.P. Contractor	Patents in Canada and Chile
Method of Improving the Usefulness of Electric Arc Furnaces	G.E. Viens R.A. Campbell G.N. Banks L. Sachdeva G.V. Sirianni	Can. Patent No. 776,106 U.S. Patent No. 3,441,651
Recording Magnetometer	P.H. Serson W.L. Hannaford	Can. Patent No. 611,194
Filler Material for Welding	K. Winterton M.J. Nolan	Can. Patent No. 746,847

Title	*Inventors*	*Status of Invention*
Apparatus for Atomizing Liquids	J. Visman	Can. Patent No. 597,146
Production of Low Silica Iron Superconcentrates	P.D. Maltby	U.S. Patent No. 3,273,707 Can. Patent No. 739,531
Slugging Cyclone	J. Visman	Can. Patent No. 798,128 U.S. Patent No. 3,366,247 Patents issued in France, and Australia. Patent application pending in South Africa.
Method and Apparatus for Sorting Ores	R.H. Goodman A.H. Bettens	U.S. Patent No. 3,476,939 Can. Patent No. 787,519
Fuel Oil Additive for Slag Prevention	E.R. Mitchell G.K. Lee	U.S. Patent No. 3,514,273 Can. Patent No. 850,577
Nuclear Magnetic Resonance Magnetometer	H. Wesemeyer	Can. Patent No. 706,520
Compacting and Forming Semi-Conductor Materials Without External Heat	E.W. Winkler J.R. Emmett J.A. Perry	U.S. Patent No. 3,517,435 Can. Patent No. 812,995
Hollow Stoker Grate	E.R. Mitchell F.D. Freidrich	U.S. Patent No. 3,014,439 Can. Patent No. 649,891
Topographical Stereoscopic Apparatus	R.E. Moore	Can. Patent No. 740,181
Method of Drawing Cross Sections from a Contoured Map and Instrument Therefor	F.D. Anderson	Can. Patent No. 585,235
Semi-Hollow Stoker Grate	E.R. Mitchell F.D. Friedrich	Can. Patent No. 646,110
Dump Grate	E.R. Mitchell F.D. Friedrich	Can. Patent No. 668,392 U.S. Patent No. 3,078,839
Process for the Preparation of Metal Oxides Having an Enlarged Pore Volume	D.S. Montgomery W.D. Machin B.I. Parsons	U.S. Patent No. 3,352,635 Can. Patent No. 748,798
Method of Treating Kyanite Concentrates	V.D. Svikis	Can. Patent No. 570,237 U.S. Patent No. 2,866,714
Ilmenite Leaching Process	B.J.P. Whalley	Can. Patent No. 591,274
Orthogonal Magnetic Anistropy	H. Gross	U.S. Patent No. 3,492,566 Can. Patent No. 830,075
Superpositioning Image Slicer	E.H. Richardson	U.S. Patent No. 3,510,203
Radiohm Method for Earth Resistivity	L.S. Collett A. Becker	Can. Patent No. 795,919
Hydrostatic-Powered Rock Core Drill Mini-mohole	J. Brooke R.L. Gilbert	Can. Patent No. 829,074
Airborne Measurement of Electrical Conductivity	A. Becker	Can. Patent No. 789,691 U.S. Application No. 731,534 filed 23-5-68
Continuous Recovery of Tungstic Trioxide (WO_3)	J.A. Vezina W.A. Gow J.J. Laliberté	Can. Patent No. 836,441
Automatic Digital Range Expander	D.F. Trigg	U.S. Patent No. 3,559,041
Cadmium Plating High Strength Steels Without Hydrogen Embrittlement	W. Dingley J. Bednar R.R. Rogers	U.S. Patent No. 3,647,648 Can. Patent No. 855,189

Title	*Inventors*	*Status of Invention*
Dual Mix Tank	J. Visman	U.S. Patent No. 3,511,480 Can. Patent No. 867,219
Total Magnetic Anisotropy Meter	H. Gross	U.S. Patent No. 3,488,577 Can. Patent No. 830,076
Direct Oxygen Probe for Liquid Metals	J.K. Pargeter	Can. Patent No. 871,239
Stable Silver Cyanide Plating Baths	W. Dingley J. Bednar	Can. Patent No. 859,116 U.S. Patent No. 3,645,858
Use of Spherical Agglomeration in the Production of Coke	J.H. Walsh B.J.P. Whalley J.C. Botham S.M. Ahmed	Can. Patent No. 841,485 Also patents in U.S.A. and U.K.
Pulp Divider for Cyclone	L.S. Sims J. Visman	U.S. Patent No. 3,487,923 Patent in Canada
Preparation of Highly Porous Alumina by Two-Stage Drying	G.T. Shaw B.I. Parsons	U.S. Patent No. 3,743,709 Can. Patent No. 861,396
Barite Flotation	R.A. Wyman	Can. Patent No. 914,809
Undirectional Liquid–Solid Filter	N. Nemeth	Can. Patent 926,310
Liquid-Liquid Separation of Copper, Cobalt and Nickel from Ammonical Ammonium Sulphate Solutions	G.M. Ritcey B.H. Lucas	Can. Patent No. 902,932 Applications pending Finland, Indonesia and Philippines. Patents issued in S. Africa, Zambia, Belgium, Rhodesia, Congo, U.S.A., U.K., Australia, France and Sweden
Beneficiating Raw Diatomaceous Earth	J. Visman J.L. Picard	Can. Patent No. 890,249
Automated Potentiometric Titrator	L.L. Sirois G.E. Alexander A.P. Page A.A. Winer	U.S. Patent No. 3,578,408 Can. Patent No. 867,483
Device for the Use of Individual Students for Production of Either Stereographic or Gnomonic Projections	R.L. Cunningham J. Ng-Yelim A.V. Grant	Can. Patent No. 887,207
Preparation of Low-Density Alumina Pellets	G.T. Shaw B.I. Parsons	Can. Patent No. 961,058
Concentration of Spodumene (Reverse Flotation)	R.A. Wyman	U.S. Patent No. 3,710,934 Can. Patent No. 930,484
DC Susceptibility Meter	H. Gross D. Symons	U.S. Patent No. 3,665,296 Can. Patent No. 926,941
Process for Separating Finely Divided Hydrophobic Particles From Watery Suspensions of Solids	C.F. Rozenhart J. Visman J.H. Walsh B.J. Whalley J.P. VanCruyningen	Can. Patent No. 876,860
Oxygen Probe System for Use in Liquid Metals	D.K. Faurschou J.C. Pope R. Hadden D. Meisner	Can Patents Nos. 895,537;917,253 Patents in Spain, U.S.A., S. Africa, and U.K. Patent application filed in Japan

Title	*Inventors*	*Status of Invention*
Program for Plotting Complex Graphs of Scientific Data	D. Fraser	To be exploited on Know-How basis
Copper Extraction from Ammonical Ammonium Solutions	G.M. Ritcey B.H. Lucas	Can. Patent No. 902,931 Patents issued in Belgium, U.S.A., U.K., Rhodesia, Congo, S. Africa, France and Zambia Applications pending in Sweden, Finland, Australia, Indonesia, and Philippines
Phase-Locked Tracking Filter	D.F. Trigg	Can. Patent No. 901,104 U.S. Patent No. 3,668,566
Forming Oxalate Conversion Coatings on Steel	W. McLeod G.R. Hoey	Can. Patent No. 930,651 U.S. Patent No. 3,806,375
Solvent-in-Pulp Extraction with Crud and Emulsion Control	G.M. Ritcey B.H. Lucas	No patent action to be taken
Co-extraction of U and Th from Leach Solutions and Recovery by Selective Stripping	G.M. Ritcey B.H. Lucas	U.S. Patent No. 3,835,213 Patent application filed in Canada.
Gyroscope Reading System	L.P. Gregorson G.R. Symons	U.S. Patent Application No. 383,117 27-7-73 Can. Patent Application No. 148,083 27-7-72
Process for Treatment of Lignite and Similar Low Rank Coal	J.P. VanCruyningen J. Visman R.P. Charbonnier J.G. Walsh	Can. Patent No. 955,550
Forming Ceramic Shell for Investment Castings	E.I. Szabo	Can. Patent No. 945,511 U.S. Patent No. 3,850,733
Survey Instrument Tower	A.F. Lambert	Can. Patent No. 960,428 U.S. Patent No. 3,815,708
Scheelite Flotation	H.L. Noblitt	Patent applications filed in Canada and U.S.A.
Cyclonic Clarification of Effluents by Controlled Flocculation Through Sequential Conditioning	J. Visman H.A. Hamya	Patent applications filed in Canada and U.S.A.
Remote Sensing Ground Data Handling System For a Resource Satellite	W.M. Strome L.W. Morley E.A. Godby	Exploited on Know-How basis
Solvent Extraction Recovery of Copper Using Quinoline Derivative	G.M. Ritcey B.H. Lucas K.T. Price	Patent application filed in U.S.A.
Flameless Atomic Absorption Spectro Photometer	Q. Bristow	Exploitation on a Know-How basis
Prep. of Investment Casting Shell Moulds by Electrophoresis	E.I. Szabo	Can. Patent Application No. 184,329 filed 26-10-73 U.S. Patent Application No. 497,039 13-8-74
Modified Packed Bed Filter Preheater Reactor	R.D. Warda R.K. Buhr J.E. Rehder	Can. Patent Application No. 193,274 22-2-74 Applications also filed in Australia, W. Germany, U.K. and U.S.A.
App. for Precise Timing of Star Meridian Transit	G.R. Symonds	No further exploitation
Solvent-in-Pulp Extraction with Colloid Addition	B.H. Lucas G.M. Ritcey	Can. Patent Application No. 192,789 filed 18-2-74 U.S. Patent Application No. 443,902 filed 19-2-74

Title	*Inventors*	*Status of Invention*
Method of Processing Coal	J. Visman	U.S. and Can. Patent applications filed
Magnesium Wire Injection Technique	R.K. Buhr M.C. Ashton	No patent action to be taken
Pulsating Pneumatic Fluid Bed Separator	G.W. Riley	No further exploitation
Computer Program (Quemop) (Quick Entry of Machine Opcodes)	Q. Bristow	To be exploited on a Know-How basis
Oxygen Probe with Self-contained Source of Oxygen Gas	A.H. Cohen A. Brooks B. Alcock C.S. Williams D.K. Faurschou	Patent Applications filed in U.S.A. and Japan
Aeromagnetic Data Automatic Mapping System	M.T. Holroyd	To be exploited on a Know-How basis
Solvent Extraction of Copper Ore Alkaline Leach Liquors	G.M. Ritcey	Patent application to be filed in Canada
Air Current / Shaking Screen Separation of Asbestos Fibre From Crushed Rock	G.W. Riley	Under investigation
Recovery of Iron from Waste Waters by Ion Exchange	A.J. Gilmore J.L. Fleury	No patent action to be taken
Computer Controlled Geochemical Analysis System for use with Atomic Absorption Spectrophotometer	Q. Bristow	To be exploited on a Know-How basis
Automatic Magnetic Observatory System (AMOS)	F. Andersen D.F. Trigg P.H. Serson	Exploitation on a Know-How basis
High Capacity Low Power Data Lagger	D.F. Trigg	Exploitation on a Know-How basis
Sponge Ferrochromium Production	M.A. Qayyum D.A. Reeve	No patent action to be taken
Triaxial Mining Method	G. Zahary	No patent action to be taken
Angled and Dished Vane Swirler for Blue Flame Burners	E.R. Mitchell T.D. Brown B.C. Post	Patent application to be filed
High Strength/Low Cement Content Material	V.M. Malhotra	No patent action to be taken
Electrically Conductive Refractories for Investment Casting Moulds	E.I. Szabo	Under investigation
Rapid Determination of Lattice Constant Using Beam Tilt Circuitry of the Electron Microscope	E.E. Lauffer J.T. Jubb K.S. Milliken	Patent application to be filed
Thixotropic Suspensions for Investment Casting Moulds	E.I. Szabo	Under investigation
Continuously Casting in a Vertical Closed Head Metallic Mould System	R. Thomson J.R. Emmett	Under investigation

Title	*Inventors*	*Status of Invention*
High-Temperature Analytical Separation	B. Nebesar	No patent action to be taken
Elongated Cyclone Separator	J. Visman	Under investigation
Thermal Hydrocracking Process	B.I. Parsons et al.	Under investigation
Survey Instrument Tower Improvements	A.F. Lambert W.M. Smith C.J. Gustafson	Under investigation

GEOLOGICAL SURVEY OF CANADA

NAME	DEGREES	CLASS TITLE
Office of the Director General		
D.J. McLaren	M.A. (Cantab), Ph.D. (Mich.), F.R.S.C.	Director General
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Environmental Marine Geology Subdivision		
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Sediment Dynamics		
E.H. Owens	B.Sc. (UK), M.Sc. (McMaster), Ph.D. (U.S.C.)	Phys. Sci.
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Marine Geochemistry		
M.A. Rashid	B.Sc. (India), M.Sc. (Okla.), Ph.D. (Utah)	Res. Sci.
R.E. Cranston	B.Sc. (Alta.), M.Sc. (Dal.)	Phys. Sci.
G.V. Winters	B.Sc. (St. Mary's)	Phys. Sci.
G.H.E. Joice	B.Sc. (Guelph), M.Sc. (U of T)	Phys. Sci.
J.D. Leonard	B.Sc. (Memorial), M.Sc. (U of T)	Phys. Sci.
R.A. Fitzgerald	B.Sc. (St. Mary's)	Tech.
K.R. Robertson		Tech.
R.G. Fanjoy		Tech.
K.W.G. Leblanc		Tech.
Paleoecology		
C.T. Schafer	B.Sc., M.Sc., Ph.D. (New York)	Res. Sci.
G. Vilks	B.Sc. (McMaster), M.Sc., Ph.D. (Dal.)	Res. Sci.
F.J.E. Wagner	B.A., M.A., (U of T), M.Sc., Ph.D. (Stanford)	Res. Sci.
D.A. Walker	B.Sc. (Dalhousie)	Phys. Sci.
F. Cole	B.A. (Queen's)	Tech.
B. Deonarine		Tech.

NAME	DEGREES	CLASS TITLE
EASTERN PETROLEUM GEOLOGY SUBDIVISION		
L.P. Purcell, Head	B.Sc. (Alta.)	Res. Man.
P.A. Hacquebard	B.Sc., M.Sc. (Leiden, Holland), Ph.D. (Groningen), F.R.S.C.	Res. Sci.
P. Ascoli	B.A., M.Sc., Ph.D. (Milano, Italy)	Res. Sci.
F.M. Gradstein	B.Sc., M.Sc., Ph.D. (Utrecht)	Res. Sci.
I.M. Harris	B.A. (Acadia), B.Sc. (Alta.), M.Sc. (Dalhousie) Ph.D. (Edinburgh)	Res. Sci.
R.D. Howie	B.Sc. (St. Francis Xavier)	Phys. Sci.
L.F. Jansa	B.Sc., M.Sc., Ph.D. (Czechoslovakia)	Res. Sci.
G.L. Williams	B.Sc. (U College, London), Ph.D. (Sheffield)	Res. Sci.
A.C. Grant	B.A. (Acadia), B.Sc. (Dalhousie), M.Sc. (UNB) Ph.D. (Dal.)	Phys. Sci.
J.A. Wade	B.Sc. (Mt. Allison)	Res. Sci.
I.A. Hardy	B.Sc., (Dalhousie)	Phys. Sci.
W.A.M. Jenkins	B.Sc. (Durham), Ph.D. (Sheffield)	Res. Sci.
M.S. Barss		Tech.
D.A. Clattenburg		Tech.
W.G. MacMillan		Tech.
B.J. Crilley		Tech.
A.E. Jackson		Tech.
P.R. Girouard		Tech.
REGIONAL RECONNAISSANCE SUBDIVISION		
D.I. Ross, Head	B.Sc. (Victoria U.), M.Sc., Ph.D. (New Zealand)	Res. Man.
Surficial and Bedrock Geology		
L.H. King	B.Sc. (Acadia), Ph.D. (MIT)	Res. Sci.
B. MacLean	B.A. (Acadia)	Phys. Sci.
G. Fader	B.Sc. (St. Mary's)	Phys. Sci.
R.O. Miller		Tech.
Ocean Basins and Margins		
C.E. Keen	B.Sc., M.Sc. (Dalhousie), Ph.D. (Cantab.)	Res. Sci.
D.L. Barrett	B.Sc., M.Sc. (Dalhousie)	Phys. Sci.
H.R. Jackson	B.Sc. (Dalhousie)	Phys. Sci.
Geophysical Surveys		
R.T. Haworth	B.Sc. (Durham), Ph.D. (Cantab)	Res. Sci.
R.A. Follinsbee	B.Sc. (Alta.), M.Sc., Ph.D. (MIT)	Phys. Sci.
R.F. MacNab	B.A. (Laurentian), B.Sc., M.Sc. (Dal.)	Phys. Sci.
J.B. MacIntyre		Tech.
Labrador Sea Studies		
W.J.M. Van der Linden	B.Sc., M.Sc., D.Sc. (Utrecht)	Res. Sci.
S.P. Srivastava	B.Sc., M.Sc. (Kharagpur, India) Ph.D. (UBC)	Res. Sci.
R.H. Fillon	B.Sc. (Penss), M.Sc. (Vermont), Ph.D.	Res. Sci.
C.F. Stevens	B.Sc. (Dalhousie)	Tech.
PROGRAM SUPPORT SUBDIVISION		
K.S. Manchester, Head	M.Sc. (Dalhousie)	Phys. Sci.
Data Section		
K.G. Shih	M.A., Ph.D. (Oregon)	Phys. Sci.
A.G. Sherin	B.Sc. (McMaster)	Phys. Sci.
B.L. Johnston		Tech.
R. Sparkes		Tech.
D.E. Beaver		Tech.

NAME	DEGREES	CLASS TITLE
Instrument Operation and Maintenance		
T.J. Corbett		Tech.
T.F. Courtney		Tech.
W.A. Boyce		Tech.
V.F. Coady		Tech.
F.D. Ewing		Tech.
M.E. Gorveatt		Tech.
M.D. Hughes		Tech.
B.F. Inkpen		Tech.
Systems Development		
D.E. Heffler	B.Sc. (Dalhousie) M.Sc. (Sask.)	Eng.
C.A. Godden		Tech.
D.R. Locke		Tech.
Postdoctorate Fellows		
R.K.H. Falconer	B.Sc., B.Sc. (Hons.), Ph.D. (Victoria, N.Z.)	
Central Laboratories and Administrative Services Division		
J.A. Maxwell, Director	B.Sc., M.Sc. (McMaster), Ph.D. (Minn.), F.R.S.C.	Res. Man.
ANALYTICAL CHEMISTRY SECTION		
S. Abbey	B. Eng. (McGill)	Res. Sci.
CHEMICAL LABORATORIES		
S. Courville	B.Sc. (Sir George Williams)	Chem.
J.G. Sen Gupta	B.Sc., M.Sc. (Calcutta), Ph.D. (Jadavpur)	Chem.
J.L. Bouvier		Tech.
A.G. Bender		Tech.
R.J. Guillas		Tech.
F.J. Watson		Tech.
V. Grushman		Tech.
SPECTROGRAPHIC LABORATORIES		
W.H. Champ	B.A. (McMaster)	Chem.
K.A. Church		Tech.
L.J. Seymour		Tech.
D.A. Brown		Tech.
P.G. Bélanger		Tech.
C.F. Meeds		Tech.
MINERALOGY SECTION		
R.J. Traill	B.Sc., M.Sc., Ph.D. (Queen's)	Phys. Sci.
MINERALOGICAL STUDIES		
G.R. Lachance	B.Sc. (Carleton)	Res. Sci.
A.G. Plant	B.Sc., Ph.D. (Bristol)	Phys. Sci.
A.P. Stenson	B.Sc. (Man.)	Phys. Sci.
G.J. Pringle	B.Sc., M.Sc. (UNB)	Phys. Sci.
R.N. Delabio	B.Sc. (Carleton)	Phys. Sci.
M. Bonardi	Dr. (Parma)	Phys. Sci.
A.C. Roberts	B.Sc., M.Sc. (Queen's)	Phys. Sci.
J. Gravel		Tech.
MINERAL SEPARATION AND SAMPLE PREPARATION		
J.C. Paris		Tech.
B.D. Machin		Tech.
R.W. Christie		Tech.

NAME	*DEGREES*	*CLASS TITLE*
NATIONAL COLLECTIONS		
H.R. Steacy	B.Sc. (Queen's)	Phys. Sci.
H.G. Ansell	B.Sc. (Queen's)	Tech.
MINERAL AND ROCK SET PREPARATIONS		
J.M. Larose		Tech.
MECHANICAL SERVICES AND INSTRUMENT DEVELOPMENT SHOP		
G.A. Meilleur		Tech.
A.Y. Cregheur		Tech.
J.P. Fournier		Tech.
B.A. Walker		Tech.
ELECTRONIC SERVICES AND EQUIPMENT DEVELOPMENT		
F.W. Jones		Tech.
O.L. Coté		Tech.
Geological Information Processing Division		
P. Harker, Director	B.Sc. (London), B.A., M.A. (Cantab.), Ph.D. (Mich.)	Phys. Sci.
R.G. Blackadar, Asst. Director	B.A., M.A., Ph.D. (U of T)	Phys. Sci.
P.J. Griffin	B.Sc. (Ottawa)	Phys. Sci.
L.E. Vincent	B.Sc. (Laval)	Phys. Sci.
L.R. Mahoney		
PUBLICATIONS INFORMATION		
J.L. Touchette		
PHOTOGRAPHIC SERVICES		
J.W. Kempt		
LIBRARY, CENTRAL TECH. FILES, DATA PROCESSING		
D.M. Sutherland	B.A. (Sask.), B.L.S. (U of T)	Chief. Lib.
C.J. Christensen	B.A. (Carleton), B.L.S. (Ottawa)	Lib.
M.E. Williams	B.A. (Queen's), B.L.S. (McGill)	Lib.
L.S. Yee	B.A. (Hong Kong), B.L.S. (Ottawa)	Lib.
M. LaHam	B.Sc. (Ottawa)	Tech.
CARTOGRAPHY		
E.P. Nunn		A/Superintendent
DRAFTING UNIT A—COMPUTER-ASSISTED CARTOGRAPHY		
P. Debain (Acting)		
DRAFTING UNIT B		
L.W. Babcock		
DRAFTING UNIT C		
E.A. Dumbrell		
PHOTOMECHANICAL UNIT		
N.E. Buck		
INSTITUTE OF SEDIMENTARY AND PETROLEUM GEOLOGY		
D.F. Stott, Director	B.Sc., M.Sc. (Man.), M.A., Ph.D. (Princeton)	Res. Man.

NAME	DEGREES	CLASS TITLE
ENGINEERING SERVICES		
G.M. Peterkin		
REGIONAL GEOLOGY SUBDIVISION		
G.C. Taylor, Head	B.Sc. (St. Francis Xavier), M.A., Ph.D. (Princeton)	Res. Man.
Arctic Islands Section		
R. Thorsteinsson	B.A. (Sask.), M.A. (U of T), Ph.D. (Kansas), F.R.S.C.	Res. Sci.
R.L. Christie	B.A. (UBC), M.Sc., Ph.D. (U of T)	Res. Sci.
J.W. Kerr	B.Sc. (Alta.), Ph.D. (Columbia)	Res. Sci.
H.P. Trettin	Dr. Phil. (Hamburg), M.Sc., Ph.D. (UBC)	Res. Sci.
H.R. Balkwill	B.Sc. (Queen's), M.Sc. (S. Carolina), Ph.D. (Texas)	Res. Sci.
G.R. Davies	B.Sc., Ph.D. (W. Australia)	Res. Sci.
A.D. Miall	B.Sc. (London), Ph.D. (Ottawa)	Res. Sci.
D.G. Wilson	B.Sc. (UBC)	Phys. Sci.
G.E. Reinson	B.A. (Sask.) M.A. (Sask.) Ph.D. (A.N.U. Australia)	Res. Sci.
U. Mayr	Ph.D. (Ottawa)	Res. Sci.
Northern Mainland Section		
D.G. Cook	B.Sc., M.Sc., Ph.D. (Queen's)	Res. Sci.
D.K. Norris	B.A., M.A. (U of T), Ph.D. (CIT)	Res. Sci.
F.G. Young	B.Sc., M.Sc., Ph.D. (Queen's)	Res. Sci.
D.W. Myhr	B.A. (Sask.)	Phys. Sci.
J.D. Aitken	B.Sc. (UBC), Ph.D. (Calif.)	Res. Sci.
Southern Mainland Section		
R.W. Macqueen	B.A., M.A. (U of T), Ph.D. (Princeton)	Res. Sci.
N.C. Ollerenshaw	B.Sc. (Wales), M.A., Ph.D. (U of T)	Res. Sci.
D.W. Gibson	B.Sc. (Queen's), Ph.D. (U of T)	Res. Sci.
D.C. Pugh	B.Sc. (London), Ph.D. (Paris)	Res. Sci.
N.C. Meijer-Drees	B.Sc., M.Sc. (Utrecht, Netherlands)	Phys. Sci.
G.K. Williams	B.Sc. (Alta.)	Phys. Sci.
R.I. Thompson	B.Sc. (Queen's) Ph.D. (Queen's)	Res. Sci.
D.W. Morrow	B.Sc. (UBC) Ph.D. (Texas)	Res. Sci.
J.R. McLean	B.Sc. (Sask) Ph.D. (Sask.)	Res. Sci.
Marine Geology Co-ordinator		
C.J. Yorath	B.Sc. (UBC), M.Sc. (Alta.), Ph.D. (Queen's)	Res. Sci.
Curation and Services		
L.L. Price	B.Sc. (Man.)	Phys. Sci.
W.O. McEwan		Tech.
W.W. Banning		Tech.
D. Moncrieff		Tech.
A. Bjarnson		Tech.
M.A. McKenzie	B.A. (Cal.)	Tech.
R.J. Broadfield	B.Ed. (Cal.)	Tech.
PALEONTOLOGY SUBDIVISION		
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Macropaleontology Section		
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W.W. Nassichuk	B.Sc. (UBC), M.Sc., Ph.D. (Iowa)	Res. Sci.
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NAME	DEGREES	CLASS TITLE
Micropaleontology Section		
T.T. Uyeno	B.Sc. (UWO), M.Sc., Ph.D. (Iowa)	Res. Sci.
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T.P. Chamney	B.Sc. (Sask., Alta.), M.Sc. (Col. Sch. Min.)	Res. Sci.
W.S. Hopkins, Jr.	B.Sc. (Washington), M.Sc., Ph.D. (UBC)	Res. Sci.
A.R. Sweet	B.Sc. (Alta.), Ph.D. (Calgary)	Res. Sci.
Ottawa Paleontology Section		
E.T. Tozer	M.A. (Cantab.) Ph.D. (U of T), F.R.S.C.	Res. Sci.
J.A. Jeletzky	B.Sc., M.Sc., Ph.D. (Kiev School of Mines), F.R.S.C.	Res. Sci.
T.P. Poulton	B.Sc., M.Sc. (Calgary), Ph.D. (Queen's)	Res. Sci.
M.F. McLaughlin	B.Sc. (Queen's)	Phys. Sci.
Paleontological Laboratories		
R.D. Michie		Tech.
M. Tomica		Tech.
D.F. Haden		Tech.
H.M. Johnson		Tech.
L.L. Heisler		Tech.
S.A. Pickering		Tech.
ENERGY SUBDIVISION		
R.G. McCrossan, Head	B.A. (UBC), M.Sc., Ph.D. (Chicago)	Res. Man.
R.M. Proctor, Asst. Head	B.Sc., M.Sc. (Man.), Ph.D. (Kansas)	Res. Man.
Geochemistry Section		
T.G. Powell	B.Sc., Ph.D. (Newcastle-on-Tyne)	Phys. Sci.
A.E. Foscolos	B.Sc. (Thessaloniki), M.Sc., Ph.D. (Berkeley)	Res. Sci.
L.L. Snowdon	B.Sc. (Calgary)	Chem.
A. Heinreich		Tech.
R.R. Barefoot		Tech.
E.M. Northcott		Tech.
M.R. Khan	B.Sc. (Alta.)	Tech.
Geology of Petroleum Section		
K.J. Roy	B.A.Sc. (UBC), Ph.D. (Northwestern)	Res. Sci.
G. Drake		Tech.
N.E. Haimila	B.A.Sc. (UBC), Ph.D. (Michigan State)	Phys. Sci.
J.N. Van Elsburg	B.Sc., M.Sc., Ph.D. (Utrecht)	Phys. Sci.
Geology of Coal Section		
B.A. Latour	B.A. (Sask.)	Phys. Sci.
T.F. Birmingham	B.Sc. (St. Francis Xavier)	Phys. Sci.
A.R. Cameron	B.Sc. (St. Francis Xavier), M.Sc., Ph.D. (Penn State)	Res. Sci.
J.A. Irvine	B.Sc. (UBC)	Phys. Sci.
P.R. Gunther	M.Sc. (Calgary)	Phys. Sci.
B.R. Cormier		Tech.
C. Gange-Harris		Tech.
Geophysics Section		
R.G. Walker	B.Sc. (Utah)	Phys. Sci.
C.R. Bosgra		Tech.
GEOLOGICAL INFORMATION SUBDIVISION		
E.J.W. Irish	M.A. (UBC), Ph.D. (Ill.)	Phys. Sci.
C.E. Findlay	B.A. (Sir George Williams)	
Cartography		
L. MacLachlan		

NAME	DEGREES	CLASS TITLE
Library		
M. Jones		Lib.
J.C. Graff		Lib.
Photography		
D.G. Lawrence		
Regional and Economic Geology Division		
J.E. Reesor, Director	B.A.Sc. (UBC), Ph.D. (Princeton)	Res. Man.
I.M. Stevenson, Asst. Director	B.Sc., M.Sc., Ph.D. (McGill)	Res. Man.
W.N. Houston, Data Manager	B.Sc., M.Sc. (McMaster)	Phys. Sci.
CORDILLERA AND PACIFIC MARGIN SUBDIVISION		
H. Gabrielse, Head	B.A.Sc., M.Sc. (UBC), Ph.D. (Columbia) F.R.S.C.	Res. Man.
G. Eisbacher	Dr. Phil. (Innsbruck), M.A., Ph.D. (Princeton)	Res. Sci.
J.G. Souther	B.A.Sc. (UBC), Ph.D. (Princeton)	Res. Sci.
H.W. Tipper	B.Sc. (UWO), Ph.D. (State College of Washington)	Res. Sci.
B.E.B. Cameron	B.Sc., M.Sc. (Alta.), Ph.D. (Stanford)	Phys. Sci.
R.B. Campbell	B.A.Sc. (UBC), M.Sc., Ph.D. (CIT)	Res. Sci.
J.E. Muller	B.Sc. (Groningen), M.Sc. (Leiden), Ph.D. (Groningen)	Res. Sci.
J.A. Roddick	B.A.Sc. (UBC), M.Sc. (CIT), Ph.D. (Washington)	Res. Sci.
S.L. Blusson	B.A.Sc. (UBC), Ph.D. (Berkeley)	Res. Sci.
J.W.H. Monger	B.Sc. (Reading), M.Sc. (Kansas), Ph.D. (UBC)	Res. Sci.
D. Tempelman-Kluit	B.Sc., M.A.Sc. (UBC), Ph.D. (McGill)	Res. Sci.
S.F. Leaming	B.A. (Brandon), M.A. (U of T)	Phys. Sci.
D.L. Tiffin	B.A.Sc., Ph.D. (UBC)	Res. Sci.
T.A. Richards	B.Sc., Ph.D. (UBC)	Res. Sci.
R. Currie	B.Sc., M.Sc. (UBC)	Phys. Sci.
C.J. Dodds	B.Sc., (London), M.Sc. (Alberta)	Phys. Sci.
I.I. Frydecky	B.A.Sc. (UBC)	Tech.
PRECAMBRIAN SUBDIVISION		
W.F. Fahrig, Head	B.Sc. (Man.), M.Sc., Ph.D. (Chicago)	Res. Man.
R. Skinner	B.A.Sc. (UBC), M.Sc., Ph.D. (McGill)	Res. Sci.
M.J. Frarey	B.Sc. (UWO), M.Sc., Ph.D. (Mich.)	Res. Sci.
W.C. Morgan	B.Sc., M.Sc., Ph.D. (Aberdeen)	Res. Sci.
L.P. Tremblay	B.A., B.Sc., M.Sc. (Laval), Ph.D. (U of T)	Res. Sci.
K.E. Eade	B.Sc. (Queen's), M.Sc., Ph.D. (McGill)	Res. Sci.
R.H. Ridler	B.A.Sc., M.A.Sc. (U of T), Ph.D. (Wisconsin)	Res. Sci.
W.W. Heywood	B.A.Sc. (UBC), M.Sc., Ph.D. (Washington)	Res. Sci.
J.A. Fraser	B.A.Sc. (U of T), M.A. (UBC), Ph.D. (Minn.)	Res. Sci.
J.C. McGlynn	B.Sc., M.Sc. (Queen's), Ph.D. (Chicago)	Res. Sci.
G.D. Jackson	B.Sc., M.Sc., Ph.D. (McGill)	Res. Sci.
A. Davidson	B.Sc., M.Sc., Ph.D. (UBC)	Res. Soc.
F.W. Chandler	B.Sc. (London), Ph.D. (UWO)	Res. Sci.
P.F. Hoffman	B.Sc. (McMaster), M.A., Ph.D. (Johns Hopkins)	Res. Sci.
W.L. Davison	B.Sc., M.Sc. (Dalhousie)	Res. Sci.
W.R.A. Baragar	B.A.Sc. (UBC), M.Sc. (Queen's), Ph.D. (Columbia)	Res. Sci.
I.F. Ermanovics	B.Sc. (Carleton), M.Sc. (UWO), Ph.D. (Queen's)	Res. Sci.
F.C. Taylor	B.Sc. (UWO) M.Sc., Ph.D. (McGill)	Res. Sci.
J.B. Henderson	B.Sc. (Queen's), M.Sc. Ph.D. (Johns Hopkins)	Res. Sci.
T. Frisch	B.Sc. (Queen's), Ph.D. (California)	Res. Sci.
R.A. Frith	B.Sc. (Mt. Allison), Ph.D. (McGill)	Res. Sci.
M.B. Lambert	B.Sc., M.Sc. (UBC), Ph.D. (Carleton)	Res. Sci.
M.P. Schau	B.Sc., Ph.D. (UBC)	Res. Sci.
F.H.A. Campbell	B.Sc., M.Sc. (Dalhousie), Ph.D. (Man.)	Res. Sci.
J. Bourne	B.Sc. (McGill), M.Sc., Ph.D. (Queen's)	Res. Sci.
A.N. LeCheminant	B.Sc. (Carleton), Ph.D. (UBC)	Res. Sci.
J.H. Maley	B.Sc. (Queen's)	Phys. Sci

NAME	DEGREES	CLASS TITLE
Paleomagnetism Section		
E.J. Schwarz	B.Sc., M.Sc., Ph.D. (Utrecht)	Res. Sci.
J.H. Foster	B.Sc. (Sir George Williams), M.Sc. (McGill), Ph.D. (Columbia)	Res. Sci.
K.W. Christie	B.Sc. (Queen's)	Phys. Sci.
ECONOMIC GEOLOGY SUBDIVISION		
G.B. Leech, Head	B.A.Sc. (UBC), M.Sc. (Queen's), Ph.D. (Princeton) F.R.S.C.	Res. Man.
F.D. Anderson	B.Sc. (UNB), M.Sc., Ph.D. (McGill)	Res. Sci.
Mineral Resources Liaison Officer and NREP Co-ordinator		
D.C. Findlay	B.Sc., M.Sc. (McGill), Ph.D. (Queen's)	Res. Sci.
Mineral Commodity Reviewer		
P. Moyd	B.A. (Columbia), M.A. (Bryn Mawr)	Phys. Sci.
Special Projects		
H.W. Little	B.A.Sc., M.A.Sc. (UBC), Ph.D. (U of T)	Res. Sci.
A. Boyer	B.Sc. (Montreal)	Phys. Sci.
G.A. Gross	B.A., M.A. (Queen's), Ph.D. (Wisconsin)	Res. Sci.
V. Ruzicka	Abs., Dr. R. Nat. (Charles U., Czechoslovakia)	Res. Sci.
Mineral Deposits Geology Section		
D.F. Sangster	B.Sc. (Bishop's), B.Sc., M.Sc. (McGill), Ph.D. (UBC)	Res. Sci.
J.J. Carrière	B.Sc. (Laurentian)	Phys. Sci.
K.R. Dawson	B.Sc. (UNB), M.A., Ph.D. (U of T)	Res. Sci.
O.R. Eckstrand	B.Sc., M.Sc. (Sask.), Ph.D. (Harvard)	Res. Sci.
J.L. Jambor	B.A., M.Sc. (UBC), Ph.D. (Carleton)	Res. Sci.
R.V. Kirkham	B.Sc., M.Sc. (UBC), Ph.D. (Wisconsin)	Res. Sci.
C.R. McLeod	B.A. (Acadia)	Phys. Sci.
R. Mulligan	B.Sc. (Alta.), M.Sc., Ph.D. (McGill)	Res. Sci.
N. Prasad	M.Sc. (Lucknow) M.Sc. (McMaster)	Phys. Sci.
J.Y.H. Rimsaite	B.Sc. (Kaunas, Lithuania), M.A. (Queen's), Ph.D. (George August, Germany)	Res. Sci.
E.R. Rose	B.A. (UWO), M.A., Ph.D. (Queen's)	Res. Sci.
R.I. Thorpe	B.Sc. (Acadia), M.Sc. (Queen's), Ph.D. (Wisconsin)	Res. Sci.
R.D. Lancaster	B.Sc. (St. Francis Xavier)	Phys. Sci.
F.M. Vokes	B.Sc., M.Sc. (Leeds), Ph.D. (Oslo)	Res. Sci.
A.E. Soregaroli	B.Sc. (Iowa State), M.Sc. (U of Idaho), Ph.D. (UBC)	Res. Sci.
K.M. Dawson	B.Sc., Ph.D. (UBC)	Res. Sci.
Geomathematics Section		
F.P. Agterberg	B.A., M.Sc., Ph.D. (Utrecht)	Res. Sci.
C.F. Chung	B.Sc. (Sogang College, Korea), M.Sc. (Carleton)	Comp. Sci.
A.G. Fabbri	B.A., M.A. (Bologna)	Phys. Sci.
R.M. Laramée	B.Sc. (Montreal)	Phys. Sci.
Mineral Data Bank Unit		
D.R.E. Whitmore	B.A., M.A. (Queen's), Ph.D. (Princeton)	Phys. Sci.
D.G. Rose	B.Sc. (UNB)	Phys. Sci.
CORRELATION AND STANDARDS SUBDIVISION		
W.H. Poole	B.A.Sc. (UBC), Ph.D. (Princeton)	Res. Man.
D.G. Benson	B.Sc., M.Sc. (UNB), (MIT), Ph.D. (McGill)	Res. Sci.
Lapidary—Paleontological Service Unit		
B.J. Botte		Tech.

NAME	DEGREES	CLASS TITLE
Petrology Section		
E. Froese	B.Sc., M.Sc. (Sask), Ph.D. (Queen's)	Res. Sci.
K.L. Currie	B.Sc. (Queen's), M.Sc., Ph.D. (Chicago)	Res. Sci.
T.M. Gordon	B.A.Sc. (UBC), M.A., Ph.D. (Princeton)	Res. Sci.
R.F. Emslie	B.Sc., M.Sc. (Man.), Ph.D. (Northwestern)	Res. Sci.
M.N.H. Turay	Licence Sc. (U. Cath. Louvain, Belgium)	Phys. Sci.
A.V. Okulitch	B.A.Sc., Ph.D. (UBC)	Res. Sci.
Geochronology Section		
R.K. Wanless	B.Sc., M.Sc., Ph.D. (McMaster)	Res. Sci.
R.D. Stevens	B.Sc., M.Sc. (Sydney)	Phys. Sci.
W.D. Loveridge	B.Sc., M.Sc. (Man.)	Phys. Sci.
R.W. Sullivan	B.Sc. (Carleton)	Chem.
Eastern Paleontology Section		
W.T. Dean	B.Sc., D.Sc. (Leeds), Ph.D. (Bristol)	Res. Sci.
D.C. McGregor	B.A., M.Sc., Ph.D. (McMaster)	Res. Sci.
M.J. Copeland	B.A., M.A. (U of T), Ph.D. (Mich.)	Res. Sci.
W.H. Fritz	B.Sc., M.Sc., Ph.D. (Washington)	Res. Sci.
Appalachian Section		
H.H. Bostock	B.Sc. (Queen's), M.A.Sc. (UBC), Ph.D. (Wisconsin)	Res. Sci.
L.M. Cumming	B.Sc.,M.Sc. (UNB), Ph.D. (Wisconsin)	Res. Sci.
B.V. Sanford	B.Sc. (Acadia)	Res. Sci.
Resource Geophysics and Geochemistry Division		
A.G. Darnley, Director	B.A., M.A., Ph.D. (Cantab.)	Res. Man.
SPECIAL PROJECTS		
R.W. Boyle	B.Sc., M.Sc., Ph.D. (U of T), F.R.S.C.	Res. Sci.
Q. Bristow	B.Sc. (London)	Phys. Sci.
B.E. Manistre	B.A., M.A. (Cantab.)	Phys. Sci.
ELECTRICAL METHODS		
L.S. Collett	B.Sc. (McMaster), M.A. (U of T)	Res. Sci.
A.P. Annan	B.A.Sc., M.Sc. (U of T) Ph.D. (Memorial)	Res. Sci.
J.L. Davis	B.Sc. (Loyola), M.Sc. (Cantab.)	Phys. Sci.
A.V. Dyck	B.Sc. (Waterloo), M.Sc. (U of T)	Phys. Sci.
T.J. Katsube	B.Eng., M.Eng., Dr.Eng. (Tokyo)	Res. Sci.
W.J. Scott	B.A., M.A. (U of T), Ph.D. (McGill)	Res. Sci.
A.K. Sinha	B.Sc. (Ranchi College, India) M.Tech., Ph.D. (India Inst. of Tech.)	Res. Sci.
D.C. Butterfield		Tech.
J. Frechette		Tech.
C. Gauvreau		Tech.
R.J. Sloka		Tech.
SEISMIC METHODS		
R.A. Burns	Diploma (Ryerson)	Tech.
R.M. Gagne		Tech.
R. Good		Tech.
J.A.M. Hunter	B.Sc., M.Sc., Ph.D. (UWO)	Res. Sci.
H.A. MacAulay		Tech.
A. Overton	B.Sc. (UBC)	Res. Sci.

NAME	DEGREES	CLASS TITLE
MAGNETIC METHODS		
P.J. Hood	B.Sc. (London), M.A.,Ph.D. (U of T)	Res. Sci.
M.E. Bower	B.Sc. (Alberta)	Res. Sci.
L.J. Kornik	B.Sc., M.Sc. (Manitoba)	Phys. Sci.
P.H. McGrath	B.Sc., M.Sc. (UWO)	Phys. Sci.
K.H. Owens		Tech.
S. Washkurak		Tech.
RADIATION METHODS		
K.A. Richardson	B.A. (U of T), M.A., Ph.D. (Rice Inst. Houston)	Res. Sci.
G.W. Cameron	B.Sc. (Carleton)	Phys. Sci.
J.M. Carson	B.Sc. (Queens), M.Sc. (Western)	Phys. Sci.
B.W. Charbonneau	B.Sc. (Carleton)	Phys. Sci.
B.E. Elliott	B. Math (Waterloo)	Comp. Sci.
R.L. Grasty	B.Sc., Ph.D. (Imperial College, London)	Res. Sci.
P.B. Holman	B.Sc. (Carleton)	Phys. Sci.
P.G. Killeen	B.Sc. (Montreal), M.Sc. Ph.D. (Western)	Res. Sci.
V.R. Slaney	B.Sc. (U. College of Wales) M.Sc. (Delft)	Res. Sci.
Y.B. Blanchard		Tech.
DIGITAL COMPILATION		
M.T. Holroyd	B.Sc. (Manchester), M.Sc. (Durham)	Comp. Sci.
D.D. Abbinett		Tech.
I. Butt		Comp. Sci.
S.D. Dods		Comp. Sci.
R.J. Langlois		Tech.
F.W. Zieman		Tech.
EXPERIMENTAL AIRBORNE OPERATIONS		
P. Sawatzky	B.Sc. (U of T)	Res. Sci.
A. Dicaire		Tech.
T.R. Flint		Tech.
H.W.C. Knapp		Tech.
D.G. Olson		Tech.
CONTRACT SURVEYS		
A. Larochelle	B.A., B.Sc. (Laval), M.Sc. (St. Louis) Ph.D. (McGill)	Res. Sci.
K. Anderson		Tech.
M.B. Chretien		Tech.
E.J. Derouin		Tech.
E.L. Haley		Tech.
W.A. Knappers		Tech.
L. Lawley		Tech.
E.E. Ready		Tech.
D. Reveler		Tech.
GEOCHEMISTRY		
E.M. Cameron	B.Sc., Ph.D. (Manchester)	Res. Sci.
R.J. Allan	B.Sc. (Aberdeen), M.Sc. (Wisconsin), Ph.D. (Dartmouth)	Res. Sci.
G. Aslin	B.Sc. (Exeter), M.Sc. (Imperial College)	Chem.
C.C. Durham		Tech.
W. Dyck	B.A., M.Sc. (Sask.)	Res. Sci.
R. Garrett	B.Sc., Ph.D. (London, UK)	Res. Sci.
G. Gauthier		Tech.
H.D. Hobbs	B.Sc. (Carleton)	Comp. Sci.
E.W.H. Hornbrook	B.Sc. (Queen's)	Phys. Sci.
R. Horton	B.Sc. (Carleton)	Tech.
I.R. Jonasson	B.Sc. (Melbourne), Ph.D. (Adelaide)	Res. Sci.

NAME	DEGREES	CLASS TITLE
P.J. Lavergne		Tech.
N.G. Lund	B.Sc. (Math & Geol) Carleton	Phys. Sci.
J.J. Lynch	B.Sc. (Ottawa)	Chem.
A. MacLaurin		Tech.
W.H. Nelson		Tech.
J. Parker		Tech.
J.C. Pelchat		Tech.
E. Ruzgaitis		Tech.

Terrain Sciences Division

J.S. Scott, Director	B.Sc. (McMaster), Ph.D. (Ill.)	Res. Man.
B.G. Craig, Asst. Director	B.Sc. (UWO), M.Sc., Ph.D. (Mich.)	Res. Man.

SCIENTIFIC AND TECHNICAL SERVICES

H. Dumych	B.A. (Sask.)	Phys. Sci.
G. Mizerovsky	B.A., M.A. (Ottawa)	Phys. Sci.
D.A. Proudfoot	B.Sc. (UNB)	Phys. Sci.
K. Shimizu	B.A. (UBC)	Stat.

SPECIAL PROJECTS

J.E. Armstrong	M.Sc. (UBC), Ph.D. (U of T), F.R.S.C.	Res. Sci.
O.L. Hughes	B.Sc. (UBC), Ph.D. (Kansas)	Res. Sci.
E.B. Owen	B.A. (UWO)	Phys. Sci.
V.K. Prest	B.Sc., M.Sc. (Man.), Ph.D. (U of T), F.R.S.C.	Res. Sci.
A.M. Stalker	B.A., M.Sc., Ph.D. (McGill)	Res. Sci.

GEOTECHNICAL SUBDIVISION

B.C. McDonald	B.Sc. (Man.), M.Sc. (McGill), Ph.D. (Yale)	Res. Sci.

SEDIMENTOLOGY AND MINERAL TRACING SECTION

W.W. Shilts	B.A. (Depaw), M.Sc. (Miami), Ph.D. (Syracuse)	Res. Sci.
T.J. Day	B.A., M.A. (UBC), Ph.D. (Canterbury)	Res. Sci.

SEDIMENTOLOGY LABORATORY

R.G. Kelly		Tech.
D.E. Field		Tech.

MINERAL TRACING LABORATORY

C.M. McFarlane		Tech.

FLUME LABORATORY

D.M. Morel		Tech.

ENGINEERING AND ENVIRONMENTAL GEOLOGY SECTION

P.A. Carr	B.A. (U of T), Ph.D. (Ill.)	Res. Sci.
N.R. Gadd	B.Sc. (UWO), M.Sc. (Laval), Ph.D. (Ill.)	Res. Sci.
J.A. Heginbottom	B.Sc. (London), M.Sc. (McGill)	Phys. Sci.
P.J. Kurfurst	B.Sc., M.Sc., Ph.D. (Prague)	Res. Sci.

GEOPHYSICS LABORATORY

J.G. Bisson		Tech.

URBAN PROJECTS UNIT

J.E. Harrison	B.A. (Harpur College), M.A. (State U of N.Y.), Ph.D. (Syracuse)	Res. Sci.
J.R. Bélanger	B.A., M.A. (Ottawa)	Phys. Sci.
F.M. Morin	B.Sc. (Loyola), M.Sc. (McGill)	Phys. Sci.

NAME	DEGREES	CLASS TITLE
QUATERNARY SUBDIVISION		
Regional Projects Section		
R.J. Fulton	B.Sc. (Man.), Ph.D. (Northwestern)	Res. Sci.
D.M. Barnett	B.Sc. (Univ. College, London), M.Sc. (McGill)	Phys. Sci.
J.J. Clague	A.B. (Occidental College), M.A. (U of Calif.), Ph.D. (UBC)	Res. Sci.
D.R. Grant	B.Sc., M.Sc. (Dalhousie), Ph.D. (Cornell)	Res. Sci.
D.A. Hodgson	B.Sc. (Sheffield), M.Sc. (Penn. State)	Phys. Sci.
R.W. Klassen	B.Sc., M.Sc. (Alta.), Ph.D. (Sask.)	Res. Sci.
J.A. Netterville	B.Sc. (Alta.), M.Sc. (Calg.)	Phys. Sci.
S.H. Richard	B.A., B.Sc. (Laval), M.A. (Sorbonne)	Phys. Sci.
R.G. Skinner	B.Sc. (Queen's), M.Sc., Ph.D. (Washington)	Phys. Sci.
J.J. Veillette	B.A. (Ottawa), M.A. (Waterloo)	Phys. Sci.
J.S. Vincent	B.A., M.A. (Ottawa)	Phys. Sci.
Paleoecology and Geochronology Section		
W. Blake, Jr.	A.B. (Dartmouth), M.Sc. (McGill), Ph.D. (Ohio State), Fil. Lic. (Stockholm)	Res. Sci.
T.W. Anderson	B.Sc. (Dalhousie), M.Sc., Ph.D. (Waterloo)	Res. Sci.
S. Federovich	B.Sc., M.Sc. (Man.), Ph.D. (Trent)	Res. Sci.
J.V. Matthews, Jr.	B.Sc., M.Sc. (Alaska), Ph.D. (Alta.)	Res. Sci.
Paleoecology Laboratory		
R.J. Mott	B.Sc. (Carleton)	Phys. Sci.
L. Wilson		Tech.
Radiocarbon Laboratory		
J.A. Lowdon	B.Sc. (Carleton)	Phys. Sci.
I.M. Robertson		Tech.
S.M. Chartrand		Tech.
Marine and Coastal Section		
C.F.M. Lewis	B.A., M.A., Ph.D. (U of T)	Res. Sci.
B.D. Bornhold	B.Sc. (Waterloo), A.M. (Duke) Ph.D. (Mass. Inst. Tech.)	Res. Sci.
C.P. Lewis	B.A. (Waterloo), M.A. (UBC)	Phys. Sci.
J.L. Luternauer	B.A. (Colby), M.A. (Duke), Ph.D. (UBC)	Res. Sci.
P. McLaren	B.Sc., M.Sc. (Calg.)	Phys. Sci.
R.B. Taylor	B.A., M.Sc. (McMaster)	Phys. Sci.

CANMET STAFF
(FORMERLY MINES BRANCH)

NAME	DEGREES	CLASS TITLE
Director General's Office		
D.F. Coates	B.Eng., M.Eng., Ph.D. (McGill), B.A., M.A. (Oxford)	Director General
V.A. Haw	B.S., M.Sc. (Queen's)	Deputy Director General
M.C. Campbell	B.Sc., (St. Francis Xavier), B.E. (N.S. Tech.), M.Sc. (London), P. Eng.	Phys. Sci.
V.L. Caron	B.A., M.A.Sc.	Phys. Sci.
PROGRAM MANAGEMENT		
D.S. Montgomery	B.Sc., Ph.D. (McGill)	Director, ERP
W.A. Gow	B.A.Sc. (Toronto), P. Eng.	Director, MRP
INFORMATION SERVICES		
A.S. Romaniuk	B.Sc. (Queen's)	Phys. Sci.
R.J.R. Welwood	B.Sc. (Queen's)	Phys. Sci.
I. Slowikowski	M.A., Ph.D. (Beirut)	Foreign Language Spec.
EDITORIAL AND PUBLICATIONS		
C. Mamen	B.Eng. (McGill), P. Eng.	Phys. Sci.
LIBRARY		
G. Peckham	B.A., B.L.S. (McGill)	Head Librarian
A. Hobson	B.A., B.L.S. (Toronto)	Librarian
K. Nagy	B.A. and Cert. (McGill)	Librarian
S.K. Ho	B.A. and Cert. (Ottawa)	Librarian
Energy Research Laboratories		
F.L. Booth	B.Sc. (Queens), P. Eng.	Chief of ERL
B.I. Parsons	B.Sc. Ph.D., D.Phil. (Oxford)	Asst. Chief of ERL
SPECIAL STUDIES		
B.J.P. Whalley	B.Sc., Ph.D. (McGill)	Res. Sci.
ENGINEERING, DESIGN AND CONSTRUCTION GROUP		
R.E. Carson	B.Sc. (Queen's), P.Eng.	Engineer
CANADIAN FOSSIL FUELS RESEARCH LABORATORY		
W.H. Merrill	B.A.Sc. (Toronto), P.Eng.	Manager
Process Engineering		
J.M. Denis	B.A.Sc. (Ottawa), P.Eng.	Res. Sci.
W.A.O. Herrmann	B.Sc., M.Sc., Dr.Eng. (Berlin)	Res. Sci.
R.B. Logie	B.Sc. (Chem. Eng.) (UNB)	Engineer
L.P. Mysak	B.A.Sc. (Ottawa), P.Eng.	Engineer
Catalysis Research		
B.I. Parsons	B.Sc., Ph.D., D.Phil. (Oxford)	Res. Sci.
M. Ternan	B.A.Sc., Ph.D. (McGill)	Res. Sci.
Research on Bituminous Substances		
D.M. Clugston	B.Sc., Ph.D. (McMaster)	Res. Sci.
H. Sawatzky	B.S.A., M.S.A., Ph.D. (Toronto)	Res. Sci.

NAME	DEGREES	CLASS TITLE
Petroleum and Gas Laboratory		
R.G. Draper	B.Sc. (Chem. Eng.) (Sask.)	Engineer
A. Yates	B.Sc. (Manitoba)	Chemist
Coal and Peat Resource Evaluation		
T.E. Tibbetts	B.Sc., B.Ed. (Dalhousie)	Res. Sci.
Evaluation of Fine Structure of Coal, Coke and Carbon		
B.N. Nandi	B.Sc., M.Sc., Dr.Ing. (Karlsruhe Univ.) (Karlsruhe, W. Germany)	Res. Sci.
Solid Fuel Analysis and Standardization		
W.J. Montgomery	B.S.A. (Toronto)	Phys. Sci.
J.Z. Skulski	Chem. Eng. (Wroclaw, Poland)	Chemist
Petrographic Research Resource Evaluation		
J.R. Donaldson	B.A. (Acadia)	Phys. Sci.
Western Research Laboratory		
J. Visman	M.I., Dr. T.W. (Delft), P.Eng.	Manager
J. Picard	B.Sc. (Alberta)	Phys. Sci.
CANADIAN EXPLOSIVE ATMOSPHERES LABORATORY		
G.K. Brown	B.Sc. (Manitoba)	Manager
S. Silver	B.Sc. (Manitoba)	Res. Sci.
E.D. Dainty	B.A.Sc., M.A.Sc. (Toronto), P.Eng.	Res. Sci.
P. Mogan	B.A.Sc. (Toronto), P.Eng.	Res. Sci.
J.A. Bossert	B.Sc. (Queen's)	Res. Sci.
D.D. Stewart	B.Sc., M.Sc. (Queen's), P.Eng.	Res. Sci.
CANADIAN COMBUSTION RESEARCH LABORATORY		
E.R. Mitchell	B.Sc. (Queen's), P.Eng.	Manager
G.K. Lee	B.Sc., M.Sc. (Queen's), P.Eng.,	Res. Sci.
F.D. Friedrich	B.Sc. (Saskatchewan), M.Sc. (Queen's) P.Eng.	Res. Sci.
R.G. Fouhse	B.Sc. (Saskatchewan), P.Eng.	Engineer
H. Whaley	B.Sc. Ph.D. (Sheffield), P.Eng.	Res. Sci.
T.D. Brown	B.Sc. (Durham), Ph.D. (Sheffield)	Res. Sci.
A.C. Hayden	B.Eng., M.Eng. (Carleton), P.Eng.	Res. Sci.
CANADIAN METALLURGICAL FUEL RESEARCH LABORATORY		
J.C. Botham	B.Sc. (Queen's), P.Eng.	Manager
D.A. Reeve	B.Sc., Ph.D. (Birmingham)	Res. Sci.
T.A. Lloyd	B.Sc. (Carleton)	Phys. Sci.
J.G. Jorgensen	B.Sc. (Carleton)	Phys. Sci.
S.M. Ahmed	B.Sc., M.Sc. (India)	Chemist
W. Gardiner	Assoc., Royal Inst. of Chemistry	Eng. Support
W.R. Leeder	B.Sc., Ph.D. (UBC)	Res. Sci.
J.T. Price	B.Sc. (Alberta), M.Sc. (Western) Ph.D. (UBC)	Res. Sci.
J.F. Gransden	B.Sc., Ph.D. (Western)	Res. Sci.
PYROMETALLURGY RESEARCH LABORATORY		
G.E. Viens	B.A. (McMaster)	Manager
G.N. Banks	B.A. (UBC)	Res. Sci.
R.A. Campbell	B.Sc., M.Sc. (Queen's)	Res. Sci.
G.V. Sirianni	B.Sc. (United College, Winnipeg)	Res. Sci.
G.W. Montgomery	B.Eng. (McGill), P.Eng.	Res. Sci.

NAME	DEGREES	CLASS TITLE
MINING RESEARCH LABORATORIES		
T.S. Cochrane	B.A.Sc., M.Sc. (Washington), P.Eng.	Chief of MRL
W.M. Gray	B.A., M.A., Ph.D. (Toronto)	Res. Sci., Senior Scientist
Rock Mechanics Laboratory		
G.E. Larocque	B.Sc. (Carleton)	Res. Sci.
F.L. Casey	B.Sc. (Queen's)	Engineer
A. Dubnie	B.A.Sc., M.A. (Carleton)	Engineer
A. Fustos	B.S.F.—For.Eng, B.Sc. (U.B.C.), P.Eng.	Engineer
L.B. Geller	Dipl.Eng., B.Sc., Eng., M.A.Sc. (Toronto), P.Eng.	Res. Sci.
M. Gyenge	Dipl.Eng. (Budapest), P.Eng.	Res. Sci.
B. Hoare	B.Eng., M.Eng., D.Eng. (Waterloo)	Res. Sci.
A.L. Job	A.C.S.M. (England)	Engineer
R. Sage	B.Sc. (Bristol), M.A.Sc. (Ottawa), P.Eng.	Engineer
N.A. Toews	B.Sc. (Queen's), M.Sc. (Carleton)	Res. Sci.
Y.S. Yu	B.Sc., M.Eng. (McGill)	Res. Sci.
Rock Fracture Group, Quebec City		
M.D. Everell	B.A.Sc., M.A.Sc., D.A.Sc. (Ecole Polytechnique)	Res. Sci.
G.T. Turcotte	M.Sc. (Laval)	Engineer
Elliot Lake Laboratory		
G. Zahary	B.Sc., M.Eng. (McGill), P.Eng.	Res. Sci.
V. de Korompay	Dipl.Min.Eng. (Budapest), P.Eng.	Phys. Sci.
D.G.F. Hedley	B.Sc., Ph.D. (Newcastle), P.Eng.	Res. Sci.
G. Herget	Dipl.Geol., Ph.D. (Munich), P.Eng.	Res. Sci.
G. Knight	B.Sc. (Birbeck, London)	Res. Sci.
P.C. Miles	B.A.Sc. (Windsor)	Engineer
D.R. Murray	B.A.Sc. (McDonald College)	Phys. Sci.
M. Savich	M.Sc. (McGill)	Res. Sci.
R.O. Tervo	B.A.Sc. (Toronto), P.Eng.	Res. Sci.
R.A. Washington	B.Sc., M.Sc., Ph.D. (McGill)	Res. Sci.
Canadian Explosives Research Laboratory		
J.A. Darling	B.A. (Hon.) (Queen's)	Res. Sci.
E. Contestabile	B.Sc. (Carleton)	Phys. Sci.
K.K. Feng	B.Sc., M.Sc., Ph.D. (Iowa)	Res. Sci.
R.R. Vandebeek	B.Sc., M.Sc. (Carleton)	Chemist
C.A. Vary	B.Sc. (Ottawa)	Tech. Offr.
Western Office, Calgary, Alberta		
K. Barron	B.Sc., M.Sc. (London), Ph.D. (London)	Res. Sci.
H.U. Bielenstein	B.Sc., M.Sc., Ph.D. (Queen's)	Res. Sci.
R.N. Chakravorty	B.Ch.E. (Calcutta), Ph.D. (Nottingham)	Res. Sci.
M.Y. Fisekci	Dipl.Eng., M.E., Ph.D. (Sheffield)	Res. Sci.
F. Grant	B.Sc. (Alberta)	Res. Sci.
J. Tomica	B.Sc. (Ostrava), M.Sc. (Queen's), P.Eng.	Engineer
Mineral Sciences Laboratories		
R.L. Cunningham	B.Sc., M.Sc., Ph.D. (McGill)	Chief of MSL
J.C. Ingles	B.A. (Western Ontario)	A/Assistant Chief MSL
CHEMICAL LABORATORY		
R.C. McAdam	B.Sc. (Manitoba)	Manager
Operations		
C.H. McMaster	B.Sc., M.Sc. (Queen's)	Chemist

NAME	DEGREES	CLASS TITLE
Metals and Alloys		
R.G. Sabourin	B.Sc., (Ottawa)	Chemist
J.F. Fydell	B.A.Sc. (Toronto)	Chemist
E.H. MacEachern	B.Sc. (Mt. Allison)	Chemist
A.L. Letendre	B.Sc. (Sherbrooke)	Chemist
Ores and Fire Assay		
J.C. Hole	B.A. (Toronto)	Chemist
R.R. Craig	B.Sc. (Glasgow)	Chemist
Solution Chemistry		
R.J. Guest	B.Sc. (Acadia)	Res. Sci.
D.J. Barkley	B.Sc. (Carleton)	Chemist
J.E. Atkinson	B.A. (Queen's)	Chemist
A.D. King	B.Sc. (UBC)	Chemist
G.A. Hunt	B.Sc. (Carleton)	Chemist
Spectrochemistry		
G.L. Mason	A.Metallurgy (Sheffield)	Chemist
J.B. Zimmerman	B.A. (McMaster)	Res. Sci.
J.L. Dalton	B.S., M.Eng. (Carleton)	Chemist
T.R. Churchill	B.Sc. (Western Ontario)	Phys. Sci.
V.C. Armstrong	B.Sc., Ph.D. (Exeter)	Chemist
Special Analyses		
A. Hitchen	B.Sc. (McMaster)	Chemist
B. Nebesar	M.Sc. (McGill)	Res. Sci.
V. Rolko	B.Sc. (Manitoba)	Chemist
C.W. Smith	M.Sc., Ph.D. (Queen's)	Chemist
Special Projects (Research, standard methods and reference materials)		
G.H. Faye	B.A. (Saskatchewan)	Res. Sci.
D.J. Charette	B.Sc. (Ottawa)	Chemist
E.M. Donaldson	B.Sc. (Manitoba)	Res. Sci.
H.F. Steger	B.Sc., Ph.D. (McMaster)	Res. Sci.
E. Mark	B.A. (Toronto)	Chemist
ORE PROCESSING LABORATORY		
J.C. Ingles	B.A. (Western Ontario)	A/Manager
Hydrometallurgy		
G.M. Ritcey	B.Sc. (Dalhousie)	Res. Sci.
B.H. Lucas	B.Sc. (Queen's) P.Eng.	Res. Sci.
A.J. Gilmore	B.Sc. (Manitoba)	Res. Sci.
V.M. McNamara	B.Sc., B.Eng., M.A.Sc., (Toronto), P.Eng.	Res. Sci.
H.W. Parsons	B.Sc. (Alberta)	Res. Sci.
L. Shaheen		Sr. Tech.
Non-metallic Ore Processing		
R.A. Wyman	B.Sc. (Manitoba)	Res. Sci.
F.H. Hartman	B.A.Sc. (Toronto), P.Eng.	Res. Sci.
G.A. Kent	B.Sc., M.Sc. (McGill)	Chemist

NAME	DEGREES	CLASS TITLE
Non-ferrous Ore Processing		
R.W. Bruce	B.Sc. (Queen's), P.Eng.	Res. Sci.
G.I. Mathieu	B.A., B.Sc. (Laval)	Res. Sci.
D. Raicevic	B.Sc. (Belgrade)	Res. Sci.
A. Stemerowicz	B.Sc. (Queen's), P.Eng.	Res. Sci.
T.F. Berry		Sr. Tech.
A.J. Boisonnault		Sr. Tech.
Uranium Ore Treatment		
H.H. McCreedy	B.Sc., M.Sc. (Alberta), P.Eng.	Res. Sci.
J.M. Skeaff	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Res. Sci.
W.D. Moffett	B.A., Ph.D. (Ottawa)	Res. Sci.
Ferrous Ore Processing		
G.O. Hayslip	B.Sc. (Queen's), P.Eng.	Res. Sci.
R.P. Bailey	B.A.Sc. (Toronto)	Res. Sci.
G.W. Riley	B.Sc. (Camborne School of Mines), P.Eng.	Res. Sci.
I.B. Klymowsky	M.Eng. (McGill), P.Eng.	Engineer
Technical and Economic Evaluation		
W.J.S. Craigen	B.Sc. (Queen's)	Phys. Sci.
V.F. Harrison	B.Sc. (Queen's)	Res. Sci.
Industrial Liaison and Information		
E.G. Joe	B.Sc. (Queen's)	Phys. Sci.
Environmental		
A. Jongejan	Geol. Can. Drs. (Amsterdam), Ph.D.	Res. Sci.
Metallic Minerals Research Laboratory		
L.L. Sirois	B.A., E.Eng., M.Eng. (McGill), P.Eng.	Res. Sci.
H. Noblitt	H.Sc. (Alberta)	Res. Sci.
PHYSICAL SCIENCES LABORATORY		
A.H. Gillieson	B.Sc., Ph.D. (Edinburgh)	A/Manager
Mineralogy		
D.C. Harris	B.Sc., M.A., Ph.D. (Toronto)	Res. Sci.
L.J. Cabri	B.Sc., M.Sc., Ph.D. (McGill)	Res. Sci.
M'r. Hughson	B.Sc. (Western Ontario)	Phys. Sci.
A.E. Johnson	B.Sc., M.Sc., Ph.D. (Western Ontario)	Res. Sci.
S. Kaiman	B.S., M.A. (Toronto)	Phys. Sci.
W. Petruk	B.Eng., M.Sc., Ph.D. (McGill)	Res. Sci.
Solid State Physics		
M.G. Townsend	B.Sc., Ph.D. (Southampton)	Res. Sci.
J.L. Horwood	B.A. (Toronto)	Res. Sci.
J.R. Gosselin	B.Sc. (Ecole Polytechnique, Montreal)	Res. Sci.
Crystal Structure		
S.R. Hall	B.Sc., Ph.D. (W. Australia)	Res. Sci.
J.F. Rowland	B.Sc., M.Sc. (Queen's)	Res. Sci.
J.T. Szymanski	B.Sc., Ph.D. (London)	Res. Sci.

NAME	DEGREES	CLASS TITLE
Physical Chemistry		
A.H. Webster	B.A., M.A., Ph.D. (UBC)	Res. Sci.
S.M. Ahmed	B.Sc., M.Sc., Ph.D. (Saskatchewan)	Res. Sci.
D.M. Farrell	B.Sc. (UBC)	Chemist
F.J. Kelly	B.Sc. (N.S. Tech.), P.Eng.	Res. Sci.
R.F. Pilgrim	B.Sc. (Queen's)	Res. Sci.
L.G. Ripley	B.Sc., M.A. (Queen's)	Res. Sci.
R. Sutarno	B.E., M.E., Ph.D., (N.S. Tech.)	Res. Sci.
W.S. Bowman	B.Sc. (Carleton)	Sr. Tech.
Metallurgical Chemistry		
A.W. Ashbrook	B.Sc., Ph.D. (Carleton)	Chemist
J.E. Dutrizac	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Res. Sci.
D.J. Francis	B.Sc., Ph.D. (Alberta)	Res. Sci.
R.J.C. MacDonald	B.Sc. (St. Francis Xavier)	Phys. Sci.
D.J. MacKinnon	B.Sc., M.A., Ph.D. (Ottawa)	Res. Sci.
E. Rolia	B.A. (UBC)	Chemist
V.S. Sastri	B.Sc., M.A., Ph.D. (State U. of New York)	Chemist
Corrosion		
G.R. Hoey	B.Sc., M.Sc., Ph.D. (Toronto)	Res. Sci.
A.W. Lui	B.Sc., M.A.Sc. (Windsor)	Res. Sci.
J.C. Saiddington	Chem. Eng., M.A.Sc. (Toronto)	Phys. Sci.
W. Dingley		Sr. Tech.
INDUSTRIAL MINERALS LABORATORY		
J.G. Brady	B.E., M.Sc. (Saskatchewan)	Manager
Ceramics		
K.E. Bell	B.E. (Saskatchewan), P.Eng.	Res. Sci.
V.V. Mirkovich	Ph.D. (Toronto)	Res. Sci.
T.B. Weston	B.A. (Toronto)	Res. Sci.
T.A. Wheat	Ph.D. (Leeds)	Res. Sci.
Mineralogy		
R.M. Buchanan	B.A., M.A. (Toronto)	Phys. Sci.
R.S. Dean	B.Sc., M.Sc., Ph.D. (McGill), P.Eng.	Res. Sci.
J.A. Soles	B.A.Sc., M.A.Sc., Ph.D. (McGill), P.Eng.	Res. Sci.
Non-metallic and Waste Minerals		
R.K. Collings	Eng. Dipl., B.E. (N.S. Tech.), P.Eng.	Res. Sci.
D.G. Feasby	M.Sc. (Queen's)	Phys. Sci.
A.A. Winer	B.A.Sc. (Toronto), P.Eng.	Res. Sci.
Construction Materials		
V.M. Malhotra	B.Sc., B.E. (W. Australia)	Res. Sci.
G. Garette	B.Sc. (Laval)	Engineer
H.S. Wilson	B.E. (Saskatchewan)	Res. Sci.

NAME	DEGREES	CLASS TITLE
Physical Metallurgy Research Laboratories		
S.L. Gertsman	B.A. (Hon.), M.A. (Queen's)	Chief of PMRL
H.V. Kinsey	B.Sc. (Queen's), P.Eng.	Asst. Chief of PMRL
R.C.A. Thurston	B.Sc. (London), P.Eng.	Research Co-ordinator
H.M. Weld	B.Sc. (McMaster)	Special Projects Physical Scientist
D.K. Faurschou	B.A.Sc. (Toronto)	Res. Sci.
M.J.A. Lavigne	B.A., M.Sc., Ph.D. (Laval)	Res. Sci.
D.W.G. White	Sc.M., Sc.D. (M.I.T.)	Res. Sci.
CORROSION		
G.J. Biefer	B.Sc., Ph.D. (McGill)	Res. Sci.
J.B. Gilmlur	B.Sc. (Queen's), Ph.D. (McMaster), P.Eng.	Res. Sci.
I.C.G. Ogle	B.Sc., Ph.D. (UBC)	Res. Sci.
ENGINEERING PHYSICS AND REFRACTORY METALS		
A.J. Williams	B.Sc., M.Sc., Ph.D. (Birmingham), P.Eng.	Res. Sci.
D.C. Briggs	B.Eng., M.Eng. (McGill), Ph.D. (Queen's)	Res. Sci.
M.J. Godden	B.Met., Ph.D. (Sheffield)	Res. Sci.
D.M. Fegredo	B.Sc., M.Sc., Dipl.I.I.Sci., Ph.D. (Sheffield), A.I.M.	Res. Sci.
L.P. Trudeau	B.A.Sc., M.A. (Toronto)	Res. Sci.
F.W. Marsh	B.A.Sc. (Toronto)	Phys. Sci.
O. Vosikovsky	B.A.Sc., Ph.D. (Prague)	Res. Sci.
F. Jeglic	B.Sc., M.Sc., Ph.D. (Waterloo Lutheran U)	Res. Sci.
FERROUS METALS		
E. Smith	M.A., Ph.D. (Cambridge)	Res. Sci.
D.R. Bell	B.Eng. (McGill)	Res. Sci.
R.D. McDonald	B.Sc. (Queen's)	Res. Sci.
R.F. Knight	B.Sc., M.Sc. (Queen's)	Res. Sci.
D.E. Parsons	B.A.Sc. (Toronto)	Res. Sci.
J.D. Boyd	Ph.D. (Cambridge)	Res. Sci.
W.R. Tyson	B.A., Ph.D. (Cambridge)	Res. Sci.

NAME	DEGREES	CLASS TITLE
FOUNDRY		
R.K. Buhr	B.Eng. (McGill)	Res. Sci.
E.I. Szabo	M.Sc., Ph.D. (Nottingham)	Phys. Sci.
A.E. Murton	B.Met.Eng. (Col. School of Mines)	Res. Sci.
K.G. Davis	B.Sc., M.A.Sc., Ph.D. (UBC)	Res. Sci.
C.J. Adams	B.Sc., M.Sc. (MET) (McGill)	Res. Sci.
MECHANICAL TESTING		
P.J. Todkill	B.A. Sc. (Toronto)	Engineer
J. Harbec	B.Eng. (McGill), P.Eng.	Engineer
METAL PHYSICS		
W.N. Roberts	M.A., Ph.D. (Leeds)	Res. Sci.
E.E. Laufer	B.Sc., M.Sc., Ph.D. (Virginia)	Res. Sci.
K.S. Milliken	B.Sc. (Queen's)	Res. Sci.
C.M. Mitchell	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Res. Sci.
R.H. Packwood	B.Sc., Ph.D. (Birmingham)	Res. Sci.
K.M. Pickwick	B.Sc. (Tech.), Ph.D. (Manchester)	Res. Sci.
Y.L. Yao	B.Sc., M.Eng., Ph.D. (Lehigh)	Res. Sci.
J. Ng-Yelim (Miss)	B.Sc. (Ottawa)	Res. Sci.
NONDESTRUCTIVE TESTING		
W.E. Havercroft	B.Sc. (Sir George Williams)	Phys. Sci.
W.H. Bott	B.Sc. (McGill)	Phys. Sci.
NONFERROUS METALS		
J.O. Edwards	B.Sc., M.Sc. (Manchester), P.Eng.	Res. Sci.
A. Couture	B.A., B.A.Sc. (Laval), P.Eng.	Res. Sci.
A.F. Crawley	B.Sc., Ph.D. (Glasgow)	Res. Sci.
B. Lagowski	B.A., M.Sc. (Polish Univ., London)	Res. Sci.
G.E. Ruddle	B.A.Sc., M.Sc., D.Sc. (Virginia)	Res. Sci.
W.A. Pollard	B.Sc., A.R.S.M. (London), P.Eng.	Res. Sci.
J.J. Sebisty	B.A.Sc. (Toronto), P.Eng.	Res. Sci.
R. Thomson	B.Sc. (Glasgow), A.R.C.S.T., Ph.D. (U.K.)	Res. Sci.
J.L. Dion	B.Sc.A. (Montreal)	Engineer
L.V. Whiting	B.Sc., M.Sc., Ph.D. (McGill)	Res. Sci.
NUCLEAR AND POWDER METALLURGY		
N.S. Spence	B.Sc. (Queen's), P.Eng.	Res. Sci.
H.M. Skelly	B.Sc., Ph.D. (Glasgow)	Res. Sci.
C.F. Dixon	B.Eng. (N.S.Tech.), P.Eng.	Phys. Sci.
WELDING		
K. Winterton	B.Sc., Ph.D. (Birmingham), P.Eng.	Res. Sci.
J. Gordine	B.Sc., Ph.D. (Leeds)	Res. Sci.
Z. Paley	B.Sc., M.Sc., Ph.D. (McGill)	Res. Sci.
W.P. Campbell	B.Sc. (Queen's), P.Eng.	Res. Sci.
METAL FORMING		
M.J. Stewart	B.A.Sc., Ph.D. (UBC)	Res. Sci.
J.T. Jubb	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Res. Sci.
TECHNICAL SERVICES		
E.K. Swimmings	B.Sc. (Queen's), P.Eng. M.I.E.E.E.	Chief of T.S.
D.M. Norman	M.E.I.C., M.I. Mech.Eng. (U.K.)	Mechanical Engineer

EARTH PHYSICS BRANCH

NAME	DEGREES	CLASS TITLE
Director's Office		
K. Whitham	M.A. (Cantab.), Ph.D. (Toronto), F.R.S.C.	Director
ADMINISTRATION AND TECHNICAL SERVICES DIVISION		
ADMINISTRATION		
J.L. Kelly	B. Comm. (Ottawa)	Chief Admin.
J.J. Parks		Asst. Admin. Offr.
PERSONNEL SERVICES		
L.F. Matheson		Personnel Adviser
SCIENCE LIBRARY		
L.P. Boucher	B.A., L.Ph., B.L.S. (Ottawa)	Chief Libr.
C. Levesque	B.A. (Carleton)	Asst. Librarian
MACHINE SHOP		
G.E. Sanders		Tech. Offr.
DRAFTING SECTION		
J.W. Geuer		Chief Draftsman
PHOTOGRAPHIC SERVICES		
E.J. Gelinas		Tech. Offr.
DIVISION OF GEOMAGNETISM		
P.H. Serson	B.A., M.A., Ph.D. (Toronto)	Res. Man.
GEOMAGNETIC OBSERVATORIES		
D.R. Auld	B.A.Sc. (UBC)	Phy. Sci.
G.A. Brown		Tech. Offr.
A.B. Cook	B.A. (Queen's)	Phys. Sci.
R.V. Green	B.Sc. (Victoria)	Tech. Offr.
J. Hruska	Dip. Phys., Ph.D., RNDr. (Charles U, Prague)	Phys. Sci.
G. Jansen van Beek	B.Sc. (Alberta)	Phys. Sci.
O.J. Jensen	B.A. (McGill)	Tech. Offr.
E.I. Loomer	B.Sc., M.Sc. (McGill)	Res. Sci.
GEOMAGNETIC CHARTS		
J.F. Clark	B.A.Sc. (Saskatchewan)	Res. Sci.
R.L. Coles	B.Sc. (Liverpool), M.Sc., Ph.D. (Manitoba)	Res. Sci.
E. Dawson	B.Sc. (McMaster), M.A. (Toronto)	Res. Sci.
G.V. Haines	B.Sc. (Dalhousie), M.Sc. (Carleton)	Res. Sci.
L.R. Newitt	B.Sc. (McMaster)	Phys. Sci.

NAME	*DEGREES*	*CLASS TITLE*
RAPID VARIATIONS		
P.A. Camfield	B.Sc. (Queen's), S.M. (Mass. Inst. of Technology), Ph.D. (Alberta)	Res. Sci.
J.M. DeLaurier	B.Sc. (Queen's)	Res. Sci.
J.C. Gupta	B.Sc., M.Sc. (Agra, India), Ph.D. (California)	Res. Sci.
L.K. Law	B.A.Sc. (Toronto), M.Sc. (UWO), Ph.D. (Cantab.)	Res. Sci.
A. Nandi	B.Sc. (Calcutta), B.E.E. (Jadavpur), M.Sc. (Queen's)	Comp. Sci.
E.R. Niblett	B.A., M.A. (Toronto), Ph.D. (Cantab.)	Res. Sci.
F.C. Plet	B.Sc. (Carleton)	Tech. Offr.
J.K. Walker	B.E., M.Sc. (Sask.), Ph.D. (Alberta)	Res. Sci.
INSTRUMENTATION		
F. Andersen	B.A. (UBC)	Res. Sci.
G.L. Carr		Tech. Offr.
W.F. Hannaford	B.Sc., M.Sc. (Ottawa)	Res. Sci.
D.F. Trigg	B.A.Sc. (UBC)	Res. Sci.
PALEOMAGNETISM		
E. Irving	B.A., M.Sc., D.Sc. (Cantab.), F.R.S.C.	Res. Sci.
P. Lapointe	B.Sc., M.Sc. (Ottawa)	Phys. Sci.
J.K. Park	B.Sc. (Cal.)	Phys. Sci.
J.L. Roy	B.A. (Laval), B.Sc. (Montreal)	Res. Sci.
POSTDOCTORATE FELLOWS		
Y. Honkura	B.Sc., M.Sc., Ph.D. (Tohoku, Japan)	
R.D. Kurtz	B.Sc., M.Sc. (Alberta), Ph.D. (Toronto)	
D.R.K. Rao	B.Sc., M.Sc. (Andhra, India), Ph.D. (Bombay, India)	
Gravity Division		
J.G. Tanner	B.Sc., M.Sc. (UWO), Ph.D. (Durham)	Res. Man.
SURVEYS AND INTERPRETATION		
Surveys		
J.B. Boyd		Tech. Offr.
W.E.F. Burke		Tech. Offr.
R.V. Cooper	B.Sc. (St. Mary's)	Tech. Offr.
D.W. Halliday		Tech. Offr.
D.B. Hearty	B.A. (Carleton)	Tech. Offr.
L.E. Stephens	B.Sc., M.Sc. (Queen's)	Phys. Sci.

NAME	DEGREES	CLASS TITLE
Interpretation		
R.A. Gibb	B.Sc. (Aberdeen), M.Sc., Ph.D. (Birmingham)	Res. Sci.
A.K. Goodacre	B.A., M.A. (UBC)	Res. Sci.
D. Nagy	B.Sc. (Sopron), M.A.Sc., Ph.D. (Toronto)	Res. Sci.
L.W. Sobczak	B.A.Sc. (Toronto)	Res. Sci.
R.P. Riddihough	B.Sc. (Kings Coll. London), D.I.C., M.Sc. (Imp. Coll. London), Ph.D. (Univ. of London)	Res. Sci.
R.A. Stacey	B.Sc. (Nottingham), M.Sc., Ph.D. (Durham)	Res. Sci.
J.F. Sweeney	B.A., M.A., Ph.D. (S.U.N.Y. Buffalo)	Res. Sci.
M.D. Thomas	B.Sc., Ph.D. (Wales-Swansea)	Res. Sci.
Geodynamics		
C. Beaumont	B.Sc. (Univ. of Sussex), Ph.D. (Dalhousie)	Res. Sci.
D.R. Bower	B.Sc., M.A. (Carleton) Ph.D. (Durham)	Res. Sci.
J.J. Labrecque	B.A. (Jean-de-Brébeuf), B.Sc., M.Sc. (U. Montreal)	Res. Sci.
A. Lambert	B.Sc., M.A. (UBC), Ph.D. (Dalhousie)	Res. Sci.
J.A. O'Brien		Tech. Offr.
J.A. Orosz		Tech. Offr.
M.K. Paul	B.Sc., M.Sc. (Calcutta), Ph.D. (Jadavpur, India)	Res. Sci.
J. Popelar	M.Sc., RNDr. (Charles U., Prague)	Res. Sci.
S.B. Sim		Tech. Offr.
R.I. Walcott	B.Sc. (New Zealand), Ph.D. (Victoria), D.I.C.	Res. Sci.
J.R. Weber	B.Sc., M.Sc. (Zurich), Ph.D. (Alberta)	Res. Sci.
M.O. Wheeler	B.A. (UBC)	Phys. Sci.
L.G. Dussault		Tech. Offr.
Standards and Information		
R.J. Buck	B.Sc. (Queen's)	Phys. Sci.
R.K. McConnell	B.Sc. (Carleton, UWO)	Phys. Sci.
P.J. Winter		Tech. Offr.
Rock Physics		
M.R. Dence	B.Sc. (Sydney)	Res. Sci.
R.A.F. Grieve	B.Sc. (Aberdeen), M.Sc., Ph.D. (Toronto)	Res. Sci.
P.B. Robertson	B.Sc. (Carleton), M.Sc. (Penn. State), Ph.D. (Durham)	Res. Sci.
R.L. Wirthlin		Tech. Offr.
Instrumentation		
J.F. Halpenny	B.Sc. (Carleton)	Tech. Offr.
H.D. Valliant	B.Sc. (Carleton), M.Sc. (UWO)	Res. Sci.
Postdoctorate Fellows		
P. Kearey	B.Sc., Ph.D. (Dunelm)	Res. Sci.

NAME	DEGREES	CLASS TITLE
Seismology Division		
M.J. Berry	B.Sc., M.A., Ph.D. (Toronto)	Res. Man.
SPECIAL PROJECTS		
E.B. Manchee	B.A.Sc., M.A. (Toronto)	Res. Sci.
D.H. Weichert	B.A.Sc., M.Sc., Ph.D. (UBC)	Res. Sci.
SEISMICITY, SEISMIC HAZARDS AND APPLICATIONS		
F.M. Anglin	B.Sc. (Ottawa), M.Sc. (UWO)	Res. Sci.
P.W. Basham	B.A.Sc., M.Sc. (UBC)	Res. Sci.
R.J. Halliday	B.Sc. (Toronto)	Phys. Sci.
H.S. Hasegawa	B.Sc., M.Sc. (Alberta), Ph.D. (UBC)	Res. Sci.
R.B. Horner	B.Sc. (Manitoba)	Phys. Sci.
G. Leblanc	B.A. (Montreal), L.Ph. (Immaculate Conception), M.A. (Mass.), M.Sc. (Boston), Ph.D. (Pa. State)	Res. Sci.
W.E. Shannon	B.Sc. (UBC)	Phys. Sci.
A.E. Stevens	B.Sc. (McMaster), M.Sc. (UWO), Ph.D. (UWO)	Res. Sci.
R.J. Wetmiller	B.Sc. (Manitoba), M.Sc. (UBC)	Res. Sci.
SEISMOTECTONICS AND SEISMIC HAZARDS		
G.A. McMechan	B.A.Sc. (UBC), M.Sc. (Toronto)	Res. Sci.
W.G. Milne	B.A. (Toronto), Ph.D. (UWO)	Res. Sci.
G.C. Rogers	B.Sc. (UBC), M.A. (U. Hawaii)	Phys. Sci.
SEISMOLOGICAL STUDIES OF EARTH STRUCTURE		
G.G.R. Buchbinder	B.Sc., M.Sc. (Dalhousie), Ph.D. (Columbia)	Res. Sci.
D.A. Forsyth	B.A.Sc. (Queen's), M.Sc. (UBC)	Phys. Sci.
J.A. Lyons	B.Sc. (Toronto), M.Sc. (UWO)	Phys. Sci.
J.A. Mair	B.Sc. (Alberta), M.A., Ph.D. (Toronto)	Res. Sci.
A.J. Wickens	B.A. (Sask.), M.Sc. (Ottawa)	Res. Sci.
C. Wright	B.Sc. (Durham), Ph.D. (ANU)	Res. Sci.
SEISMOLOGICAL INSTRUMENTATION LABORATORY		
M.N. Bone	B.A.Sc. (Toronto)	Phys. Sci.
R.T. Grogan	B.A.Sc., B.Eng. (Carleton)	Tech. Offr.
R.B. Hayman	B.Sc. (Bristol), P.Eng.	Phys. Sci.
F. Kollar	B.Sc. (Budapest), Ph.D. (UBC)	Res. Sci.
F. Lombardo		Tech. Offr.
D.J. Monsees		Tech. Offr.
J.T. Thomas		Tech. Offr.
W. Tyrlik		Tech. Offr.
GEOTHERMAL STUDIES		
A.M. Jessop	B.Sc., Ph.D. (Nottingham)	Res. Sci.
A.S. Judge	B.Sc. (London), Ph.D. (UWO)	Res. Sci.
T.J. Lewis	B.A.Sc., M.Sc. (UBC)	Phys. Sci.
A.E. Taylor	B.Sc. (McMaster), M.Sc. (Ottawa)	Phys. Sci.
POSTDOCTORATE FELLOWS		
A.G. Green	B.Sc. (Hull), Ph.D. (Newcastle)	Res. Sci.

SURVEYS AND MAPPING BRANCH

NAME	DEGREES	CLASS TITLE
Director		
R.E. Moore	B.E. (Nova Scotia Tech.), B.Sc. (Delft Technical Institute-Netherlands), P.Eng. (Ontario)	SX
EX. ASSIST. DIRECTOR		
W.L. MacLellan	Nova Scotia Land Surveyor	SUR
PERSONNEL ADVISOR		
H.T. Posten		PE
TECHNICAL TRANSLATOR		
H.V. Valin	B.A. (Ottawa), B.Ed. (Ottawa)	AS
FOREIGN AID		
J.I. Thompson	B.A.Sc. (Toronto), P.Eng. (Ontario)	SUR
L.E. Pelton	B.Sc.F. (New Brunswick), B.Sc.S.E. (New Brunswick), Dominion Land Surveyor	SUR
Branch Administration		
J.A. McArthur		AS
J.M. McGuire		FI
SCIENTIFIC ADVISER		
L.A. Gale	B.Sc. (Queen's), Dominion Topographic Surveyor	SUR
ASSISTANT DIRECTOR (PLANS)		
G. Babbage	B.Sc. (Cape Town), Dominion Land Surveyor, Nova Scotia Land Surveyor, Ontario Land Surveyor, P.Eng. (Ontario)	SUR
INFORMATION SERVICES		
J.F. Mazerall	B.Sc. (New Brunswick)	SUR
J.D. Tremblay		IS
B.A. McAulay	B.A. (New Brunswick)	IS
SYSTEM CONTROL		
L. Chouinard	B.A. (Laval), B.Sc. (Laval)	SUR
B. Lerner		AS
BRANCH SECRETARIAT		
E.W. Kerr	Ontario Land Surveyor, Dominion Land Surveyor	SUR
R.B. Dennis		DD
RESEARCH AND TRAINING		
J.R. Gauthier	D.Ing. (France), B.Sc. (New Brunswick), Ing. (Quebec)	SUR
T. Wray	B.Sc. (Queen's, Belfast, Northern Ireland), M.A. (Toronto)	MASTA
W.J. Clark		DD
R.J. Fitzgerald	B.Eng. (McGill)	ENG
LIBRARY		
V.E. Hoare	B.A. (Carleton)	LS
Geodetic Survey Division		
DOMINION GEODESIST		
L.J. O'Brien	B.Eng. (Toronto), M.S. (Ohio State, USA)	SUR

NAME	DEGREES	CLASS TITLE
TECHNICAL CO-ORDINATION		
L.P. Robertson	B.Sc. (Iowa, USA)	SUR
P.C. Atkinson	B.Sc. (New Brunswick)	SUR
ADMINISTRATION		
J.E. Raymond		AS
FIELD OPERATIONS		
J.V. Thompson	B.A.Sc. (British Columbia), Dominion Land Surveyor	SUR
PRIMARY HORIZONTAL CONTROL		
A.D. Selley	B.Sc.C.E. (Manitoba), Dominion Land Surveyor, P.Eng. (Ontario)	SUR
G. Gibling	B.Sc.C.E. (Alberta), Dominion Land Surveyor	SUR
G.A. Corcoran	B.Sc. (Ottawa), B.Eng. (McGill), Dominion Land Surveyor	SUR
G.L. Fraser	B.Sc.C.E. (Queen's), Dominion Land Surveyor	SUR
R.H. McDowell	B.Sc.E.E. (New Brunswick)	SUR
M.T. Swanson	B.Sc.C.E. (Manitoba), Dominion Land Surveyor	SUR
C.G. Vigneault	B.A.Sc. (Laval), Quebec Land Surveyor	SUR
G.D. Hueston		ESS
PRIMARY VERTICAL CONTROL		
F.W. Mosienko	B.S. (Saskatchewan)	SUR
F.W. Young	B.Eng. (Nova Scotia Tech.), P.Eng. (Nova Scotia)	SUR
P. Boudreault	B.A. (Laval), B.Sc. (Laval), P.Eng. (Quebec)	SUR
Y. Gilbert	B.Sc. (Laval), P.Eng. (Quebec)	SUR
R.S. Smith	B.Sc. (Mt. Allison), B.E. (Nova Scotia Tech.)	SUR
C.I. Schulz	Nova Scotia Land Surveyor	ESS
R.I. Emmett	Nova Scotia Land Surveyor	ESS
SUPPLEMENTARY CONTROL		
C.R. Colwell	B.Sc.C.E. (New Brunswick)	SUR
G.M. Armstrong	B.Sc. (New Brunswick)	SUR
J.V. Brown	Nova Scotia Land Surveyor	SUR
R. Chewpa	B.Sc. (Toronto), Dominion Land Surveyor	SUR
D.L. Macquarrie	Nova Scotia Land Surveyor	SUR
V.J. Doucette	B.Sc. (Nova Scotia Tech.)	SUR
B.R. Justason	B.Sc. (New Brunswick), New Brunswick Land Surveyor	SUR
L.J. Frenette	B.Sc. (New Brunswick)	SUR
P.E. Langlais	B.A. (Laval), B.Sc. (Laval)	SUR
A.R. Eaton	B.Sc. (McGill)	SUR
C.R. Penton	B.Sc.S.E. (New Brunswick)	SUR
INSTRUMENT MAINTENANCE		
N. Bramwell		ESS
Geodesy		
C.D. McLellan	B.A. (Queen's), M.A. (Queen's)	SUR
PHYSICAL GEODESY		
J. Kouba	D.Ing. (Czech. Tech. University), M.Sc. (New Brunswick)	SUR
S. Vamosi	B.Sc. (Sopran, Hungary), M.Sc. (Ohio State, USA)	SUR
R. Blais	B.Sc. (Montreal), M.A. (Toronto)	STAT

NAME	DEGREES	CLASS TITLE
TECHNOLOGICAL RESEARCH		
L.F. Gregerson	B.Eng. (Budapest Technical University), B.Sc. (Royal Hungarian Military Academy)	SUR
N.H. Frost	B.Sc. (Manitoba)	SUR
R.J. Carriere	B.Sc.S.E. (New Brunswick)	SUR
COMPUTATIONS AND ADJUSTMENTS		
J.P. Henderson	B.A.Sc. (Toronto), M.Sc. (New Brunswick)	SUR
D.S. Beattie	B.Sc. (Mt. Allison), B.E. (Nova Scotia Tech.)	SUR
L.W. Churcher	B.Sc. (Queen's)	SUR
N.J. Mosienko	B.Sc. (Saskatchewan), M.E. (New Brunswick)	SUR
M.C. Pinch	B.Sc. (New Brunswick)	SUR
J.D. Boal	B.A.Sc. (Toronto), P.Eng. (Ontario)	SUR
D.V. St. Helene	B.Sc. (Dalhousie), B.E. (Nova Scotia Tech.)	SUR
DATA SERVICES		
C.E. Hoganson	B.Eng. (Nova Scotia Tech.)	SUR
R.L. Forgues	B.Sur., B.A.Sc. (Laval)	SUR
K.C. Mackenzie	B.Sc. (New Brunswick)	SUR
R.A. Forbes		ESS
R.B. Roberts	B.A. (Trinity College, Dublin, Ireland)	ESS
International Boundary Commission		
COMMISSIONER		
A.F. Lambert	B.A. (Queen's), Dominion Topographical Surveyor, Dominion Land Surveyor	SUR
ENGINEERS		
W.M. Smith	B.Sc. (New Brunswick), Dominion Land Surveyor	SUR
N. Paquette	B.Sc.App. (Arpentage) (Laval), Quebec Land Surveyor	SUR
C.J. Gustafson	B.Eng. (Carleton)	SUR
Topographical Survey Directorate		
ACTING DIRECTOR		
E.A. Dixon		ESS
ADMINISTRATION		
L.L. Aubrey		DD
PHOTOGRAMMETRICAL ENGINEERING DIVISION		
R.A. Stewart	B.Sc. (New Brunswick), M.Sc., (Ohio State, U.S.A.) Ph.D. (Ohio State, U.S.A.), P.Eng. (Ontario)	SUR
RESEARCH AND DEVELOPMENT SECTION		
M.E.H. Young	B.Sc. (Queen's), M.A.Sc. (Toronto), P.Eng. (Ontario)	SUR
E.A. Fleming	B.A. (British Columbia)	SUR
M.M. Allam	B.Sc. (Alexandria, United Arab Republic), Ph.D. (Moscow Geodesy, Air Photography Cartography, Institute)	SUR
B.A. Low	B.Sc. (Victoria)	SUR
J.D. Mears	B.A. (Western)	CS
G.K. Schliebener	B.Eng. (Ottawa), P.Eng. (Ontario)	SUR
MAPPING PROGRAM SECTION		
L.M. Sebert	B.A.Sc. (Toronto), Dominion Land Surveyor, P.Eng. (Ontario)	SUR
J.H. O'Donnell	B.A.Sc. (Laval), Quebec Land Surveyor	SUR
R.K. Rose	B.Sc. (New Brunswick)	SUR
R.R.M.G. Gareau	B.Sc. (New Brunswick)	SUR
K.B. Hodgins		DD
C.K. Chaly	B.Sc. (Kerala State, India), M.Sc. (New Brunswick), P.Eng. (Ontario)	SUR

NAME	DEGREES	CLASS TITLE
TOPOGRAPHIC MAPPING DIVISION		
D.G. Anderson		DD
D.A. Mackay	B.Sc. (Dalhousie), B.Sc. (Nova Scotia Tech.)	SUR
J.R. Holt	B.Sc. (Stephen F. Austin, U.S.A.)	SUR
Mapping Section #1		
J.D. MacDonald		DD
M.E. Sabourin		DD
W.J. Winges		DD
E. Jessiman		DD
Mapping Section #2		
A.E. Kemp		DD
R.F. Snook		DD
S.M. Yllyett		DD
H.J. Handy		DD
J.R. Lortie		DD
R.M. Simser		DD
AERIAL PHOTOGRAPHY DIVISION		
W.G. Landles		AS
INTERDEPARTMENTAL COMMITTEE ON AIR SURVEYS		
D.H. Baker		AS
NATIONAL AIR PHOTO LIBRARY		
P. Andrews		PM
P. Furlong	B.A. (Toronto)	PM
M. McLaughlan	B.A. (Carleton)	CR
D. Rombough	B.A. (Carleton)	CR
NATIONAL AIR PHOTO LIBRARY REPRODUCTION CENTRE		
G.M. Nitschky		AS
D. Myer	B.Sc. (Rochester Institute of Technology, U.S.A.)	ESS
W.J. Dilworth		PY
J. Hyams		PY
CANADA MAP OFFICE		
G.A. Clemmer		PG
Legal Surveys Division		
SURVEYOR GENERAL		
D.R. Slessor	B.Sc. (C.E.) (Manitoba), Ontario Land Surveyor, Dominion Land Surveyor, P.Eng. (Ontario)	SUR
ASSISTANT SURVEYOR GENERAL		
W.V. Blackie	B.Sc. (Cape Town), Nova Scotia Land Surveyor, Dominion Land Surveyor, Ontario Land Surveyor	SUR
ADMINISTRATION		
J.W. Bacon		AS

NAME	DEGREES	CLASS TITLE
FIELD SURVEYS		
L.L. Anderson	B.A.Sc. (Toronto), Alberta Land Surveyor, Dominion Land Surveyor, P.Eng. (Ontario)	SUR
W.D. Stretton	Ontario Land Surveyor, Dominion Land Surveyor	SUR
T.A. Maki	B.Eng. (McGill)	SUR
S.A. Repstock	Dominion Land Surveyor	SUR
R.G. McBurney	B.A.Sc. (Waterloo), P.Eng. (Ontario), Dominion Land Surveyor	SUR
S. Hutchinson	Dominion Land Surveyor	ESS
J. Brennan	B.Sc. (New Brunswick)	SUR
I.M.D. Fox	B.Eng. (McGill), Dominion Land Surveyor, British Columbia Land Surveyor	SUR
M.H. Collins	British Columbia Land Surveyor, Dominion Land Surveyor	SUR
D.K. Neilson	British Columbia Land Surveyor	SUR
W.R. Barraclough	Dominion Land Surveyor	ESS
W.R. Griese	Dominion Land Surveyor	SUR
G.E. Olsson	Alberta Land Surveyor, Dominion Land Surveyor	SUR
D.A. Bouck	Dominion Land Surveyor	SUR
G.J. Zeldenrust	Saskatchewan Land Surveyor	SUR
A. McTaggart	Dominion Land Surveyor, Manitoba Land Surveyor	SUR
P.E. Stevens	Manitoba Land Surveyor	SUR
D.H. Browne	Ontario Land Surveyor, Dominion Land Surveyor, Nova Scotia Land Surveyor	SUR
D.J. MacDonell	Ontario Land Surveyor	SUR
D.G. McMaster	Ontario Land Surveyor	SUR
A.M. MacLeod	Dominion Land Surveyor	SUR
E.F.L. Cole	Ontario Land Surveyor	SUR
G. Raymond	B.Sc. (Laval), Quebec Land Surveyor, L.L.L.	SUR
G. Drolet	B.A.Sc. (Laval), Quebec Land Surveyor	SUR
D.A. Tétreault	Quebec Land Surveyor, B.A. (Montreal)	SUR
W.D. McLellan	New Brunswick Land Surveyor	SUR
J. Covert	Dominion Land Surveyor, Prince Edward Island Land Surveyor, Nova Scotia Land Surveyor	SUR
INSTRUCTIONS AND SUPPORT		
R.G. Snowling	B.A.Sc. (British Columbia), Dominion Land Surveyor, P.Eng. (Ontario)	SUR
R.O. Semper	Nova Scotia Land Surveyor, Dominion Land Surveyor, Prince Edward Island Land Surveyor, New Brunswick Land Surveyor	SUR
S.W. Young	B.SO. (Alberta)	ESS
F. Vanderkuip	B.Sc., Minerva Academy, Greningen (Holland)	DD
P.I.R. Sauvé	Ontario Land Surveyor, Dominion Land Surveyor	SUR
PLAN EXAMINATION		
R.T.B. McCurdy	Dominion Land Surveyor, Ontario Land Surveyor, Nova Scotia Land Surveyor	SUR
M. Wuhr	Nova Scotia Land Surveyor, Dominion Land Surveyor, Alberta Land Surveyor, New Brunswick Land Surveyor, Prince Edward Island Land Surveyor	SUR
C.D. Cox	Ontario Land Surveyor	SUR
W.W. Clark	B.Sc. (Carleton)	ESS
A.E. Dickson	Dominion Land Surveyor	SUR
V.J. Vinette	B.A. (Ottawa)	ESS
R.G. Wallis	Nova Scotia Land Surveyor	ESS
M. Patterson (Mrs.)	Philippines Land Surveyor (Philippines)	ESS

NAME	DEGREES	CLASS TITLE
RESEARCH AND DEVELOPMENT		
H.E. Jones	B.Sc. (Queen's), P.Eng. (Ontario), Dominion Land Surveyor, Nova Scotia Land Surveyor	SUR
C. Bonnell	B.Sc. (New Brunswick), Nova Scotia Land Surveyor	SUR
J.C. Mitchell	B.Sc. (Ottawa), Dominion Land Surveyor	SUR
G.E. Le Sueur	B.A. (Toronto), M.REL. (Toronto), Dominion Land Surveyor, Alberta Land Surveyor	SUR
C.A. Silliphant	P.Eng. (P.E.I.), B.Sc. (New Brunswick)	SUR
E. Kappler	Dominion Land Surveyor	SUR
Directorate of Map Production		
DIRECTOR		
T.H. Kihl	Dominion Land Surveyor	SUR
ADMINISTRATION		
L.P. St. Pierre		AS
RESEARCH PLANNING AND DEVELOPMENT		
S.A. Yaskowich	B.Sc.Eng. (Saskatchewan), Dominion Land Surveyor, P.Eng. (Saskatchewan)	SUR
CO-ORDINATOR, MAP PRODUCTION		
D.H. Ketch	B.Sc.C.E. (New Brunswick)	GT
L. Baker		GT
AUTOMATED CARTOGRAPHY		
T.A. Porter	B.A.Sc., M.A. (Toronto), P.Eng. (Ontario), M.Sc. (Waterloo)	CS
G. Tunstall		CS
T.C. Bartello		EL
S. Law	B.Math., M.Math. (Waterloo)	CS
AERONAUTICAL CHARTS DIVISION		
R.M. Defoe	B.Sc. (Royal Military College), P.Eng. (Ontario)	SUR
D.F. Miller		GT
R.A. Delaney		DD
T.M. Cobb		DD
R.E. Reinburg		DD
N.G. Grant	B.A. (Carleton)	SUR
CARTOGRAPHY DIVISION		
G. Montagano		ESS
L. Peskett		DD
G. Millette		GT
G. Shoup		DD
G. Laidlaw		DD
G. Peer		DD
R. Aunaste	B.A. Economics (Tartu, Estonia)	DD
J. Curran		DD
D. Joiner		DD
L.P. Trudel		DD
B.B. Robertson		DD
J. Hewitt	B.A. (Toronto)	GT
MAP REPRODUCTION DIVISION		
T. Frith		AS
M.C. Hamilton		DD
A. Hammond		PRSES
J. Hurtubise		PRSES
A.A. Baldock	B.A. (Carleton)	OFESUP

GEOGRAPHY DIVISION

NAME	DEGREES	CLASS TITLE
G. Falconer	B.A. (Cantab.), M.A. (Cantab.)	PC
B. Cornwall	B.A., M.A. (British Columbia)	PC
J.M.O. Morawiecki	B.A., M.A. (Ottawa)	PC
B. Berghout	B.A. (Carleton)	PC
B. Brickman	B.A. (Carleton), M.A. (Carleton)	PC
C. Chapdelaine	B.A. (Montréal)	PC
D.M. Fairbairn	B.A. (Queen's)	PC
C. Gosson	B.A. (Ottawa)	PC
P. Harker	B.A. (McMaster), M.A. (Waterloo)	PC
R. Jay	B.A. (Queen's), M.A. (Queen's)	PC
I. Jost	B.A. (Warsaw, Poland), M.A. (Ottawa)	PC
D. Leclerc	B.A. (Ottawa)	PC
K. Lightfoot	B.A. (Carleton)	PC
D. Mackay	B.A. (Carleton), M.A. (Carleton)	PC
I. Marshall	B.Sc. (Saskatchewan), P.Ag. (Ontario)	PC
W. Mitchell	B.A. (Carleton)	PC
C. Ravel	B.A. (Sherbrooke)	PC
J. Thompson	B.A. (Carleton)	PC
R. Vasko	B.A. (Brock)	PC
V. Wilson	B.Sc. (Hull, England), M.A. (Simon Fraser)	PC
H. Mindak		DD
P. Baldock		DD
C.L. Bohm		DD
J.C. Allen		DD
L. Leafloor		CR

CANADA CENTRE FOR REMOTE SENSING

NAME	DEGREES	CLASS TITLE
Director's Office		
L.W. Morley	B.A., M.A., Ph.D. (Toronto), P.Eng.	Director
E.A. Godby	B.Sc., M.Sc. (Alberta), P.Eng.	Associate Director
Program Planning and Evaluation Unit		
J.C. Henein	B.Sc.Eng. (Cairo), P.Eng.	Chief
A.K. McQuillan	B.Sc., M.Sc. (Western), Ph.D. (Toronto)	Program Evaluation
Administration Division		
J.G. Arbique	C.P.S.S. (Carleton)	Chief, Admin. Officer
B.G. McGurrin	B.A. (Loyola), B.L.S. (Ottawa)	Head, Scientific Information Retrieval
Personnel		
F.B. Macdonnell	B.A. (Queen's)	Personnel Administrator
Data Acquisition Division		
R.C. Baker	B.Eng. (McGill), M.Sc. (Stanford), P.Eng.	Chief
Airborne Operations Section		
E.J. McLaren		Head
G.J. Fitzgerald		Operations Officer
J.F. Fleming	B.Sc. (Carleton)	Quality Control
C. Petzinger	B.A.Sc. (UBC)	Sr. Mission Manager
R. McKibbon		Operations Technician
Airborne Systems Section		
J.E. Smyth	B.Sc. (Alberta), P.Eng.	Head
J. Granot	B.Sc. (Israel), M.Sc. (Israel), P.Eng.	Electronic Engineer
K. Bures	B.Sc., M.Sc., Ph.D. (Wisconsin)	Electronic Engineer
J.R. Gibson	B.Sc.Eng.Sc., M.Sc. (Sask)	Electronic Engineer
J. Waddell		Sr. Electronic Technician
J. Rene de Cotret	Dip. (Hull)	Electronic Technician
J.E. Allen	Dip. (Ryerson)	Electronic Technician
M. Lalonde	Dip. (Algonquin)	Jr. Electronic Technician
Program Development Section		
L. Bronstein	B.Eng. (McGill), M.Sc. (M.I.T.), P.Eng.	Head
Sensor Development Section		
J.N. de Villiers	B.Sc. (Edinburgh), Ph.D. (Cantab.)	Head
A.L. Gray	B.Sc. (Belfast), M.Sc., Ph.D. (Calgary), P.Eng.	Research Scientist
R.A. O'Neil	B.Sc. (Calgary), Ph.D. (McMaster)	Research Scientist
W.D. McColl		Sensor Technician
N. Giffin	Dip. (Algonquin)	Sensor Technician
Data Processing Division		
E. Shaw	B.Sc., Ph.D. (Birmingham)	Chief

NAME	DEGREES	CLASS TITLE
Instrumentation Section		
D.N. Davis	B.Sc., (Alberta), M.Sc.Eng. (London), D.I.C. (Imperial College), P.Eng.	Head
T.J. Butlin	B.Sc. (Dundee)	Senior Electronic Engineer
M.C. Lim	B.Sc. (UBC)	Electronic Engineer
A.M. Baillie	B.Eng., M.Eng. (UBC)	Electronic Engineer
T.O. Froelich	Ing. (West Berlin)	Sr. Electronic Engineer
S. Methot	Dip. (Algonquin)	Electronic Technician
K. Hannam	Dip. (Mohawk)	Electronic Technician
J.S. Garand	Dip. (Hull)	Electronic Technician
R. Shergold	O.N.C. (England)	Draftsman
Systems Section		
B.A. Hodson	B.Sc. (Manchester)	Head
F.E. Guertin	B.A. (Montreal), B.Sc. (Laval) M.Sc., E.E. (M.I.T.), P.Eng.	Sr. Systems Engineer
H. Edel	B.A.Sc. (Ottawa)	Systems Scientist
S.S. Vishnubhatla	B.Sc. (India), M.Sc. (Carleton), Ph.D. (Ottawa)	Systems Scientist
G.W. Plunkett	B.Eng. (Carleton)	Systems Engineer
Data Control and Distribution Section		
(Vacant)		Head
R.L. Irwin		Station Manager, Prince Albert Satellite Station
C.J. Edwards		Administrator, Prince Albert Satellite Station
J. Hooton		Station Technician, Prince Albert Satellite Station
Operations Section		
M.A. Jager	O.N.C. (England)	Head
R.E. Moore		Shift Supervisor
D. Presley		Shift Supervisor
D.C. Latour	B.Sc. (Carleton)	Image Analyst
Applications Division		
W.M. Strome	B.Sc. (Alberta), M.A.Sc. (UBC) Ph.D. (Carnegie Mellon), P.Eng.	Chief
Applications Development Section		
K.P.B. Thomson	B.Sc. (Belfast), M.A., Ph.D. (Toronto)	Head
R.A. Ryerson	B.A., M.A. (McMaster)	Applications Scientist
T.T. Alfoldi	B.A.Sc., M.A. (Toronto), P.Eng.	Applications Scientist
W.D. Bruce	B.A. (Brock), M.Sc., Ph.D. (McMaster)	Applications Scientist
J. Cihlar	B.Eng. (Prague), M.A. (Guelph), Ph.D. (Kansas)	Applications Scientist
G. Rochon	B.Sc., M.Sc. (Laval)	Applications Scientist
Methodology Section		
D.G. Goodenough	B.Sc. (UBC), M.Sc., Ph.D. (Toronto)	Head
S. Shlien	B.Sc. (McGill), D.Sc. (M.I.T.)	Research Scientist
F. Ahern	A.B. (Cornell), Ph.D. (Maryland)	Research Scientist
R. Lowry	B.Sc. (Saskatchewan), Ph.D. (Imperial College)	Research Scientist

POLAR CONTINENTAL SHELF PROJECT

NAME	*DEGREES*	*CLASS TITLE*
G.D. Hobson	B.A. (McMaster), M.A. (Toronto), P. Geoph.	Director
W.S.B. Paterson	M.A. (Edin.), Ph.D. (UBC)	Res. Sci.
R.M. Koerner	B.A. (Sheffield), M.A. (Sheffield), Ph.D. (London)	Res. Sci.
D.L. Cameron		Admin. Off.
F.P. Hunt		Field Op. Mgr.

EXPLOSIVES BRANCH

NAME	*DEGREES*	*CLASS TITLE*
E.J. Fraser	B.S.A.	Director
B.P. McHugh	B.Sc.	Assistant Director
T.R. Robertson	B.Sc.	Explosives Inspection Specialist
L.J.F. Saulnier	M.Sc.	Regional Inspector Atlantic Region
A. Leclerc	B.A.	Regional Inspector Quebec Region
J.R. desRivières	B.Sc.	Explosives Inspection Specialist
W.O. Taylor	B.Sc.	Regional Inspector Central Region
P.A. Houldsworth	B.Sc.	Assistant Regional Inspector Ontario Region
D.I. Campbell	B.Sc.	Regional Inspector Pacific Region
L.B. Buchanan	M.Sc.	Regional Inspector Ontario Region

CANADIAN CENTRE FOR GEOSCIENCE DATA

NAME	*DEGREES*	*CLASS TITLE*
C.F. Burk, Jr.	B.Sc. (UWO), Ph.D. (Northwestern)	Phys. Sci.
K.L. Gunn	B.Sc., M.Sc. (U of T)	Phys. Sci.

OFFICE OF ENERGY RESEARCH AND DEVELOPMENT

NAME	*DEGREES*	*CLASS TITLE*
R.P. Charbonnier	B.Sc., M.A., E.M., D.Sc. (Paris)	Director
B.D. Cook	B.A. Hons. (Sheffield), M.Sc., (McGill) (Seconded from the Department of the Environment since February 1974)	Coordinator
P.J. Dyne	Ph.D. (Seconded from AECL, February-May 1974)	Panel Chairman.