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

ACTIVITIES OF THE SCIENCE AND TECHNOLOGY SECTOR

1976-77

1SSN 0383-3399

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

ACTIVITIES OF THE SCIENCE AND TECHNOLOGY SECTOR

1976-77

INTRODUCTION

The Science and Technology Sector of the Department of Energy, Mines and Resources carries out activities primarily in response to three Acts of Parliament for which the Minister has responsibility: the Resources and Technical Surveys Acts 1966-67 (subsumed within the Department of Energy, Mines and Resources Act), the Canada Land Surveys Act, and the Explosives Act. Under the Resources and Technical Surveys Act, the Minister is directed to "make a full and scientific examination and survey of the geological structure and mineralogy of Canada" and also undertake such chemical, mechanical, metallurgical, and other researches and investigations as are necessary or desirable to carry out the purposes and provisions of the Act, and particularly to aid the mining and metallurgical industry of Canada. Under the Canada Land Surveys Act, the Minister is obligated "to cause surveys to be made of public lands upon the request of a minister of any department of the Government of Canada administering such lands, and in any other case in which he deems it to be expedient. The Explosives Act enables the Minister to issue licences to factories and magazines, to issue certificates permitting the storage for sale of authorized explosives, to recommend to the Governor in Council approval of the nature of components and of the final explosive product, and to issue permits for the importation of authorized explosives.

In addition to carrying out the tasks assigned to the Minister by Parliament, the Science and Technology Sector responds to government decisions relating to the use of Canada's mineral and energy resources. Much of the challenge inherent in these responsibilities arises from the characteristics of the country's physical environment.

Canada is a large country with a relatively small population that is concentrated within a few hundred miles of the southern border. It has extensive natural resources, which extend far beyond established areas of settlement into lands that are barely touched by existing transportation and communication networks. A large proportion of the work of the Sector is concerned with identifying and appraising resources in these remote areas, both on land and in the surrounding oceans.

The work of the Sector contributes to two major programs of the Department: the Mineral and Energy Resources Program and the Earth Sciences Program. Activities under these programs are carried out by seven branches: the Geological Survey of Canada, the Canada Centre for Mineral and Energy Technology, the Earth Physics Branch, the Surveys and Mapping Branch, the Canada Centre for Remote Sensing, the Polar Continental Shelf Project, the Explosives Branch, and the Canada Centre for Geoscience Data. Together these organizational units embrace a wide range of scientific disciplines, technology, and skills; but they share the common purpose of collecting and analyzing data, providing information, and acquiring new knowledge about Canada's landmass. Currently, efforts are being concentrated on the establishment of a sound data base which can be used to guide decisions on national resource development. The Explosives Branch, the eighth organizational unit within the Sector, carries out the responsibilities specified in the Explosives Act.

In response to the growing concern of government to achieve self-sufficiency with respect to energy supplies, in the past two years there has been a significant shift of emphasis within the Sector to energy-related activities. In 1976-77, for example, the budget for energy research by the Canada Centre for Mineral and Energy Technology was doubled and the personnel allocation increased by 25%. Adjustments also were made on a smaller scale, in the activities undertaken by the Geological Survey of Canada and the Earth Physics Branch.

While this concentration on energy resources is undoubtedly important to Canada's economic well-being, it should be recognized that it has been undertaken at the expense of research in other areas. At the Canada Centre for Mineral and Energy Technology, the emphasis on energy research has resulted in a 1% increase in budget and a 2% reduction in the personnel engaged in minerals research. To the extent that resources are borrowed from other program areas to advance the energy component, the Sector will find it increasingly difficult to maintain its competence in all fields of scientific endeavour.

The present report describes the work performed by the eight branches in 1976-77. Some achievements of particular national importance should be mentioned here.

During the year, five provinces participated in the joint federal-provincial Uranium Reconnaissance Program, which is aimed at evaluating Canada's uranium supply. The Program employs airborne surveys and geochemical sampling and analysis to identify areas for potential development. Other research related to nuclear energy included development of a seismic risk model that will be valuable in determining suitable areas for the underground storage of nuclear waste.

The joint government-industry project to develop the Huntec Deep Tow High Resolution Seismic System was placed on a firm footing in 1976-77. When this project is completed, by 1981-82, Canadian industry will have the capability to perform continuous shallow seismic mapping of the ocean floor. The sophistication of the technology being developed will be important in delineating the structure of the shallow seabed and will greatly facilitate exploration for energy resources.

Government approval was obtained for the Department's participation in the SEASAT-A experiment soon to be launched by the U.S. National Aeronautics and Space Administration. The objective is to determine the applicability of satellite-borne microwave sensors to surveillance requirements. Although the experiment is not limited to offshore areas, it is expected that a successful demonstration will greatly increase Canada's capability to manage the 200-mile limit.

A significant by-product of the Sector's expertise in the earth sciences and resource technology is its contribution to interagency environmental programs. Having participated in the government's environmental studies relative to the northern pipeline and Beaufort Sea drilling decisions, the Sector is also undertaking geological and permafrost research along the Polar Gas and Alcan pipeline routes. The Sector is currently conducting coastal research and developing remote sensing technology to detect oil-in-ice as part of the Arctic Marine Oil Spill Program of Fisheries and Environment. The Department has the responsibility under the Federal Environmental Assessment and Review Process to implement environmental reviews of projects sponsored by the Department. The Science and Technology Sector contributes to this process by supplying technical reviews of Environmental Impact Statements for both the department and the Federal Environmental Assessment and Review Office as well as serving on and as technical witnesses to various Assessment Panels.

In addition to laboratory and field investigations, the Department supports research in universities through the Research Agreement Program. The purposes of the Program are threefold: to ensure a university research capability in subject areas where the Department has a research and development responsibility; to ensure that scientific and engineering manpower will be available to meet Canada's current and future needs; and to take advantage of university capability to augment and enrich departmental activities. Research is supported in universitites throughout Canada; and in 1976-77, 136 projects were funded for a total of approximately $1.1 million.

The management and dissemination of information are crucial in achieving benefits from data collected and knowledge generated. The Canada Centre for Geoscience Data is currently engaged in the development of an index of geoscience data produced by industry, provincial governments, and the federal government. When established, the system will facilitate access to information and will provide users with the titles of all documents available in a wide range of subject areas.

In 1976-77, the Science and Technology Sector expended approximately $96 million and employed a staff of about 3,000, of whom 900 were classified as professionals. Staff turnover at the professional level during the year was approximately 10% and at the support level, approximately 12%. These figures indicate general trends only; some areas of the Sector are experiencing difficulty in retaining creative personnel in the face of increasing opportunities and financial rewards in industry, particularly in those areas associated with exploration. The situation is exacerbated by the need to pursue new lines of research as new possibilities and requirements become apparent. The continuing expansion of the knowledge, coupled with the need for economy, is making it difficult for the Science and Technology Sector to sustain the level of expertise and scientific excellence for which it has been noted in the past. While the effects of the present situation cannot easily be quantified, the long term costs could be significant if we are not in a position to take advantage of new opportunities as they arise.

CONTENTS

SCIENCE AND TECHNOLOGY SECTOR OFFICERS

Assistant Deputy Minister
J.D. Keys, Ph.D.

Senior Advisor, Energy Technology
J.H. Walsh, B.Eng., M.Eng., Sc.D., Eng.

Coordinator, Departmental Environmental Matters
R.G. Skinner, Ph.D.

Director-General, Geological Survey of Canada
J.D. McLaren, M.A., Ph.D., F.R.S.C.

Director-General, Canada Centre for Mineral and Energy Technology
D.F. Coates, B.A., B.Eng., M.A., M.Eng., Ph.D.

Director-General, Earth Physics Branch
K. Whitham, M.A., Ph.D., F.R.S.C.

Director-General, Surveys and Mapping Branch
R.E. Moore, B.Sc., B.Eng. (Civil)

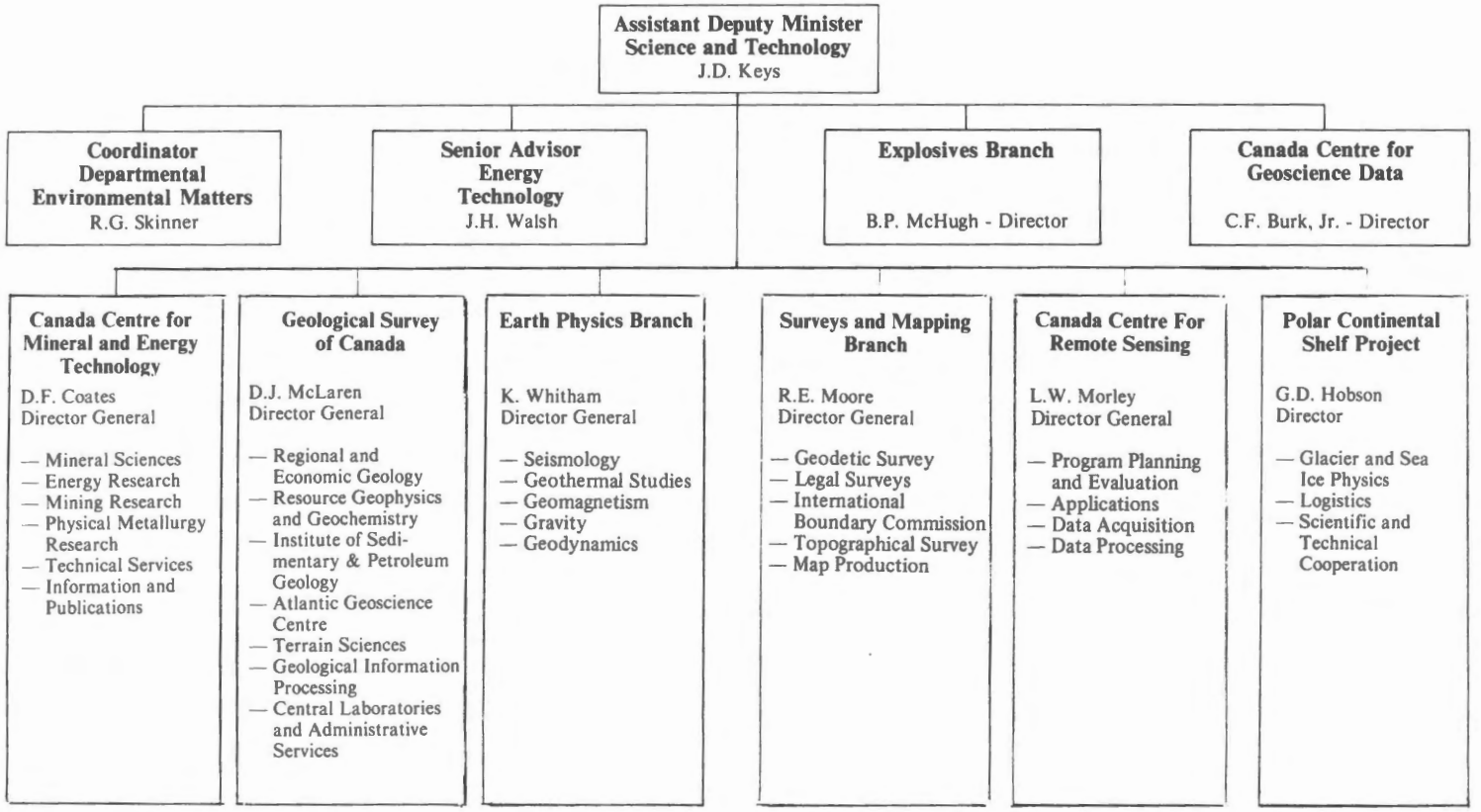
Director-General, Canada Centre for Remote Sensing
L.W. Morley, B.A., M.A., Ph.D., F.R.S.C.

Director, Polar Continental Shelf Project
G.D. Hobson, B.A., M.A.

Director, Explosives Branch
B.P. McHugh, B.Sc.

Divisional Director, Canada Centre for Geoscience Data
C.F. Burk, Jr., B.Sc., Ph.D.

Organization of the Science and Technology Sector



GEOLOGICAL SURVEY OF CANADA

D.J. MCLAREN, DIRECTOR-GENERAL

J.O. WHEELER, DEPUTY DIRECTOR-GENERAL

The Geological Survey of Canada has four principal missions or objectives:

To determine the potential of Canada's mineral and energy resources

To elucidate the geological framework of the country and thereby facilitate the discovery of needed resources

To investigate the capability of the landmass to withstand the pressures of resource development, urban growth, and disposal of waste

To provide the geoscientific information required in the conservation of Canada's natural environment

Towards the achievement of these objectives, the Branch conducts systematic surveys and regional studies and produces national compilations of geological data. Information is obtained on bedrock geology and on the evolution and nature of the Canadian landscape, including its surficial materials, terrain properties, processes, hazards, and capability for use. This information contributes to the knowledge base required for identifying and appraising Canada's mineral and fossil fuel resources, for evaluating the impact of resource development, and thus for formulating national policy on the use of resources and the maintenance of mineral and energy supplies.

Activities of the Geological Survey are carried out through seven divisions: the Atlantic Geoscience Centre, Central Laboratories and Administrative Services, Geological Information, the Institute of Sedimentary and Petroleum Geology, Regional and Economic Geology, Resource Geophysics and Geochemistry, and Terrain Sciences. Together these divisions make an important contribution to both the Mineral and Energy Resources and the Earth Sciences programs of the Department of Energy, Mines and Resources. The program emphasis within each division varies, however, according to the particular objectives of the organization.

In 1976-77, the Branch employed about 900 persons, of whom more than 300 were scientific staff. Four hundred and fifty-nine projects were initiated, continued, or completed, and half of these involved field work. The Branch had a budget of $29.7 million for the year, including nearly $6 million in funds allocated to contract work in the private sector.

During the year, the Geological Survey released a three-part, 1,200-page Report of Activities, comprising 221 individual reports on current scientific studies. In addition, 65 other reports were published, ranging from detailed treatises to 20-page papers on a variety of subjects. To meet the growing need of the general public for rapid access to information, 111 items were placed on Open File; and wherever possible, arrangements were made for copies of these items to be supplied on demand through commercial outlets.

ATLANTIC GEOSCIENCE CENTRE

B.D. Loncarevic, Director

The Atlantic Geoscience Centre was established in 1972 with responsibility for undertaking the geoscientific description and inventory of offshore and adjacent onshore regions of Eastern Canada. During the past five years, the Centre has developed an integrated research program to produce information on existing geological structures and the processes through which they have evolved. It has also participated in several international programs and numerous scientific meetings and workshops in marine geology and related fields.

To carry out the research program, the Centre is organized into four subdivisions: Eastern Petroleum Geology, Regional Reconnaissance, Environmental Marine Geology, and Program Support. All are based in the Centre's facilities at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia.

The Eastern Petroleum Geology Subdivision directs its main efforts towards the study of sedimentary basins in onshore and offshore areas of Eastern Canada, with a view to understanding their geological structure and history. Such work is important to the development of a data base for estimating the extent and accessibility of energy resources, particularly oil, gas, and coal.

The principal objective of the Regional Reconnaissance Subdivision is to trace the recent and ancient history of development of the continental margin of Eastern Canada. Emphasis is placed on studies of the transition zone between continent and ocean, evolution of adjacent oceanic areas, bedrock and surficial geology, and Arctic marine geology. Systematic geological and geophysical surveys are carried out for specific areas, and maps are produced based on survey data. Subsequently, the survey and mapping information is synthesized and analyzed, and additional studies of adjacent areas are performed, leading to regional interpretations of structural evolution.

A Benthos gravity corer in use in the Straits of Canso by staff of the Atlantic Geoscience Centre.

Considerable importance is attached to the development of new technology and methodology for improving the scope and efficiency of surveys.

The Environmental Marine Geology Subdivision conducts studies of contemporary and ancient sedimentary processes and environments in coastal and marine areas of Eastern Canada. The objective of the research is to improve the understanding of those physical, chemical, and biological processes that control the development and stability of marine geological features and resources. The work of the Subdivision is carried out by four scientific groups: Paleoecology, Organic Geochemistry, Inorganic Geochemistry, and Coastal Geodynamics. These groups perform independent studies and also collaborate on multi-disciplinary projects.

The Program Support Subdivision provides a broad range of services to facilitate the initiation, operation, and completion of the Centre's marine and field projects. In the early stages of planning, scientists are advised of the availability of personnel and equipment, and the capability of these resources to achieve desired scientific results; technical personnel are assigned; and equipment is assigned or acquired, designed, and modified as required. In some instances, liaison with other agencies must be established and maintained for the duration of the project. At later stages, equipment and supplies are transported to the project site and installed. During the operation, machinery, instruments, and other equipment are maintained; and sometimes special services are provided (such as seismic shooting and scuba diving). On termination of the project, all equipment must be disassembled, brought back from the site, refurbished, and repaired or replaced. In addition, data and samples must be properly curated, classified, and distributed to processing units for analysis.

The activities of the Atlantic Geoscience Centre contribute to the Department's two major programs: Mineral and Energy Resources, and Earth Sciences. In 1976-77, the professional staff of the Centre published 42 reports, articles, and scientific papers and produced more than 100 unpublished manuscripts. Specific projects carried out during the year are described in the pages that follow.

MINERAL AND ENERGY RESOURCES

The Centre's work in the energy field in 1976-77 was concentrated on the determination of oil and gas resources. Two scientists from

the Eastern Petroleum Geology Subdivision participate in the federal Interdepartmental Subcommittee on Geological Potential. During the past year, the Subcommittee initiated two studies related to energy resources: one aimed at determining the distribution of oil and gas pools in the sedimentary basins of Eastern Canada, and a second directed to the assessment of oil and gas potential of the Middle and Upper Devonian formations of northern Alberta and northeastern British Columbia. The data produced by the Eastern Canada study are being used in economic studies undertaken by the Energy Sector; those of the second study have become part of a comprehensive inventory of oil and gas resources in Western Canada.

Other studies of hydrocarbon potential also were carried out by the Centre. A special assessment of the Baffin Island Shelf was undertaken to provide data required for policy decisions by the Department of Indian Affairs and Northern Development. In addition, geochemical studies were begun with a view to determining the source rock potential and the degree of maturation of hydrocarbons in offshore sedimentary basins. Sixty-two wells have been examined and data collected on types of organic matter and determination of thermal indices, and a summary report has been published. Vitrinite reflectance measurements for four offshore wells also have been completed. The integration of data from these studies with data on gas resources will provide a more comprehensive interpretation of hydrocarbon rock source potential and a more accurate estimation of oil and gas resources in the offshore basins.

EARTH SCIENCES

Geological Service

Standards, Correlations and Processes

In 1976-77, 12 deep exploratory wells were added to the Centre's existing data bank, to bring the total to 50 wells. On the Labrador Shelf, biostratigraphic and paleoecologic investigations of Cretaceous-Tertiary sediments have progressed to a point where little significant increase in knowledge is expected unless more cores are taken during future drillings. Comparisons are now being made between Cretaceous palynology of the Labrador Shelf and that of Greenland. Also, with foreign collaboration, a program has been initiated to relate the foraminiferal assemblages in the dark Shelf shales of Late Cretaceous-Early Tertiary age to strikingly similar assemblages in other tectonically active continental margin graben with terrigenous sedimentation.

On the Scotian Shelf and the Grand Banks, detailed palynologic studies have provided the first firm evidence of the age of underlying Mesozoic salts in the North Atlantic sub-basin. A report on Mesozoic-Cenozoic zonations in the area is in the final stages of preparation. Participation in Legs 41 and 44 of the Deep Sea Drilling Project is continuing. Studies of microfossils found in the Mesozoic-Cenozoic sediments of the North Atlantic have advanced our understanding of the stratigraphy and paleoecology of the Canadian Atlantic margin; and examination of other core material is planned with the object of evaluating the distribution of Scotian Shelf-Grand Banks Cenozoic zone markers throughout the North Atlantic.

Studies of microfossils in cuttings and core samples from exploration wells on the Atlantic margin provide detailed well-to-well correlations and relate subsurface beds to the standard chronostratigraphy. Correlations with the linear time scale make it possible to determine rates of subsidence and sedimentation at well sites and in the basins in general. In addition, paleoecologic and biogeographic studies of core materials contribute to our knowledge of the environments in which subsurface strata were originally deposited and to the reconstruction of the opening of the Labrador Sea and the North Atlantic Ocean proper. Such analyses and reconstructions provide the basis for comparing local basins with Mesozoic-Cenozoic sedimentary basins that were once adjacent to the eastern Canadian margin and in which exploration for hydrocarbons is currently being undertaken.

Paleoenvironmental studies of Pleistocene and Holocene sediments from the shelf areas and coastal bays of Eastern Canada have continued. Basic sediment and faunal analysis has been completed for several areas, and the initial synthesis of paleo-oceanographic models has begun. Pollen and paleomagnetic analyses of cores from St. Georges Bay, Nova Scotia, have provided a chronostratigraphic framework for Holocene paleoecological studies by cross-correlation of different dating techniques for Upper Holocene events. The sedimentology and microfauna of 21 cores (323 subsamples) from the Labrador Shelf have been analyzed to provide a basis for the development of paleosedimentary models, and the relationship between paleo-oceanographic conditions and the geochemistry of methane-producing Holocene basins of the east coast has been investigated.

Trawl dredging in the Beaufort Sea.

Geoscience Surveys

Offshore Bedrock

A fully integrated bedrock mapping technique has been developed for use in offshore areas of Eastern Canada. The technique includes Huntec deep tow, side-scan sonar, and seismic profiling methods, combined with bathymetry, magnetic, and gravity data and information obtained from samples taken with the BIO electric drill. Maps and reports covering the Scotian Shelf, the northeast Newfoundland Shelf, and the south Labrador Shelf have been completed; data have been collected for the area south of Newfoundland; and surveys of the Grand Banks and the southeast Baffin Island Shelf are approximately 50% complete. This basic geological mapping makes it possible to define the extent of terrestrial geological provinces across the continental shelves, offers insights into the sedimentary development of continental margins, and provides a data base that can be used in the exploration for fossil fuel resources.

Multi-disciplinary Hydrographic-geophysical Surveys

In cooperation with the Department of Fisheries and the Environment, the Centre has prepared and published natural resource maps, based on bathymetry, gravity, magnetic and some seismic reflection data for the Gulf of St. Lawrence and the Grand Banks. In 1976, as part of a 20-mile spacing survey of the Labrador Sea, a 1-mile line survey of three-quarters of Saglek Bank was completed. In addition, gravity and magnetic maps for 12 natural resource map areas were completed and released during the year. Data for six additional areas are now being collected.

Hydrographic-geophysical surveys provide valuable data for use in commercial hydrocarbon exploration. They are also used extensively in regional analyses and syntheses carried out by the Centre.

Baffin Bay

As part of a major cruise to the Arctic in 1976, geological and geophysical data were collected on the continental margins of Baffin Bay and Davis Strait. These data will provide a basis for determining the geological structure of the Baffin Bay area – a frontier region in the search for hydrocarbons.

Regional Analyses and Syntheses

Scotian Shelf-Grand Banks

Data for six new wells on the Scotian Shelf have been correlated, and the lithology on several wells on the Grand Banks has been described. A section of Triassic evaporites has been identified, the first to be described on the North American margin. Interpretation of 4,750 miles of new confidential seismic data has led to the development of a preliminary structural and stratigraphic framework for the Georges Bank Basin, and the establishment of seismic correlations from the Scotian Shelf through the slope to the rise. This work will show the relationship of the Mesozoic-Cenozoic horizons on the Scotian Shelf to those in the oceanic areas, and it will also add to the data base for hydrocarbon inventory.

Deep-sea Drilling

Data from the Deep Sea Drilling Project are being synthesized to add to our knowledge of the North Atlantic basin. Eventually information about deep-sea Mesozoic-Cenozoic units will be correlated with data on the shelf formations to provide a regional interpretation of geological structures.

Labrador Shelf-Baffin Bay

Samples from nine wells on the Labrador Shelf have facilitated the analysis of geophysical data and the definition of plays and prospects for the appraisal of oil and gas resources. In addition, the first round of structure maps has been completed for the Davis Strait area, based on tens of thousands of miles of seismic data. This analysis has produced a preliminary inventory of oil and gas potential in Davis Strait and Baffin Bay. Also during 1976, a one-month field study was undertaken in the Nugssuaq Embayment of central West Greenland, the site of a delta of Cretaceous to Paleocene age.

Paleozoic Basins

In the Maritime Provinces, a synthesis has been completed of Lower Paleozoic geology, with emphasis on the Appalachian belt. The study provides a basis for interpreting the plate tectonic evolution of the region and relating early tectonic history to successor basin development.

During the past year, a report on the Upper Paleozoic evaporite basins of Eastern Canada was completed. The research was part of a Canada-wide evaporite study, undertaken at the request of Atomic Energy of Canada Limited. The report identified a number of areas in New Brunswick, Nova Scotia, and western Newfoundland that may be suitable for long-term storage of nuclear waste. A more detailed study of these individual deposits is now under way.

North Atlantic Plate Tectonics

A continent-ocean structural section has been deduced for western Baffin Bay to complement similar sections obtained for the Scotian Shelf, the Grand Banks, and the Labrador Sea. On the basis of these sections, and using magnetic lineations mapped throughout the area, it has been possible to calculate the time of opening of the Labrador Sea and of the Atlantic north of Flemish Cap.

Magnetic and seismic data for the Newfoundland Basin have so far proved incapable of deciphering the development of this region during the early opening of the North Atlantic, principally because similar data for the Eastern Atlantic are not available. The problematic behaviour of this area, the vertical tectonics of the deep-water continental shelf northeast of Newfoundland, and the indeterminate interpretation of seismic refraction results on the Labrador margin have raised questions as to the possible extent of continental material beyond the shelf break. Benchmark geophysical information on the nature of oceanic crust has been obtained from a crustal refraction profile at Site 12 of the International Project of Ocean Drilling in the North Atlantic.

Continental Margins

Seismic reflection and refraction data on the continental margin of Eastern Canada have been interpreted as indicating a narrow continent-ocean transition zone within which the lower crustal units are disturbed. The physiography of the continental margin has been progressively modified by sedimentary processes; consequently, existing structures may not accurately reflect the initial geometry of the North Atlantic margins. Structures of the Canadian Appalachians have been mapped to the continental margin northeast of Newfoundland, and comparisons are being made with structures observed at the west European margin. Such comparisons are valuable in extending our knowledge of the development of local geological zones.

Organic Compounds and Carbons

Organic geochemical investigations of samples obtained from offshore hydrocarbon exploration wells continued in 1976-77. Data from 24 wells have been analyzed in detail to determine the qualitative and quantitative distribution of hydrocarbons, other organic compounds, and organic carbon. Six comprehensive geochemical reports have been prepared which deal with several wells drilled in frontier areas of exploration on the east coast. They consist of analytical data on organic carbon, gaseous hydrocarbons, bitumens, heavy hydrocarbons, non-hydrocarbons, carbon isotopic composition, elemental analysis of kerogen, and pattern of distribution of n-alkanes. Interpretations and information are also given on the type and richness of the source rock, diagenesis and maturation of organic matter, quality and concentrations of hyrocarbons, and rating of source rocks. These reports, which are classified as confidential at this time, will be useful in developing an inventory of oil and gas resources in Eastern Canada.

Support Services

Interpretation Methods

Inversion techniques have been developed for the interpretation of gravity and magnetic data, for use in determining density differences in the mantle across the ocean-continent boundary and in building models of the origin

of oceanic magnetic lineations. An interactive graphics approach to classical modelling methods also has been developed. Such techniques allow for increased accuracy and efficiency in the use of potential field data for the determination of crustal structure.

Huntec Seabed Project

For the past three years, the Centre has participated in a joint project with Huntec '70 Ltd., a private research company. The purpose of the project is to analyze the physical properties of marine sediments through the measurement of acoustic signatures effected from such sediments. Work on the project in 1976-77 was impeded by reduced funding. Thus, although data were collected for the Labrador Sea and Arctic, complete analyses were not carried out. Progress was, however, made towards the identification of sonogram characteristics that correlate with lithologic and other properties of geological units. Successful completion of the project will result in a survey tool which will be capable of remote determination of the properties of geological units, and will thereby greatly increase the efficiency of geoscience surveys.

Data Processing Systems

To facilitate geophysical data processing, preliminary shipboard data reduction and curation services have been provided in the field, permitting the immediate use of such data by project scientists. This approach contributes to the efficient design of surveys and studies, and provides effective quality control during the data collection process. All the geophysical data collected during 1976-77 have been final-processed and entered into the digital data base (Geofile), from which they can be easily retrieved for scientific interpretation.

In the past, the Centre has used the Computing Services facilities of the Bedford Institue of Oceanography, but these facilities will eventually be replaced. Accordingly, in 1976-77, the Centre participated in the design of a new data system (Geofrey), which will increase the efficiency of information retrieval and permit more versatile use of scientific data. Design work has also been carried out on the shipboard geophysical data processing system.

During the past year, 10 Geological Survey Open Files were prepared and issued by staff of the Centre. Some older data records have been entered into the Public Archives Record Centre for permanent safe storage, freeing space for new data, and a composite index of all data submitted to the Archives has been compiled to facilitate easy retrieval.

Through the Centre's geological data management services, about 38% of geological samples collected over the past 14 years have been catalogued for retrieval and use in future studies. In 1976-77, the curation staff responded to 53 requests for services by scientists of the Centre and 13 requests from other agencies, performing tasks ranging from the retrieval of sample material to extensive sample splitting, describing, and photographic logging of core materials.

During the year, the geological sample information was computerized, providing for storage and retrieval of information on 1,431 samples. In addition, the first of a standard in-house suite of maps was produced, showing the type, location, and density of distribution of samples in the file. The maps will contribute to the efficient planning of sampling projects and the completion of offshore mineral inventories.

Work on the establishment of analytical geological data files has produced software for handling palynology data from offshore wells, taxonomic and geological data from piston cores, and sediment size analysis data of all surficial samples. It is now possible to store such data in forms that are amenable to use for graphic, statistical, and modelling purposes. In addition, the data from 1,326 sediment size analyses performed during the year have been consolidated in a computer file to assist scientific staff in carrying out interpretations.

New Instrument Development

Ocean-bottom seismometers are capable of recording seismic events of a far lower level than those that can be detected by surface sonobuoys. They are sensitive to natural seismicity and can detect shearwaves; they are stable and therefore more accurate than surface instruments; and they provide good performance under poor weather conditions. Ocean-bottom seismometers have been used in Geological Survey work on the west coast. Throughout 1976, they have been tested, modified, and improved at the Atlantic Geoscience Centre, and four units are being assembled for use later in 1977.

Techniques and instrumentation for recording and playing back side-scan sonar data have been developed, resulting in a 50% increase in the range of usable data on surficial geology mapping projects. In addition,

modifications have been made to expendable sonobuoy instrumentation, greatly improving the quality of data collected. Techniques for towing seismic reflection instrumentation also have been improved, so that a larger survey area can be covered more rapidly than was previously possible.

Technical Support in the Field

Technical support has been provided for the acquisition of supplies, installation of instrumentation, operation and maintenance of equipment at sea, removal of instrumentation, and refurbishing of equipment for two major shipboard projects covering the complete range of modern marine geophysical and geological measuring and sampling techniques. The routine instrument maintenance service required both at sea and in the laboratory has been efficiently supplemented by contract support, to the limit of available funds. The provision of an integrated and versatile technical support capability has relieved project scientists of a significant burden of administrative responsibility, increasing the time available to them for carrying out interpretations and preparing maps and reports.

Terrain Evaluation Service

Sedimentary and Geomorphic Processes

Multi-disciplinary Study of the Miramichi Estuary, New Brunswick

Three comprehensive field monitoring surveys were carried out in the estuary bay, in May and September 1976 and in February 1977, to determine the effect of seasonal variations in hydrologic, ecological, and hydrodynamic conditions on sediment transport and geochemical and ecological stability. In situ measurements were conducted for salinity, current speed and direction, visible light attenuance as specific wavelength, and dissolved oxygen. Water samples were collected for analysis of labile and total concentrations of manganese, iron, zinc, copper, lead, cadmium, and aluminum, and of total concentrations of mercury, suspended particulate matter, dissolved oxygen, and particulate organic carbon. In May, four river stations were monitored over an eight-day period; in September, four river stations were monitored for four days, and thirteen stations throughout the estuary were sampled; in February, two river stations and five innerbay stations were monitored over an eight-day period. Laboratory experiments have been conducted to develop conversion factors for specific wavelength attenuance measurements, to provide semi-quantitative data on suspended particulate matter and qualitative data on dissolved organic matter. Laboratory analysis and data reduction are nearing completion, and a model is being developed to explain seasonal and tidal variations in the dissolved and suspended aqueous phases. The analysis will include the chemical mass balancing of the trace metal constituents and the distribution and transport of suspended particulate matter.

Geochemical analyses of the sediments of the Miramichi estuary and bay indicate the sources and transport mechanisms of environmentally sensitive trace metals and the depth to which the bottom sediments are in communication with the overlying sea water. A laboratory study of the mechanisms for the removal of trace metals by reaction with suspended sediments and through coprecipitation with dissolved species indicates that there may be rapid removal of certain metals from the water column. Paleoecological studies relating to contemporary sedimentary processes have been undertaken in the Miramichi embayment and also in St. Georges Bay, Nova Scotia, where analyses of molluscs and foraminifera allow environmentally sensitive areas to be identified. A series of in situ experiments has measured the mobility of foraminifera populations, and laboratory tank experiments have identified active species that could be expected to colonize sterile substrata following storms or dredging operations. The distribution of surficial sediments in the estuary has been mapped, and five major sedimentary environments have been recognized: river channel, inner bay, tidal-delta complex, coastal barrier, and outer bay. Variations in the distribution of textural types correspond closely to the various depositional environments.

The results of the study, together with those of the earlier Strait of Canso study, provide an integrated approach to developing quantitative models of estuarine dynamics, which may be applied to other bays and estuaries of the Atlantic coast. The definition, measurement, and analysis of significant physical, chemical, and biological parameters provide an excellent tool for environmental assessments.

Sediment Dynamics of the Minas Basin, Bay of Fundy

The aim of the study is to explain and predict sediment transport patterns and sedimentation rates within a highly dynamic, macro-tidal environment. The analysis has been organized according to the sediment budget concept, and quantitative data have been obtained, by a

variety of techniques, on the sources, fluxes, and sinks of sediment in the basin. Cliffline recession is the main source of new sediment entering the basin. Measurements of the bedload transport of the sand fraction in the intertidal zone along the north shore indicate that there is a net transport eastwards towards the head of the bay. Two new techniques have been employed successfully in the study: the use of satellite imagery (LANDSAT) to determine suspended sediment concentrations and the use of a radioactive tracer to determine sediment transport rates in the intertidal zone. The tracer experiment, which took place in October-November 1976, was the first documented use of the technique in Canada. Sedimentation resulting from existing man-made structures has been documented, and a new map of the surficial sediments of the basin has been prepared.

Knowledge of contemporary sedimentation processes is a basic requirement for planning both the construction and the operation of the proposed tidal power barrages in the Bay of Fundy. The Minas Basin study is providing this information for part of the system.

Beach and Nearshore Sediment Dynamics

An analysis of channel and shoal morphology, bedforms, and sediments at the entrance to the Miramichi estuary of New Brunswick has demonstrated the control of tidal inlet processes over sedimentation patterns. The effect of storms on the nearshore morphology of adjacent barrier islands also has been documented. Regular surveys throughout the year in a different environment, at Martinique Beach, Nova Scotia, provide a basis for assessing seasonal changes and the long-term stability of open ocean beaches.

These studies provide basic data for a variety of engineering and environmental assessments, such as port and harbour construction, ocean dumping and channel maintenance, sand and gravel resources, and oil spill clean-up strategies. They are part of a continuing series of investigations aimed at characterizing the Atlantic coastline of Canada.

Surficial Surveys

Surveys of surficial sediments on the continental shelf have been completed for the Gulf of Maine, the Bay of Fundy, and portions of the Scotian Shelf and the Labrador Shelf, using seismic profiling, side-scan sonar, and Huntec deep tow equipment, and the "ground truth" provided by cores and grab samples. Maps and reports covering these areas are published or in press. Activities in 1976 were concentrated on the Grand Banks, Saglek Bank, and the Baffin Shelf, with increased dependency on the Huntec deep tow technique for determination of sediment type.

The results of these surveys contribute directly to engineering studies in support of energy development and to evaluations of the mineral potential of the seafloor. Published maps also are used heavily by fishermen to determine the probable location of the fish stocks.

Regional Analyses and Syntheses

The glacial history and paleo-oceanography of the Labrador Sea and Banks are being investigated through surficial surveys of Hamilton Bank and Saglek Bank, and from regional sampling throughout the area. Hamilton Bank was covered by grounded Wisconsinan ice sheet, and its glacial features were subsequently modified, reflecting changes in the circulation of the Labrador Sea. In contrast, the surface of Saglek Bank shows much modification by iceberg gouges.

The feasibility of future hydrocarbon exploration and production on the Labrador Shelf is highly dependent upon knowledge of the vertical and horizontal distribution of surficial sediments and their modifications through time. In the past, exploration wells have been abandoned because of problems encountered in drilling through surficial material. Within the constraints of the model, such problems should be minimized by the results of surficial surveys and analyses.

Support Services

The support services provided to terrain evaluation projects are essentially the same as those described for geological research. Many new techniques have been developed and older standard techniques and equipment modified in order to provide field support in the Minas Basin and Miramichi estuary areas. A new low-frequency, high-resolution seismic profiling system has been acquired and used in conjunction with a new small-boat side-scan sonar system, producing valuable information on the quantities and morphology of surficial sediments.

The use of all-terrain vehicles and snowmobiles for touring tents mounted on sleds has increased the mobility of field parties carrying out sampling and monitoring experiments during the winter months, and also has expanded the scope of such experiments. The Centre has developed a new technique of vibrocoring through holes in the ice over water

Portable drilling apparatus mounted on a modified all-terrain vehicle (ATV), specifically designed by Terrain Sciences personnel for gathering geotechnical information on unconsolidated deposits in the Arctic.

less than 15 m deep. The method allows efficient and fast acquisition of surficial cores that are 10 cm in diameter and up to 3 m long, using standard inexpensive components. It is now possible to obtain samples readily and economically in areas where extraction has previously been difficult and expensive.

The logistics of nearshore field operations have been improved by the use of containerized laboratories and standard freight containers for shipping equipment and supplies and for storing them on site. The technique has reduced the chance of loss and damage of supplies and instruments in servicing nearshore projects.

Many new techniques and types of equipment have been developed for safely handling and transporting radioactive isotopes. These techniques and instruments were used successfully in October 1976 for the study of sediment transport patterns in the Minas Basin.

In 1976-77, approximately 90% of the planned projects in terrain evaluation were successfully completed. Malfunctioning equipment and similar problems accounted for the 10% shortfall.

Support to Other Agencies

In 1976-77, the Atlantic Geoscience Centre continued to participate in a survey of the continental margin of the coast of Senegal and the Gambia. The project is funded by the Canadian International Development Agency (CIDA), and the leading participant is the Canadian Hydrographic Service of the Department of Fisheries and the Environment. Following completion of the survey early in 1976, gravity and magnetic maps were compiled and interpretations made, based on the maps and on seismic reflection profiles. A summary report is being prepared for submission through CIDA.

This undertaking will provide basic geoscience data to countries that would otherwise be unable to obtain them. Equally important, it has demonstrated the requirements of such countries for scientific information and the problems involved in effectively transferring expertise and knowledge to them.

CENTRAL LABORATORIES AND ADMINISTRATIVE SERVICES DIVISION

J.A. Maxwell, Director

The many and varied scientific activities of the Geological Survey of Canada require a range of support services to facilitate the attainment of scientific objectives. These services include scientific and technical support, as well as assistance in the areas of administration, finance, and personnel. The Central Laboratories and Administrative Services Division is responsible for providing such support to other divisions of the Geological Survey Branch.

The greatest demand for support services is generated by the Ottawa-based divisions, but some scientific and technical support and more extensive financial and administrative services are required by Branch units in Dartmouth, Calgary, and Vancouver. The Division also provides services to the Canadian public, related to the field of mineralogy.

To carry out the support function, Central Laboratories and Administrative Services is organized into five sections: Analytical Chemistry, Mineralogy, Technical Services, Branch Administrative Services, and Branch Financial Services.

The Analytical Chemistry Section, through its chemical and instrumental laboratories (using optical emission, x-ray fluorescence, and atomic absorption techniques), provides compositional data on rocks and minerals submitted by Branch scientists. It also functions as a national and international centre for the development of methods and techniques, and for the study and compilation of data on reference samples of geological materials.

The scientists, support staff, and laboratories of the Mineralogy Section provide

the Branch with the facilities and expertise to pursue mineralogical studies, undertaking sample preparation and mineral separation, as well as work in the specialized fields of crystallography, x-ray diffraction, and electron microbeam analysis. The Reference Series of the National Mineral Collection is developed and maintained as an active working reference collection, and the Section is also responsible for curation of the National Meteorite Collection and the Geological Survey of Canada Reference Rock Collection. Mineralogical services to the public include specimen identification (for which no charge is made); the preparation of mineral guidebooks, for use by mineral collectors and also by tourists; and the preparation and sale of sets of rocks and minerals.

The Technical Services Section is responsible for the provision of mechanical and electronic engineering support and maintenance services for Branch projects, including the design and fabrication of new equipment for both field and laboratory operations, and the servicing of existing equipment. The Section also recommends and supervises the contracting out of work as required.

Two sections, the Branch Administrative Services and Branch Financial Services, together with the Branch Personnel Unit, carry out the increasingly complex business of meeting Branch needs for accounting services; accommodation, secretarial, messenger, and registry services; inventory maintenance; vehicle supply; purchasing and stores, financial control and information; safety and security; pay; and personnel management functions, such as classification, recruitment, and promotion.

The activities of the Division are directed towards the Department's Earth Sciences Program. Subactivities include work on geological standards, correlations, and processes, and a variety of other support services. Although for Branch reporting purposes, these subactivities are described separately, here they overlap within the Division's broad operating framework.

GEOLOGICAL STANDARDS, CORRELATIONS, AND PROCESSES

Geological services related to standards, correlations, and processes, provide indirect support to scientific activities carried out by other divisions. In 1976-77, the Division continued to expand established mineralogical collections and to improve the techniques used in geological analysis.

The Reference Series of the National Mineral Collection is a valuable research tool for mineralogical studies and geoscience research. In the past year, there was an increase of 3% in both the number of specimens added (295) and the number of species acquired that were previously not represented (56). Field collections of rare and unusual minerals were made at 18 localities in Ontario and Quebec, including acquisition of eudialyte and agrellite samples from the syenitic complex near Kipawa, Quebec. In addition, mineralogical studies were undertaken in support of the Uranium Reconnaissance Program over a six-week period, and research studies of lanthanite and of a silicocarbonatite sill at the Francon quarry in Montreal were completed. In response to 77 requests for mineral specimens for research, 253 specimens were provided from the Collection.

In 1976-77, the Division began to computerize cataloguing of the Collection as part of the national inventory program of the National Museums of Canada, and data were tabulated on approximately 200 specimens. Two hundred and ninety-eight mineral and rock specimens were identified for the public through 51 written and 53 verbal reports, and about two weeks were devoted to providing consultative services outside the Branch, including advice on mineralogical aspects of Bill C-33.

Work continued on the compilation of data for Supplement 2 of the Catalogue of Canadian Minerals, and about 900 entries are now on file. The Supplement is expected to be published in 1978.

Two new Canadian meteorites and 12 specimens from other countries were added to the National Mineral Collection. The Canadian additions were the Blaine Lake, Saskatchewan, chondrite and the very recent (February 1977) fall in Innisfree, Alberta. The latter has the distinction of being the third meteorite in the world whose orbit is known as a result of photographic observation, its fall east of Edmonton having been observed by the MORP photographic network of the National Research Council. Twelve suspected meteorites submitted by the public were studied and found to be of terrestrial origin.

In 1976-77, x-ray fluorescence techniques were refined, and the range of sample composition that can be handled by this analytical system was extended. Progress was made in the development of improved methods for determining carbon dioxide and water (by non-dispersive infra-red absorptiometry),

fluorine (by a selective-ion electrode), individual rare earth elements (mainly by atomic absorption spectroscopy), and uranium (by fluorimetry). Further refinements, mainly designed to minimize unexpected interference effects, were also introduced into the automated optical emission direct-reading spectrographic system. In addition, a start was made on the establishment of new, more versatile, and more sensitive methods for the determination of "volatile" trace elements and the semi-quantitative analysis of various geological materials. Both systems are based on photographic optical emission spectrographic analyses, and current procedures do not meet the increasing needs of geologists for these kinds of data.

Based on results reported from more than 60 different laboratories in 21 countries, a second report was issued on the composition of three proposed international reference samples — specifically, two syenites from Bancroft, Ontario, and a gabbro from Mount Royal, Montreal, Quebec. Recommended values of varying degrees of reliability were assigned for the concentrations of 15 major and minor constituents and 35 "trace" elements in these samples. Our own laboratories provided compositional data for reference samples originating in Canada, the United States, the United Kingdom, France, Scandinavia, East Germany, and the U.S.S.R.

DIRECT GEOLOGICAL SUPPORT SERVICES

Direct support activities of the Division laboratories and other units include the provision of compositional data by chemical, x-ray fluorescence, emission spectrographic, x-ray diffraction, and electron microbeam methods; sample preparation and mineral separation; the manufacture and sale of sets of rocks and minerals, the preparation of guidebooks on Canadian mineral localities, and the provision of mineralogical information to the public; and assistance with the administrative, financial, and personnel operations of the Branch.

Some aspects of the scientific and technical output of the Division for 1976-77 are presented in Table 1. The increased use of automated analytical systems, such as the x-ray fluorescence spectrometer and the direct-reading emission spectrometer, resulted in a 17% increase in the number of samples completed and a 22% increase in the number of determinations made over those reported for 1975-76. Valuable exchanges of information took place with visitors from six provincial and federal organizations, two Canadian universities, and nine foreign countries; and information on equipment, methods, and reference samples was supplied in response to eight requests.

Selected Productivity Data, 1976-77

Compositional analyses completed	6,591	X-ray diffraction analyses made	3,992
Chemical, x-ray fluorescence, and spectrographic determinations made	161,139	Diffractometer patterns prepared for clay mineral analysis	885
Mineral concentrates prepared	382	Electron microbeam support studies made (in hours)	2,394
		Sets of rocks and minerals prepared and distributed	5,885

Mineralogical research completed or in progress during 1976-77 included studies on new hydrated calcium-uranium phosphate and hydrated ferrous-ferric phosphate minerals, on the strontium-analogue of dresserite and a hydrated sodium zirconate mineral from the Francon quarry, Montreal, and on a new hydrated calcium-yttrium carbonate from the Evans-Lou mine, Quebec. Optical microscope examinations and x-ray diffractometer analyses were completed on 174 samples in direct support of the radiometric age determination program of the Geological Survey of Canada, and 67 new entries were added to the reference file of standard x-ray powder patterns.

The establishement of the scanning electron microscope laboratory was a significant accomplishment during the year. This development will materially enhance the scope of services now provided by the electron microprobe laboratory. After careful detailed examination of five different instruments, including visits to the manufacturers to conduct tests, the ETEC Corporation Autoscan SEM, with added energy and wavelength dispersive x-ray spectrometer systems, was selected for purchase. The instrument was delivered in mid-February, and installation and testing for acceptance were continued for the balance of the fiscal year. Highlights of the analytical work carried out by the electron microprobe laboratory included completion of a comprehensive study of basalts from Leg 37 of the Deep Sea Drilling Project, support for nine projects

associated with the Uranium Reconnaissance Program, studies of copper-sulphur-selenium minerals and of metamorphic assemblages in granulites and pelitic schists, and the analysis of chromium-micas and associated minerals and their relationship to gold deposits.

Field investigations of mineral occurrences in the Bay of Fundy area were completed, and a guidebook will be prepared. Guidebooks for the use of mineral collectors and the general public are in preparation for Bancroft, Ontario, and for the area from Sudbury, Ontario, to Winnipeg, Manitoba. Replies were provided to 133 requests from the public for mineral information.

In support of Branch projects, 2,731 samples were prepared for subsequent study, including 5,081 heavy liquid and 3,633 other separations to provide the 382 mineral concentrates listed in Table 1. In addition, more that 26 tons of minerals, rocks, ores, and fossils were collected from 71 localities in British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, and Quebec, for the preparation of Prospector's Sets of Rock and Mineral Chips, Raw Materials of the Canadian Mineral Industry sets, and collections supplied to the National Film Board.

During the past year, the Electronic Services and Development Section was combined with the Instrument Development Shop to form the Technical Services Section. Despite expansion and reorganization of space and facilities for the Shop, the demand for support of Branch projects continued to exceed production capacity, and a sizable backlog of work was carried into 1977-78. The 116 requisitions for services received by the Section included requests for the design and fabrication of a 10 in. radius mass spectrometer tube and supporting frame, the inspection and repair of sampling drills, the fabrication of grab samplers, and the design and fabrication of a new system to be integrated with a direct-reading spectrograph. In 1976-77, there was also a significant increase in emergency requests for routine assistance, which are received daily.

GEOLOGICAL INFORMATION DIVISION

P. Harker, Director

The Geological Information Division provides support to all divisions of the Geological Survey of Canada, by maintaining capabilities and physical facilities related to scientific editing and information services, cartography, library services, technical photography, and the distribution of publications.

The Division manages a comprehensive scientific publication program and issues Geological Survey reports as Memoirs, Bulletins, Economic Geology Reports, Miscellaneous Reports and Papers. All are well-established serials with a substantial publication record and are widely sold and distributed through exhange arrangements with numerous institutions in Canada and abroad.

In 1976-77, 66 printed reports were published, many of them extensively illustrated with photographs, figures and maps produced in the Division. The Report of Activities was again issued, in three volumes totalling just over 1,200 pages. This publication provides an important outlet for short summary reports of current research. The introduction of a computerized word processing system that uses magnetic tape has simplified production, proofreading, correction, and layout procedures for the publication of Survey reports; it has also enhanced the appearance of the reports by providing for justified margins and the use of a wide range of type styles for headings and captions.

Open File releases continue to provide an important supplement to conventional publications. Such files are made available for viewing at the offices of the Survey; and through the cooperation of the Minister of National Resources, Ontario, some files have also been released in Toronto as a service to the mining community. In 1976-77, a record number of 111 Open File releases was made, involving the preparation of 294 maps.

A significant number of research findings produced by Geological Survey staff are published in scientific journals. Each year the Division prepares a volume of abstracts of these papers and issues it in the Geological Survey Paper Series.

The Division includes a Geological Cartography Section which prepares manuscript material for printing as multi-coloured geological maps and single-colour preliminary maps, and also produces line graphics to illustrate geological publications. During the year, 28 new geological maps were issued, most of them printed in colour; and 15 existing maps were reprinted, all requiring some cartographic preparation. In addition, 67 aeromagnetic maps were prepared by outside contractors.

The Photomechanical Unit of the Cartography Section prepares base maps on which field officers plot and compile their data. Further advances have been made in computer-assisted cartography for map production. Pro-

gress has, however, been hindered by downtime in the system and by the reorganization of the computer program at Surveys and Mapping Branch, which controls the final automated plotting and scribing. A display illustrating computer-assisted cartography, including colour proofs of final maps, was prepared for the 25th International Geological Congress, held in Sydney, Australia, in August 1976, where it attracted considerable interest.

A monthly information circular is produced by the Division and mailed as a free service to several thousand addresses in Canada, in the United States, and overseas. The circular announces all publications and Open Files released during the month, as well as items of immediate economic significance to users in government and industry, which may have a specified time and date of release.

All maps and reports are issued through the Publications Distributions Section. In 1976-77, the Section distributed more than 200,000 items; it also handled many thousands of requests for publications and for information on publications. Sales facilities for geological maps and reports are maintained at the Survey's offices in Calgary and Vancouver, and both outlets report a high volume of business. As well as providing a useful distribution service, these offices perform a valuable role in directly representing the activities of the Department and the Branch to a large clientele that is geographically distant from head office.

The Geological Survey Library has a large and nationally important collection of books and periodicals on geology and related sciences, occupying more than two miles of shelving and comprising about 150,000 volumes, microfilms, and maps. In addition to the main Library in Ottawa, branch libraries are maintained in Dartmouth, Calgary, and Vancouver. The Library provides an essential support service to Branch staff and also serves the research needs of the scientific community at large, by making interlibrary loans and offering bibliographic services to researchers outside the Department.

Retrospective bibliographic services are offered on demand, on a partial cost-recovery basis, by means of bibliographic files in CAN/OLE and files available in Canada through INFOMART, mainly GEO.REF. A computerized information dissemination service, CAN/SDI, provides monthly bibliographic references, according to the user's scientific interest profile. Services are offered in collaboration with the National Research Council's Institute for Scientific and Technical Information, and users pay for them by annual subscription. Although the volume of service has remained constant in recent years, a number of subscriptions have been cancelled, possibly reflecting a general tightening of budgets for institutional research. There has, however, been a steady growth in the number of retrospective searches carried out from year to year.

In 1975-76, the Department's Management Consulting Service Division carried out a study of library operations. Several of the consultants' proposals for reorganizations have been implemented, but major physical changes related to layout and office arrangements still await the completion of work by the Department of Public Works. To relieve congestion on the main floor of the Library, stacks have been installed in a large basement area occupied by the map library and non-current and seldom-used material is being transferred into this area. The basement has also been modified to incorporate the Rare Book Room and central technical files. With respect to management of the Library, a policy committee has been established, chaired by the Director of the Division and including representatives from various scientific disciplines. The role of the committee is to provide guidance to the Branch and to library staff in managing library services.

The Geological Information Division serves the general public by providing geoscience information on a wide variety of topics in response to requests received by telephone and by mail. Frequently, staff of the Division are the first point of contact between the Department and the enquiring public.

As a service organization, the Division is concerned primarily with the preparation and release of results of scientific research carried out by the Branch. Necessarily, the productivity of the Division is directly related to that of the research divisions. Throughout 1976-77, a high level of productivity was maintained, and there was no significant backlog of manuscripts awaiting processing for publication at the end of the fiscal year.

INSTITUTE OF SEDIMENTARY AND PETROLEUM GEOLOGY

D.F. Stott, Director

The Institute of Sedimentary and Petroleum Geology provides comprehensive, up-to-date information on the sedimentary basins of Western and Arctic Canada. Its area of responsibility extends from the Canadian Shield to the Rocky Mountain Trench and from the 49th Parallel

A geologist carrying out field investigations in Yoho National Park, British Columbia, uses a fallen tree to ford the swollen Ice River.

(the Canada – United States border) to the Arctic Archipelago. One of the principal responsibilities of the division is the study of bedrock geology of this vast area, which contains most of Canada's known reserves of oil, natural gas, and coal. Other responsibilities on a national scale, include the geological appraisal of potential resources of petroleum, natural gas, and coal. Results of research at the Institute are published as geological maps and descriptive reports, which contribute directly to explorations for hydrocarbons, coal, and other minerals, as well as to basic research. Information provided by the division is used in planning the long-term employment of energy and other mineral resources, evaluating the adequacy of those resources, and stimulating resource industries to achieve desired levels of production.

The Institute, which is located in Calgary, Alberta, is organized into six subdivisions: Regional Geology, Paleontology, Energy, Coal Geology, Geological Information, and Administration. The following paragraphs summarize the aims and responsibilites of all but the last of these.

The work of the Regional Geology Subdivision is aimed at increasing our understanding of the nature, origin, and history of Proterozoic and Phanerozoic sedimentary rocks of Western and Arctic Canada. Research carried out by the Subdivision provides the necessary data base for appraising the potentialities of these sedimentary suites, both as reservoirs for and sources of oil and gas, and as hosts for other mineral deposits, including coal, potash, lead, zinc and copper.

The Subdivision is organized into four sections, three defined by similar geographic characteristics and one with a service orientation:

The Sverdrup-Mackenzie Section is responsible for carrying out surface and subsurface geological research on Upper Paleozoic, Mesozoic, and Cenozoic rocks in the Sverdrup Basin (Arctic Archipelago) and the Beaufort-Mackenzie region of the northern mainland and adjacent offshore area.

The Arctic Islands Section undertakes geological studies of some sedimentary areas of the Arctic Islands, particularly the Paleozoic rocks of the Parry Island Fold Belt and the Franklinian Geosyncline and adjacent shelf.

The Mainland Section is concerned with the geology of the Yukon and mainland Northwest Territories exclusive of the Mackenzie Delta, and of the more southerly sedimentary regions lying within British Columbia, Alberta, Saskatchewan, and Manitoba.

The Curation and Technical Services unit provides support for the entire division with respect to the curation of field lithologic (rock), paleontologic (fossil) and coal samples. It also monitors and effects

Geologists working in the High Arctic clear soft snow to enable the pilot who has brought them supplies to make a safe take-off.

the loan of curated materials to the public, as directed by the responsible scientific authorities. Technical services relate mainly to the preparation of rock sections for microscopic examination.

The Institute is the repository for cutting samples, cores, and other data resulting from both onshore and offshore exploration drilling by industry in Yukon Territory and the Northwest Territories, including the Arctic Islands, and for samples from all provinces and continental shelves of Western Canada. About nine million samples are stored at the Institute, and this number increases by about 300,000 each year. With the exception of samples from wells in Alberta, all are available to the public for free examination. Files are maintained of all the logs and other data related to more than 60,000 wells drilled in Western and Arctic Canada.

The Paleontology Subdivision is responsible for scientific studies in paleontology and biostratigraphy is support of exploration for and assessment of the non-renewable resources of Western and Northern Canada. Research is closely coordinated with the work of other subdivisions of the Institute, with similar activities undertaken by the Atlantic Geoscience Centre and the Regional and Economic Geology Division, and with programs of a number of universities in Canada, the United States, France, and the United Kingdom. A substantial and increasing portion of the Subdivision's work is carried out under contract by consulting companies and by university scientists.

The Subdivision consists of three scientific sections and a number of technicians and laboratories that provide required support services:

The Micropaleontology Section is responsible for research in the paleontology of microfossils specifically, the establishment and further refinement of biochronology, the interpretation of the environments with which fossils are associated, and the related reconstruction of the geography of ancient seas and land areas. Accurate dating and correlation of strata, together with the proper comprehension of their depositional history, are prerequisite to a thorough analysis of the hydrocarbon potential of a given area. Microfossils are especially adaptable to subsurface study because they are small enough to be recovered from rock fragments generated by drilling. Much of the activity of the Section is directed towards provision of biostratigraphic and paleoecologic data in support of projects conducted by scientists of other subdivisions and, occasionally, by personnel outside the federal government, where such participation produces a mutual benefit.

Staff of the Macropaleontology Section are responsible for research in invertebrate macropaleontology, including the allied fields of biostratigraphy, biochronology, paleobiogeography, and paleoecology. Precise dating and correlation of strata by means of fossils and knowledge of depositional environments and the history of sedimentary basins are of fundamental importance in the search for and assessment of mineral deposits. The establishement and refinement of biochronological zonation of Phanerozoic rocks is a continuing task that is being gradually extended into the frontier areas. The main area of responsibility includes the four western provinces, Yukon Territory, and the Mackenzie and Franklin districts.

The Ottawa Paleontology Section is staffed by scientists specializing in studies of the macropaleontology and biostratigraphy of the Mesozoic rocks of Northern and Western Canada.

The Macropaleontology Labratory provides services for the preparation of macrofossils for study by research scientists. The main function is to produce precisely oriented thin-sections showing the internal structures of fossils. Other duties include chemical and mechanical extraction techniques; casting and moulding; and grinding, sawing, and polishing of rocks.

The Energy Subdivision is responsible for the Institute's activities in the evaluation of energy resources (specifically, oil and natural gas) located in the sedimentary basins of Western Canada, for conducting research into the mode of origin and occurrence of these resources, and for related activities that provide the necessary background for the evaluation studies. At the same time, the Subdivision investigates more fundamental but associated problems and publishes basic information designed to stimulate and increase the efficient development of resources.

The Subdivision coordinates its resource evaluation activities with the other research endeavours and with related activities of other subdivisions and other agencies within the federal government. It is responsible also for the security and control of confidential information produced by resource administration agencies within the federal government.

The Energy Subdivision is organized into three sections:

The Petroleum Resources Section is responsible primarily for assessing Canada's petroleum resources, conducting research on the habitat of oil, and developing methods of resource evaluation. In addition, it develops and maintains computer files of data on wells and oil and gas pools, and other relevant information. Much of the work of the Section involves coordination with related activities of the Institute, the Atlantic Geoscience Centre, the Resource Management and Conservation Branch (Department of Energy, Mines and Resources), and the Department of Indian Affairs and Northern Development.

The Geochemistry Section provides scientific services to the division; develops 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. Crude oil studies also are undertaken to determine oil-source relationships and to document geochemical changes in crude oil composition that occur in the reservoir. Most of these studies are carried out on material from the Arctic Islands, the Mackenzie Delta region, and offshore areas of Eastern Canada; and they provide valuable data for use in evaluating petroleum resources.

The Data Management Section maintains a mini-computer facility and provides systems analysis and programming services to the various subdivisions of the Institute. The main work of the Section consists of establishing and maintaining files, integrating operating systems, enhancing assessment systems, and developing new programs.

The role of the Coal Geology Subdivision is to establish a sound geoscience base related to coal measures throughout Canada and to develop and maintain an evaluation of Canadian coal deposits, in collaboration with the provinces, to meet national inventory requirements of the Energy Development Sector (Department of Energy, Mines and Resources). The dramatic reversal in energy outlook over the past decade clearly identifies coal as a primary potential source for electrical power generation, at least until the turn of the century.

The Subdivision comprises three sections:

The Geology of Coal Section conducts independent and team research on the coal measures of Canada, carrying out some projects in collaboration with the provinces. These investigations are aimed at formulating conceptual and factual models of the stratigraphy and structural geometry of Canadian coal deposits, to assist in the establishment of a geoscience data base from which resource evaluations can be made. Insofar as increases in the future domestic demand for coal are expected to be associated primarily with electrical power generation, it is anticipated that this newly formed Section will concentrate its activities on the geology of low-rank deposits in Western and Northern mainland Canada.

The Resource Evaluation Section is responsible for the broad assessment of Canada's coal resources, particularly with respect to their occurrence, nature, quantity, quality, and mineability. It is responsible also for planning and conducting field programs, alone or jointly with the provinces, including the performance of drilling and geophysical logging operations that are specifically designed to provide the type of data required in making evaluations.

The Coal Technology Section is engaged mainly in carrying out studies of the petrographic characteristics of coal seams and applying the results to seam identification, correlation, and prediction of the quality of known resources. The Section also undertakes specific studies of the maturation of organic material, including coal, as contained in fine-grained clastic rocks of both marine and non-marine origin. The results of these studies are useful in predicting the nature and quality of hydrocarbons, which are important elements of resource evaluation.

The principal objective of the Geological Information Subdivision is the communication of the results of Institute activities to government, industry, and other interested groups and individuals. Information is made available through scientific publications of the Geological Survey, through publications in outside technical journals, and by means of an Open File system. In support of its objective, the Subdivision maintains capabilities and facilities for scientific editing and information services, cartography, technical photography, library services, and the distribution of publications. It is organized into five sections:

The Manuscript Processing Section is responsible for the critical reading and editing of all manuscripts; the final typing, proofreading, and layout of all

camera-ready (offset printing) jobs; and the preparation of manuscript material to be placed on Open File.

The Photographic Section is responsible for providing all general and specialized photographic services for Institute staff.

The Library provides a complete information service to the scientists and other staff of the Institute and general services to accredited members of the public, particularly personnel of the energy industries and the staff and students of the University of Calgary. It also provides an outlet for the Geological Survey Open File system.

All publications of the Geological Survey, publications of the Surveys and Mapping Branch for areas west of the Canadian Shield, and various departmental publications are sold and distributed by the Publications and Air Photo Section. Orders for aerial photographs are forwarded to the National Air Photo Library in Ottawa.

All maps and illustrations required by Institute staff for publication are prepared in the Geological Cartography Section. The work includes drafting for black-and-white and multi-colour illustrations, as well as photomechanical and reproduction work. The Section also handles a large amount of miscellaneous drafting for slides and Open File items.

Through its various subdivisions, the Institute contributes to both the Mineral and Energy Resources Program and the Earth Sciences Program. The main achievements within these programs for 1976-77 are described in the pages that follow.

MINERAL AND ENERGY RESOURCES

The Institute's responsibilities under the Mineral and Energy Resources Program are concentrated on determining the nature and extent of Canada's resources, particularly oil, gas, and coal. Data management and laboratory services are provided in support of these activities.

Oil and Gas

Conventional Oil and Gas Potential Estimates

The most significant activity in 1976-77 was the publication of estimates of natural oil and gas resources (Departmental publication EP77-1), explaining the details of assessment methods and providing the first comprehensive, published set of probability distributions by area for the country. This report can be regarded as the most up-to-date examination of Canada's future supply base that is available to the public.

The petroleum potential of all prospective oil and gas regions in Canada was examined and updated during the year. The project included revision of data on the Arctic Islands, completion of the play-by-play analysis for Western Canada, preparation of a preliminary estimate for Baffin Bay, and updating of information for all regions. In addition, material was provided to the Energy Sector for use in economic analyses. This information consisted of several thousand pool descriptions, including thickness of pay, porosity, productivity, depth, location, and so forth, derived from the estimates of undiscovered potential for all regions.

The work carried out in 1976-77 has advanced the level of knowledge on undiscovered oil and gas resources to a point where it is now possible to develop consistent economic evaluations of future supply. Play-by-play evaluations have been performed, at least partially, for most regions, providing information that is fundamental to a proper understanding of the economics of resource use.

Continuing efforts are being directed to the design of additional modules for the oil and gas program, in order to handle problems related to heavy oils and low-productivity gas sands. In addition, attempts are being made to link estimates of the abundance of resources with the economic overlay work being undertaken, in the Energy Sector, with a view to refining assessments of future supply.

Development of Petroleum Data Base

Limited progress has been made in the preparation of a file of data on oil and gas pools for all the Prairie Provinces. The file, when it is completed, will represent a thoroughly documented collection of petroleum parametric data. Analysis of these data will provide a much-improved ability to engage in statistical approaches to the evaluation of resources, permit the forecasting of production rates, identify a variety of economic parameters, and facilitate testing of the reliability of other estimates.

Non-conventional Gas Resources

During the year, an investigation of gas resources related to very low-quality reservoirs was initiated. Activities included the compi-

lation of some background information from published documents and other sources, and planning for future work on resource evaluation.

Development of Evaluation Methodology

In 1976-77, the work on evaluation methodology emphasized improvement of the computer program that is used in pay evaluation. A number of minor program changes have been made; the flexibility of the program has been increased, so that it can handle a variety of input parameters; some improvement in output characteristics has been achieved; and several subroutines have been prepared that are directly related to the Western Canada data base. Minor progress also has been made in the compilation of parametric data for incorporation into manuals, to assist evaluators in achieving a more uniform approach to the assessment of very different regions, using different data bases.

Hydrocarbon Geochemistry

Important new ideas are being generated in hydrocarbon geochemistry, and solid geochemical information is being provided in support of oil and gas evaluation activities. Research activity in this field produced several important publications in 1976-77.

Detailed organic geochemical studies have been carried out in the Arctic Archipelago and on Upper Cretaceous-Tertiary sediments in the Richards Island area of the Mackenzie Delta, resulting in an assessment of petroleum source rock potential. Similar studies are in progress in the east coast offshore area, the Beaufort Sea, and the southern and eastern flanks of the Beaufort-Mackenzie Basin. In addition, oil source correlation studies are being conducted in the Arctic Islands and the Mackenzie Delta.

Geochemical studies in the Sverdrup Basin indicate that most of the hydrocarbon product from source rocks is likely to be gas, with only a minor potential for oil. In the Lower Paleozoic rocks of the Franklinian Geosyncline and the Arctic Platform, source rocks with oil potential occur more frequently but closer to the surface. Sediments in the Richards Island area are immature and generally have only a potential for early diagenetic gas. The oil and gas condensate that has been discovered may be derived from a particular organic facies comprising a concentration of resins derived from the land plants. This organic facies has not hitherto been recognized as a potential source for liquid hydrocarbons.

Diagenetic Studies

Diagenetic research is continuing in the Mackenzie Delta and Sverdrup Basin. Investigations involve the use of clay minerals and inorganic geochemical parameters as diagenetic indicators; assessment of pore fluid composition in relation to cementation of oil and gas reservoirs; evaluation of mineralogical changes upon diagenesis as a possible source of water for primary oil migration; and response of different types of organic matter to diagenesis.

These studies have shown the precise relationship between organic maturation and clay transformation. Organic matter of different types undergoes petroleum-forming reactions at different stages in the diagenesis of a sediment. (The vitrinite reflectance scale provides a convenient means for measuring these stages of diagenesis). Recognition of various types of organic matter combined with measurement of the maturation of sediments, is therefore critical to the evaluation of source rock potential.

Studies of mixed-layer clays have shown that these sediments are far more complex than had previously been thought. They consist of a quaternary intergrowth of montmorillonite, illite, vermiculite, and chlorite. The mixed-layer clays undergo their first dehydration before the main phase of petroleum generation. Since it is thought that vermiculite is an intermediary mineral in the formation of illite from montmorillonite, it is likely that the second dehydration step occurs in the phase of gas generation. It therefore appears that water derived from montmorillonite dehydration is not a factor in petroleum migration.

Coal

Appraisal of Canada's coal resources continued in 1976-77. New resource estimates were prepared for Nova Scotia, based on data generated by an exploration program funded by the Department of Regional Economic Expansion. A joint drilling program with the British Columbia Department of Mines in the upper Elk Valley was completed within the fiscal year, and the results of the project are now being analyzed.

Saskatchewan Lignite Resource Evaluation

A study of the lignite resources of Saskatchewan is in the final stages of completion, and detailed estimates of these resources have been made. Publication of an atlas and report is expected in the 1977-78 fiscal year. Much effort has been spent in the interpretation of data for entry to the computer's data file.

Data have been verified, edited, updated, and integrated, and manipulative programs have been developed to facilitate further analysis.

Evaluation of Coal Deposits of Western Canada

A detailed study of the coal-bearing Kootenay Formation has been completed, using field mapping scale (1:16,000), corehole drilling (1,640 m cored) and chemical and petrographic analyses in the upper Elk Valley. As a result of this study, numerous coal seams of mineable thickness have been identified. An almost complete section of the Kootenay Formation has been produced, as well as a detailed geological map of the region.

The study has resulted in the development of a technique for solving geological structure problems from coal reflectance information and geophysical logs. In addition, the work carried out in 1976-77 will serve as a basis for future investigations.

Studies are continuing of the stratigraphy, sedimentology, and structure of the Jurassic Kootenay Formation and of the Lower Cretaceous Blairmore Group on the eastern flank of the Cordilleran orogen. Basic data are being collected on the presence, number, thickness, lateral continuity, and quality of bituminous and semi-anthracitic coal seams, which are mined primarily as a metallurgical commodity.

Field work in 1976-77 consisted of measuring and describing in detail 19 field sections of the Kootenay Formation in British Columbia and Alberta. In addition, four testholes drilled by the Geological Survey were logged and sampled in detail in the Kootenay Formation of the upper Elk River valley. Coal seams in the Kootenay Formation were found to decrease in number and thickness eastwards from British Columbia to Alberta.

Structural Analysis of the Fernie Basin

In 1976, field work was completed in the Dominion Coal Block, Parcel 73, involving mapping (scale 1:400) and structural interpretation of the coal-bearing Kootenay Formation. Four major coal seams have been mapped in a series of imbricate thrust-faulted plates.

The determination and anlaysis of the thickness, quality, distribution, structural configuration, and relationships of commercial coal seams in the area have permitted assessment of these resources and their approximate value. In addition, a new understanding of structural style and development in the coal-rich Fernie Basin has been developed. This work is pertinent to any future evaluation of important deposits in the Dominion Coal Blocks.

Optical Properties of Canadian Coals

Current coal petrography studies are concerned with the lignites of the Paleocene Ravenscrag Formation of southern Saskatchewan and the bituminous and semi-anthracitic coals of the Jurassic Kootenay Formation of Alberta and British Columbia, and of the Lower Cretaceous Gething Formation of northeastern British Columbia. Organic maturation studies are under way for material from the Mackenzie Delta and the Sverdrup Basin.

During 1976-77, rank analyses by reflectance measurements were carried out on Kootenay coals recovered from the upper Elk Valley drilling project. The results contributed significantly to the interpretation of the structure and stratigraphy of the Kootenay Formation in a region intermediate between the Cascade and Fernie coal areas. The Kootenay Formation in the upper Elk Valley contains coals that are significantly lower in rank than those occurring in the formations to the north and south.

Support Services

Data Management

In 1976-77, a real time operating system was installed on the mini-computer, allowing multiple users access to the system's facilites. In addition, the graphics devices (digitizer, plotters, and tektronix scope) were integrated to aid in data input and output.

The hydrocarbon assessment system was converted to run on the mini-computer. With the addition of a data flow monitor, the scientist's interface with the system and its stored assessment data has been simplified and enhanced.

During the year, the Data Management Section participated in a study of the relationship of resource pool size with pool rank within a basin. The results were integrated in the program module that generates pool parameters for economic analysis. A further analysis was executed to determine a probabilistic expression for target areas that might exist for exploration in Western Canada.

New system development included a Fourier analysis of clay mineralogy data to determine diagnostic, diagenetic parameters. Also, a hardware system design was completed

for a gas chromatograph and x-ray diffractometer data acquisition system. The system will interface with existing data analysis programs and files.

Geochemical Laboratories

Laboratory procedures have been improved over the past year. A kerogen isolation system has been devised that allows the preparation of smear slides and the performance of elemental analyses using the same kerogen preparation. A high-speed, high-resolution gas chromatographic column has been developed, and a geochemical data file has been created. Techniques have been developed for the quantitative analysis of sedimentary rocks by x-ray fluorescence. Infra-red spectrophotometry has been found to be useful for following diagenesis in clay minerals.

These innovations in laboratory procedures and data storage greatly facilitate work flow and data manipulation and recovery. The new gas chromatographic column is innovative and has considerable application in the analysis of petroleum-like mixtures, in environmental studies, and for combined gas chromatography in mass spectrometric studies in all fields. Infra-red spectroscopy provides a rapid method for following the diagenesis of mixed-layer clays.

EARTH SCIENCES

Activities contributing to the Earth Sciences program include the performance of geoscience surveys and regional analyses based on survey data and other information collected by the Institute. Curation, laboratory, and data processing services are provided in support of this work, and a complete publishing and information facility is maintained.

Standards, Correlations, and Processes

Paleontological Standards

Nine comprehensive paleontological studies of northern wells were completed during the year, and these will eventually be placed on Open File. In addition, 125 internal reports on 1,194 individual lots of fossils were written for direct quotation in Survey and outside manuscripts. Both of the foregoing achievements are critical to the Survey's studies of the geology of Canada and its assessments of fossil fuel and mineral resources. Two Bulletins, eleven Papers or parts of Reports of Activities, and three manuscripts published in outside journals presented refined models of biostratigraphic zonation and provided standards necessary for the effective application of paleontological studies. For example, one Bulletin gives detailed taxonomic descriptions of 106 species of microplankton and correlation of marine Upper Jurassic and Lower Cretaceous rocks in Northwestern Canada; the other is a comprehensive monograph of two ammonoid genera widely distributed in the Lower Cretaceous rocks of the Sverdrup Basin.

Biostratigraphy

The Institute conducts lithostratigraphic and biostratigraphic studies in association with the Cordillera and Pacific Margin Subdivision of the Regional and Economic Geology Division, providing these studies with a biostratigraphic dimension. One Memoir, a Bulletin, and four manuscripts for outside journals were produced during the year. The Memoir, which was prepared in association with the Mines Branch of the Manitoba government, is a comprehensive synthesis of information on the Devonian rocks and fauna of southern Manitoba. The Bulletin provides stratigraphic, sedimentological, and biochronological descriptions of the Otto Fiord Formation, an Upper Paleozoic evaporite unit in the Arctic Islands.

Biostratigraphy of Coal Deposits

Other than reports provided directly to the Coal Subdivision, the main contribution to geological studies of coal resources is a detailed lithostratigraphic application of the palynological studies of coal-bearing sequences to the identification and correlation of individual coal seams within coal fields. A major biostratigraphic contribution to the Canada-Saskatchewan study of the Estevan region is essentially complete and awaiting compilation with parallel studies using other geological tools.

Geoscience Surveys

Previous reconnaissance mapping projects have resulted in completion of the basic 1:250,000 map coverage of all the mainland regions and most of the Arctic Islands. Only a few areas within the latter region will be left unmapped after completion of current projects. During the year, compilation of data for the northern Ellesmere Island mapping project continued, and preparations were made for the second phase of field work, to be carried out in 1977-78.

Stratigraphy and Structure of Vendom Fiord and Devon Island Mapping of Vendom Fiord and most of eastern Devon Island was initiated on a scale of 1:250,000 to refine the understanding of the stratigraphic record. Preliminary work has resulted in photo compilation maps and extensive field work on the

Haughton Astrobleme, an apparent impact feature of large dimensions.

This project will virtually complete the 250,000 scale mapping of the Franklinian Geosyncline and adjacent shelf. Significant potential exists in the area for both hydrocarbon accumulation and base-metal mineralization.

Operation Boothia

In 1976-77, the mapping of the Precambrian and Phanerozoic rocks of the Boothia Peninsula and Somerset Island was completed (scale 1:250,000). As a result of this survey, important advances were achieved in the understanding of the stratigraphic record, both in sedimentology and its subsequent structural deformation.

This project was timely in view of the proposed construction of an Arctic gas pipeline, which would almost certainly pass through this terrain. In addition, the area is marginal to areas of significant hydrocarbon potential and significant Pb-Zn deposits that are both stratigraphically and structurally controlled.

Regional Analyses and Syntheses

In 1976-77, manuscripts related to regional analyses and syntheses included 2 Geological Survey Memoirs, 3 Bulletins, 5 "A" Series Maps, 18 Papers, 13 outside papers, and 3 additional abstracts. A major internal report on the evaporites of Canada was produced for the Department and the Atomic Energy Commission; and the Institute provided the Department of Indian Affairs and Northern Development with all the geological topographic maps for northern wells released from confidential status during the year.

Surface and subsurface studies of rocks in the Sverdrup Basin were continued. A milestone was reached in ongoing studies of the Beaufort-Mackenzie Basin with publication in late 1976 of a comprehensive paper on the geology of a large part of the region.

Cenozoic Geology of the Beaufort-Mackenzie Basin

A major project was initiated to provide information on offshore wells in the Beaufort-Mackenzie Basin; to develop orderly biostratigraphic subdivisions, stratigraphic nomenclature, and correlations for the region; and to assess hydrocarbon potential. This region is of high interest in the exploration for oil and gas resources.

Structure and Stratigraphy, Western Queen Elizabeth Islands

In 1976, field work was begun on a new project aimed at studying the structure and stratigraphy of the Western Queen Elizabeth Islands. Mapping was completed on Mackenzie King and Lougheed Islands, and on the Sabine Peninsula (Melville, Island), resulting in significant refinement of regional stratigraphy and structural history. These studies, particularly for Triassic and Jurassic rocks, are directly applicable to hydrocarbon assessment and exploration.

Helikian and Hadrynian Stratigraphy

A project has been undertaken to establish a coherent picture of Helikian and Hadrynian events in Western and Northwestern Canada and to emphasize study of those events that may have created exploitable mineral and/or hydrocarbon deposits. A Helikian unit in Mackenzie Arc which was previously little understood has been studied, and an internal stratigraphy has been formulated, including the establishment of stromatolitic reefs of high relief within the unit.

The study has contributed substantially to our understanding of facies relationships within the unit, particularly the distribution of extensive gypsum deposits. As the unit contains zinc mineralization, a clearer understanding of the distribution of sub-units will be a valuable aid to current exploration for this mineral.

Structure and Stratigraphy in Halfway River Map Area

A study of the Halfway River map area of northeastern British Columbia has involved detailed mapping to establish the regional stratigraphic and structural setting of this part of the Rocky Mountains. In 1976-77, field work was completed, maps were compiled (scale 1:50,000), and preparation of structure sections and a report was commenced.

This project has increased our understanding of regional stratigraphic relationships, including the stratigraphic setting of the Robb Lake lead-zinc deposit, which is the largest known lead-zinc accumulation of Pine Point type in the Canadian Cordillera. The study has also provided new insights into the nature of deformation in this part of the Canadian Rockies.

Support Services

Curation and Technical Services

Curation Services in 1976-77 included the cataloguing of rock and fossil collections for the current year, as well as the curation of field collections from previous years. The latter activity will eventually result in the curation of all samples now held in storage. More than 13,000 samples were catalogued and over 3,000 lots packed for shipping.

The lapidary unit maintained its quality of production, although total output was slightly reduced during the year owing to decreased demand related to resignations of scientific staff. The Core and Sample Repository continued to provide an important public service. Approximately 2,100 visitors required core, sample, or related information; and samples from 900 wells and 700 boxes of core were requested for examination.

Paleontology Laboratories

During the year, laboratory personnel of the Foraminiferal Laboratory processed 280 surface (outcrop) samples and 1,056 subsurface (well cuttings and core) samples. In addition, 1,328 samples were picked for microfossils by outside contract. Services performed as direct scientific support included photomicrography, drafting, log plotting, microfossil lists, local field assistance, and operation of a scanning electron microscope.

Services provided by the Palynology Laboratory were not available for four months in 1976-77 during reconstruction of the facilities. During the operable time, 1,319 surface and subsurface samples were processed for palynomorph study and 153 samples for kerogen study. Of the palynomorph preparations, 1,251 samples were for miospore study and 68 for megaspore study. Of the total samples processed, 735 were prepared for projects led by palynologists and the remainder for other Geological Survey projects.

In the past year, 1,800 thin sections of corrals, foraminifers, and fusulinids were prepared. There were 14 samples of acid residues picked, and 15 plaster casts were made. In the Conodont Laboratory, 339 samples were processed, picked, and recorded.

Data Management

Files and retrieval programs have been developed for curation data, library holdings, conodont bibliographies, and extract analysis of data on Alberta and the northern frontier. In 1976-77, the Data Management Section also provided advice and assistance on the development of the KREMP file of paleontological data.

Information Services

The Geological Information Subdivision maintained a full scientific publishing program in 1976-77. During the year, the editorial staff processed for publication 3 Geological Survey Memoirs, 8 Bulletins, 56 Papers, 4 A-series multicolour maps, and 15 papers for publication in outside scientific journals. Eight Open File items were initiated.

The Photographic Section showed a small decrease in production related to a reduction in demand for services. Nevertheless, more that 10,000 prints and several thousand other items were processed during the year.

Publications and Aerial Photographs

In 1976-77, 3,007 orders and enquiries were received, and 38,840 items were sold, at a total value of $59,000. The self-serve system for topographical maps continued to prove effective, and many customers indicated their appreciation of the procedure.

RESOURCE GEOPHYSICS AND GEOCHEMISTRY DIVISION

A.G. Darnley, Director

The objective of the Resource Geophysics and Geochemistry Division is to provide the geophysical and geochemical information required to facilitate the discovery and evaluation of Canada's uranium and mineral resources. To attain this objective, the Division is responsible for the design and management of national, systematic geophysical and geochemical surveys. Specific activities include the acquisition, interpretation, and use of geophysical and geochemical data; the development, testing, calibration, and standardization of the relevant technology and instrumentation; and the integration of such data with available geological information. In addition, the Division serves as a national centre for research and development in geophysical and geochemical methods related to metalliferour exploration technology, terrain investigations, and regional geology; and as such, it provides advice on these matters at national and international levels.

To accommodate the diversified activities of the Division, projects are grouped within four subprograms: Resource Explora-

tion, Regional Geophysics, Terrain Geophysics, and CIDA. These subprograms draw upon the specialized knowledge of nine sections: Analytical and Nuclear Instrumentation, Contract Surveys, Digital Compilation, Electrical Methods, Experimental Airborne Operations, Geochemistry, Magnetic Methods, Radiation Methods, and Seismic Methods.

The Resource Exploration subprogram has two objectives: to identify and evaluate regions of Canada favourable for the discovery of economic concentrations of uranium and other metallic commodities and to develop effective methods for such identification and evaluation. For administrative purposes, projects are classified in two categories, Radiometry and Geochemistry. Current activities include extensive use of airborne gamma-ray spectrometry and regional geochemistry (as part of the federal-provincial Uranium Reconnaissance Program) and a variety of supportive projects that are small scale or experimental in nature, such as magnetic gradiometer and seismic surveys.

The Regional Geophysics subprogram is responsible for developing and using geophysical methods to map bedrock geology, to provide information that can be used in mineral exploration. Principal activities are management of the federal-provincial Aeromagnetic Survey Program, development of methods of data interpretation, and development of sensitive aeromagnetic techniques. In addition, regional seismic surveys are carried out as aids to geological mapping, and interpretations are made of LANDSAT imagery.

The objectives of the Terrain Geophysics subprogram are to contribute to the solution of problems in engineering geology and surficial geological mapping by the conduct of geophysical surveys and development of new techniques; and to develop new electrical and electromagnetic methods of mineral exploration.

The CIDA subprogram coordinates geoscience services provided by the Geological Survey to various aid projects of the Canadian International Development Agency. These services may include recommendations on the selection of methods and consulting services, preparation of specifications for contracted services, assessment of contractors' proposals, and monitoring of contractors' work.

Major changes in the emphasis of the Division's activities were triggered by the energy crisis of the early 1970s. Subsequently, there has been a large increase in regional survey coverage, supported in part by joint federal-provincial programs, and a smaller increase in research projects involving industry. In recent years, about 70% of the Division's annual operations budget has been devoted to contracts with the air survey industry, industrial laboratories and consultants, and scientific staff have been required to devote an increasing proportion of their time to the preparation and administration of these contracts. In addition, mass production methods have had to be developed for data processing and presentation. As a result of these activities, technologists outside the federal government have become aware of the need for national standardization and calibration facilities for various types of geoscientific survey, and considerable work has been undertaken in this area. Unfortunately, the efforts of scientists in the Division have been diverted, to some extent, from long-range research, to the detriment of future technological development, both in government and in the Canadian exploration industry.

In 1976-77, work was carried out on 50 projects, contributing to both the Mineral and Energy Resources Program and the Earth Sciences Program. Documents produced during the year included 35 papers for publication in outside scientific journals, 8 Geological Survey Papers, 26 GSC Open File releases, 29 Report of Activity reports, 80 aeromagnetic maps, 42 NTS quarter-million sheets with radiometric coverage, and 16 NTS quarter-million sheets with geochemical coverage.

MINERAL AND ENERGY RESOURCES

Mineral Resource Determination

Under the federal-provincial Uranium Reconnaissance Program, data are collected on the abundance of 10 elements in the various areas covered by the geochemical component of the Program. Although these data are accumulated as a by-product of the uranium program, they are very valuable for use in mineral exploration work by industry and in the development of resource estimation by government.

Mineral Technology Development

In 1976-77, a major project was completed on the geochemistry of gold and its deposits; a manual of computer programs was produced; new methods were developed for the analysis of selenium, tellurium, and bismuth; further automation of laboratory instrumentation was achieved; and improvements were made in instrumentation for the rapid sampling and analysis of waters on board helicopters. In

addition, work was carried out jointly with industry on the development of portable field instrumentation for the analysis of base metals and uranium.

In borehole geophysics, the cooperative program that was initiated in 1974 between industry and the Geological Survey continued with experiments in downhole electromagnetics. A report, evaluating the state of the art in borehole geophysics, was distributed to the five participating companies.

In the Electrical Rock Properties Laboratory, measurements were made on the specimens of metallic minerals and on mineralized rock specimens. Also, a new theoretical model is being developed of the mechanisms of conduction of electricity in rocks. This model will aid in the use of induced polarization measurements, which are now commonly made by industry in prospecting for metallic minerals. Induced polarization measurements are the most expensive type of ground geophysical work commonly performed by industry in the search for metallic minerals, and any improvement in their interpretability will be of widespread benefit.

Energy Resource Determination

In 1976-77, studies were made by radioactive minerals through the performance of three types of surveys under the Uranium Reconnaissance Program: orientation surveys, which are aimed at establishing an appropriate methodology and specifications: large-scale reconnaissance surveys, carried out mainly by contractors; and follow-up surveys, carried out in selected areas to monitor program effectiveness and provide a basis for interpretation of reconnaissance data. Work undertaken during the year included:

Further lake sediment and lake water reconnaissance in the Canadian Shield, specifically in southeastern Ontario, northern Manitoba, southern Keewatin, and the Baker Lake area. The total area covered was 112,600 km^2.

Follow-up investigations in areas where lake sediment reconnaissance was carried out in 1975.

Large-scale stream sediment and water reconnaissance in southern British Columbia and the Yukon, covering an area of 74,200 km^2. Work in the Yukon included extensive orientation surveys.

The application of the well-water techniques used in the Maritime Provinces in 1975 to a 15,400-km^2 area of southwestern Saskatchewan.

Most of the anomalies outlined by the 1975 geochemical reconnaissance were staked or held by permit by the mining industry before the 1976 field season was under way. Consequently, follow-up activities in 1976-77 were largely carried out over company ground. While this circumstance led to useful cooperation between government and industry, it also greatly increased the administrative load for the Geological Survey, because data had to be provided to a number of companies as soon as they were available.

In 1976, the first full year of the Uranium Reconnaissance Program, approximately 110,000 line kilometres of high-sensitivity airborne gamma-ray spectrometry data were collected. Contract surveys were flown in New Brunswick, Ontario, Manitoba, Saskatchewan, and the Northwest Territories. The results of these surveys will be published during 1977. In addition to surveys carried out by contractors, more detailed airborne radiometric surveys were conducted via Geological Survey Skyvan aircraft over the northeastern extension of the Wollaston fold belt from Saskatchewan through northwestern Manitoba into the Northwest Territories, and in the Tatamagouche, Uniacke, and Kennetcook map sheets of Nova Scotia. Reconnaissance surveys were flown by the Skyvan in southern Nova Scotia, the Kingston to Bancroft area of Ontario, and the Cypress Hills in Saskatchewan. Altogether, contract surveys in 1976-77 covered 108,160 line kilometres and 540,790 km^2 and Skyvan Surveys encompassed 22,600 line kilometres and 49,535 km^2.

In 1976, follow-up investigations took place principally in northern Manitoba and to a lesser extent in northern Saskatchewan. The ground work generally consisted of gamma spectrometry, scintillometry, sampling, and some geological mapping. Approximately 20 individual radiometric anomalies were evaluated on the ground, as well as one block between Snyder Lake and Kasmere Lake in northern Manitoba. The individual anomalies investigated generally related to granites or pegmatites with above-normal uranium concentrations. Within this latter block, uranium mineralization was found to relate to pegmatites, fractures, and broad stratigraphic control. The area has been the site of extensive exploration activity by industry, following the release of 1975 federal-provincial radiometric and geochemical data, and preliminary press

reports indicate that mineralization of good grade has been intersected by drilling. Additional ground investigations took place in the Pembroke area of Ontario and in Prince Edward Island, where a truck-borne spectrometer survey was made following completion of an airborne reconnaissance survey of the province.

It should be noted that in 1976-77 federal-provincial Uranium Reconnaissance Program Agreements were in effect with Ontario, Manitoba, Saskatchewan, British Columbia, and New Brunswick. Provincial contributions to the Program totalled $701,000.

Energy Technology Development

In geochemistry, little research work was undertaken in 1976-77, because of the priority given to establishing, managing, and monitoring the Uranium Reconnaissance Program. Some development of a portable helium analyser did, however take place; and a Monte Carlo simulation was carried out of optimum reconnaissance sampling densities. The latter exercise was undertaken in order to demonstrate that neither too few nor too many samples are being taken for the purpose of delineating regional uranium anomalies.

In order to maintain the Geological Survey's position of leadership the performance of radioactivity studies, the high-sensitivity airborne system, in use since 1968, has been modernized. New prismatic gamma-ray detectors and improved methods of system control and display have been added to the mini-computer system for data acquisition. Complete spectra will be recorded to provide data for the research program in airborne gamma-ray spectrometry. This program is aimed at obtaining greater sensitivity from a given detector volume (the principal cost factor in the use of airborne radiometric equipment).

An identical data acquisition and control system is being mounted in a truck for use in a borehole gamma-ray spectrometry research program. The high degree of hardware-software compatibility between the two systems will permit the combination of data for analyses and interpretation.

In 1976, a back-pack portable gamma-ray spectral logging system with digital recording was successfully assembled and field tested. A truck-mounted digital logging system has been designed, and this will be field tested in the summer of 1977. Model boreholes are under construction at Bells Corners near Ottawa for calibrating gamma-spectral logging systems. Also during the year, studies continued on the calibration of airborne gamma-ray spectrometer systems, with a view to assembling airborne surveys from all parts of the country for comparative purposes.

EARTH SCIENCES

Geological Service

Four aeromagnetic surveys are currently under way, covering a total of 614,100 km^2 in the Northwest Territories, Labrador, northern British Columbia, and northern Quebec. To date, 5,334 one-mile, 486 four-mile and 1:250,000, and 547 aeromagnetic maps at other scales have been published. In December 1976, a listing of the best LANDSAT images of Canada was placed on Open File.

An aeromagnetic reconnaissance of the Gulf of Boothia and Admiralty Inlet was carried out in April 1976 to ascertain the depths of underlying sedimentary rock formations. The North Star aircraft formerly used for such surveys has now been demobilized and replaced by the Convair-580. During the year, digital aeromagnetic data collected previously in Baffin Bay, Hudson Bay, the Arctic Ocean and the north Atlantic Ocean were released through Geological Survey Open Files.

In 1976-77, seven field and gradiometer surveys amounting to 27,250 line kilometres were flown as part of the high-resolution experiment in British Columbia, Saskatchewan, Ontario, and Nova Scotia. These included:

A survey of southern Vancouver Island, intended to assist geological mapping

A series of eight lines flown across the southeastern corner of the Athabasca sandstone in the Geikie River area of northern Saskatchewan, to ascertain the usefulness of the method in delineating the subsurface sandstone basement contact (which is believed to control uranium mineralization)

A survey of the Grimsthorpe granite of southeastern Ontario, to detect the presence of faults and other structural features (this rock formation has been under investigation as a possible site for disposal of radioactive waste)

Surveys of the Yarmouth and Halifax areas at the request of the Nova Scotia Department of Mines, funded in part by the Department of Regional Economic Expansion to stimulate mineral exploration in Nova Scotia.

During the year, an interpretation was made of Queenair gradiometer data concentrating on the information obtained for Grimsthorpe and for the Athabasca sandstone area. To complement the aeromagnetic gradiometer study of the Athabasca sandstone, a refraction seismic survey was carried out in March 1977. Approximately 30 single-ended spreads were laid out, with short points located in lakes in the southeastern part of the area. The greatest thickness measured for the Athabasca sandstone was about 660 m. Interpretation of seismic refraction data in the Sverdrup Basin of the Arctic Islands continues, and velocity depth cross-sections have been produced that correlate with known geological structures in this sedimenary basin.

In order to maintain the quality of aeromagnetic surveys for which the Geological Survey is responsible, both domestically and overseas, the digital data acquisition system of the Survey's gradiometer-equipped Queenair aircraft has been redesigned to record Doppler and VLF navigational information. The automatic compensator, which is used to nullify the magnetic effects of the survey aircraft, also has been rebuilt in order to provide a visual display of the current flowing through each of the compensation coils. This innovation is intended to speed up the compensation process. In May 1976, the results of the first gradiometer survey conducted by the Queenair in the White Lake area of Ontario were placed on Open File.

The development of an airborne Squid gradiometer by CTF Systems Inc. of Port Coquitlam, B.C., is proceeding under a contract with the Department of Supply and Services. First flight trials are planned for 1978. If successful, the Squid gradiometer will provide a new generation of airborne magnetometers, permitting the use of a high-sensitivity, short-based gradiometer. Such an instrument would facilitate magnetic compensation of gradiometer survey aircraft and eliminate the need to maintain an elaborate double-boom system, such as the one currently installed on Queenair aircraft.

In 1976-77, digital compilation of aeromagnetic data entered a new phase with the introduction of a software system called Automated Compilation and Cartography of Earth Science Surveys (ACCESS). This system is intended as a generalized development of the ADM (Aeromagnetic Data Automatic Mapping) system, designed to expand its functions and make them available to a wider range of users.

Terrain Evaluation Service

Permafrost Studies

During analysis of 16,000 industry seismic records, a map was compiled showing the distribution of sub-seabottom ice-bonded permafrost in the southern Beaufort Sea. With improved jet-drilling techniques, bottom temperatures were obtained in drill holes at five sites, to provide control data for the permafrost map.

Shallow marine seismic studies were carried out in Lancaster Sound as part of a multi-disciplinary survey of some potential pipeline crossing sites. No sub-seabottom ice-bonded permafrost was identified in this work.

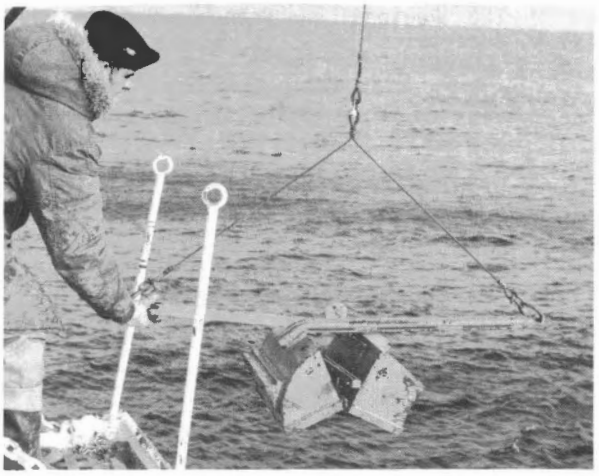
Development continued on a system for continuous marine resistivity surveying. Preliminary experiments in 1975 proved the usefulness of this technique for mapping discontinuous shallow sub-bottom permafrost.

On land, permafrost work was directed primarily at studies of near-surface ice-rich zones. Several techniques were used to log shallow holes at sites in the Mackenzie Valley and Delta, and at Rea Point, Melville Island. Seismic velocities were compiled from measurements at various sites in the Arctic Islands, where drill-hole data were available. Measurements were made at five Arctic sites with the newly acquired GSSI Mark III impulse radar subsurface profiling system. The eventual end of this work is the development of a technique or techniques that will provide reliable estimates of ground-ice content in permafrost, as a guide to estimating the sensitivity of the ground to disturbance. Measurements of frozen materials also were undertaken in the Electrical Rock Properties Laboratory.

In 1976-77, a computer program was developed for interactive interpretation of DC resistivity soundings. Such information has been used in estimating permafrost thicknesses in the Mackenzie Delta.

Soil Moisture Studies

Field experiments designed to aid in the measurement of moisture content of soils were carried out with the GSSI radar and with the Time-Domain Reflectometer. Laboratory measurements were made of the dependence of the dielectric constant on moisture content. This work has been carried out in cooperation with the Soil Research Institute, Agriculture Canada. Development of methods for remote



The Van Veen bottom grab being lowered into the Beaufort Sea from C.S.S. Hudson.

measurement of soil moisture content is of great importance in modern agriculture.

Overburden Thickness Mapping

Interpretation procedures were developed for handling Tridem airborne electromagnetic data through a layered model. These procedures were applied to data from the Timmins area to produce an interpretation of overburden thickness. This work supports development of the ARES airborne EM system for overburden mapping.

Hammer seismic surveys were completed on a total of 911 sites at Rivière-du-Loup, Quebec, and Saint John, New Brunswick. This work supplied detailed data on overburden thickness to complement urban geology studies being carried out by the Terrain Sciences Division.

Structural Studies

Preliminary experiments were carried out on the surface (taking VLF EM and VLF resistivity radar soundings) and in boreholes (collecting electrical, electromagnetic, and seismic data) at the White Lake (Ontario) experimental site established by the Geological Survey in cooperation with Atomic Energy of Canada Limited. The results of these studies will be used in designing a geophysical program for evaluating possible structural weakness at sites which are being considered for the storage of nuclear waste. In the Electrical Rock Properties Laboratory, measurements were made of a variety of crystalline rocks in support of this work.

Support to Other Agencies

In 1976-77, support was given to CIDA projects in four countries: Brazil, Pakistan, Ivory Coast, and Kenya. The major commitment continued to be directed to the Brazil-Canada Projecto Geofisico (Goias Project), involving advisory and inspection visits, monitoring of contractors' work, review of specifications, and training of Brazilian technicians. This project includes geochemical as well as geophysical components. An aeromagnetic survey was supervised in Pakistan; airborne geophysical surveys in Ivory Coast were completed and advice given on follow-up activities; and advice was given on specifications for an airborne survey in Kenya.

Very detailed radioactivity maps of the Port Hope and Uranium City areas were prepared for the Atomic Energy Control Board. Closely spaced lines were flown by the Skyvan aircraft, and special techniques of rapid sampling and data filtering were devised for the purpose.

The national geochemical surveys being undertaken as part of the Uranium Reconnaissance Program identify areas of the country where harmful levels of certain elements may exist. Mercury is an example. Both the Department of Fisheries and the Environment and the Department of National Health and Welfare are beginning to use such information in developing their own programs, such as the establishment by Health and Welfare of a national alert system for detecting natural toxic contaminants of drinking water.

REGIONAL AND ECONOMIC GEOLOGY DIVISION

J.E. Reesor, Director

The Regional and Economic Geology Division has four main objectives: (1) to provide a systematic study of the geological framework of Canada in order to assist the discovery of mineral resources and the evaluation of resource potential; (2) to provide standards, controls, and reference material to ensure consistent correlation and uniform description of the geology of Canada; (3) to identify geological settings that are favourable to the occurrence of mineral deposits and fuels; and (4) to establish the potential abundance and probable distribution of mineral resources in Canada. In accordance with these objectives, the Division is responsible for studying all aspects of the bedrock geology of Canada, excluding the Western Canada and Arctic sedimentary basins, but including the Pacific continental margin. In addition, units of the

division are responsible for integrating regional geological information with mineral deposit data and metallogenic concepts, and for using the results to project Canada's mineral resource potential.

The Division is organized into four subdivisions, each comprising several sections: Cordilleran and Pacific Margin, Precambrian, Correlation and Standards, and Economic Geology.

The Cordilleran and Pacific Margin Subdivision, based in Vancouver, conducts geological investigations in the Cordilleran orogen which provide information on the composition, structure, origin, and evolution of the Cordillera. These features are related to the mineral deposits of the region to help in assessing mineral and energy potential and to guide mineral exploration. Within the Subdivision, the Marine Geology unit is responsible for carrying out a long-range program of geological and geophysical studies of the Pacific offshore area.

The Precambrian Subdivision, based in Ottawa, has similar responsibilities, related to the nature and development of the Canadian Shield. The Subdivision is organized into three sections — the Bear-Slave Section, the Northern Churchill Section, and the Superior-Grenville Section — each responsible for studying large geographic tracts of the Shield.

The Correlation and Standards Subdivision provides isotopic geochronological, biochronological, and petrological standards by which age relations, and processes of formation of rock assemblages are established. In addition, geologic studies are carried out in the Appalachian orogen of Eastern Canada. The Subdivision is organized into four sections: Isotope Geochronology, Eastern Paleontology, Petrology, and Appalachian Geology.

Through field and laboratory investigations, the Economic Geology Subdivision interprets the geological characteristics of mineral deposits and their relationship to the geologic environment. The Subdivision is responsible for applying metallogenic and geomathematical methods to evaluate the mineral resources of Canada (excluding hydrocarbons). Four sections — Mineral Deposits Geology, Uranium Resources Evaluation, Geomathematics, and Mineral Data Bank — carry out activities related to commodity metallogeny, regional metallogeny, geomethematical research in resource evaluation, and development and operation of a data bank of documentary and computerized information.

The Regional and Economic Geology Division undertakes work in both Mineral and Energy Resources and Earth Sciences. The following account presents the highlights of activities for 1976-77. Although projects are described in relation to the program activity structure of the Sector, in practice they are not easily classified within this structure. Activities carried out by the Division are closely integrated and interdependent. Thus, bedrock mapping and regional studies have an impact on uranium resource and other commodity studies; investigations of the relationship between mineral deposits and the geologic environment affect work and observations in the field of bedrock geology; and geochronology is an essential tool in both mineral deposit geology and bedrock geology. In view of these interrelationships the organization of the discussion that follows must be regarded as somewhat arbitrary; its main purpose is to satisfy the requirement for consistency in reporting and to permit assessment of Division activities within the broader context of the Geological Survey.

MINERAL AND ENERGY RESOURCES

Mineral Resource Determination

The core of the Division's work in commodity metallogeny concerns uranium, copper, lead, zinc, nickel, molybdenum, gold, silver, iron, and manganese. Barium, fluorine, strontium, and the rare-earth elements (REE) are the subject of term studies. In addition, the Division monitors developments related to the geology and the significance of resources of titanium, vanadium, and certain other elements and industrial minerals, some of which have been the subject of previous term studies. Two regional metallogenic studies are under way, one in the northern part of the Canadian Cordillera and the other in the southwestern part of the Canadian Shield. Commencement of a study of regional metallogeny in the northwestern part of the Shield has been delayed until the appropriate scientific expertise becomes available for the project.

Interaction with industry and with other government agencies is an important aspect of the Division's activities. Exchanges of information with industry are a vital part of commodity and regional metallogeny studies, as is the sharing of data among government organizations. The expansion of federal-provincial agreements related to exploration for and development of mineral resources has generated new information flows, but has also increased work pressures. The volume of material potentially available through such agreements surpasses the capacity of available manpower resources to process it for efficient use.

Recently, it has become apparent that new flows of useful information may jeopardize work in progress. Through the cooperative interest of provincial governments, partly because of federal-provincial agreements, and through contract and winter works projects outside Ottawa, the index data on thousands of mineral deposits have been retrieved and coded for inclusion in a computerized file (CANMINDEX). To ensure the integrity and workability of the file, the coded material must be edited before entry; but the editing of this influx of data competes with the needs of ongoing projects for data processing services. This is a problem that will have to be resolved during the next few years.

The following list of major accomplishments in 1976-77 indicate the range of activities that were carried out in the area of mineral resource determination:

Revised estimates of resources. Estimates of resources of lead, zinc, nickel, copper, and molybdenum, additional to the reserves identified in the 1972 internal report, "Operation September", were revised and summarized for use in departmental publications. The new estimates incorporate modifications of the "Operation September" methodology, including the use of "subjective probability" and Monte Carlo techniques. It appears that resources additional to reserves of these commodities are probably adequate to cover the shortfall of known reserves relative to projected demand to the year 2000 A.D., provided that appropriate discovery rates are maintained.

In the case of iron deposits, 1972 estimates of reserves were revised, as well as estimates of resources additional to reserves. The summary report on iron resources draws attention to the importance of considering regional distributions and characteristics of iron ores when drawing conclusions from quantitative estimates.

Interpretation of lead isotopes in sulphide ore deposits. Lead isotopic data for more than 100 Canadian sulphide deposits in the Superior and Southern provinces have been interpreted by a variety of single and multiple-stage models of isotopic evolution, to determine the history of the deposits. Model lead-isotopic ages of galena from most of the conformable and some of the vein deposits correspond closely to the uranium/lead/and rubidium/strontium ages determined for their host rocks. The method may thus be used to determine the age of deposition of these deposits. Studies of the isotopic composition of trace lead in pyrite from some of the deposits show that metamorphic events have rehomogenized this lead at a younger (in many cases, Kenoran) time, and that secondary "anomalous" lead systems are products of complex depositional and metamorphic processes. Anomalous isotopic compositions of galena and pyrite of Chibougamau result from a multi-stage, possibly epigenetic origin. In summary, such studies can serve to give the age of deposition of some conformable deposits, classify deposits (many deposit types have characteristic lead isotopic signature), and help to unravel the depositional and metamorphic history of the ores.

Metallogenic studies in the Selwyn Basin. Synthesis of field studies and other data on metallogeny of the Selwyn Basin in the northern Cordillera suggests that three distinct metallogenic provinces are superimposed in time and space within the Basin. The oldest province is defined by stratabound lead-zinc-silver and stratiform zinc-copper-silver-lead deposits in clastic sedimentary rocks of Upper Proterozoic to Lower Cambrian age. The second province is characterized by stratiform lead-zinc deposits in carbon-rich shales flanking a central Lower Ordovician to Mid-Devonian chert and shale-filled trough of deep-water origin. The youngest province embraces stratiform lead-zinc-silver-barium deposits closely associated with an extensive barite horizon in Devono-Mississippian shales. Inasmuch as the Selwyn Basin is large and contains rocks ranging in age from Middle Proterozoic to Cretaceous, recognition of these metallogenic provinces and their character helps to focus exploration in time and space, and strengthens the basis for estimating mineral resources.

Field test for rare-earth elements. A new method has been developed for detecting REE in natural materials by means of a simple chromatographic test using chemically treated paper. The test will commonly permit rapid recognition of REE occurrences at the outcrop. The method has a practical lower limit of detection of 0.1-0.5% in most rocks and minerals, although it is much lower in some cases. Because positive identification of REE in the field has not previously been possible, this test will be of great value in future exploration for rare-earth elements.

Modelling of nickel sulphide deposits. A numerical model has been developed to simulate the formation of magmatic nickel sulphides during the differentiation of mafic and ultramafic magmas through fractionation of olivine and molten sulphide. The model

enables use of experimental data to calculate the expected compositions and relative proportions of sulphide melt, silicate melt, and olivine crystals at any point in the crystallization history. In preliminary trials, the model accurately predicts the composition of ore in a large well-known nickel sulphide deposit, indicating that it should be an invaluable tool in testing our understanding of the genesis of magmatic nickel sulphide deposits. Furthermore, the model suggests that ore-bearing and barren ultramafic rocks should be geochemically distinct, a feature of importance for exploration, if demonstrated to be valid.

Geomathematics. Until recently the quantification of geological maps has been performed largely by the coding of presence-absence data for equal-area cells belonging to a grid. This procedure has generally resulted in a multivariate distribution that can be used to attempt the delineation of environments favourable to occurrence of mineral deposits of different types. A more flexible method would consist of working with a generalized multivariate distribution, using parameters that are modelled as functions of cell size. During the past year, progress was made in studying the effect of cell size by the application of geostatistical models and automated digitizing methods. The purpose of this work is to model simultaneously relevant factors in local settings and regional environments of mineral deposits. The techniques are being tested on data from the Canadian Appalachian Region and the Abitibi Volcanic Belt in the Superior Province.

In 1976-77, selected patterns of rock types and mineral deposits were digitized and analyzed on the Quantimet 720 of the Ecole Polytechnique in Montreal. The Division is currently developing a system of techniques for digitizing the patterns on the flying spot scanner of the National Research Council's Computer Graphics Section in Ottawa, and for processing the resulting outputs on the departmental computer.

The Division has begun to carry out a statistical analysis of size and grade data for various types of Canadian and foreign mineral deposits. So far, the emphasis has been on volcanogenic massive sulphide deposits. A spin-off of this work has been the development of a method to extrapolate from size-grade data for known resources to lower-grade material at present below the economic cut-off levels.

Attempts have been made to perform Monte Carlo simulations of subjective frequency distribution data for undiscovered resources. This work has led to the completion of an interactive graphic program for simulating the frequency distribution of any type of mathematical function of up to eight independent random variables.

Energy Resource Determination

Radioactive Minerals

Through the Uranium Resources Evaluation Section of the Economic Geology Subdivision, annual estimates are provided of Canada's uranium and thorium resources additional to reserves. These estimates are presented to the Department's Uranium Resource Appraisal Group (URAG) through reports of the Subcommittee on Uranium Resources Additional to Reserves, which is chaired by the head of the Section. The Section also contributes to the work of a companion URAG Subcommittee on Uranium Reserves, chaired by the Canadian Centre for Mineral and Energy Technology.

To attain resource estimates, the staff of the Section investigate the nature and distribution of uranium deposits and the relationship of these deposits to their geological environments, in Canada and abroad. Studies are aimed at determining the metallogenic processes that govern the uranium potential of each region of Canada and to establish guidelines to facilitate the discovery of deposits. An important part of the work is the development of methods whereby quantitative and qualitative information from the explored deposits and their environs can be combined with data on the various Canadian regions, to produce qualitative estimates of regional resources. In carrying out their work, Section staff cooperate closely with industry, particularly with respect to the exchange of information.

For the 1976-77 report to URAG, estimates of uranium resources were prepared for 24 areas of Canada, variously located in the Atlantic Provinces, Quebec, Ontario, Saskatchewan, British Columbia, and the Yukon and Northwest Territories. During the year, work continued on the development of a uranium CANMINDEX file, and approximately 1,100 uranium occurrences are now coded and ready for editing.

The Section Head also assisted in the preparation of Canada's contribution to the International Uranium Resources Evaluation Program, organized by the International Atomic Energy Agency and the Nuclear Energy Agency.

Other achievements may be summarized as follows:

Conceptual models simulating the formation of fundamental types of uranium deposits were developed and areas favourable for occurrence of these types delineated. These models can guide the use of data in uranium resource evaluation and aid industry in formulating uranium exploration strategies.

The relationship between uranium mineralization and intrusive (discordant and concordant) and volcanic breccias in central Yukon was established. These and preliminary stratigraphic studies (carried out in collaboration with a scientist at the University of Western Ontario) suggest that uranium and possibly other metals were mobilized from black epiclastic sediments cut by the diatremes. This model can be applied to similar environments in the Cordillera.

Geological reconnaissance of the Permo-Carboniferous Basin of Atlantic Canada led to the discovery of previously unreported uranium occurrences on Prince Edward Island and the Magdalen Islands, and to the establishment of genetic models for three different styles of sandstone-type mineralization. These results provide a basis for evaluating uranium resources throughout the Basin, and they can be expected to stimulate exploration activity.

Mineralogical and isotopic studies on ore and host rock samples from the Rabbit Lake deposit, Saskatchewan, determined paragenetic relationships between uranium-bearing and non-radioactive minerals, and allowed interpretation and some ore-forming and alteration processes that were active in the formation of this uranium deposit. Information on the liberation, removal, and migration of uranium and lead from the decomposing "primary" radioactive minerals and their redeposition in altered rocks, soils, and clay minerals can be usefully applied in metallogenic, geochemical, and ecological studies.

Detailed mapping and subsequent mineralogic studies of uranium mineralization of the Proterozoic Dubawnt succession, District of Keewatin, showed that the mineralization within the Kazan and South Channel Formations is polymetallic and may be attributed to a hydrothermal process initiated by the emplacement of Christoper Island alkalic dykes. In addition, the distribution of the mineralization is spatially related to fault systems that controlled deposition of the Dubawnt succession. This interpretation of the genesis of mineralization will facilitate estimation of potential uranium resources and aid exploration in this and similar geological environments.

Other Renewable Resources

In 1976-77, geothermal studies were carried out by outside contractors. Much new information was provided on the age and composition of young volcanic rocks in the Cordillera, and detailed mapping was undertaken in the Meager Creek area. A belt of granitic plutons as young as 6.8 million years, trending northwesterly through the southern Coast Mountains, has been identified as an important mineral exploration target. The source of the widespread Bridge River Ash, a recent volcanic ash deposit, has been almost certainly located in the Meager Mountain area, one of the most promising geothermal localities in the Cordillera.

EARTH SCIENCES

Geological Service

Standards, Correlations, and Processes

The age of processes that lead to the formation of rocks — deposition, metamorphism, volcanism, and intrusion — is a major element of all geological studies. Information on aging processes aids in the establishment of a sequence of geological events in one specific area and in the correlation of events between areas. The age of rocks and minerals is determined by study of the isotopic decay of parent isotopic elements in relation to daughter elements. The Division's, geochronological laboratory uses three chemical techniques to determine age. During 1976-77, it completed 205 potassium-argon determinations, 26 rubidium-strontium isochrons, and one or more portions of 39 separate zircon samples, requiring a total of 170 lead and 84 uranium analyses. Samples were collected from most regions of Canada.

A granite from northeastern Newfoundland was shown to be of late Cambrian age (~510 million years), the oldest known sample of terrain thought to have been ocean floor at that time. New age determinations for a Precambrian stock in northeastern Ontario have resolved uncertainties introduced by earlier geochronological studies. The existence of excess radiogenic argon in some Precambrian rocks in the Yellowknife area was confirmed, thus explaining anomalies in earlier determinations. Zircon age determinations have provided evidence of very old (3.4 billion years) gneisses in the Keewatin Province and 3.7

billion year-old rocks on the coast of Labrador, the latter being among the oldest measured samples in the world.

"Relative time" is established by the study of fossil fauna and flora, and their evolutionary paths, contained in the younger part of Canada's terrain. Identification of the effects of ancient environments on fossil forms and recognition of a province or realm of like fossils that evolved independently of others, separated by land or ocean barriers, contribute to our understanding of the geological history of large areas of terrain.

In Eastern Canada, paleontologic studies of early Paleozoic faunal provinces have continued through the description and refinement of age measurements for trilobites, ostracodes, and palynomorphs. The results of a study of selected fossiliferous sequences of Ordovician strata in localities in eastern and western Newfoundland will become standards against which fossils from other sequences can be compared. Spores from Late Silurian and Devonian plants in the Gaspé Peninsula, Hudson Bay, and Arctic regions are yielding biostratigraphic reference sequences in otherwise unfossiliferous or poorly fossiliferous strata that may be keyed to marine fossil standards.

Using portable high-discharge fire-fighting pump to create clean stratigraphic exposures of perennially frozen till, Kazan River, District of Keewatin.

In the eastern Cordillera, a sedimentary transitional zone is the focus of base metal exploration activity. Studies of trilobites, ostracodes, and other fossils, along with stratigraphic investigations, are being used to help delineate this zone where shelf carbonates grade westwards into slope clastic strata. Separate and correlatable biostratigraphic standards of Early Cambrian trilobites are being developed for each of the shelf facies and the slope facies.

An understanding of the complex processes by which various rocks and associated mineral deposits were formed is important to exploration geologists and other earth scientists. Such knowledge assists in the tracing of geological history and in the prediction of probable locations of economically exploitable mineral deposits. The Division is currently pursuing several studies of granites, of the anorthosite suite, and of metamorphism and structural development in various regions of Canada:

In northeastern Newfoundland, the distribution of metamorphic and plutonic rocks and the sequence and ages of geological processes are being re-examined, and earlier proposed models of development are being challenged. The area is used as a key to understanding the crystalline belt that extends southerly through eastern Newfoundland.

Anorthosite intrusions and associated rocks in the eastern Canadian Shield contain major deposits of titanium-iron and some copper-nickel. The rocks originated as magma deep within the crust and upper mantle; and, contrary to earlier theories, they are most likely to be anorogenic – that is, not related to normal mountain-building processes. Titanium-rich ferrodiorites, one member of the complex suite, represent the most favourable target for economic titanium-iron (ilmenite) deposits.

Medium-grade to high-grade metamorphic rocks are common in the Canadian Shield. Their classification and recognition are much debated questions. During the year, field work in the Sherridon area of Manitoba was completed, resulting in the mapping of three sulphide-rich beds through a metamorphic terrain. In addition, further progress was made in the development of a system of computer programs which will facilitate the analysis of chemical data on selected metamorphic minerals and the derivation of estimates of their temperature and pressure of formation. Once developed and applied, the system will permit "map-

ping" variations across metamorphic terrains, such as the ubiquitous grey granitic gneiss, whose conditions of formation are not now easily subdivided on mineral assemblages alone. In connection with this work, a contract has been let for the collection of critical thermochemical data on one mineral species.

The structural and metamorphic development of a key area in the Melville Peninsula is being studied to provide an understanding of its tectonic style. In this area, Aphebian supracrustal strata lying upon Archean basement have been metamorphosed to medium grade and folded and thrust-faulted in a complex manner.

In the Appalachian region of Eastern Canada, an example of Ordovician island arc volcanics in northeastern Newfoundland is being carefully studied. Small massive base-metal sulphide deposits, similar in style to those of the Bathurst and Noranda mining camps, are related to the volcanic assemblage. Stratigraphy of these difficult rocks is being established and the chemistry of the volcanics studied, in an attempt to reconstruct the arc belt and its development in Ordovician time and to place the sulphide deposits in that setting. It is hoped that the results can be used to improve predictions of target areas for sulphide deposits in ancient arc assemblages.

The Mississippian Windsor Group in the Atlantic Provinces is host to salt, potash, gypsum, strontium, and lead-zinc-copper deposits and occurrences. In 1976-77, field study of the Windsor strata on Cape Breton Island was completed. This work confirmed the stratigraphy of the basal Windsor strata and the southeastern edge of an evaporite basin (containing deposits of salt, potash, and gypsum) centred to the west.

Work on the magnetic properties or paleomagnetism of rocks is carried out in cooperation with geologists from other branches of the Geological Survey in remote parts of the country where other paleomagnetism groups normally do not operate. The results of studies in this field in 1976-77 may be summarized as follows:

A study of a norite (1900 m.y.) and a diabase (1250 m.y.) dyke contact near Sudbury, Ontario, yielded a depth estimate of the present level of erosion of 7 km ± 2 km at the time of diabase intrusion. The estimate is based on establishment of a zone of hybrid magnetic directions in the norite 50 m from the diabase contact, maximum temperatures reached in this zone based on the magnetics, and calculations of the thermal effect of the dyke. At this time, this procedure is the only quantitative method of arriving at depth of burial estimates in the Precambrian Shield.

Stable magnetization was isolated in Aphebian igneous and sedimentary rocks from Richmond Gulf, the second collection area of the Circum-Ungava Belt. A third collection was made from near Sutton Lake. The results so far are coherent, if the magnetization is assumed to be older than the folding (Hudsonian).

A study of basalt samples from Leg 37 of the Deep Sea Drilling Project indicated that high-intensity remnant magnetization with directions conforming to present field directions is carried by essentially single-component magnetic mineralogy. Scattered directions and low intensity appear to correlate with multicomponent magnetic mineralogy resulting from oxidation.

Geoscience Surveys — Regional Analyses and Syntheses

East Arm, Great Slave Lake

The Proterozoic rocks of the East Arm of Great Slave Lake were originally mapped on a reconnaissance scale in 1929-31, restudied as a basin analysis in 1966-67, and finally mapped on a 1:50,000 scale in 1976. The recent mapping revealed spectacular new features of the structural and magmatic evolution of the aulacogen:

Faulting was found to have resulted from early block faulting; later movement of hugh nappes; and, finally, dextral strike-slip displacement of regional scale.

The stratigraphic relationships within and between the Wilson Island, Union Island, and Sosan Groups were established.

A succession of mid-Aphebian events, including metamorphism to amphibolite, grade mylonitization of regional extent, and intrusion of a diabase dyke swarm coextensive with the aulacogen, was recognized in the pre-aulacogen basement.

The distribution of 40 volcanic centres in the aulacogen was shown. The Stark Formation was reinterpreted as a salt solution collapse megabreccia of regional extent.

Hackett River-Back River Area

During the year, field work for the 1:250,000 scale mapping of the Hackett River-Back River greenstone belt in the Nose Lake E 1/2 — Beechey Lake W 1/2 map area was completed. The survey has disclosed that base metal deposits are preserved along an exhalite horizon at or near the top of the Archeozoic Hackett River volcanics, over a distance of at least 15 km near the north end of the belt and over a similar distance about 40 km farther south near the centre of the belt. The exhalite is intimately associated with acid pyroclastic rocks and a possible subareal-subaqueous transition into overlying sedimentary rocks.

Baker Lake Area

Field work for two 1:250,000 scale mapping projects (Thirty Mile-MacQuoid and Tulemalu Lake) was completed. Study of the nature and environment of the Dubawnt volcanics and sediments indicates numerous volcanic centres and probable structural control of the volcanic and sedimentary basins. Uranium mineralization in the region which may be related to the alkaline volcanism, is concentrated in fractures in the lower part of the section and in underlying basement rocks.

Havre-St. Pierre Area

The first of three seasons of field work for a 1:250,000 scale study of a little-known area of the Grenville Province in eastern Quebec was completed in 1976. Hitherto unknown basement rocks to the Wakeham Group were recognized and defined, and a significant volume of acid and intermediate volcanic rocks was found to be interbedded with the metasedimentary rocks of the Wakeham Group. Copper mineralization is present in similar volcanic rocks immediately south of the area under study.

Metamorphism in the Canadian Shield

A major program involving a large part of the Precambrian Subdivision staff and the cooperation of 24 scientists from provincial surveys and universities has resulted in the accumulation of data for use in preparing the first metamorphic map of the Canadian Shield. The map will be presented early in May 1977 at a special symposium on the metamorphism of the Canadian Shield. The map will lead to increased understanding of the pressure and thermal regimes that existed during the development of the Precambrian Shield. An understanding of the metamorphic history will influence our thinking on the tectonic and metallogenic development of the Shield and its mineral potential.

Pacific Continental Shelf

The marine unit made a number of dives with a Pisces submersible to test its usefulness in the geological mapping of the Pacific contential shelf. The success of these experiments indicates that the submersible will be of fundamental importance in a long-range program of reconnaissance work on the continental shelf and slope.

Vancouver Island, Victoria Area

Field work directed towards reconnaissance geological mapping of the Victoria area of Vancouver Island was essentially completed in 1976-77. Local, detailed investigations are required to conclude the project, which has been under way for about 12 years. The field work has shown that the Eocene Metchosin Volcanics grade upwards, from a pillow lava sequence in the lower part to layered, commonly amygdaloidal basalt flows in the upper part. The succession and the related Sooke gabbro intrusion are believed to have formed in an oceanic setting, with the volcanics building up above sea level. Field work was seriously hampered throughout the Cordillera by bad weather, which in many regions was the worst on record.

Finlayson and Quiet Lake Area

Geological reconnaissance studies were completed in Pelly Mountains and adjacent areas northeast of Tintina Trench in southcentral Yukon Territory. Further definition was obtained of at least two major allochthonous gently dipping sheets of oceanic and crystalline rocks on both sides of Tintina Trench. Probable correlations across Tintina Trench, requiring about 450 km of restoration on a dextral transcurrent fault, have important implications for mineral exploration controlled by stratigraphy.

Ogilvie and Wernecke Mountains

In 1976-77, reconnaissance studies were carried out in the Ogilvie and Wernecke Mountains of British Columbia, in conjunction with work on a uranium sampling program.

Mackenzie Mountains

Further detailed studies of the Rapitan Group and related rocks were carried out in the northwestern Mackenzie Mountains, in conjunction with studies of other projects dealing

with older rocks in the region. Data on hand suggest that at least some of the sedimentation was related to faulting that began during the time interval represented by the copper-bearing Redstone River Formation below the Rapitan rocks.

Toodoggone and Ware W 1/2 Areas

Reconnaissance geological studies were mainly completed in the Cassiar, Omineca, and Northern Rocky Mountains within the project area. Evidence was obtained in support of the concept that major dextral displacements have taken place on a system of regional faults, including faults along the Northern Rocky Mountain Trench.

Hazelton Area

Field work continued in southeastern Bowser Basin and adjacent Skeena Arch. The derivation of sediments in the southeastern part of the basin was coeval with uplift and granitic emplacement in Skeena Arch beginning in the Mid-Jurassic period. The distribution of zeolitized volcanic rocks suggests the existence of paleogeothermal systems, which could be of great significance in the distribution of copper.

Support to Other Agencies

In 1976-77, the Division contributed to the study of evaporite basins in Canada initiated by Atomic Energy of Canada Limited. As noted earlier in this report, the purpose of the study is to identify areas that might be suitable for the underground storage of nuclear waste. An extensive regional inventory of salt deposits in Canada was completed as Phase 1 of the investigation. In Phase 2, now under way, about 10% of the salt-bearing regions in Saskatchewan, southern Ontario and the Maritimes is being examined in greater detail; subsequently, sites will be selected for testing by drilling and for further study. In addition to serving the main purpose of the study, the project is contributing to our understanding of the processes leading to the evolution of oil and gas, sulphide, and industrial mineral deposits associated with evaporite basins.

A variety of geoscientific activities in the broad field of mineral development is being undertaken in three Atlantic Provinces through federal-provincial agreements coordinated and funded mainly by the Department of Regional Economic Expansion. Geological advice and evaluation of proposed studies are provided to provincial geologists and management committees, either informally or through subcommittees. Paleontological service also is made available to provincial field parties by arrangement.

TERRAIN SCIENCES DIVISION

J.S. Scott, Director

Work of the Terrain Sciences Division is directed towards five broad objectives: (1) to provide 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; (2) to identify and assess the occurrence and magnitude of natural terrain hazards; (3) to provide geoscience information to assist in the use, maintenance, and restoration of the physical environment; (4) to provide standards, controls, and reference materials to ensure consistency of correlation between geological events of the Pleistocene and Holocene epochs; and (5) to develop and maintain standards for mapping of surficial geology appropriate to national needs. The principal responsibilities of the Division are related to the provision of geoscientific data and interpretive information on the surficial geology and geomorphic processes of the Canadian landmass,

Coring raised marine sands on Somerset Island in order to examine ground ice (permafrost) properties. Equipment is transported to study sites in the trailer (left centre) towed by an all-terrain motor tricycle (right foreground).

and on any geotechnical aspects of bedrock geology that may have a bearing on engineering use of the terrain. These responsibilities are national in scope and include the coastal and adjacent offshore regions, exclusive of the regional responsibilities of the Atlantic Geoscience Centre.

The Division is organized into six sections: Special Projects, Regional Projects, Paleoecology and Geochronology, Marine and Coastal, Engineering and Environmental Geology, and Sedimentology and Mineral

Tracing. To some extent this organization structure is determined by discipline; but the division of activities along these lines is not always possible, because many projects call for an interdisciplinary approach. Staff of the Division are based permanently in Ottawa, but small operational units are maintained at the Institute of Sedimentary and Petroleum Geology in Calgary and at the Vancouver office of the Geological Survey.

The Special Projects Section comprises senior scientific staff with special expertise in the terrain sciences. This staff is involved in developing regional compilations of surficial geology data, studying unique Quaternary geological features, and providing scientific and technical advice to other sections of the Division and other government agencies.

The activities of the Regional Projects Section are largely directed towards providing a Canada-wide inventory of 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. Information generated by the Section is of particular value to the forestry, agriculture, engineering, construction, and mineral industries; it also contributes to land-use and environmental impact studies.

The Paleoecology and Geochronology Section essentially provides laboratory services, including analyses of fossil materials (especially pollen, mosses, wood, insects, seeds, and diatoms) and radiocarbon dating, for other sections of the Division and for outside organizations and individuals. A particular effort is made to identify all materials dated by the radiocarbon laboratory. The Section also determines variations in the radiocarbon content of modern materials, as background for other research, and investigates the chronology of fossil-bearing deposits. Research is currently being conducted on changes in the environment and in the distribution of plants, insects, and marine invertebrates during the Quaternary period.

Work in the Marine and Coastal Section is a natural extension of terrain analysis into the coastal zone and offshore areas of the Arctic and Pacific continental shelves and inter-island channels. Projects are designed to contribute to the development of an inventory of sediments, to produce information on stratigraphic and environmental history, and to develop regional understanding about physical processes and engineering attributes that control the stability and character of coastline, seafloor, and sediments. Knowledge in the latter area can assist the planning and assessment of offshore hydrocarbon development, ecological studies, and the preparation of mineral resource estimates, including the identification of aggregate sources.

The Engineering and Environmental Geology Section has broad responsibility for conducting studies of the physical and engineering characteristics of geological materials and processes. These characteristics are important in determining the appropriate use of terrain for engineering or other purposes. Staff of the Section also provide expert advice and consultation in their fields of specialization to various government departments, and they are involved in special programs for which the Terrain Sciences Division has participant responsibility.

The Sedimentology and Mineral Tracing Section is concerned with the study of active geomorphological and sedimentological processes and with the development of mineral prospecting techniques that use glacial drift as the prospecting medium. The Section also provides laboratory services that support these and other analytical and technical requirements of the Division.

The work of the Terrain Sciences Division contributes to the Earth Sciences Program of the Department of Energy, Mines and Resources. One long-term project for the Division is the mapping of major features of Canada's glacial geology on a scale of 1:250,000. To date, only 20% of the country has been mapped on the scale, and less than 5% on a scale of 1:50,000.

In 1976-77, a major portion of the Division's resources was directed towards the provision of information on the terrain of the Arctic islands and central Keewatin, to support recent developments in the fields of hydrocarbon and mineral exploration. Systematic terrain mapping of these areas was complemented by specialized studies of the botanical cover and the geotechnical characteristics of terrain units.

Activities related to petroleum development in the Arctic have also generated a requirement for information on coastal and offshore regions. Accordingly, studies have been conducted in the Beaufort Sea, high Arctic Islands, and Lancaster Sound.

Other important projects carried out during the year include studies of permafrost in northern transportation corridors, particularly in the Mackenzie Valley and the central

Arctic Islands; engineering geological investigations, combined with stratigraphic studies, of the landslide-prone marine (Leda) clay in the Ottawa-St. Lawrence Lowlands; an evaluation of igneous rock types as potential hosts for storage of nuclear waste; the development of innovative mineral prospecting techniques to facilitate the search for ore deposits; and the performance of prototype urban geology studies for selected centres with distinctive physiographic-geologic characteristics. Detailed information about these and other activities is provided below.

STANDARDS AND CORRELATIONS

During the year, seven projects were carried out, to provide paleoecological and geochronological data required by scientists in the Division for current research projects in the field of Quaternary chronology and related glacial events. Such information can shed light on crustal movement and on the rates of geological processes, such as sedimentation, in a variety of environments. Most of the projects undertaken in 1976-77 involved both a research and a service component.

Radiocarbon Dating Laboratory

A total of 196 age determinations were carried out on 181 samples, an increase of 33 over the number performed in 1975-76. Of the samples, 163 were geological and 18 geochemical. Determinations of $^{13}C/^{12}C$ ratios on 130 samples were carried out under contract at the University of Waterloo. Radiocarbon Date List XVI (GSC Paper 76-7) contains information on 83 determinations carried out on 80 samples.

Paleoecology

The Palynology Laboratory processed 144 pollen samples in 1976-77, and 24 internal reports were prepared, based on 24 samples. Identification of wood samples is carried out for most Laboratory. During the year, 64 reports were prepared on 196 samples. Work is continuing in building up a diatom reference collection; more than 600 file cards have been compiled, providing information on the ecological and geographical distribution of various taxa, and 1,166 photo-micrographs are available for reference. Twenty-two diatom reports were prepared for 137 samples submitted for analysis. The seed reference collection has been increased by the preparation of 423 samples, and 15 reports were prepared on other plant macrofossils. Twenty-one fossil arthropod reports also were prepared.

Other investigations included studies in the Carey Islands, Greenland, aimed at acquiring additional information on the glacial history of the northern part of Baffin Bay, and a joint interdisciplinary study with scientists of the National Museums of Canada, the "Yukon Refugium Project".

SEDIMENTARY AND GEOMORPHIC PROCESSES

Coastal and Nearshore Processes

Studies of coastal and nearshore processes are being carried out in the Arctic and Pacific coast areas. Most projects are multidisciplinary in nature and are related to investigations in other activity areas. Six scientific projects are currently under way, involving field investigations on the Fraser River delta front, at Kay Point in the Beaufort Sea, and in the coastal areas of Lancaster Sound and the central high Arctic Islands.

Investigations operating from C.S.S. HUDSON yielded one of the research highlights of the year. Side-scan sonar studies were carried out in Lancaster Sound, particularly in the inlets and along the south coast of Devon Island, revealing ice-scour tracks in water depths of more than 150 m. The occurrence of scourage, particularly in such deep waters, is highly relevant to the engineering design of seabed pipelines.

The field component of coastal studies in the Barrow Strait (northern Somerset Island, southeast Bathurst Island, and adjacent islands) has been completed. Short and long-term coastal changes have been documented for 72 beach profiles, and preliminary manuscripts have been prepared. In addition, through project funding provided by the Ministry of Transport, coastal information has been obtained by outside contractors for Ellef Ringnes, King Christian, Cameron, and Bathurst islands.

A multi-disciplinary project is planned for the 1977 field season to study the coasts and geomorphic processes at the eastern entrance of Lancaster Sound and northeastern Baffin Island. Funds are being provided by the Environmental Protection Service, Department of Fisheries and the Environment, as part of the Arctic Oil Spills Countermeasures Program.

During the year, a comprehensive 170-page report was prepared on bottom scour in the Beaufort Sea. The report contains the results of investigations carried out over several years by the Marine Sciences Branch, Arctic Petroleum Operators Association, and

the Terrain Sciences Division. Field work has been completed for the Kay Point investigations, and a report is pending. Work is continuing in the Fraser Delta area providing fundamental geological knowledge about the dispersal of sediments in estuaries and generating valuable information on the depositional history of the delta.

Fluvial and Lacustrine Processes

Five scientific projects on fluvial and lacustrine processes are currently under way. The main emphasis for field investigation has been on Banks Island, in the Norman Wells area, and in central Keewatin. The Banks Island and Norman Wells projects are being carried out over a period of several years to permit the collection of sequential data.

The Banks Island study is designed to be applicable to rivers in other Arctic areas. Flume laboratory projects are being conducted in conjunction with this project, to provide precise data on variation of stream-bed characteristics under controlled conditions. During the year, eight manuscripts relating to these projects were submitted for publication.

The studies in the Norman Wells area are designed to determine the effects on the environment of bridge crossings along the proposed Mackenzie Highway route. Funding has been provided by the Hydraulic Design Committee of the Mackenzie Highway Environmental Working Group and by the Department of Indian Affairs and Northern Development. Two reports were produced in 1976-77, and the work is continuing for at least one more year.

Associated with drift process studies (described below) extensive sediment sampling and lake-bottom photography were carried out, using scuba techniques, in several large lakes in central Keewatin. Data from these dives, from subbottom profiling, from profile measurements of water chemistry, and from studies of diatoms in core samples are being used to guide further studies of lake sediment budgets and siltation rates of lakes adjacent to the proposed Polargas pipeline route.

Glacial and Drift Processes

Studies of glacial and drift processes are aimed primarily at developing a better understanding of the mode of emplacement and post-depositional changes that affect glacial and associated deposits. Work in this area has been concentrated in the District of Keewatin. Investigations include:

Field studies of the applicability of drift sampling in the exploration for base metal and uranium deposits in areas of permafrost.

Field and laboratory studies of chemical and physical aspects of sedimentation in Arctic lakes and the relationship of lake sediments to glacial sediments in their basins.

Field studies of the effects of recent tundra fire on terrain and on nutrient availability in areas of the Canadian Shield.

Pilot study of trace element uptake by various species of tundra plants in areas of differing types of mineralization.

In central Keewatin, glacial dispersal trains have been identified by visual inspection and chemical analysis of the clay-sized fraction of till. These trains, which exist on scales ranging from several hundred metres to hundreds of kilometres, can be geochemically defined by metal levels that are either channel (positive) or depressed (negative) relative to adjacent terrain.

The configuration of a metal-poor, "negative" train of till containing hematitic pigment from redbeds of the Dubawnt Group has been mapped by its distinctive red colour and has been shown to extend from the Baker Lake area southeastwards to the Hudson Bay coast, covering an area of 80 x >300 km. Adjacent to this train is a "positive" train of molybdenum-uranium-rich till that covers an area about half as large and seems to begin in an area of younger (Aphebian) Precambrian rocks north of Baker Lake. Parts of this train appear to be related closely to airborne radiometric anomalies. Furthermore, the train indicates areas of uranium mineralization that are presently unknown from conventional geologic techniques.

The glaciated landscape (95% of Canada) is visualized as being influenced by overlapping trains of varying scale and comprising chemically and physically distinct detritus. The largest of these trains must be defined in order to interpret natural variations in metal levels (either for exploration or pollution studies) or natural variations in geotechnical properties (such as terrain stability and ice content). The larger-scale trains can even influence gross vegetation or settlement patterns or, possibly, animal migration routes. Base-line studies of glacial processes and

drift properties are being continued in Western Canada and the Eastern Townships. Ten manuscripts were prepared during the past year.

Permafrost Processes

Investigations related to permafrost processes have two basic objectives: to provide fundamental information that can be applied to a variety of studies which are under way in northern regions; and to provide specific information on permafrost materials as they may be affected by man's activities. Projects are continuing in the Mackenzie Valley and the Arctic Islands, two areas that are or may be affected by petroleum development, and in the Mackenzie Delta. Laboratory investigations have indicated that measurement of the acoustic properties of frozen soil samples, along with field geophysical surveys, assists in the delineation of the extent of permafrost and determination of the ground ice content. Use of this technique can reduce the amount of drilling required for construction projects and thereby lower project costs. Ten manuscripts on permafrost studies were prepared in 1976-77.

SURFICIAL SURVEYS

The largest part of the Division's work is concentrated on the performance of surficial surveys. In 1976-77, 29 projects were carried out, of which 16 had field components, including both land-based and marine geological operations. Surveys are conducted across Canada, but the greatest effort is directed towards the northern regions.

Field work for a total area of about 150,000 km^2 was completed during the year. Data for most of this area are currently being compiled for preliminary Open File release. Maps covering an area of 100,000 km^2 were released on Open File, and maps covering 110,000 km^2 in the southern Mackenzie Valley and released previously on Open File were prepared for publication. In order to provide advance information to various urban planning agencies, maps at 1:50,000 scale were released on Open File for much of the area between Ottawa and the St. Lawrence River, covering about 14,000 km^2.

The Division is conducting a series of regional surveys along the transportation corridor on the west side of Hudson Bay. Field work in 1977 will provide data in a broad zone extending from the Arctic Islands to the north end of Lake Winnipeg.

Marine geological investigations in the Beaufort Sea were cancelled in 1976, when the M.V. PARIZEAU returned to Vancouver after receiving severe damage from floating ice. In the eastern Arctic, however, the cruise of the C.S.S. HUDSON provided an opportunity for high-resolution seismic work combined with sediment coring, permitting analysis of surficial sediments; determination of seabottom temperatures, sediment and water thermal gradients, and sediment thermophysical properties, all of which contribute to assessment of the potential for ice-bounded subsea permafrost; and delineation of surficial sediment distribution by seismic, magnetic, and gravity profiling. A new technique for ice platform investigations of the sea floor was tested in March 1977, in a cooperative project with Panarctic Oils Limited, the Geological Survey of Canada, the Polar Continental Shelf Project, and the Canada Centre for Inland Waters. An unmanned submersible, TROV (Tethered Remotely Operated Vehicle), was fitted with a variety of geophysical, side-scan sonar, and sampling equipment and its capabilities tested through the ice off Drake Point, Melville Island. Results are as yet preliminary, but there is every indication that this device will play an increasingly important role in Arctic marine geology studies.

ENVIRONMENTAL AND ENGINEERING GEOLOGY

In 1976-77, work continued on a major project to determine the feasibility of using a mined cavity for retrievable storage and ultimate isolation of high-level radioactive waste. The study was requested originally by Atomic Energy of Canada Limited. As part of this program, plutonic crystalline rocks are being investigated as potential host rocks for the proposed underground facility. Data pertaining to structural and groundwater conditions at several mines in Ontario and Quebec are being compiled, and a test site on a small granite pluton near Ottawa has been established to test equipment and theoretical concepts. Because of environmental concerns expressed by local residents in one of the areas planned for intensive investigations in 1977, another area for further study has yet to be selected. Three reports have been published and several internal reports prepared as a result of these investigations.

Preliminary results of studies of the marine (Leda) clay in the Ottawa area have been released on Open File as a series of 17 maps showing the distribution of sensitive clay and landslides. Field work is complete, and final reports are in preparation.

Data from boreholes collected in 1971-72 and related to the urban geology of 28 municipalities are being prepared for release, on magnetic tape and on microfiche. Files were released for Ottawa-Hull and Vancouver during the year, and data for Montreal, Toronto, and eight other Ontario centres will be released shortly. An urban geology study of the Ottawa-Carleton Regional Municipality has been submitted for publication, a similar study for Hamilton is nearing completion, and studies are under way in Rivière-du-Loup and Saint John. Geotechnical and geological data from over 11,600 boreholes in the Mackenzie Valley netic tape and on microfiche.

REGIONAL ANALYSES AND SYNTHESES

Four major syntheses designed to result in compilation maps or series of maps are in progress:

A map for all Canada at 1:5,000,000 scale, showing the thickness and form of the late Wisconsin ice-sheet complex, is almost complete.

Also nearing completion is a multi-disciplinary compilation of oceanographic, biological, geological, meteorological, and similar data related to the Beaufort Sea. These data, which have been contributed by numerous government agencies, will result in a series of maps, tables, graphs, photographs, and graphical records, to be published jointly by the Department of Energy, Mines and Resources and the Department of Fisheries and the Environment.

Projects aimed at synthesizing the Quaternary geology of various regions of Canada are in progress for the Prairie Provinces and the Canadian Cordillera.

SUPPORT SERVICES

Scientific and technical support is provided to scientists in the Division in the fields of photogrammetry, editing, drafting, and data management, and through the provision of laboratory services related to sedimentology and engineering geology. In 1976-77, quantitative photogrammetric techniques were used to analyze aerial photographs for the preparation of detailed maps of geomorphic and geologic features pertinent to 30 projects in Quebec, Ontario, British Columbia, and the Arctic. The Divisional Scientific Editor reviewed 12 manuscript reports prepared for final publication, 55 short manuscripts for publication in the Report of Activities series, and 15 manuscripts for publication in scientific journals or as internal reports. Approximately 20 maps and 400 figures were drafted to illustrate printed and oral communications arising from the scientific program of the Division.

The Sedimentology-Engineering Geology Laboratories carry out a variety of analyses and tests to provide data on the physical and engineering properties of unconsolidated materials, to extract material for geochemical analysis and clay mineral identification, and to provide technical support for flume experiments (discussed in this report). The laboratories process approximately 3,000 samples per year.

LIST OF PUBLICATIONS

Branch publications comprise memoirs, bulletins, economic geology reports, papers, miscellaneous reports, maps, and Open File items. Included in the paper series is the Report of Activities, which during 1976-77 was issued in three parts comprising 221 individual papers and about 1,200 pages.

Members of the staff also publish in the world-wide scientific press, in most instances short articles in scientific journals; but from time to time, lengthy contributions to treatises or complete books. In the following list, these items will be found under the heading "Other Scientific Publications".

In addition to reports and geological maps, the Branch publishes a series of aeromagnetic maps, which are the product of surveys carried out under the auspices of the federal-provincial Aeromagnetic Program. During the report period, 67 aeromagnetic maps were issued. They are not included in the following list. The vast amount of data being generated by the Uranium Reconnaissance Program is being published whenever possible in microfiche form. The data resulting from radiometric surveys are being released in microfiche form in the geophysical series of maps. They are included in the following lists.

Some reports have been prepared by members of more than one division. In such cases, the report is cited only under the name of the first author by alphabetical listing.

OFFICE OF THE DIRECTOR-GENERAL

Branch Publications

Bolton, T.E. Canadian Geoscience Council. Current research in the geological sciences in Canada, May 1975-April 1976. Geol. Surv. Can., Paper 76-5, 100 p.

Douglas, R.J.W. Geology, La Biche River, District of Mackenzie, Geol. Surv. Can., Map 1380A.

Douglas, R.J.W. and Norris, D.K. Geology, Fort Liard, District of Mackenzie. Geol. Surv. Can., Map 1379A.

Other Scientific Publications

McLaren, Digby J. The Silurian-Devonian Boundary Committee. A final report. In the Silurian-Devonian boundary. IUGS Series A, no. 5, 1-34, Stuttgart.

ATLANTIC GEOSCIENCE CENTRE

Branch Publications

Evitt, W.R., Lentin, J.K., Millioud, M.E., Stover, L.E., and Williams, G.L. Dinoflagellate cyst terminology. Geol. Surv. Can., Paper 76-24, 11 p.

Folinsbee, R.A. and Haworth, R.T. Marine gravity and magnetic digital data, northeast of Newfoundland. Geol. Surv. Can., Open File 391.

Gradstein, F.M., Jenkins, W.A.M. and Williams, G.L. Biostratigraphy and depositional history of Amoco IMP Skelly B-1 Egret K-36, Grand Banks, Newfoundland, Geol. Surv. Can., Open File 396.

Gradstein, F.M. and Williams, G.L. Biostratigraphy of the Labrador Shelf, Part I. Geol. Surv. Can., Open File 349.

Haworth, R.T. and MacIntyre, J.B. Gravity and magnetic fields of the Gulf of St. Lawrence, Canada. Geol. Surv. Can., Paper 75-42, 11 p.

Jansa, L.F., Gradstein, F.M., Harris, I.M., Jenkins, W.A.M. and Williams, G.L. Stratigraphy of the Amoco-IOE Murre G-67 well, Grand Banks of Newfoundland. Geol. Surv. Can., Paper 75-30, 14 p.

King, L.H. and MacLean, B. Geology of the Scotian Shelf. Geol. Surv. Can., Paper 74-31, 31 p.

MacIntosh, M., Willey, J.D. and Courneya, C. A compendium of the sampling and analytical techniques used by the Environmental Marine Geology Subdivision, Atlantic Geoscience Centre, Bedford Institute of Oceanography, Dartmouth, Nova Scotia. Geol. Surv. Can., Open File 397.

Piper, D.J.W. and Keen, M.J. Geological studies in St. Margaret's Bay, Nova Scotia. Geol. Surv. Can., Paper 76-18, 18 p.

Reinson, G.E. Surficial sediment distribution in the Miramichi estuary and implications for dredging. Geol. Surv. Can., Open File 395.

Shih, K.G. Data storage and retrieval using geodatabase with application of geophysical data in Marsden Square 151. Geol. Surv. Can., Open File 337.

Shih, K.G. Six-minute grid mean values of free air gravity and magnetic anomalies in Marsden Squares, 150, 149 and 186. Geol. Surv. Can., Open Files 348, 387, 404.

Sparkes, R. and Grant, A.C. Seismic reflection data from Cruise D'IBERVILLE 064-68. Geol. Surv. Can., Open File 359.

van der Linden, W., Fillon, R.H. and Monahan, D. Hamilton Bank, Labrador margin: Origin and evolution of a glaciated shelf. Geol. Surv. Can., Paper 75-40, 31 p.

van der Linden, W., Fillon, R.H. and Monahan, D. Marine geophysical data collected in Baffin Bay area. Geol. Surv. Can., Open File 343.

The following papers were published in Report of Activities, Part B; Geol. Surv. Can., Paper 76-1B, 1976.

Barss, M.S. and Crilley, B. A mounting medium for palynological residues, pp. 131-132.

Hardy, I.A. and Umpleby, D.C. Lithostratigraphy of the Labrador Shelf, pp. 31-36.

Jansa, L.F. Lower Paleozoic Radiolaria-bearing limestones from the Baffin Island shelf, pp. 99-105.

The following papers were published in Report of Activities, Part C; Geol. Surv. Can., Paper 76-1C, 1976.

Amos, C.L. Suspended sediment analysis of seawater using LANDSAT imagery, Minas Basin, Nova Scotia, pp. 55-60.

Haworth, R.T., Grant, A.C. and Folinsbee, R.A. Geology of the continental shelf off southeastern Labrador, pp. 61-70.

King, L.H. and Fader, G.B. Application of the Huntec deep two high-resolution, seismic system to surficial and bedrock studies – Grand Banks of Newfoundland, pp. 5-7.

Reinson, G.E. Channel and shoal morphology in the entrance to the Miramichi estuary, New Brunswick, pp. 33-35.

Reinson, G.E. Surficial sediment distribution in the Miramichi estuary, New Brunswick, pp. 41-45.

Schafer, C.T. Distribution of foraminifera in Chaleur Bay, New Brunswick-Quebec, pp. 19-23.

Schafer, C.T. In situ environmental responses of benthonic foraminifera, pp. 27-32.

Schafer, C.T. and Scott, D. Multidisciplinary environmental marine geological analsis of a coastal area, pp. 1-3.

Wagner, F.J.E. Mullusc distributions, Miramichi estuary, New Brunswick, p. 45.

Willey, J.D. Seasonal variations in the oceanography and sediment geochemistry in the Miramichi estuary, New Brunswick: a preliminary report, pp. 47-50.

Willey, J.D. Reactions which remove trace metals from seawater: preliminary observations, p. 71.

The following papers were published in Report of Activities, Part A; Geol. Surv. Can., Paper 77-1A, 1977.

Loncarevic, B.D. and Falconer, R.K. An oil slick occurrence off Baffin Island, p. 523.

Other Scientific Publications

Barrett, D.L. and Keen, C.E. Mesozoic magnetic lineations, the magnetic quiet zone, and sea floor spreading in the northwest Atlantic. J. Geophys. Res., 81, 26, 1976.

Duedall, Iver W., Dayal, Ramesh and Willey, John D. The partial molal volume of silicic acid in 0.725 M NaCl. Geochim. Cosmochim. Acta, 40, 1185-1189, 1976.

Haworth, R.T. Appalachian structural trends northeast of Newfoundland as delineated by detailed seismic reflection, magnetic and gravity surveys. Geol. Soc. Am., Abstr., 9, 3, 273, 1977.

Haworth, R.T. The continental crust northeast of Newfoundland and its ancestral relationship to the Charlie Fracture Zone. Nature, 266, 246-249, 1977.

Haworth, R.T. et Lefort, J.P. Etude Géophysique des fractures du socle sumbergé à l'ouest de l'Europe et à l'est du Canada — Fracturation tardihercyieene et correlations transatlantiques. Réunion annuelle des sciences de la Terre, France, 1977.

Haworth, R.T. et Lefort, J.P. L'arc Ibéro-armoricain: une structure précambrienne de la plate-forme avalonienne. Réunion annuelle des sciences de la Terre, France, 1977.

King, L.H. Relict iceberg furrows on the Laurentian Channel and western Grand Banks. Can. J. Earth Sci., 13, 1082-1092, 1976.

Robertson, K.R. and Rashid, M.A. Effect of solutions of humic compounds on concrete. J. Am. Concrete Inst., Oct. 1976, 577-580.

Vilks, G. Comparison of Globorotalia pachyderma (ehrenberg) in the water column and sediments of the Canadian Arctic. J. Foram. Res., 5, 4, 313-325, 1975.

Vilks, G. Foraminifera of an ice-scoured nearshore zone in the Canadian Arctic. First Int. Symp. on Benthonic Foraminifera of Continental Margin. Part A. Ecology and Biology. Marit. Sediments, Spec. Publ. 1, 267-277, 1976.

Vilks, G. and Rashid, M.A. Post-glacial paleo-oceanography of Emerald Basin, Scotian Shelf. Can. J. Earth Sci., 13, 1256-1267, 1976.

Willey, John D. Geochemistry and environmental implications of the surficial sediments in northern Placentia Bay, Newfoundland. Can. J. Earth Sci., 13, 1393-1410, 1976.

CENTRAL LABORATORIES AND ADMINISTRATIVE SERVICES

Branch Publications

Sabina, A.P. Roches et minéraux du collectionneur: Hull-Maniwaki, Québec; Ottawa-Peterborough, Ontario. Comm. Géol. Can., Etude 69-50, 181 p.

Sabina, A.P. Roches et minéraux du collectionneur: Ottawa-North Bay, Ontario; Hull-Waltham, Québec. Comm. Geol. Can., Etude 70-50, 146 p.

Sabina, A.P. Rocks and minerals for the collector: the Magdalen Islands, Quebec, and the Island of Newfoundland. Geol. Surv. Can., Paper 75-36, 199 p.

The following papers were published in Report of Activities, Part B; Geol. Surv. Can., Paper 76-1B, 1976.

Ansell, H.G., Pringle, G.S. and Roberts, A.C. A hydrated neodymium-lanthanum carbonate from Curitiba, Parana, Brazil, pp. 353-355.

Bouvier, J-L. and Abbey, Sydney Improvements in the "screw-rod" method for determination of lithium, rubidium and cesium, p. 13.

Champ, W.H. and Meeds, C.F. Application of spectrochemical methods to trace element determinations in geological materials, p. 11.

Sabina, A. P. The Francon Quarry, a mineral locality, pp. 15-19.

The following papers were published in Report of Activities, Part A; Geol. Surv. Can., Paper 77-1A, 1977.

Sabina, A.P. New occurrences of minerals in parts of Ontario, pp. 335-339.

Other Scientific Publications

Abbey, Sydney. Determinations of rare alkalis and alkaline earths in USGS standard rocks. U.S. Geol. Surv. Prof. Paper 840, 117-118, 1976.

Abbey, Sydney. "Standard samples": how "standard" are they? Geostandards Newsletter, 1, 39-45, 1977.

Abbey, Sydney, Gillieson, A.H. and Perrault, Guy. SY-2, SY-3 and MRG-1. A report on the collaborative analysis of three Canadian rock samples for use as certified reference materials. CANMET Report MRP/MSL 75-132 (TR), 1975.

Abbey, Sydney. SY-2, SY-3 and MRG-1. A report on the collaborative analysis of three Canadian rock samples for use as certified reference materials – supplement 1. CANMET Report 76-36, 1976.

Abbey, Sydney. Topics on "Geostandards" during the Interan '76 conference on analysis of geological materials. Geostandards Newsletter, 1, 1, 5-6, 1977.

Dence, M.R., Grieve, R.A.F. and Plant, A.G. Apollo 17 grey breccias and crustal composition in the Serenitatis Basin region. Proc. Lunar Sci. Conf. 7th, 1821-1832, 1976.

Maxwell, J.A. Sampling and sample preparation at the Geological Survey of Canada – the what, why, and how. In National Bureau of Standards, Spec. Pub. 422, 1976.

Sen Gupta, J.G. Determination of lanthanides and yttrium in rocks and minerals by atomic-absorption and flame-emission spectrometry. Talanta, 23, 343-348, 1976.

GEOLOGICAL INFORMATION DIVISION

Branch Publication

Blackadar, R.G. The Geological Survey of Canada: past achievements and future goals – a short history of the Geological Survey of Canada. Geol. Surv. Can., 44 p., Cat. No. M40-38/76.

INSTITUTE OF SEDIMENTARY AND PETROLEUM GEOLOGY

Branch Publications

Andrechuk, J.W. (compiler). Biostratigraphic determinations from the sub-surface of the districts of Mackenzie and Franklin and the Yukon Territory. Geol. Surv. Can., Open File 431.

Balkwell, H.R. and Roy, K.J. Surface bedrock geology, King Christian Island, District of Franklin. Geol. Surv. Can., Open File 400.

Berry, W.B.N. et al. Contributions to Canadian paleontology. Geol. Surv. Can., Bull. 256, 71 p.

Brideaux, W.W. and Fisher, M.J. Upper Jurassic-Lower Cretaceous dinoflagellate assemblages from Arctic Canada. Geol. Surv. Can., Bull. 259, 53 p.

Brideaux, W.W. et al. Biostratigraphic determinations from the sub-surface of the Districts of Franklin and Mackenzie and the Yukon Territory. Geol. Surv. Can. Paper 75-10, 18 p.

Cook, D.G. and Aitken, J.D. Geological maps of Blackwater Lake (96 B) and Fort Norman (96 C), District of Mackenzie. Geol. Surv. Can., Open File 402.

Frebold, H. The Toarcian and lower Middle Bajocian beds and ammonites in the Fernia Group of southeastern British Columbia and parts of Alberta. Geol. Surv. Can., Paper 75-39, 33 p.

Jelitzky, J.A. Mesozoic and Tertiary rocks of Quatsino Sound, Vancouver Island, British Columbia. Geol. Surv. Can., Bull. 242, 243 p.

Kerr, J.Wm. Stratigraphy of central and eastern Ellesmere Island, Arctic Canada. Part III. Upper Ordovician (Richmondian), Silurian and Devonian. Geol. Surv. Can., Bull. 260, 55 p.

McLean, R.A. Middle Devonian cystiphyllid corals from the Hume Formation, northwestern Canada. Geol. Surv. Can., Bull. 274, 80 p.

Miall, A.D. Proterozoic and Paleozoic geology of Banks Island, Arctic Canada. Geol. Surv. Can., Bull. 258, 77 p.

Norris, D.K. and Hopkins, W.S. The geology of the Bonnett Plume Basin, Yukon Territory. Geol. Surv. Can., Paper 76-8, 20 p.

Norris, D.K. and Yorath, C.J. Geological map of parts of Yukon Territory Districts of Macknezie and Franklin. Geol. Surv. Can., Open File 399.

Ollerenshaw, N.C. Geology, Jumping Pound Creek (east and west halves), Alberta. Geol. Surv. Can., Maps 1419A, 1420A.

Trettin, H.P. Results of analyses on rock specimens from the Hazen, Cape Phillips, Imina and Eids formations and from the undivided Allen Bay and Read Bay formations in the Canon Fiord region of Ellesmere Island, Arctic Canada. Geol. Surv. Can., Open File 354.

Yorath, C.J. Mesozoic and Tertiary geology of the Northwestern District of Mackenzie. Geol. Surv. Can., Open File 336.

Young, F.G., Myhr, D.W. and Yorath, C.J. Geology of the Beaufort-Mackenzie Basin Geol. Surv. Can., Paper 76-11, 65 p.

The following papers were published in Report of Activities, Part B; Geol. Surv. Can., Paper 76-1B, 1976.

Balkwell, H.R. and Hopkins, W.S. Jr. Cretaceous stratigraphy, Hoodoo Dome, Ellef Ringnes Island, District of Franklin, pp. 329-334.

Brideaux, W.W. and Myhr. D.W. Lithostratigraphy and dinoflagellate cyst succession in the Gulf Mobil Parsons N-10 well, District of Mackenzie, pp. 235-249.

Brideaux, W.W. Taxonomic notes and illustrations of selected dinoflagellate cyst species from the Gulf Mobil Parsons N-10 well, pp 251-257.

Christie, R.L. Tertiary rocks at Lake Hazen, northern Ellesmere Island, pp 259-262.

Cooke, D.G. and Aitken, J.D. Two cross-sections across selected Franklin Mountain structures and their implications for hydrocarbon exploration, pp 315-322.

Hopkins, W.S., Jr., and Sweet, A.R. A microflora from a short section of the Paleogene Kishenehn Formation, southeastern British Columbia, pp. 307-309.

McLean, J.R. Cadomin Formations: eastern limit and depositional environment, pp. 323-327.

McLean, R.A. Genera and stratigraphic distribution of the Silurian and Devonian rugose coral family Cystiphyllidae Edwards and Haime, pp. 295-301.

Myhr, D.W. and Barefoot, R.R. Geochemical properties of Cretaceous rocks and their use as a correlation tool, Mackenzie Delta and Yukon coastal plain areas, pp. 311-314.

Norris, D.K. Geological time symbols used on Operation Porcupine, pp. 263-265.

Pedder, A.E.H. Initial records of two unusual Late Silurian rugose coral genera from Yukon Territory, pp. 285-286.

Pedder, A.E.H. First records of five rugose coral genera from Upper Silurian rocks of the Canadian Arctic Islands, pp. 287-293.

Poulton, T.P. and Callomon, J.H. Major features of the Lower and Middle Jurassic stratigraphy of northern Richardson Mountains, northeastern Yukon Territory, and northwestern District of Mackenzie, pp. 345-352.

The following papers were published in Report of Activities, Part C; Geol. Surv. Can., Paper 78-1C, 1976.

Brideaux, W.W. Berriasian dinoflagellate assemblage, Martin Creek, northwestern District of Mackenzie, pp. 115-127.

Christie, R.L. and Rouse, G.E. Eocene beds at Lake Hazen, northern Ellesmere Island, pp. 153-159.

Davies, G.R. "Bitumen" in post-burial diagenetic calcite, pp. 107-114.

Gunther, P.R. A study employing optical methods to evaluate organic metamorphism and oil-generating potential of sediments in the Mackenzie Delta area, District of Mackenzie, pp. 143-152.

Morrow, D.W., Taylor, G.C., Dawson, K.R., Krouse, R.W. and Ghent, E.C. Sulphur isotope composition and strontium content of barite from Devonian rocks in northeastern British Columbia, pp. 195-201.

Pedder, A.E.H. and McLean, R.A. New records and range extensions of seven rugose coral genera in Silurian strata of northwestern and Arctic Canada, pp. 131-141.

The following papers were published in Report of Activities, Part A; Geol. Surv. Can., Paper 77-1A, 1977.

Aitken, J.D. New data on correlation of the Little Dal Formation and a revision of Proterozoic map-unit "H5", pp. 131-135.

Aitken, J.D. Redstone River Formation (Upper Proterozoic) in Mount Eduni and Bonnett Plume Lake map-areas, District of Mackenzie, pp. 137-138.

Cook, D.G. Two stages of faulting, Virginia Falls, map-area, District of Mackenzie pp. 113-115.

Gibson, D.W. The Kootenay Formation of Alberta and British Columbia — a stratigraphic summary, pp. 95-97.

Gunther, P.R. and Meijer-Dress, N.C. Devonian coal in the subsurface of Great Slave Plain: a guide to exploration for oil and gas, pp. 147-150.

Kerr, J.Wm. and de Bries, C.D.S. Structural geology of Somerset Island and Boothia Peninsula, District of Franklin, pp. 107-111.

Kozur, H. and Nassichuk, W.W. Permian conodonts in the Canadian Arctic Archipelago — biostratigraphic discussion, pp. 139-143.

MacQueen, R.W. and Bamber, E.W. Occurrence of Palaeoplysina (Hydrozoan?) in Upper Carboniferous (Lower Moscovian) carbonate rocks, northeastern British Columbia, pp. 145-146.

McLean, J.R. An occurrence of coal in the Blairmore Group on Waiparous Creek, central Foothills, Alberta, pp. 151-154.

Miall, A.D. and Kerr, J.Wm. Phanerozoic stratigraphy and sedimentology of Somerset Island and northeastern Boothia Peninsula, pp. 99-106.

Ollerenshaw, N.C. Canadian Government coal block, parcel 73, Fernie Basin, British Columbia, pp. 155-159.

Other Scientific Publications

Aitken, J.D. and Long, D.G.F. Helikian of Mackenzie Arc. Geol. Assoc. Can. Mineral. Assoc. Can., Abstr., 2, 4, 1977.

Cameron, A.R. Principles of coal petrography. Proc. Symp. Coal Evaluation, Oct. 31-Nov. 1, 1974. Alta. Res. Counc. Info. series 76, 51, 1976.

Fang, J.H., Robinson, Paul D., Starks, T.H. and Cameron, Alex. Geostatistical evaluation of some coal-seam characteristics and their geological implications. Geol. Soc. Am., Abstr., 8, 860, 1976.

Foscolos, A.E., Powell, T.G. and Gunther, P.R. The use of clay minerals and inorganic and organic geochemical indicators for evaluating the degree of diagenesis and oil generating potential of shales. Geochim. Cosmochim. Acta, 40, 953-966, 1976.

Foscolos, A.E., Powell, T.G. and Gunther, P.R. Classification of diagenesis based on mineralogical, inorganic and organic geochemical indicators. Abstr. 29th Meeting Geol. Assoc. Can., 21st Meeting Mineral. Assoc. Can., Edmonton.

Frebold, Hans and Poulton, T.P. Hettangian (Lower Jurassic) rocks and faunas, northern Yukon Territory. Can. J. Earth Sci., 14, 89-101, 1977.

Irvine, J.A. and Williams, G.D. A computer-assisted national coal inventory. Can. Min. Metall. Bull., 70, 68, 1977.

Kerr, J.Wm. Geology of outstanding Arctic aerial photographs; 3. Margin of Sverdrup Basin, Lyall River, Devon Island. Bull. Can. Pet. Geol., 24, 2, 139-153, 1976.

Kerr, J.Wm., McLaren, D.J. and Thorsteinsson, R. Canadian Arctic Archipelago. In the Silurian-Devonian boundary. IUGS Series A, no. 5, 281-288, Stuttgart, 1977.

Latour, B.A. Coal resources of Canadian Cordillera — summary. Am. Assoc. Pet. Geol. Mem., 105 pp., 1976.

Mayr, Ulrich. Middle Silurian reefs in southern Pearyland, North Greenland. Bull. Can. Pet. Geol., 24, 3, 440-449, 1976.

McIlreath, Ian and Aitken, J.D. Yoholaminites (Middle Cambrian), problematical calcareous sediment-stabilizing organism. Geol. Assoc. Can/Mineral. Assoc. Can., Abstr., 1, 84, 1976.

Miall, A.D. Palaeocurrent and palaeohydrologic analysis of some vertical profiles through a Cretaceous braided stream deposit, Banks Island, Arctic Canada. Sedimentology, 23, 459-483, 1976.

Miall, A.D. Sedimentary structures and paleocurrents in a Tertiary deltaic succession, Northern Banks Basin, Arctic Canada. Can. J. Earth Sci., 13, 1422-1432, 1976.

Miall, A.D. Post-paleozoic geology of Banks, Prince Patrick and Eglinton islands, Arctic Canada. Can. Soc. Pet. Geol., Mem. 5, 557-587, 1975.

Nassichuk, W.W. and Hodgkinson, K.A. Scaphopods from the Permian Assistance Formation, Canadian Arctic Archipelago. J. Paleontol., 50, 6, 1150-1156, 1976.

Norris, D.K. The North American Cordillera in Canada north and east of the Tintina Fault. 25th Int. Geol. Cong., Abstr., 3, 690-692, 1976.

Poulton, T.P. Distribution and significance of trigonid bivalves in the Mesozoic of Canada. Geol. Assoc. Can., Vancouver, 1977, Abstr., 2, 42.

Rutter, N.W., Foscolos, A.E. and Hughes, O.L. Climatic trends during the Quaternary in central Yukon based upon pedological and geomorphological evidence. In Proc. Quat. Soils. Symp., W.C. Mahaney, ed.

Tozer, E.T. Definitions and limits of Triassic stages and substages; suggestions prompted by comparisons between North America and the Alpine-Mediterranean regions. In Oesterreichische akademie der wissenschaften. Schriftenreihe der Erdwissenschaftlichen Kommissionen, Bd. 2, 195-206.

Wall, J.H. A foraminiferal zonal scheme for the Cretaceous system in the interior plains of Canada. Geol. Assoc. Can., 1976 Ann. Meet., Edmonton, Alberta, Abstr., 1, 45.

Wall, J.H. Marginal marine foraminifera from the Late Cretaceous Bearpaw-Horseshoe Canyon Transition, southern Alberta, Canada. J. Foram. Res., 6, 3, 193-201, 1976.

Young, G.M. and Long, D.G.F. Ice-wedge fasts from the Huronian Ramsay Lake Formation (>2,300 million years old) near Espanola, Ontario, Canada. Palaeogeogr., Palaeoclimatol., Palaeoecol., 19, 191-200, 1976.

Young, G.M. and Long, D.G.F. Stromatolites and basin analysis: an example from the Upper Proterozoic of northwestern Canada. Palaeogeogr., Palaeoclimatol., Palaeoecol., 19, 303-318, 1976.

REGIONAL AND ECONOMIC GEOLOGY DIVISION

Branch Publications

Early Archean basement in the Canadian Shield. Geol. Surv. Can., Paper 76-14.

Bostock, H.H. Itchen Lake map-area, Northwest Territories. Geol. Surv. Can., Open File 338.

Bostock, H.H., Cumming, L.M., Williams, H., Smyth, W.R. and Cajka, C.J. Strait of Belle Isle region, Newfoundland. Geol. Surv. Can., Open File 347.

Chandler, F.W. and Mukherji, K.K. Wollaston Lake fold belt, Saskatchewan. Geol. Surv. Can., Open File 358.

Currie, K.L. The alkaline rocks of Canada. Geol. Surv. Can., Bull. 239, 228 p.

Eade, K.E. and Chandler, F.W. Geology of Waterson Lake map-area, District of Keewatin. Geol. Surv. Can., Paper 76-64, 10 p.

Fritz, W.H. Ten stratigraphic sections from the lower Cambrian Sekwi Formation, Mackenzie Mountains, northwestern Canada. Geol. Surv. Can., Open File 346.

Fritz, W.H. Ten stratigraphic sections from the Lower Cambrian Sekwi Formation, Mackenzie Mountains, northwestern Canada. Geol. Surv. Can., Paper 76-22, 42 p.

Froese, E. Applications of thermodynamics in metamorphic petrology. Geol. Surv. Can., Paper 75-43, 37 p.

Gabrielse, H. Geology of Fort Grahame map-area, British Columbia. Geol. Surv. Can., Paper 75-33, 28 p.

Henderson, J.B. Yellowknife and Hearne Lake map-areas, District of Mackenzie, N.W.T. Geol. Surv. Can., Open File 353.

Henderson, J.B. Geology of Keskarrah Bay, Point Lake, Northwest Territories. Geol. Surv. Can., Open File 447.

Jackson, G.D., Davidson, A. and Morgan, W.C. Geology of the Pond Inlet map-area, Baffin Island, District of Franklin, Geol. Surv. Can., Paper 74-25, 33 p.

Jambor, J.L. Geology and hydrothermal alteration at the Magpie porphyry copper-molybdenum deposit, south-central British Columbia. Geol. Surv. Can., Paper 75-17, 41 p.

McGlynn, J.C. Geology of the Bear-Slave structural provinces. Geol. Surv. Can., Open File 445.

McGregor, D.C. and Camfield, M. Upper Silurian to Middle Devonian spores of the Moose River Basin, Ontario. Geol. Surv. Can., Bull. 263, 63 p.

Muller, J.E. Nootka Sound map-area, British Columbia. Geol. Surv. Can., Open File 344.

Okulitch, A.V., Gordon, T., Henderson, J.R., Hutcheon, I.E. and Reesor, J.E. Geology of the south half of Barrow River map-area, Northwest Territories. Geol. Surv. Can., Open Files 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443.

Read, P.B. and Monger, J.W.H. Geology and mineral deposit maps of Kluane and Alsek ranges, Yukon Territory. Geol. Surv. Can., Open File 381.

Richards, T.A. McConnell Creek map-area (east half), British Columbia. Geol. Surv. Can., Open File 342.

Rose, E.R. A field test for rare-earth elements. Geol. Surv. Can., Paper 75-16, 10 p.

Sanford, B.V. Distribution, thickness and three-dimensional geometry of salt deposits in southwestern Ontario. Geol. Surv. Can., Open File 401.

Sanford, B.V. and Grant, G.M. Physiography map of Eastern Canada and adjacent areas. Geol. Surv. Can., Map 1399A; 4 sheet, 1:2,000,000.

Sanford, B.V. and Norris, A.W. Devonian stratigraphy of the Hudson Platform. Geol. Surv. Can., Mem. 379, Pt. I, 124 p.; Pt. II, 248 p.

Stevenson, I.M. Géologie de la région du lac Joseph (23 A), Terre-Neuve et Québec. Comm. géol. Can., Etude 67-62, 5 p.

Tiffin, D.L. and Currie, R.G. Magnetic anomaly map, Queen Charlotte Sound. Geol. Surv. Can., Open File 393.

Tiffin, D.L. and Currie, R.G. Magnetic anomaly map, west coast of Vancouver Island. Geol. Surv. Can., Open File 392.

Tiffin, D.L. and Clague, J. Continuous reflection seismic profiling data from Strait of Georgia, British Columbia. Geol. Surv. Can., Open File 394.

Tipper, H.W. and Richards, T.A. Jurassic stratigraphy and history of northcentral British Columbia. Geol. Surv. Can., Bull. 270, 73 p.

Tipper, H.W. and Richards, T.A. Smithers map-area, British Columbia. Geol. Surv. Can., Open File 351.

Tremblay, L.P. Geology of northern Contwoyto Lake area, District of Mackenzie. Geol. Surv. Can., Mem. 381, 56 p.

The following papers were published in Report of Activities, Part B; Geol. Surv. Can., Paper 76-1B, 1976.

Copeland, M.J. Leperditicopid ostracodes as Silurian biostratigraphic indices, pp. 83-88.

Currie, R.G. and Muller, J.E. Magnetic susceptibility as a diagnostic parameter of Vancouver Island volcanic rocks, pp. 97-98.

Fahrig, W.F. Paleomagnetism and age of the Schefferville diabase dykes, pp. 153-155.

Gordey, S.P. and Tempelman-Kluit, S.P. Stratigraphic and structural studies in the Pelly Mountains, Yukon Territory, pp. 1-5.

Jambor, J.L. New occurrences of the hybrid sulphide tochilinite, pp. 65-69.

Jambor, J.L., Plant, A.G., and Steacy, H.R. A dawsonite-bearing silicocarbonatite sill from Montreal Island, Quebec, pp. 357-362.

Jambor, J.L. and McMillan, W.J. Distribution and origin of the "Gypsum Line" in the Valley Copper porphyry deposit, Highland Valley, British Columbia, pp. 335-341.

Poole, W.H. Plate tectonic evolution of the Canadian Appalachian region, pp. 113-126.

Ruzicka, V. Evaluation of uranium resources in the Elliot Lake-Blind River area, Ontario, pp. 127-129.

Schwarz, E.J. Paleomagnetism of the Circum-Ungava Belt: east coast of Hudson Bay, pp. 37-38.

The following papers were published in Report of Activities, Part C; Geol. Surv. Can., Paper 76-1C, 1976.

Jambor, J.L. Studies of basic copper and zinc carbonates: three-powder x-ray data for zincian malachite, rosasite, and cobalt analogues, pp. 97-105.

The following papers were published in Report of Activities, Part A; Geol. Surv. Can., Paper 77-1A, 1977.

Bell. R.T. Geology of some uranium occurrences in Western Canada, pp. 31-32.

Bell, R.T. and Delaney, G.D. Geology of some uranium occurrences in Yukon Territory, pp. 33-37.

Bourne, J.H., Stott, G., Borduas, B. and Lalonde, A. Lac de Morhiban and Natashiquan River map-areas, Quebec, pp. 199-204.

Currie, K.L. and Pajari, G.E.Jr. Igneous and metamorphic rocks between Rocky Bay and Ragged Harbour, northeastern Newfoundland, pp. 341-346.

Dawson, K.M. Regional metallogeny of the northern Cordillera, pp. 1-4.

Duke, J.M. Mineralogy of serpentinized ultramafic rocks and associated nickel deposits, p. 15.

Eade, K.E. and Blake, D.H. Geology of the Tulemalu Lake map-area, District of Keewatin, pp. 209-211.

Eisbacher, G.H. Tectono-stratigraphic framework of the Redstone Copper Belt, District of Mackenzie, pp. 229-234.

Eisbacher, G.H. Rockslides in the Mackenzie Mountains, District of Mackenzie, pp. 235-241.

Frith, R.A., Fyson, W.K. and Hill, J.D. The geology of the Hackett-Back River Greenstone Belt – second preliminary report, pp. 415-423.

Gabrielse, H., Dodds, C.J. and Mansy, J.L. Operation Finlay, British Columbia, pp. 243-246.

Geldsetzer, H.H.J. The Windsor Group of Cape Breton Island, Nova Scotia, pp. 425-428.

Henderson, J.B. and Easton, R.M. Archean supracrustal-basement rock relationships in the Keskarrah Bay map-area, Slave Structural Province, District of Mackenzie, pp. 217-221.

Heywood, W.W. Geology of the Amer Lake map-area, District of Keewatin, pp. 409-410.

Hoffman, P.F., Bell, I.R., Hildebrand, R.S. and Thorstad, L. Geology of the Athapuscow Aulacogen, East Arm of Great Slave Lake, District of Mackenzie, pp. 117-129.

Lambert, M.B. The Southwestern margin of the Black River Volcanic Complex, District of Mackenzie, pp. 179-180.

Leaming, S.F. Nephrite jade occurrences in British Columbia and Yukon Territory, pp. 297-299.

LeCheminant, A.N., Blake, D.H., Leatherbarrow, R.W. and deBie, L. Geological studies: Thirty Mile Lake and MacQuoid Lake map-areas. District of Keewatin, pp. 205-208.

Monger, J.W.H. Upper Paleozoic rocks of northwestern British Columbia, pp. 255-262.

Muller, J.E. Metchosin volcanics and Sooke intrusions of southern Vancouver Island, pp. 287-294.

Okulitch, A.V., Gordon, T., Henderson, J.R., Reesor, J.E. and Hutcheon, I.E. Geology of the Barrow River map-area, Melville Peninsula, District of Franklin, pp. 213-215.

Richards, T.A. Geology of Hazelton map-area, British Columbia, p. 247.

Ridler, R.H. Regional metallogeny and volcanic stratigraphy of the Superior Province, pp. 197-198.

Roddick, J.A. and Woodsworth, G.J. Coast Mountain Project, pp. 271-272.

Ruzicka, V. Conceptual models for uranium deposits and areas favourable for uranium mineralization in Canada, pp. 17-25.

Ruzicka, V. Assessment of selected uranium occurrences and areas favourable for uranium mineralization in Canada, pp. 27-37.

Sangster, D.F. Some grade and tonnage relationships among Canadian volcanogenic massive sulphide deposits, pp. 5-12.

Schau, M. and Hulbert, L. Granulites, anorthosites and cover rocks northeast of Baker Lake, District of Keewatin, pp. 399-407.

Tempelman-Kluit, D.J. Stratigraphic and structural relations between the Selwyn Basin, Pelly-Cassiar Platform, and Yukon Crystalline Terrane in the Pelly Mountains, Yukon, pp. 223-227.

Tiffin, D.L. and Riddihough, R.P. Gravity and magnetic survey off Vancouver Island, 1975, pp. 311-314.

Tipper, H.W. Jurassic studies in Queen Charlotte Islands, Harbledown Island, and Taseko Lakes area, British Columbia, pp. 251-254.

Watson, D.M. and Sangster, D.F. A preliminary study of iron oxide and manganese oxide units associated with volcanogenic sulphide deposits, Sherbrooke area, Quebec, pp. 13-14.

Yorath, C.J., Tiffin, D.L. and Cameron, B.E.B. Submersible operation on the Pacific continental margin, pp. 301-310.

Other Scientific Publications

Agterberg, F.P. New problems at the interface between geostatistics and geology. In Advanced geostatistics in the mining industry, 403-421. D. Reidel Publishing Company, Dordrecht-Holland, 1976.

Agterberg, F.P. Statistical methods for regional resource appraisal. Can. Min. Metall. Bull., 70, 1-3, 1977.

Boyle, R.W., Wanless, R.K. and Stevens, R.D. Sulfur isotope investigation of the barite, manganese, and lead-zinc-copper-silver deposits of the Walton-Cheverie area, Nova Scotia. Canada. Econ. Geol., 71, 749-762, 1976.

Davidson, A. and McGregor, D.C. Palynomorphs indicating Permian rocks in the Ethiopia. Nature, 262, 371-373, 1976.

Duke, J.M. Distribution of the period four transition elements among olivine, calcic clinopyroxene and mafic silicate liquid: experimental results. J. Petrol., 17, 4, 499-521, 1976.

Duke, J.M. and Naldrett, A.J. Activity of nickel oxide in some silicate melts. Geol. Assoc. Can./Mineral. Assoc. Can., Abstr., 2, 16, 1977.

Duke, J.M. and Naldrett, A.J. Sulfide mineralogy of the main irruptive, Sudbury, Ontario. Can. Mineral., 14, 450-461, 1976.

Eisbacher, G.H. Sedimentology of the Dezadeash Flysch and its implications for strike-slip faulting along the Deanli Fault, Yukon Territory and Alaska. Can. J. Earth Sci., 13, 1495-1513, 1976.

Froese, Edgar and Gunter, Avril, E. A note on the pyrrhotite-sulfur vapor equilibrium. Econ. Geol., 71, 1589-1594, 1976.

Gabrielse, H. Environments of Canadian Cordillera depositional basins. Am. Assoc. Pet. Geol., Mem. 25, 492, 1976.

Herd, R.K., Chandler, F.W. and Ermanovics, I.F. Weathering of Archean granitoid rocks, Island Lake, Manitoba. Geol. Assoc. Can./Mineral. Assoc., Can., Abstr., 1, 72, 1976.

Hutcheon, Ian, Gunter, Avril E. and LeCheminant, A.N. Serendibite from Penrhyn Group Marble, Melville Peninsula, District of Franklin. Can. Mineral., 15, 108-112, 1977.

Poliscuk, V.E. and Cumming, L.M. Geology of the Strait of Belle Isle tunnel project. Can. Min. Metall. Bull., 70, 82, 1977.

Ridler, R.H. Volcanic stratigraphy and metallogeny of the Rankin-Ennadai Belt, District of Keewatin, N.W.T. Geol. Assoc. Can., Spec. Paper 14, 659-660, 1976.

Rimsaite, J.Y.H. Progressive alteration of pitchblende in an oxidation zone of uranium deposits. 25th Int. Geol. Cong., Abstr., 2, 594-595, 1976.

Roddick, J. Summary of the Coast Plutonic Complex of British Columbia. Geol. Soc. Am., Abstr., 8, 3, 405, 1976.

Ruzicka, V. Geological favourability for various types of uranium deposits in Canada. Geol. Assoc. Can./Mineral. Assoc. Can., Abstr., 1, 38, 1976.

Ruzicka, V. Uranium resources evaluation model as an exploration tool. Proc. Symp. Explor. of Uranium Ore Deposits, I.A.E.A./N.A.E., Vienna, 1976.

Sangster, D.F. Possible origins of lead in volcanogenic massive sulphide deposits of calc-alkaline affiliation. Geol. Assoc. Can., Spec. Paper 14, 1976.

Woodsworth, G.J., Pearson, David E. and Sinclair, A.J. Metal distribution patterns across the eastern flank of the Coast Plutonic Complex, southcentral British Columbia. Econ. Geol., 72, 170-183, 1977.

RESOURCE GEOPHYSICS AND GEOCHEMISTRY DIVISION

Branch Publications

Ballantyne, S.B. Geochemical orientation surveys for uranium in southern British Columbia. Geol. Surv. Can., Open File. 341.

Boyle, R.W. Mineralization processes in Archean greenstone belts. Geol. Surv. Can., Paper 75-15, 45 p.

Dyck, W., Garrison, E.W., Godoi, H.O., and Wells, G.S. Minor and trace element contents of well waters, Carboniferous basin, Eastern Canada. Geol. Surv. Can., Open File 340.

Dyck, W., Pelchat, J.C., and Meilleur, G.A. Equipment and procedures for the collection and determination of dissolved gases in natural waters. Geol. Surv. Can., Paper 75-34, 12 p.

Gleeson, C.F. and Boyl, R.W. The hydrogeochemistry of the Keno Hill area, Yukon Territory. Geol. Surv. Can., Paper 75-14, 22 p.

Grasty, R.L. A calibration procedure for an airborne gamma-ray spectrometer. Geol. Surv. Can., Paper 76-16, 9 p.

Hood, P.J., Sawatzky, P., Kornik, L.J. and McGrath, P.H. Aeromagnetic gradiometer survey, White Lake, Ontario. Geol. Surv. Can., Open File 339.

Hornbrook, E.H.W. and Garrett, R.G. Regional geochemical lake sediment survey, east-central Saskatchewan (NTS 63M, 64D and parts of 63K, L, N, 73 I, O, P, and 74A). Geol. Surv. Can. Paper 75-41, 20 p.

Hornbrook, E.H.W., Garrett, R.G. and Lynch, J.J. Regional lake sediment geochemical reconnaissance data, Nonacho Belt, east of Great Slave Lake, Northwest Territories. Geol. Surv. Can., Open Files 324, 325, 326.

Hornbrook, E.H.W., Garrett, R.G. and Lynch, J.J. Regional lake sediment geochemical reconnaissance data, Great Bear Lake, Northwest Territories. Geol. Surv. Can., Open Files 327, 328.

Jonasson, I.R. Detailed hydrogeochemistry of two small lakes in the Grenville geological province. Geol. Surv. Can., Paper 76-13, 31 p.

Jonasson, I.R. and Goodfellow, W.D. Orientation studies in uranium exploration in the Yukon. Geol. Surv. Can., Open File 388.

Killeen, P.G. and Carmichael, C.M. Radioactive disequilibrium determinations. Part I: Determination of radioactive disequilibrium in uranium ores by alpha-spectrometry. Geol. Surv. Can., Paper 75-38.

Maurice, Y.T. Geochemical orientation studies in southern Baffin Island. Geol. Surv. Can., Open File 444.

Richardson, K.A., Holman, P.B. and Elliott, B.E. Reconnaissance airborne gamma-ray spectrometry data (64E, 64L, 74A, 74G, 74H, 74F). Geol. Surv. Can., Open Files 309, 310, 311, 312, 313, 314

Slaney, V.R. LANDSAT images of Canada. Geol. Surv. Can., Open File 386, 60 p.

Uranium Reconnaissance Program. Airborne gamma-ray spectrometry data, Ontario. Geol. Surv. Can., Open Files 329, 330.

Uranium Reconnaissance Program. Airborne gamma-ray spectrometry data, Quebec. Geol. Surv. Can., Open File 331.

Uranium Reconnaissance Program. Airborne radioactivity maps and profiles, Ontario (31C). Geol. Surv. Can., Open File 428.

Uranium Reconnaissance Program. Airborne radioactivity maps and profiles, Nova Scotia (21A, 21B, 20 O). Geol. Surv. Can., Open File 429.

Uranium Reconnaissance Program. Airborne radioactivity maps, Manitoba (64N/6, 64N/11). Geol. Surv. Can., Open File 430.

Uranium Reconnaissance Program. Airborne gamma-ray spectrometric maps and profiles, northern Manitoba (54L/w 1/2, 54M/w 1/2, 64G, 64I, 64P). Geol. Surv. Can., Geophysical Maps 36254G, 36354G, 35964G, 36664G.

Uranium Reconnaissance Program. Airborne gamma-ray spectrometric maps (55, 46 and 56, 65, 75, 66 and 76, 86 and 96). Geol. Surv. Can., Geophysical Maps 37055G, 37056G, 37065G, 37075G, 37076G, 37096G.

National Geochemical Reconnaissance. Regional lake sediment geochemical reconnaissance data, northeastern Manitoba (64I, 54L/W 1/2; 64P, 54M/W 1/2). Geol. Surv. Can., Open Files 407, 408.

The following papers were published in Report of Activities, Part B; Geol. Surv. Can., Paper 76-1B, 1976.

Dicaire, A., Flint, T.R., Knapp, H.W.C., Olson, D. and Sawatzky, P. The Geological Survey of Canada aeromagnetic gradiometer system: progress report, pp 303-305.

Grasty, R.L. The circle of investigation of airborne gamma-ray spectrometers, pp. 77-79.

Grasty, R.L. The "field of view" of gamma-ray detectors — a discussion, pp. 81-82.

Hood, P.J. and Ready, E. Federal-Provincial Aeromagnetic Survey Program of Canada: progress report, pp. 267-272.

Jonasson, I.R. Trace metals in snow strata as indicators of silver-arsenide vein mineralization. Camsell River area, District of Mackenzie, pp. 71-75.

Katsube, T.J. New requirements for electrical exploration methods and for laboratory R and D, pp. 229-233.

Sinha, A.K. A technique for obtaining correct ground resistivity from airborne wave tilt measuring systems, pp. 281-283.

Swan, D., Frydecky, I., and Currie, R.G. A library of computer programs for the prospecting of hyperbolic and range-range navigation data, p. 95.

The following papers were published in Report of Activities, Part C; Geol. Surv. Can., Paper 76-1C, 1976.

Annan, A.P. Density of ice samples from "Involuted Hill" test site, District of Mackenzie, pp. 91-95.

Bower, M.E. VLF navigation in the North Star aircraft of the National Aeronautical Establishment, pp. 79-82.

Cameron, E.M. Geochemical reconnaissance for uranium in Canada; notes on methodology and interpretation of data, pp. 229-236.

Coker, W.B. Geochemical follow-up studies, northwestern Manitoba, pp. 263-267.

Dyck, W., Whitaker, S.H., and Campbell, R.A. Well water uranium reconnaissance, southwestern Saskatchewan, pp. 249-253.

Goodfellow, W.D., Jonasson, I.R. and Lund, N.G. Geochemical orientation and reconnaissance surveys for uranium in the central Yukon, pp. 237-240.

Jonasson, I.R. and Gleeson, C.F. On the usefulness of water samples in reconnaissance surveys for uranium in the Yukon Territory, pp. 241-248.

Judge, A.S., Macaulay, H.A. and Hunter, J.A. An application of hydraulic jet drilling techniques to mapping of sub-seabottom permafrost, pp. 75-82.

Katsube, T.J., Wadleigh, M. and Erickson, R. Electrical properties of permafrost samples, pp. 83-90.

Killeen, P.G., Bernius, G.R. and Hall, N. Carbon gamma-ray survey, Prince Edward Island, pp. 269-271.

Maurice, Y.T. Detailed geochemical investigations for uranium and base metal exploration in the Nonacho Lake area, District of Mackenzie, pp. 259-262.

McGrath, P.H., Kornik, L.J. and Dods, S.D. A method for the compilation of high quality calculated first vertical derivative aeromagnetic maps pp. 9-17.

Overton, A. Seismic techniques for reconnaissance studies in difficult ice-covered offshore areas, pp. 73-174.

Overton, A., Burns, R.A., Gagne, R.M. and Good, R.L. Seismic instrument tests in Kugmallit Bay, District of Mackenzie, p. 25.

Sinha, A.K. An interactive graphic system for interpretation of dipole e.m. sounding data, pp. 51-53.

Sinha, A.K. Interpretation of Tridem airborne e.m. data, pp. 221-224.

Sinha, A.K. A field study for sea-ice thickness determination by electromagnetic means, pp. 225-228.

Smee, B.W. and Ballantyne, S.B. Examination of some Cordilleran uranium occurrences, pp. 255-258.

The following papers were published in Report of Activities, Part A; Geol. Surv. Can., Paper 77-1A, 1977.

Bristow, Q. A system for the offline processing of borehole gamma-ray spectrometry data on a Nova minicomputer, pp. 87-89.

Killeen, P.G. and Cameron, G.W. Computation of in situ potassium, uranium, and thorium concentrations from portable gamma-ray spectrometer data, pp. 91-92.

Slaney, V.R. LANDSAT imagery — a Canadian listing, pp. 361-362.

Washkurak, S. Meteorological satellites aid airborne operations in remote regions, pp. 93-94.

Other Scientific Publications

Annan, A.P. and Davis, J.L. Impulse radar sounding in permafrost. Radio Sci., 11, 4, 383-394, 1976.

Cagatay, M.N. and Boyle, D.R. Geochemical prospecting for volcanogenic sulphide deposits in the Eastern Black Sea ore province, Turkey. Sixth Int. Geochem. Expl. Symp., Sydney, Australia, 1976.

Cameron, E.M. and Hornbrook, E.H.W. Current approaches to geochemical reconnaissance for uranium in the Canadian Shield. Proc. Symp. Explor. of Uranium Ore Deposits, I.A.E.A./N.E.A., Vienna, 1976, 241-266, 1976.

Cameron, G.W., Elliott, B.E. and Richardson, K.A. Effects of line spacing on contoured airborne gamma-ray spectrometry data. Proc. Symp. Explor. of Uranium Deposits, I.A.E.A./N.A.E., Vienna, 1976.

Charbonneau, B.W., Kileen, P.G., Carson, J.M., Cameron, G.W. and Richardson, K.A. The significance of radioelement concentration measurements made by airborne gamma-ray spectrometry over the Canadian Shield. Proc. Symp. Explor. of Uranium Ore Deposits, I.A.E.A./N.A.E., Vienna, 1976.

Collett, L.S. Future trends in geophysical mineral exploration. Chap. 12 in World Mineral Supplies, Assessment and Perspective, Elsevier, 1976.

Darnley, A.G. The advantages of standardizing radiometric exploration measurements, and how to do it. Can. Min. Metall. Bull., 70, 91-95, 1977.

Darnley, A.G. The Canadian Uranium Reconnaissance Program; Int. Conf. World Nuclear Energy — a status report. Am. Nuc. Soc. Trans., 24, 113-114, 1976.

Davis, J.L., Scott, W.J., Morey, R.M. and Annan, A.P. Impulse radar experiments on permafrost near Tuktoyaktuk, Northwest Territories. Can. J. Earth Sci., 13, 1584-1590, 1976.

Dyck, W. The use of helium in mineral exploration. J. Geochem. Explor., 5, 3-20, 1976.

Dyck, W., Chatterjee, A.K., Gemmell, D.E. and Murricane, K. Well water trace element reconnaissance, Eastern Maritime Canada. J. Geochem. Explor., 6, 139-162, 1976.

Dyck, W., Jonasson, I.R. and Liard, R.F. Uranium prospecting with ^{222}Rn in frozen terrain. J. Geochem. Explor., 5, 115-127, 1976.

Grasty, R.L. Airborne Gamma-ray survey calibration in Canada. Uranium Geophysical Tech. Symp. U.S. Energy Research and Development Administration, Grand Junction, Colo., 1976.

Hornbrook, E.H.W. Geochemical reconnaissance for uranium utilizing lakes of the Canadian Shield. In Sask. Geol. Soc., Spec. Pub. 3, 1976.

Katsube, T.J. Electrical properties of rocks. In Induced polarization for exploration geologists and geophysicists. 15-44; University of Arizona Geophysical Society and the University of Arizona, 1977.

Katsube, T.J. and Collett, L.S. Electromagnetic propagation characteristics of rocks. In The physics and chemistry of minerals and rocks, R.G. Strens. ed., 279-296. John Wiley & Sons, N.Y., 1976.

Killeen, P.G. and Bristow, Q. Uranium exploration by borehole gamma-ray spectrometry using off-the-shelf instrumentation. Proc. Symp. Explor. of Uranium Ore Deposits, I.A.E.A./N.A.E., Vienna, 1976.

Richardson, K.A. Canada's Uranium Reconnaissance Program: Uranium Geophysical Tech. Symp., U.S. Energy Research and Development Administration, Grand Junction, Colo., 1976.

Scott, W.J. and Hunter, J.A. Applications of geophysical techniques in permafrost regions. Can. J. Earth Sci., 14, 117-127, 1977.

Sinha, A.K. Determination of ground constants of permafrost terrains by an electromagnetic method. Can. J. Earth Sci., 13, 429-441, 1976.

Sinha, A.K. and Frisch, Thomas. Whole-rock Rb/Sr and zircon U/Pb ages of metamorphic rocks from northern Ellesmere Island, Canadian Arctic Archipelago, II. The Cape Columbia Complex. Can. J. Earth Sci., 13, 774-780, 1976.

Tammenmaa, J., Grasty, R.L. and Peltoniemi, M. The reduction of statistical noise in airborne radiometric data. Can. J. Earth Sci., 13, 1351-1357, 1976.

TERRAIN SCIENCES DIVISION

Branch Publications

Belanger, J.R. and Harrison, J.E. Vancouver subsurface information data bank. Geol. Surv. Can., Open File 382. Ottawa subsurface information data bank. Geol. Surv. Can., Open File 383.

Clague, J.J. Sedimentology and geochemistry of marine sediments near Comox, British Columbia. Geol. Surv. Can., Paper 76-21, 21 p.

Fransham, P.B., Gadd, N.R. and Carr, P.A. Sensitive clay deposits and associated landslides in the Ottawa Valley. Geol. Surv. Can., Open File 352.

Harrison, J.E. Evolution of a landscape: the Quaternary period in Waterton Lakes National Park. Geol. Surv. Can., Misc. Rep. 26, 33 p.

Klassen, R.W. and Veillette, J. Landforms and surface materials at selected sites in a part of the Shield, north-central Manitoba. Geol. Surv. Can., Paper 75-19, 41 p.

Lawrence, D.E. and Proudfoot, D.A. Mackenzie Valley geotechnical data bank. Geol. Surv. Can., Open Files 421, 422, 423, 424, 425.

Lowdon, J.A. and Blake, W., Jr. Geological Survey of Canada radiocarbon dates XV. Geol. Surv. Can., Paper 75-7, 32 p.

Netterville, J.A., Dyke, A.S. and Thomas, R.D. Surficial geology and geomorphology, Somerset, northern Prince of Wales and adjacent islands. Geol. Surv. Can., Open File 357.

Proudfoot, D.A. and Lawrence, D.E. Mackenzie Valley geotechnical data bank. Geol. Surv. Can., Open File 350.

Richard, S.H. Surficial geology, southeastern Ontario and adjacent parts of Quebec. Geol. Surv. Can., Open Files 360, 361, 362, 363, 364, 365, 366, 368, 369.

Richard, S.H. and Gadd, N.R. Surficial geology, Russel, Ontario. Geol. Surv. Can., Open File 367.

Ryder, J.M. Terrain inventory and Quaternary geology Ashcroft (92 I NW), British Columbia. Geol. Surv. Can., Paper 74-49, 17 p.

Shilts, W.W., Kettles, I.M. and Arsenault, L. Surficial geology, southeast Keewatin. Geol. Surv. Can., Open File 356.

Tarnocai, C., Boydell, A.N., Netterville, J.A. and Drabinsky, K.A. Geol. Surv. Can., Open File 390.

Vincent, J.S. Surficial geology, Thurso and Wakefield, Quebec. Geol. Surv. Can., Open Files 370, 371.

The following papers were published in Report of Activities, Part B; Geol. Surv. Can., Paper 76-1B, 1976.

Armstrong, J.E. and Hicock, S.R. Quaternary multiple valley development of the lower Coquitlam Valley, Coquitlam, British Columbia (92 G/7c), pp. 197-200.

Blake, W., Jr. Sea and land relations during the last 15,000 years in the Queen Elizabeth Islands, Arctic Archipelago, pp. 201-207.

Clague, J.J. Pleistocene sediments in the northern Strait of Georgia, British Columbia, pp. 157-160.

Day, T.J. and Anderson, J.C. Observations on river ice, Thomsen River, Banks Island, District of Franklin, pp. 187-196.

Day, T.J. and Gale, R.J. Geomorphology of some Arctic gullies, Banks Island, District of Franklin, pp. 173-185.

Dyke, A.S. Tors and associated weathering phenomena, Somerset Island, District of Franklin, pp. 209-216.

Gale, J.E., Raven, K., Dugal, J. and Brown, P. Subsurface containment of solid radioactive wastes, pp. 147-150.

Grant, D.R. Reconnaissance of early and middle Wisconsinan deposits along the Yarmouth-Digby coast of Nova Scotia, pp. 363-369.

Jones, D.M., Shilts, W.W. and Weir, R.W. Heavy metal content of tundra plant species, pp. 273-279.

Lau, J.S.O., and Lawrence, D.E. Winter ground-ice distribution for selected map-areas, Mackenzie Valley, pp. 161-168.

Lichti-Federovich, S. A preliminary list of diatoms from sea floor sediments in Croker Bay, Devon Island, District of Franklin, pp. 133-136.

Luternauer, J.L. Fraser Delta sedimentation, Vancouver, British Columbia, pp. 169-171.

Matthews, John V. Jr. Insect fossils from the Beaufort Formation: geological and biological significance, pp. 217-227.

Taylor, R.B. Nearshore observations along the east coast of Melville Island, District of Franklin, pp. 43-58.

Yong, R.N. and Fransham, P.B. Dynamic behaviour and response of sensitive clays of Champlain Sea deposits, pp. 371-378.

The following papers were published in Report of Activities, Part C; Geol. Surv. Can., Paper 76-1C, 1976.

Anderson, T.W., Richardson, R.J. and Foster, J.H. Late-Quaternary paleomagnetic stratigraphy from east-central Lake Ontario, pp. 203-206.

Barendregt, R.W., Stalker, A. Macs. and Foster, J.H. Differentiation of tills in the Pakowki-Pinhorn area of southeastern Alberta on the basis of their magnetic susceptibility, pp. 189-193.

Blake, W. Jr. Postglacial marine submergence at Lac Ford, northern Ungava, Quebec, pp. 171-174.

Day, T.J. Preliminary results of flume studies into the armouring of a coarse sediment mixture, pp. 277-287.

Day, T.J. and Beltaos, S. Similarity analysis of a tracer mass dispersing along a meandering channel: Lesser Slave River, Alberta, pp. 305-324.

Day, T.J. and Egginton, P.A. River channel instability studies, District of Mackenzie, pp. 207-215.

Dredge, L.A. The Goldthwait Sea and its sediments: Godbout-Sept-Iles region, Quebec north shore, pp. 179-181.

Dredge, L.A. Moraines in the Godbout-Sept Iles area, Quebec north shore, pp. 183-184.

Foster, J.H. and Stalker, A. Macs. Paleomagnetic stratigraphy of the Wellsch Valley site, Saskatchewan, pp. 191-193.

Grant, D.R. Late Wisconsin ice limits in the Atlantic Provinces of Canada with particular reference to Cape Breton Island, Nova Scotia, pp. 289-292.

Harrison, J.E. Dated organic material below Mazama(?) tephra: Elk Valley, British Columbia, pp. 160-170.

Kurfurst, P.J. and Hunter, J.A. Geological and geophysical surveys — Willowlake River, Northwest Territories, pp. 161-164.

Lau, J.S.O. and Gale, J.E. The determination of attitudes of planar structures by stereographic projection and spherical trigonometry, pp. 175-177.

Luternauer, J.L. Geofisheries research off the west coast of Canada, pp. 157-159.

Medley, E. and Luternauer, J.L. Use of aerial photographs to map sediment distribution and to identify historical changes on a tidal flat, pp. 293-304.

Pelletier, B.R. Outline for a marine science atlas of the Beaufort Sea, p. 325-330.

Stalker, A. Macs. Megablocks, or the enormous erratics of the Albertan prairies, pp. 185-188.

Swan, D., Clague, J.J. and Luternauer, J.L. Some problems in the use of grain size statistics, pp. 273-275.

The following papers were published in Report of Activities, Part A; Geol. Surv. Can., Paper 77-1A, 1977.

Blake, W. Jr. Radiocarbon age determination from the Carey Islands, northwest Greenland, pp. 445-454.

Brown, P.A. and Dugal, J.J.B. A reconnaissance survey of plutonic igneous bodies within Ontario, pp. 387-392.

Clague, J.J. Holocene sediments in northern Strait of Georgia, British Columbia, pp. 51-58.

Day, T.J. and Lewis, C.P. Reconnaissance studies of Big River, Banks Island, District of Franklin, pp. 75-86.

Dilabio, R.N.W. and Shilts, W.W. Detailed drift prospecting in the southern District of Keewatin, pp. 479-483.

Dredge, L.A. and Dufour, M.F. Terrain reconnaissance, Lake Agassiz margin, northern Manitoba, pp. 45-49.

Edlund, S.A. Vegetation types of north central District of Keewatin, pp. 385-386.

Egginton, P.A. and Day, T.J. Dendrochronologic investigations of high-water events along Hodgson Creek, District of Mackenzie, pp. 381-384.

Gadd, N.R. Offlap sedimentary sequence in Champlain Sea, Ontario and Quebec, pp. 379-380.

Gale, J.E., Dugal, J.J.B., Lau, J.S.O. and Raven, K.G. Subsurface containment of solid radioactive wastes – a progress report, pp. 393-398.

Grant, D.R. Altitudinal weathering zones and glacial limits in western Newfoundland, with particular reference to Gros Morne National Park, pp. 455-463.

Harrison, J.E. Coastal studies in the Ottawa area, pp. 59-60.

Harrison, J.E. Coal mining and surface water quality: Crowsnest Pass, Alberta and British Columbia – preliminary data, pp. 319-322.

Harrison, J.E. Summer soil temperature as a factor in revegetation of coal mine waste, pp. 329-332.

Hodgson, D.A. A preliminary account of surficial materials, geomorphological processes, terrain sensitivity, and Quaternary history of King Christian and southern Ellef Ringnes Island, District of Franklin, pp. 485-493.

Klassen, R.A. and Shilts, W.W. Uranium exploration using till, District of Keewatin, pp. 471-477.

Kurfurst, P.J. Acoustic wave velocity apparatus, p. 73.

Lewis, C.F.M., Blasco, S.M., Bornhold, B.D., Hunter, J.A.M., Judge, A.S., Kerr, J. Wm., McLaren, P. and Pelletier, B.R. Marine geological and geophysical activities in Lancaster Sound and adjacent fiords, pp. 495-506.

Luternauer, J.L. Fraser Delta sedimentation, Vancouver, British Columbia, pp. 65-72.

Morin, F.J. Géologie de l'environment de Rivière-du-Loup/Cacouna, Québec, p. 300.

Raven, K.G. Preliminary evaluation of structural and groundwater conditions in underground mines and excavations, pp. 39-42.

Richard, S.H. Surficial geology mapping: Valleyfield Huntington area, Quebec, pp. 507-512.

Wahlgren, R.V. and Lewis, C.F.M. Estimation of bulk density and water content of Beaufort Sea sediment cores using radiographs, pp. 465-470.

Other Scientific Publications

Blake, Weston, Jr. Glacier ice cores, climate, and chronology around northern Baffin Bay. In Am. Quat. Assoc., Abstr. (4th Biennial Meet.) 20-21, 1976.

Brown, P.A. Geology of the Rose Blanche map area (110/10), Newfoundland, Nfld. Dept. Mines and Energy, Report 76-5, 16 p., 1976.

Brown, P.A. Geology of the Rose Blanche, Port Aux Basques, and part of the Codroy map sheets, southwest Newfoundland. In Report of Activities. Nfld. Dept. Mines and Energy, Report 76-1, 47-55, 1976.

Brown, P.A. and Colman-Sadd, S.P. Hermitage flexure: Figment or fact? Geology, 4, 561-564, 1976.

Brown, P.A. Ophilites in southwestern Newfoundland. Nature, 264, 5588, 712-715, 1976.

Cawthorn, R.G., Strong, D.F. and Brown, P.A. Origin of corundum-normative intrusive and extrusive magmas. Nature, 259, 102-104, 1976.

Dredge, L.A. and Thom, B.G. Development of a gully-flow near Sept-Iles, Quebec. Can. J. Earth Sci., 13, 1145-1151, 1976.

Fulton, R.J. Quaternary history south-central British Columbia and correlations with adjacent areas. UNESCO Int. Geol. Corr. Prog., Proj. 73-1-24, rep. 3, 1976.

Gadd, N.R. Geology of leda clay. In Yatsu, E., Ward, A.J., and Adams, F. Mass Wasting. Proc. 4th Guelph Symp. on Geomorphology, Geo. Abstracts Ltd. Univ. East Anglia, Norwich, NR47TJ, England, 137-151, 1976.

Gadd, N.R. Quaternary stratigraphy in southern Quebec. In Quaternary stratigraphy of North America, W.C. Mahaney, ed., Dowden, Hutchinson and Ross, Inc., Stroudsburg, Pa., U.S.A., 37-50, 1976.

Kurfurst, P.J. Ultrasonic wave measurements on frozen soils at permafrost temperatures. Can. J. Earth Sci., 13, 1571-1576, 1976.

Stalker, A. Macs. Indications of Wisconsin and Earlier Man from the southwest Canadian prairies. N.Y. Acad. Sci., Ann., 288, 1976.

Stalker, A. Macs. Quaternary stratigraphy of the southwestern Canadian prairies. In Quaternary stratigraphy of North America, W.C. Mahaney, ed. Dowden, Hutchinson and Ross, Inc., Stroudsberg, Pa., 1976.

CANADA CENTRE FOR MINERAL AND ENERGY TECHNOLOGY

D.F. COATES, DIRECTOR-GENERAL

V.A. HAW, DEPUTY DIRECTOR-GENERAL

The Canada Centre for Mineral and Energy Technology contributes to the Department's Mineral and Energy Resources Program by:

Performing, contracting and coordinating research on mining, extraction, utilization and conservation of minerals, metals and fuels, and on environmental problems associated with these operations;

Providing a technical knowledge base as an aid to the development of federal government policies and plans; and

Disseminating information on advanced technology related to mineral and energy resources to the public, government agencies, industry, and researchers and technologists throughout Canada.

The matrix management system introduced in 1975 is now firmly established, and its advantages in assuring more adequate response to national needs and economic imperatives are clearly evident. The clearest indication of this during 1976-77 was the relative smoothness with which significant financial and personnel resources were shifted from the Minerals Research Program to the Energy Research Program. Of CANMET's total budget of $23 million, $12.1 million was allocated to the Energy Research Program, compared with $5.1 million in 1975/76, while the share of the Minerals Research Program increased only slightly from $10.4 million to $10.9 million.

The year 1976-77 also saw significant progress in the implementation of the federal government's "make or buy" policy. A total of 67 contracts were awarded to private research agencies having a combined value of $2.8 million. Of these, 33 were concerned with mineral resouces at an aggregate value of $1.2 million; the remaining 34 at $1.6 million, related to energy supply and technology.

MINERALS RESEARCH

W.A. Gow, Director

The main concerns of CANMET's Minerals Research Program are the effective mining, processing, and use of Canada's mineral resources. Attention is focused on the development of new technology for evaluating resources, exploiting low-grade and complex mineral deposits, recycling mineral wastes, minimizing environmental damage, and maintaining the competitive position of the Canadian mineral industry. As most readily accessible high-grade mineral deposits are being depleted, increased research emphasis is being placed on recovering minerals from low-grade ores and from ores that are difficult to process because of impurities or complexities of mineral composition.

MINERAL RESOURCE DETERMINATION

Identification of Resource Base

CANMET's role in assessing mineral resources is primarily to determine the quality and producibility of reserves by carrying out mineralogical, geochemical, and related studies. In addition, processing trials are performed with ore samples from new or undeveloped deposits, such as the Peace River iron deposits of Alberta, to help to elucidate the mechanisms and potential problems associated with their use. All these studies are directed towards building an adequate knowledge base on mineral resources for the development of national policies and programs.

To date, little has been known of the nature and distribution of the platinum-group metals in mineral deposits, especially in deposits where these metals are co-products or by-products of other mineral resources. Work being conducted at CANMET may help to make the

exploitation of borderline deposits economically feasible and the mining of others more profitable. During the past year, 13 platinum-group minerals were identified and characterized from samples from the Sudbury Basin. Studies also were continued on minerals containing palladium, platinum, arsenic, antimony, and bismuth, using x-ray diffraction powder techniques. In addition, some synthetic materials, corresponding in composition to those occurring naturally, were investigated.

Appraisals have been made of alumina resources in non-bauxite materials, based on the examination of samples from Alberta, British Columbia, Nova Scotia, and New Brunswick. A study is in progress to establish whether a relationship exists between alumina in coal ash and associated coal materials, such as shales and fly ash. If it does, it might be possible to identify areas of alumina potential from coal-associated shale material. Analyses to date suggest that such a relationship may be confirmed.

The ceramic properties and the forming and firing behaviour of typical clays and shales are being studied. Other work includes experiments on glacial till samples and an investigation into characterizing the quality of different bentonite clays for pelletizing purposes by means of their electro-kinetic potential.

MINERAL TECHNOLOGY DEVELOPMENT

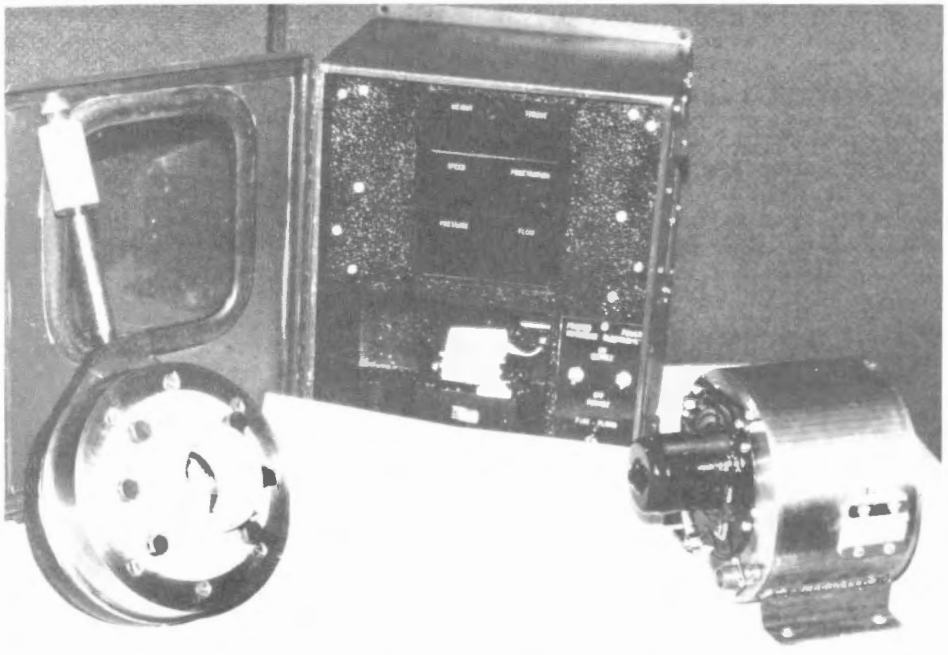
Development and Mining

Pit Slope Manual

CANMET's multi-year pit slope project is nearing completion with final preparation of a "state-of-the-art" open-pit mining manual. The manual's 10 chapters cover structural geology, mechanical properties, groundwater, design, mechanical support, perimeter blasting, monitoring, waste embankments, and environmental planning. Publication is expected by the fall of 1977. To ensure effective transfer of this technological information to industry, seminars were held during the year in Montreal, Edmonton, and Winnipeg. Further meetings are planned for 1977.

Innovative Underground Mining Methods

Canada's mineral-based economy is highly dependent upon underground mining. To increase the economic potential of deposits, there is need for technical innovation in mining operations that will enable greater recovery of resources. One source of valuable mineral is the pillars of ore that are left as support in the mine; these sometimes constitute as much as 40% of the total deposit.



Diamond drill datalogger developed for CANMET.

In uranium mines, chemical leaching offers a possible means for recovery of some of the radioactive minerals left in support pillars. Acid leaching is being applied, except for ores containing acid-consuming minerals. As an alternative, percolation leaching with alkaline solutions has been studied, but this method has proved to be much slower and more costly for extracting uranium than is acid leaching.

Ground support by pillars can often be substituted by backfill using process tailings — a technique which also helps to solve the problem of disposing of this waste product. Methods have been developed at CANMET to measure the in situ drainage properties of tailings backfill; and theoretical studies have been carried out, under contract, to establish the free-standing height of this material. Uranium tailings usually contain hazardous residual components, such as radium. Although advantage can be taken of particle size distribution to remove much of the radium before backfilling, sufficient radium could remain to produce dangerous levels of radon gas, unless adequate ventilation is provided underground.

Electro-osmotic dewatering of tailings has been investigated. A cell has been constructed for testing the dewatering and hardening of mill tailings for use as mine backfill and of clay for stabilizing embankments. Preliminary studies with tailings from the Highland Valley area of British Columbia and from the Athabasca tar sands have met with some success, but some tailings from the Sudbury area have presented complications because of their sulphuric acid content.

Conversion of Open Pit to Underground

When depth limits are reached in an open-pit mine, it may be economical to continue mining the ore body by underground methods. This conversion, however, presents problems in rock mechanics and mine planning. For the past three years, CANMET and a mining company have cooperated in carrying out studies on this subject.

An evaluation has been made of the effect of stope development on pit-wall stability, where the removal of crown pillars would ultimately break into the pit floor. This study had two practical objectives: to supply data for selecting the most favourable sequence of open-pit and underground mining operations for optimum wall stability, and to provide a pit-wall displacement monitoring system. During the year, finite element studies were completed, establishing stress distribution around slopes and pit-wall geometries of interest. The mining company involved in the project expanded a laser monitoring system developed by CANMET to provide more comprehensive coverage of all pit walls. To date, there has been no evidence of hanging-wall instability. Measurements are continuing with the CANMET-developed constant tension multi-wire extensometer to show footwall movement adjacent to mined-out stopes and stope pillar deformation. The three-dimensional finite element analysis procedure developed for this study will be of general use in analyzing complex mine structures. Progress has also been made on developing a two-dimensional finite element stress analysis method for geologic materials exhibiting elasto-plastic behaviour. Information gained through this study is being used by the company for conversions to underground mining.

Underground Nuclear Waste Disposal

In cooperation with Atomic Energy of Canada Limited, CANMET is conducting studies leading to the selection of preferred and alternative repository sites for nuclear waste. Work is nearing completion on the selection and preparation of specimens for thermal studies and on petrographic analyses of three types of rock from a potential disposal site in Ontario. Another two or more sites will be studied between now and 1981, the target year for selection. A beginning has been made on repository design with the design of a heater for in situ simulation tests. The test chamber, connecting roadway, and instrument area essential for the experiment have been developed in an operating mine.

Environmental Health and Safety

Improvement of the Mine Environment

Standards set by regulatory authorities with regard to dust, radiation, ventilation, noise, noxious fumes, and diesel emission in mines are becoming stricter. The objectives of CANMET's mine environment research have been to develop instrumentation and measuring techniques and to obtain data on the level of contaminants in various mine operations which will assist in developing realistic new standards. Researchers are also working on improvements in ventilation equipment, to reduce contaminants to acceptable levels.

In 1976, staff were reassigned to develop or provide radiometric equipment to study mine atmospheres. Airborne decay products of radon gas constitute the principal radioactive health hazard to uranium miners. Not only must the combined effect, or "working level", of the contaminants be known; their relative proportions also must be identified,

so that the effectiveness of mine ventilation systems can be assessed. These factors have important implications for operating costs of mining enterprises, as well as for the health of employees. During the past year, evaluations were made of measuring instruments, including an "Instant Working-Level Meter" developed in the United States and a multi-head radon counter. To provide assistance to the Federal-Provincial Task Force on Radio-activity, a rapid, practical procedure was developed for measuring very low concentrations of airborne radon decay products. This procedure was applied in a survey of 1,600 homes in Elliot Lake, Ontario. Very high sensitivity was achieved, to the extent that all samples were measurable — even at the low levels encountered in outdoor air. Monitoring of radon gas generation in a uranium mine also continued, with a study of the effect of various mine operations on radon production.

To protect the health and safety of underground miners, studies are under way to define the hazards associated with diesel soot in the underground atmosphere and to investigate methods of reducing its negative effects. One project being carried out under contract concerns carbon particulate retention by commercially available water scrubbers. This work has shown that 30% of the carbon in diesel exhausts is retained by a simple water scrubber and 50% by the combination of a catalytic purifier in series with a water scrubber. A second contract has been awarded for study of the possibility of collecting diesel soot with dry filters. A high-efficiency filter has been shown to be capable of collecting 99% of the exhaust particulates; the model developed is, however, too costly for practical use in mines, and the efficiency of less expensive filter materials is now being investigated.

Environmental Pollution Control

Thiosalt formation in grinding, flotation, and leaching of sulphides causes pollution because of the acidity these compounds generate in rivers and lakes. Corrosive wear of grinding media is also accelerated by these salts, and their formation is in turn influenced by the type of grinding media. During the year, a study was carried out on the effect of different grinding media — flint pebbles, cast iron balls, and steel balls — on the production of individual thiosalts. Without a pH modifier, nearly the same amount of sulphate was produced with all three media, but grinding with flint pebbles also produced thiosulphate and tetrathionate. Use of the pH modifiers — sodium carbonate, sodium hydroxide, and lime — was found to influence the production of the various thiosalts.

Thiosalts can increase acidity in streams because of natural bacterial action after discharge into the stream. In 1976-77, preliminary studies were conducted on the feasibility of discharging effluent to the ocean by pipeline and the effects of treatment by catalyzed air oxidation in effluent ponds, followed by lime neutralization.

In another study, the chemical feasibility of recovering zinc from mine water containing small amounts of alkali and heavy metals was demonstrated by a cation exchange-precipitation method.

Occupational Health in the Asbestos Industry

Increasing concern for the effects of asbestos fibre on health, particularly for those working in the asbestos industry, had led to examination of a wet-process alternative to the present dry method of separating fibre from rock. A new piece of equipment has been developed; and in tests, it has recovered up to 40% more fibre than is obtainable using dry separation techniques.

Disposal and Treatment of Uranium Tailings

An extensive study is being made of methods to reduce damage of the surface environment caused by tailings from uranium mines. The project involves demonstration of methods of establishing a vegetative cover on inactive tailings and recommendation of control methods that are capable of reducing by 50% the loading of acid, sulphate, heavy metals, and radioisotopes into natural watercourses.

Tailings from the uranium mines at Elliot Lake, Ontario, contain between 2% and 7% pyrite. This material is gradually oxidized by bacteria to form sulphuric acid, which in turn leaches the radioactive products of uranium and thorium, as well as heavy metals. Present methods of treating the seepage, runoff, and discharge water from areas with both active and inactive tailings involve addition of lime or limestone to neutralize the acidity and precipitate heavy metals. Barium chloride also may be added to precipitate radium as a sulphate. These precipitates are allowed to deposit in settling lagoons before the effluents are discharged into watercourses. As these methods meet both federal and provincial guidelines for disposal of tailings, current research is aimed at further improving water-treatment technology to reduce the total loading of pollutants during the present major expansion of uranium mining activity. Radioactivity is considered the principal problem in water

Nordic tailings pond, Elliot Lake, before revegetation (July 1971).

Nordic tailings pond, Elliot Lake, after revegetation (July 1974).

pollution control.

Another subject of serious concern is the physical, chemical, and radiological stability of abandoned tailings disposal areas. Field investigations of an abandoned uranium tailings basin are continuing. A network of wells and weirs is used to provide samples for chemical, radiological, and microbiological analyses. A survey of the mobility and transport of radioactivity has been completed, and radioisotopes in seepage have been identified. The depletion of pyrite has been determined and correlated with the acidity of subsurface water. The rate of acid generation in the tailings and its relationship with the resultant acid load on the surrounding watercourses also is being studied.

It has been established that the bacterium thiobacillus ferro-oxidans is present and active at the air-water interface within the tailings, as are numerous species of gram-negative heterotrophs. Biological acid production appears to be continuous because of vertical movement of the water table. To determine the possibility of halting bacterial oxidation of pyrite, the effect of the bacteriocide pentachlorophenol on the viability of thiobacillus ferro-oxidans and on the production of acid drainage has been evaluated. Although the acidity of the drainage decreases temporarily, a significant number of bacterial cells survives the application. The bacterium is also extremely sensitive to organic solvents currently being used for solvent extraction. The release of these solvents into a tailings area may inhibit biological acid production within the tailings of a mine which uses solvent extraction for uranium recovery. Tests must still be carried out to evaluate the effect of solvents on the surrounding environment.

Revegetation studies are being conducted to identify the types of vegetation that will grow on acid tailings, to establish growing methods, and to determine the long-term effects of revegetation on toxicity of seepage water. Plant species test plots were started in 1973 as part of a five-year establishment plan. In 1976-77, these plots were maintained with monthly applications of fertilizer, and a study was carried out on black discoloration of the vegetation. A cooperative reclamation program was started with a mining company to vegetate a 1-1/2-hectare tailings area. A major portion was seeded in 1976, after coverage with 20 to 60 cm of glacial till. Microbial assessment of the test plots indicated that the vegetation is self-sustaining. A recipe for revegetation has been formulated and tested and the most suitable grass species identified.

Laboratory tests indicate that over 90% of the pyrite in uranium tailings can be removed by flotation. It is believed that such removal would greatly reduce the amount of acid drainage and radionuclide dissolution from the tailings area.

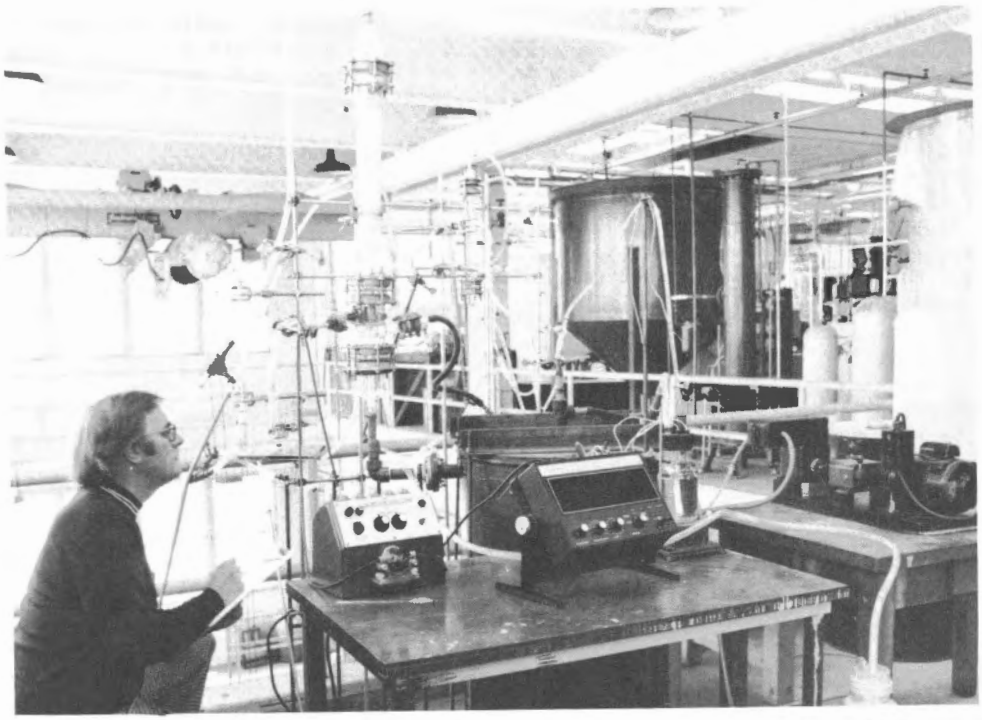
Removal of Toxic Cyanide from Gold-Mill Effluents

A joint project involving six gold-producing companies was completed during the year, in which a study was made of the technical feasibility of removing toxic cyanide from cyanidation wastes in gold-mill operations. The study demonstrated that the environmental objective of less than 0.1 ppm (0.1 mg/kg) total cyanide is attainable. A pilot plant investigation demonstrated the chemical and economic feasibility of adsorbing free cyanide and heavy-metal cyanide complexes on fixed beds of anion exchanger in the sulphate form. Another treatment method, designated Acidification/Volatilization/Reneutralization (A/V/R), was found to reduce levels of each of the cyanide and heavy-metal components from as much as 1 g/l to less than 0.1 mg/l. Where many stages of treatment are required to meet this standard, reduction to 2-4 ppm (mg/kg) followed by extended retention in a waste-water lagoon may be an acceptable alternative. Some success was also achieved with yet another method involving oxidative destruction with chlorine, which has applicability for very dilute mill waste waters.

Reduction of Foundry Pollution

To reduce air pollution by gases and dust from iron foundries and other metallurgical and processing industries, CANMET has developed a packed-bed filter system which uses cheap granular material such as limestone, gravel, and coal in a vertical bed. The system continues to create considerable industrial interest, as shown by correspondence, visits to the laboratory, and requests for information. A U.S. patent for the system has been obtained and a large commercial unit is being installed in a Winnipeg foundry.

Modifications to the laboratory unit have made it possible to double its capacity; and in the modified form, it has been used to anticipate industrial problems and to undertake confirmatory testing. Methods have been found to overcome gas-flow and bed-removal problems encountered in the first Winnipeg prototype unit, and some new design features have been introduced. Filtration efficiencies in excess of 98.8% have been achieved for simulated foundry cupola dusts.



Removing and recovering cyanide from gold-mill effluent by acidification, aeration, and neutralization.

Processing

Treatment of Complex Sulphide Ores of the New Brunswick Type

A project is being carried out to improve the overall recovery of metals and associated by-products from complex lead-zinc-copper sulphide ores typified by those occurring in the New Brunswick area, and to minimize environmental problems associated with their processing. During the year, the objective for minimum average overall recovery of metals was set at 85%. Processes given priority study for the short term were the sulphation-roast-leach process and the pressure sulphuric-acid leach process. Long-term priorities were given to the dry-way chlorination/oxidation process and to leaching processes such as ferric ion or direct HCl leaching. All processing concepts are based on producing a bulk concentrate as feed. A minimum recovery objective for bulk concentrate production from ore was set at 90%. Priority was given to comminution-classification research and to production of a bulk concentrate from the ore, with and without prior recovery of a selective lead concentrate.

Progress on development of the sulphation-roast-leach process by the New Brunswick Research and Productivity Council has led to fabrication and scale-up testing of a larger roaster which can handle slurry feeds. Development is planned of a complete flowsheet to generate material and energy balance data through roast-leach-solution, purification-electrolysis effluent treatment and waste disposal. This work is being financed by the Department of Regional Economic Expansion (DREE) through the federal-provincial General Development Agreement. The Department of Energy, Mines and Resources is represented on the management committee, and CANMET is the Scientific authority for all processing projects.

Negotiations for industry participation in the technical and economic evaluation of the pressure sulphuric-acid leach process were successfully concluded in late 1976. Laboratory tests were conducted, and an economic feasibility study is being done. This work also is funded largely by DREE.

Mineral, metal, and textural zoning is being investigated for representative sulphide ore samples from 16 mining properties in New Brunswick. Mineralogical studies and grinding, flotation, and leaching tests are being performed on ores, tailings concentrates, and other mill samples.

Mineralogical Studies

Mineralogical studies of ores are required to assist in selecting the optimum mineral dressing procedures. Knowledge of the metal-bearing ore minerals will indicate what separations are possible, and knowledge of the mineral grain size distribution will indicate the degree of comminution required to liberate mineral grains. The study of plant products serves to monitor the effectiveness of mineral dressing procedures.

Comminution and Flotation Studies

A study of the effect of grinding media on the selective flotation of copper-lead-zinc ores was carried out under contract. Using the same flotation flowsheet, three grinding methods were compared: steel balls; a two-stage pebble grinding circuit, using flint and ceramic pebbles in rubber-lined mills; and a full autogenous grinding circuit which uses no rods or balls. Steel balls produced the best grade of copper concentrate and autogenous grinding the poorest. But autogenous grinding yielded the highest copper recovery and steel balls the lowest. There was a slight increase in both the recovery and grade of zinc with pebble and autogenous grinding, apparently resulting from increased liberation of sphalerite (zinc sulphide). Further studies on the wear of grinding media will contribute to the selection of materials for grinding copper-lead-zinc ores.

Improved metal recoveries from tailings of New Brunswick lead-zinc mines have been attained by regrinding the tailings and subjecting them to zinc scavenger flotation. An investigation has been begun on a representative ore sample to determine optimum conditions for producing high-recovery bulk concentrates and to assess the feasibility of producing high-grade lead concentrates before the bulk concentrates.

Research is under way using synthetic mixtures of pure minerals to determine the effect of grain size on flotation efficiency. Another study is concerned with the effects of surface oxidation of the sulphides — galena, pyrite, chalcopyrite, and sphalerite — on their flotation properties. Chalcopyrite has been found most resistant to oxidation.

During the year, a contract was awarded for the design and construction of an x-ray fluorescence analyzer to monitor continuously six slurry streams for lead, zinc, iron, copper, and pulp density, plus other parameters as required. A 100-pound (45.4-kg) per hour continous process development unit for flotation studies is under development, but problems relating to automatic control of slurry levels and pumping rates remain to be solved.

Dry-Way Chlorination

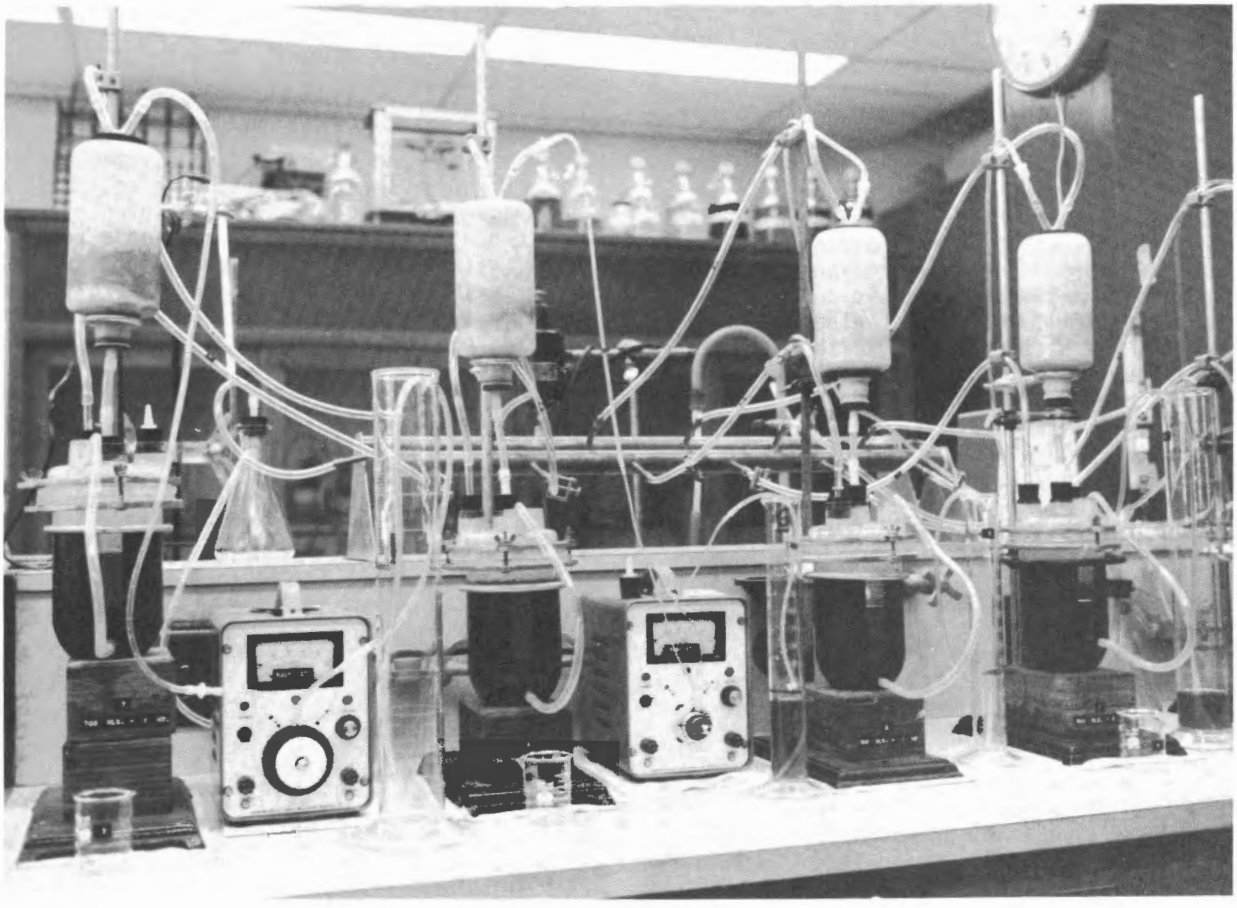
One of the investigations at CANMET to provide suitable processing methods for ores not amenable to conventional treatment involves the use of chloride metallurgy. A proposed dry-way chlorination process offers the advantage of high metal recoveries and the production of elemental sulphur, thereby circumventing the problem of sulphur dioxide emission. In the process, either volatile sulphur chlorides or elemental sulphur are formed, with simultaneous conversion of the metals to chlorides. The chlorinated calcine is oxidized to convert the iron chloride to iron oxide, lowering the soluble iron content of the liquors produced in a subsequent leach stage. The metals are recovered from solution by various techniques.

Although laboratory tests have shown the satisfactory extraction of metals to be feasible, the process still presents problems that must be solved before it can become commercially viable. These problems include the continuous bulk transfer of the sticky paste that forms during the reaction and difficulties relating to construction materials, chlorine recovery, and heat balances. Because of serious corrosion of metals during chlorination, a survey is being made to determine suitable materials, such as superalloys, for construction of the chlorinator.

Basic Studies on Ferric Ion Leaching

Experiments have continued on the leaching of high-grade sphalerite using the rotating disk technique, both to develop a ferric ion leaching process for sphalerite and to explain phenomena observed during the ferric ion percolation leaching of pyritic zinc-lead ores from Bathurst, New Brunswick. Hydrochloric acid attack has been shown to be a promising method of treating sphalerite. In 1976-77, work was completed on the kinetics of the sphalerite leaching process and the relative roles of hydrochloric acid concentration and ferric ion complexes. At acid concentrations above 0.1 M HCl, the rate of dissolution depends almost entirely on acid concentration; below this concentration, it is significantly affected by ferric ion concentration.

The rotating disk method has also been studied for ferric ion leaching of chalcopyrite (copper sulphide). Tests are in progress



Bacterial leaching ore particles under percolation recycling conditions.

to evaluate the effect of chloride and sulphate concentrations on the leaching rate. Sulphate solutions appear to interfere with the dissolution rate much more seriously than do chloride solutions.

Percolation Leaching Using Ferric Ion

A study has been conducted on the application of percolation leaching to New Brunswick zinc-lead-copper ores, using ferric ion. The purpose of the study was to determine optimum conditions for the extraction of metals from pyritic ores or high-grade tailings that are difficult to process, such as those currently produced in the Bathurst area. The development of a ferric-ion leaching process for such ores would provide an intermediate-grade bulk concentrate and thus result in increased levels of recovery. In current practice, recoveries are low because of the need to maintain a high grade of concentrate. During the year, the effect of ore column height on the amount of zinc extracted and the effect of cupric chloride on the dissolution rate were determined. Work on percolation leaching with ferric sulphate-sulphuric acid solutions revealed that leaching increases at a rate proportional to the square root of the iron concentration; this discovery was unexpected because in the corresponding chloride system the rate is directly proportional to iron concentration. Additional tests are in progress to confirm this unusual dependence on iron and to explain the mechanism. Zinc extraction has been found to vary proportionally with the solution flow rate.

Related leaching studies carried out in 1976-77 focused on ways of taking advantage of the change in metal complex redox potentials, reaction rates, and reaction product stabilities brought on by non-aqueous solvents; leaching with organic solvents and chelating agents; and materials of construction for leaching processes.

Electrochemical Leaching

Electrochemical leaching work included studies of the cathodic dissolution of chalcopyrite by cyclic voltammetry and the anodic dissolution of copper and lead sulphides. A project is also under way to design a diaphragm cell containing a membrane material that will effectively prevent the migration of chloride ion to the cathode compartment. The objective is to dissolve anodically sulphide concentrates in chloride media. After purifying the anolyte by solvent extraction, metals such as copper, nickel, and cobalt are electrowon from standard sulphate electrolytes in the cathode compartment. The advantage of this process is that the energy normally wasted in producing oxygen at an insoluble anode in metal winning can be used to aid dissolution of the feed material.

Solution Purification Studies

Because of the complex nature of the New Brunswick-type ores, the solutions eventually produced from either a chlorination process or a leaching operation will contain a large number of elements. Consequently, solution purification is required to separate zinc, lead, and copper and to remove unwanted impurities, such as iron.

Jarosite-type compounds — hydrous sulphates of iron and certain other metals — occur widely in nature under highly acidic and strongly oxidizing conditions. Recently, the zinc industry developed a process to precipitate unwanted iron as a jarosite compound from acidic leaching solutions. This method might also be used to adjust the iron concentration of leaching solutions produced during copper and nickel processing. It has now been established that many base metal cations other than iron can be incorporated in the jarosite structure and can thus be removed. Work has also been done on the synthesis of lead and mercury jarosites. The synthesis of these compounds is complicated by the insolubility of lead sulphate and by the tendency of mercury- bearing solution to hydrolyze. Two general methods — slow addition and autoclave synthesis — have been employed.

Solvent extraction was also tested as a means of separating copper, iron, and zinc from the chloride leach liquor. Screening of several extractants led to the selection of SME 529 chelate for copper and Alamine 336 at two different pH's for ferric iron and zinc.

Electrowinning Studies

Electrolysis is one of the most promising methods for recovering zinc, lead, or copper from solutions produced by leaching. A joint project on zinc electrolysis is being conducted by CANMET and private industry to improve zinc deposits and maintain high efficiency over an extended period of time. By monitoring zinc polarization curves, it has been found possible to adjust accurately the amount of agent added to the electrolyte so that the overvoltage is maintained at the proper level to produce an acceptable deposit on a regular basis. Combinations of antimony and glue have been tested as additives. Another project is directed to the control of lead contamination of zinc deposits, a recurring problem in the use of lead-silver anodes. The effects of chloride ion, organic additives, and entrained and dissolved organics also are being studied.

In the electrowinning of copper, previous studies have shown that the copper deposit morphology and orientation are optimum at a current density of 40 A/ft^2 (43.0A/m^2)

Electrowinning of copper.

and 10 ppm (mg/kg) chloride ion. Recent studies indicate that the temperature of the electrolyte has a significant effect on the deposit morphology and orientation; it appears that the best deposits are obtained at 35°C for the experimental conditions used. Continuing studies involve a detailed x-ray crystallographic examination of the copper deposits. Other work is concerned with a critical discussion of factors such as the chemical, dispersion, and depolarization effects of ultrasonics and their applications in flotation, leaching, and electrodeposition of metals.

Pyrometallurgical Studies

Most of the processing problems associated with the New Brunswick-type ores are caused by the fine grain size. In 1976-77, consideration was given to thermal processes that might result in a considerable coarsening of the mean particle size in the ore, to be used ahead of conventional selective flotation. Work was also done on the lead-zinc-iron oxide system, which is of major importance in the conventional processing of both lead and zinc.

Investigation of Peace River Iron Ore Deposits

The growing desire for expanded local steel-making facilities in Western Canada has stimulated further investigation, in cooperation with the Research Council of Alberta, of the mineralogical characteristics and processing requirements of the low-grade phosphatic iron deposit of the Peace River District of Alberta. The proximity of coking coal resources adds to the attractiveness of this prospect.

Mineralogical studies completed at the Mineral Sciences Laboratories have revealed that the material in situ comprises about 30-35% iron, 17-20% silica, and about 25% water. The material can be beneficiated simply and inexpensively by froth flotation to produce medium-grade concentrates containing 52% iron and 14.8% silica in a fired pellet. Concentrates of slightly higher grade, containing 55% iron and 11% silica, can be produced by roasting and magnetic separation of the flotation concentrates. Overall ratios of concentration were in the order of 2.5:1, and rejection of silica was approximately 80%. The concentrates appear more suitable for steel-making than does raw ore and may provide a viable alternative to importing ore into Alberta.

A two-year program on cupola smelting of Peace River iron ore was completed in 1976. About one-half ton (0.45 tonne) per hour of composite briquettes, consisting of the ore and lignite char, was smelted to produce 200 pounds (90.7 kg) of pig iron in a 16-inch (40.6 cm) internal diameter cupola. The process appears promising from a technical viewpoint but is not yet economically viable.

The pig iron thus produced was converted to steel in a 300-pound (136-kg) capacity experimental top-blown basic oxygen furnace. Since the pig iron had unusually high silicon and phosphorus content, at 3.5% and 1.5% respectively, a double-slag steel-making process was developed. During the first half of the oxygen blow, silicon is oxidized and removed by the slag; in the second half, a new lime and iron-oxide slag is used for dephosphorization treatment, yielding a commercial-grade product with phosphorus content as low as 0.034%.

Industrial Minerals

Elimination of fine quartz from kaolin is a prevalent problem in the processing of Canadian clays. A flocculation and dispersion process has been developed for selectively recovering kaolin from classifier overflows and washing the product free from fine quartz. The process involves treating the overflow with calcium chloride and sulphur dioxide to activate the kaolin and depress the quartz, then flocculating the kaolin with a polyacrylamide of high molecular weight. The flocculated product is dispersed by agitation with sodium silicate to free any entrained quartz particles and is then reflocculated. Kaolin concentrates assayed at 36-39% alumina have been produced.

Processing studies are also under way to eliminate the random growth of crystalline feldspathic compounds in clay products made from high-lime materials. These compounds lead to porosity and increased susceptibility to moisture and frost damage. Other work on industrial minerals includes beneficiation of Western Canadian sedimentary phosphates by flotation, attrition scrubbing, and classification; and studies of grindability and froth flotation behaviour of various ores and minerals. Another study has established that, although marl from Saskatchewan's low-grade lake-bottom deposits can be beneficiated to high-grade carbonate concentrates, high magnesium content limits its potential as a substitute for limestone.

Alumina from Non-Bauxite Sources

To alleviate Canada's dependency on imported bauxite and to ensure continuity of alumina

supply, CANMET is participating in a cooperative research project with the U.S. Bureau of Mines (USBM) on processing of non-bauxite sources. CANMET's contribution is to assess the technical and economic feasibility of Canadian sources, develop processes for Canadian sources, and provide technical support in operating the USBM pilot plant.

A relationship has been found between process energy and annual operating costs for acid processing of non-bauxite materials, thus making a preliminary cost estimate possible. A critique is being prepared for technical evaluation of available and proposed processes.

Laboratory research has shown that more than 98% of the alumina can be extracted from anorthosite rock by leaching with relatively dilute sulphuric or hydrochloric acid at 5-25 wt % or with 20 wt % nitric acid. Markedly improved alumina extraction rates also have been attained through the addition of fluosilicic acid to hydrochloric and sulphuric acid leaches. The fluosilicic acid disrupts the alumina-silicate bonds in clay, thus eliminating the need for calcining or dehydrating before leaching.

Experiments with the lime-soda sinter process for alumina extraction have produced high yields and revealed the dependence of extraction on reactant composition, sintering temperature, and soak time. During the year, characterization of the sinter and leach products was completed and optimum conditions for extraction established. Future work is planned on the problems of desilication of the leachate, precipitating alumina salt, and calcining to alumina suitable for production of aluminum metal. Similar studies have been conducted on the lime sinter process. Extractions exceeding 95% have been obtained from sintered mixes of Canadian anorthosite and limestone. Optimum conditions for sintering and leaching have been established, and studies are under way to clarify the chemistry of the processes. Through the use of computer methods, flowsheets and material and energy balances are being prepared for both the lime-soda and lime sinter processes.

Conservation

Conservation activities in 1976-77 concentrated on the reuse of mineral wastes as raw materials. Work related to this project is sub-divided into two areas: primary mineral wastes, which include mining and mineral-processing wastes, metallurgical slags, and chemical residues; and mineral-based materials, which include scrap metals and municipal solid waste. The objective in each case is to develop technical information and data on these wastes and on their reuse potential, to provide a basis for further research and development by government and industry. Increased utilization will aid conservation of national mineral and energy resources; it may also result in environmental improvement in some areas.

Identification, characterization, and evaluation of Canada's mineral waste resources continued during the year with the receipt of 33 samples from Quebec mining operations. A report covering Ontario was published in 1976.

Attempts to produce mineral wool for thermal insulation from steel slag were successful. Information was obtained on present practice in moving liquid waste slags to dumps to determine the feasibility of its application in mineral wool production. Preliminary studies were also initiated on the technical feasibility of producing form insulating products from various mill tailings and waste glass.

Samples of two types of chemical waste gypsum are being studied as raw material for manufacturing gypsum products. One, derived from treating waste sulphuric acid from titanium dioxide plants, is of high purity and consequently of considerable interest. The other phosphogypsum derived from phosphate fertilizer plants, is less pure but also is of interest. A principal impurity in phosphogypsum is radium, but preliminary studies indicate that its concentration may be substantially reduced by simple water washing and sizing.

Research has continued on the use as concrete aggregate of such waste materials as rock, recycled concrete, and coal mine shales. In addition, the chemical and physical properties of fly ash from Canadian sources have been examined to determine their potential for this purpose. A related study carried out by industry has indicated that fly ash may be beneficial for producing high-strength, high-quality concrete, using manufactured sand.

Research on the fabrication of dry-pressed building brick from gold-mill tailings was completed during the year. The problem of severe splitting on firing was resolved by adding up to 50% of 65-mesh (ca-228 μm) ground glass. No solution was, however, found to the problem of efflorescence of white salts (sodium sulphate) on the surface of the brick, following wetting and drying.

A project was begun in 1976 to study problems with in-plant steel mill waste.

Technical discussions with industry and a literature survey revealed that although recycling is widely practised in large steel plants where sintering capacity is available, there is still a need for recycling technology that is viable for the small producer. One class of waste product obtained from a producer consisted of very small chips of metal contaminated with both sulphur and metal oxides, mostly alumina. This material, which is produced by surface grinding of metal products, is referred to as swarf. CANMET has developed magnetic separation techniques for removing most of the contaminants from the metal chips. The company has already performed one successful pilot plant experiment using rented equipment and is working on development of a permanent installation. The significance of this work is that it has a large energy-saving potential. Only about 500 kilowatt-hours (1.8×10^9 J) of electrical energy per ton are needed to recycle this material, whereas at least 4,000 kilowatt-hours (1.44×10^{10} J) per ton would be required to replace it with material produced from new ore.

Utilization

Advanced Concrete Technology

Using a sulphur-infiltration technique, concretes of very high strength can be produced in two days. The new concrete would be ideally suited for applications such as sewage pipes, precast curbs, sidewalks, and locations where resistance to aggressive media is desired, but the apparent instability of the concrete in alkaline and natural environments may restrict its use as a construction material. Consequently, the phenomenon of leaching sulphur from infiltrated concrete is being thoroughly investigated in the laboratory. Rates of removal of sulphur from portland cement are being studied and contrasted with those from low-lime concretes.

It is believed that high-alumina cement could be a viable by-product of large-scale production of alumina from anorthosite rocks. Investigations aimed at determining the long-term performance of high-alumina cement concretes have been partly completed. Long-term studies are also in progress to determine the nature of and reasons for degradation of high-alumina concrete as a function of environmental conditions. Initial indications are that high-alumina concrete may be stabilized by curing at higher temperatures.

In cooperation with Hydro-Quebec, a study is being conducted on the durability of portland cement concrete structures exposed to acidic waters typical of northern Canadian rivers and lakes. The project, which is being carried out at the site of the James Bay hydroelectric development, is to be a five-year study, comprising controlled exposure and examination of the concrete at frequent intervals. Test specimens were put in place during 1976-77.

Corrosion and Wear in Grinding of Ores

One of the objectives of CANMET's research on materials is to maximize the benefit to be gained from available non-renewable resources by limiting corrosion and wear of machinery, plant, and equipment in the resource industries. Research has been conducted on corrosion and wear control of grinding media in grinding sulphide and hematite ores.

In one study, six types of steel were compared for corrosion and abrasion resistance in grinding nickel-copper sulphide and hematite ores. The contribution of corrosion to total wear was determined by corrosion inhibition with sodium nitrite and by measurement of the corrosion potential of the grinding balls. The results showed that research directed towards new alloys for grinding balls should include an assessment of the corrosion behaviour of alloys, in addition to an appraisal of their metallurgical properties.

Studies were also carried out on the relative roles of temperature and pH in wear during grinding of hematite and low-grade copper ores. The critical pH for passivation of steel during grinding was found to be 10.5 — below this value, corrosion played a significant role in total wear; above it, corrosion was prevented. Addition of lime or silicate was also found to reduce wear. In grinding zinc-lead-copper sulphide ores, corrosion was shown to be a significant component of wear, which could be substantially reduced with suitable corrosion inhibitors or pH adjustment.

Other studies indicated that the rate of wear of grinding media may be affected by the presence of balls or liners of different chemical composition; also, one type of steel may cathodically protect another as a result of a difference in surface potential. Electrochemical polarization and torque studies confirmed that a synergistic relationship exists between corrosion and abrasion during comminution, in that both are affected by changes in the grinding environment. Thus, efforts to minimize corrosive wear must address both factors.

Integrity of Steels and Steel Structures

The integrity of structural steels is under study as part of an effort to resolve problems in land, sea, and air transportation and communications systems, and to provide information to government bodies concerned with regulatory policies and public safety. Better and safer procedures are now available for joining "weathering" steels for structures built in the Canadian North. A welding process has been developed using a 2-1/2% nickel flux-cored electrode. The welded joints have excellent toughness at temperatures as low as -46°C and are expected to exhibit satisfactory weathering characteristics.

It has been shown that a fabricating sequence involving cold working, pickling, galvanizing, and welding can lead to cracking in high-strength structural steels when hydrogen is trapped in the hard zones of welds. The problem has been elucidated further through general studies and also specifically through experience in the erection of electrical transmission towers. The new x-ray diffraction technique developed at CANMET for measuring residual stresses has been helpful in these studies. Experimental work has shown that sensitivity to pickling hydrogen can occur when the steel strength exceeds a particular threshold value. A galvanized coating appears to restrict the egress of hydrogen; and although some hydrogen may escape in galvanizing during long immersion cycles, it cannot during short cycles. Some care should therefore be exercised in galvanizing to avoid later trouble. Use of these steels in a severe corrosion medium can cause problems if hard weld zones are present. Recently, a fundamental study of hydrogen embrittlement has been initiated which is expected to provide useful information for resolving this and other practical problems.

Work continues on lamellar tearing, and the shop test devised by CANMET has been adopted by a large construction firm as a practical device for sorting steel.

Progress in Continuous Casting

Successful procedures have been worked out for the continuous casting of tool steels, and bars of 0.875-in. (22-mm) diameter can be produced in unlimited quantities in three commercial compositions. A mould/nozzle configuration using copper, graphite/boron nitride, or quartz is proposed. Examination has shown that the bars are free of cracks and

Specialized techniques are needed in the preparation of specimens prior to examination with an electron microscope. A carbon extraction replica of rail steel is being made here for examination at very high magnification.

A cup test is widely used to determine the formability of sheet metals. This machine is used to measure the forming characteristics of sheet aluminum or steel for possible use in automobiles.

segregation and have a fine-grain structure. It was found necessary to follow the casting by hot swaging to break up the intergranular carbide networks and eutectic carbide, since the latter could not be removed by heat treatment alone.

High-Strength Steels for Defence Use

The Department of National Defence has indicated interest in the development of high-strength steels. Research, partially supported by DND, has been carried out on HY-130 steel, which has a yield strength of 130 psi (896 MPa). Studies have shown that this material is sufficiently resistant to environmental cracking to be a promising candidate for advanced marine applications, such as the construction of hydrofoil craft. Three high-strength titanium alloys also have been shown to be highly resistant to environmental cracking and similarly offer potential for marine use.

Standards and Reference Material

In 1976-77, CANMET staff continued to play an active role in national and international activities concerned with the development of reference materials, standard methods, and analytical procedures to ensure high quality, consistency, and safety margins in the products of mineral industries. The Canadian Certified Reference Materials Project was initiated in the early 1970's for the purpose of preparing compositional reference materials that are required for quality control and calibration purposes in industrial, commercial, and government laboratories in Canada, and which are not available from other sources. The emphasis is on the production of reference ores and related materials; however, a suite of soils and some alloys for emission spectrography also are in various stages of certification. To date, 26 reference materials have been issued that are in wide use in Canada and abroad. This project has established an international reputation, and several of its staff members participate in technical activities of the International Organization for Standardization and other bodies concerned with standards and specifications.

Transportation

Rail Steels

After consultation with rail and steel producers, and a study of the literature going back to 1950, a new research program on rail steel has been started. At CANMET, rails and rail steels are being examined by various physical metallurgical techniques, with emphasis on some of the new alloy steels and quenched-and-tempered compositions. The effects of welding, which are very important, are being studied with the thermal cycle simulator.

Improved Steels and Aluminum Alloys for Automobiles

To provide background for the increased use of strong lightweight materials for automobiles and other fabricated metal goods, an extensive program has been undertaken on the rolling and formability of high-strength low-allow (HSLA) steels and aluminum alloys. Controlled-rolled HSLA sheet can now be produced at CANMET through a process that includes a quench treatment to simulate the effect of industrial

cooling. Computer programs are being developed to provide rolling schedules with a minimum number of passes without exceeding mill capacity. Auxiliary data from simulated rolling studies using the cam plastometer have already been used by industry in the design of a new hot-strip mill. The effect of interstage cooling by various techniques and the effect of prior austenite grain size also are being investigated. A 4-in. (100-mm) diameter cup tester is being used on a 100-ton press to determine forming-limit curves.

A study has been made of the possible uses of aluminum alloys in the manufacture of automobiles. Such alloys are attractive for their corrosion resistance and their lightness, which offers possibilities for savings in gasoline consumption. Thermomechanical processes are being developed for producing thin sheet in two aluminum alloys, using an approach similar to that developed for HSLA steels.

Iron alloys containing 8-12% aluminum alloyed with manganese and silicon have good corrosion resistance and are regarded as a possible substitute for stainless steel in certain applications; the alloys are, however, fairly brittle at room temperature. A sheet of 0.06-in. (1.5-mm) thickness with good tensile elongation has been produced in alloys containing 8% aluminum.

Administration of the Canada Explosives Act

During the year, CANMET continued to supply essential technical support for the administration of the Explosives Act of Canada by carrying out certification tests, advising Canada's Chief Inspector of Explosives, providing expert witnesses for investigations and court proceedings, and developing standards and specifications for explosives. To reduce hazards involved in the use of explosives, studies are under way to separate non-cap-sensitive Class II explosives from more sensitive explosives. With nitroglycerine-based explosives, a correlation exists between shock sensitivity, and impact and heat tests. This correlation is sufficient for classification purposes. The more friction-sensitive the explosive, the more hazardous it is considered. New standard classification tests for shock sensitivity are required for cap-sensitive slurries; developing these was an important part of the work during the year.

Related work included the awarding of a contract for investigation of the fire explosion hazard of ammonium nitrate, to provide a better understanding of the mechanism involved and to develop criteria for distinguishing unacceptably hazardous samples.

ENERGY RESEARCH

D.A. Reeve, Director

In its energy research program, CANMET shares the Department's objective of ensuring the availability of Canada's energy resources and promoting their effective use. Work is proceeding on ways to improve the recovery, processing, and use of energy resources. In keeping with the national goals of economic self-reliance and conservation, the research program focuses on two main concerns: the development of alternative resources such as oil sands, heavy oils, and coal as substitutes for oil and gas, and of uranium for the generation of electrical energy; and the efficient use of existing energy resources.

ENERGY RESOURCE DETERMINATION

Information on existing energy resources is essential to the identification of policy options that are available to the federal government concerning resource development and energy planning. Continuous assessments must be made of the quality and recoverability of domestic fossil and nuclear fuels, and of associated processing requirements. In addition, research must be carried out on alternative sources of energy that may reduce Canada's increasing dependence on foreign suppliers as domestic reserves of conventional fuels are depleted.

Oil and Oil Sands

Oil resource assessment activities at CANMET currently deal primarily with Athabasca bitumen, both in its natural state and after treatment by thermal hydrocracking. In one study, hydrocracked bitumen samples were examined to identify the chemical changes occurring at various levels of hydrocracking severity in catalytic and non-catalytic reactions. It appears that hydrogen transfer and aromatization reactions are involved in both processes. The study of hydrogen transfer in bitumen is important, particularly in relation to coal liquefaction and bitumen processing.

Tests have been conducted on methods of separating nitrogenous and associated polar materials from Athabasca bitumen and its non-catalytically hydrocracked products, with a

view to resolving problems of recovery, extraction, and processing. Studies also are being carried out on the effects of hydrocracking on sulphur compounds, to provide clues for the development of desulphurization processes. Compounds identified in the gasoline fractions of the hydrocracked products vary in their susceptibility to desulphurization.

Geochemical studies on the maturity of frontier oils are being performed to aid geological interpretation in exploration. Athabasca bitumen undergoing hydrocracking has been found to be similar to other more mature Cretaceous oils in the Alberta basin; thus, there appears to be a positive relationship between hydrocracking and geochemical maturation processes. The results of these studies have been used to determine the degree of maturation of several oil deposits on Canada's east coast.

Quality and Mineability of Coal Resources

It is expected that coal will become increasingly important as a source of domestic energy supply. Although Canada's coal resources are large, their quality and mineability vary substantially. More information is needed to obtain a realistic assessment of the potential of existing reserves to meet current and projected demand.

Since 1972, CANMET has been involved in a federal-provincial project to evaluate the lignite resources of the Ravenscrag Formation of southern Saskatchewan. More than 700 boreholes have been drilled and more than 6,000 coal samples obtained during this project. In 1976-77, computer processing of the analytical data was completed, along with follow-up studies which included assessment of ash and mercury contents and beneficiation and combustion trials of high-ash lignite. Cooperation was continued with the Saskatchewan Research Council in studies to correlate coal chemistry data with geophysical logs. Progress was made in aligning depth measurements made by geophysical and chemical means, to correlate accurately strata depth and coal quality and to allow the use of geophysical methods alone in estimating resources.

To determine the mineability of Saskatchewan lignite beds, CANMET staff are developing methodology to derive mining costs for mineable reserves from geological data. Their work has included completion of a computer model for dragline overburden stripping, which covers determination of stable slope angles, dragline selection, capital and operating costs, and other factors. Similar selection and costing programs for truck and shovel operations are currently being worked out. Progress also has been made on the development of a computer program for selecting optimum sites for initial mining operations.

During the year CANMET continued to participate in a coal resource inventory program with the Province of Nova Scotia. The program was extended to include areas not previously assessed. The feasibility of extending the program still further to evaluate offshore resources of the Sydney coalfield is being examined. Efforts were continued to apply the computer program developed for Saskatchewan coal chemistry data to the Nova Scotia coal inventory and possibly to a similar New Brunswick inventory, for which drilling will start in 1977.

An evaluation of commercially marketed coals from both eastern and western mines was completed and reports published. These reports provide guidance for domestic and foreign purchases. The coal industry continues to rely on CANMET's capabilities in evaluating the quality of coking coals from new sources. The data thus generated will be helpful in assessing the overall quality of Canadian coal resources.

In 1976-77, CANMET cooperated with the American Society for Testing and Materials (ASTM) and the International Standards Orgazization in further development of test standards for coals, thereby ensuring the qualification of Canada's reserves for national resource assessment and international trade. An x-ray fluorescence analyzer was put into service, and a system was devised for rapid and accurate determination of the 10 major elements present in coal ash and related materials. The analytical values obtained by this method are well within acceptable ASTM limits.

Efforts were continued to provide information on Canadian peat resources, with emphasis on the use of this fuel for power generation. During the year, a study was published assessing the potential of 35 peat bogs located in Newfoundland.

Uranium Production Capacity

In 1974, a Uranium Resource Appraisal Group was formed within the Department of Energy, Mines and Resources to perform an annual audit of Canada's uranium resources. The purpose of the audit is to help to ensure that existing facilities for uranium production are capable of meeting the requirements of the domestic

Peat, a potentially great source of energy for Canada.

nuclear power program. CANMET's Mining Research and Mineral Sciences Laboratories are represented in the Appraisal Group. The Group prepares an annual compilation of measured and indicated uranium reserves and initiates studies aimed at establishing productive capacity and developing new assessment methods. Canada's production capability is expected to grow from 7,550 short tons (6,850 t) of uranium oxide in 1976 to 15,000 tons (13,608 t) by 1984. This capacity replaces the production of uranium concentrates from lower-grade ores and the decommissioning of facilities when existing reserves are mined out. As new deposits are found, production capacity can be increased accordingly.

ENERGY TECHNOLOGY DEVELOPMENT

To ensure adequate technical capability for the supply, processing, and use of energy, CANMET performs research on many aspects of energy technology. Current emphasis is on coal mining and processing, refining of bitumen from oil sands and of heavy oils, uranium extraction, and energy resource use.

The Department of Energy, Mines and Resources is the leading federal organization in the field of fossil fuel development, and CANMET provides leadership in improvement of technology. Current research is directed towards improved efficiency in processing and substitution of lower-grade fuels for those of high grade. An integral part of work in these areas is a continuing regard for preservation of the environment.

Conservation Technology

An important part of the Department's energy conservation strategy is the promotion of more efficient methods of using fuels. CANMET has developed distinctive pilot plant facilities to translate combustion fundamentals into engineering practice for Canadian use. The facilities comprise a pulverized-fired research boiler, a flame research tunnel furnace, a fluidized-bed combustor, a fuel additive evaluation boiler, and a domestic oil-burner development facility. During 1976-77, considerable attention was given to optimizing coal combustion or fuel efficiency and to de-

veloping advanced technology for converting boilers and processes back to Canadian coals.

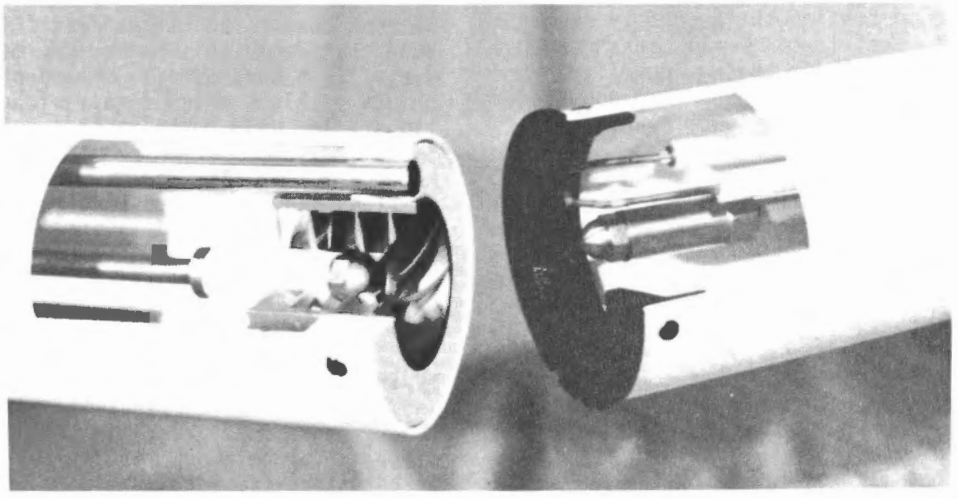
To evaluate fuel conservation strategies for domestic heating, 14 instrumented homes were selected for a field trial. The most important of these strategies are improved burner performance through overnight thermostat cut-back and changes in nozzle size, and through the installation of retrofit devices, solenoid oil valves, and safety interlocked motor-driven chimney dampers. Fuel savings of more than 20% were measured during the trial. In a related study, the deterioration of furnace efficiency in 120 homes was monitored for the heating season ending in the spring of 1976. The quality of equipment in some new homes was found to be poor. Contrary to previous belief, random total efficiency tests showed that a fairly high smoke number, up to No. 6, did not lead to significant deterioration in efficiency.

A contract was let to a Canadian company to build two prototypes of the efficient CANMET blue-flame oil burner and warm-air furnace. A Canadian patent for the burner was received by CANMET scientists in 1976. The burner-furnace units will be delivered for testing in 1977, followed by the addition of an electronic control system and modulated firing rate.

The nation-wide emphasis on energy conservation has led to a surge of interest in fuel additives that could reduce fuel consumption. Following many years of research on additives to reduce slagging of superheaters on destroyer escort vessels and to neutralize acid corrosion at the cold end of boilers, CANMET has assembled a fuel additive evaluation facility. Because the effects of fuel oil additives are usually small, they are often rendered insignificant by outside influences on heating load. A package-steam boiler of the type used in schools and small apartment buildings has been set up in the laboratory, where it is free from such outside influences. The boiler is capable of burning both No. 2 furnace oil and residual oil and is equipped to identify and measure marginal effects of additives. Similar tests of water-in-oil emulsions for improving fuel efficiency are under way.

Atmospheric Pollution Control

The relationship between chimney height and plume dispersion in airsheds is being studied for a variety of conditions. From the large volume of data collected, CANMET scientists can calculate ideal chimney heights to minimize local pollution at ground level. In another project, pilot-scale work with crude oil, residual fuel oil, and Saskatchewan lignite has shown that the use of external flue-gas recirculation as a pollution control measure is limited in its application. The technique led to decreased combustion efficiency because of increases in the carbon content of the fly ash.



The blue-flame burner (left) provides more efficient and cleaner operation than a domestic burner of conventional design (right).

Automotive Fuel Efficiency

During the year, a contract was let to a Canadian company to compare the fuel consumption of a new lean-burn system for automobiles with that of a conventional catalytic system under Canadian conditions. Initial results showed that the lean-burn system did not deteriorate as severely as the catalytic system in either fuel economy or pollutant emissions, at winter temperatures as low as 10°F, (-12°C). A second contract was prepared for completion in 1977 to confirm the tests and repeat them in colder weather conditions and using smaller engine sizes.

Other studies included testing of aerodynamic devices to reduce the wind drag on trucks, measurement of the effect of aerodynamic drag caused by police sirens on fuel consumption by police vehicles, and demonstration of the effect of automobile weight on highway gasoline mileage.

Increased Industrial and Domestic Uses of Coal

Opportunities to increase the use of pulverized coal in thermal power stations and in industry are under study, with particular emphasis on ways of optimizing combustion efficiency. Some difficulties have been encountered, resulting from the decline in quality of coal produced by new mines.

The main problem of substituting coal in equipment designed to burn oil and natural gas is that the narrow spaces between boiler tubes rapidly become plugged with ash. CANMET has pioneered a laboratory-scale demonstration of coal-in-oil combustion on the theory that the ash of 35% coal-in-oil will pass through narrow spaces without being deposited and building up on boiler tubes. A proposal for trials at a Nova Scotia power plant is under evaluation.

During the year, the combustion performance of a British Columbia coal was optimized and design criteria were determined for a proposed 5,000-Mw power station. Although this coal is reactive, it contains a large amount of bentonite clay, which is gluey when wet and converts to an abrasive refractory in the flame; this characteristic presents serious problems for handling and boiler design. Tests were also carried out on Alberta bituminous and subbituminous coals and on Saskatchewan lignites as power plant fuels, and on conditions required for converting cement kilns to the use of coal.

Fluidized-Bed Technology

Combustion of coal in fluidized beds offers improved efficiency in energy use and improved control of pollutant emissions. It also allows the use of low-quality coals, such as the subbituminous and lignite coals of Western Canada. A 12-in. (30.5-cm) diameter, water-cooled fluidized-bed combustor has been built at CANMET, complete with a highly successful ignition burner submerged in the bed. The performance of this laboratory facility has been encouraging. Operating parameters were established for evaluating the combustion performance of a series of solid fuels, including high-fusinite, low-rank coals as well as tar sands and char from tar sand extraction plants. These products are all difficult or impossible to burn in any other system without the continuous support of premium fuels. Coal drying using coal washery rejects as fuel in a fluidized bed has also been proven feasible on a small scale.

Related fluidized-bed research carried out during the year included a study of ways to control agglomeration and defluidization of coals. The objective is to help resolve practical problems associated with fluidized-bed combustion of coals, oxidation of coals high in volatile matter for formed coking, and fluidized-bed devolatilization or charring of coals.

New Methods for Mining Oil Sands

The oil sands of Alberta vary in depth of overburden from zero to about 2,000 feet (610 m). The sands can be mined by open-pit methods down to about 200 feet (61 m), but beyond that depth this method may be too expensive. The nature of oil sand deposits creates unique problems which require innovative solutions. To help reach these solutions, CANMET is studying various alternative mining methods. An assessment of surface mining problems and associated research needs has begun. During the past year, a research contract was awarded to private industry for a study of the feasibility of underground mining systems. Ground movement and gas emissions were investigated in the Saline Creek diversion tunnel being constructed in the oil sands by the Alberta Department of Transportation. The construction of this tunnel — the first underground excavation in the oil sands — offers a valuable opportunity to gather data on potential underground mining problems.

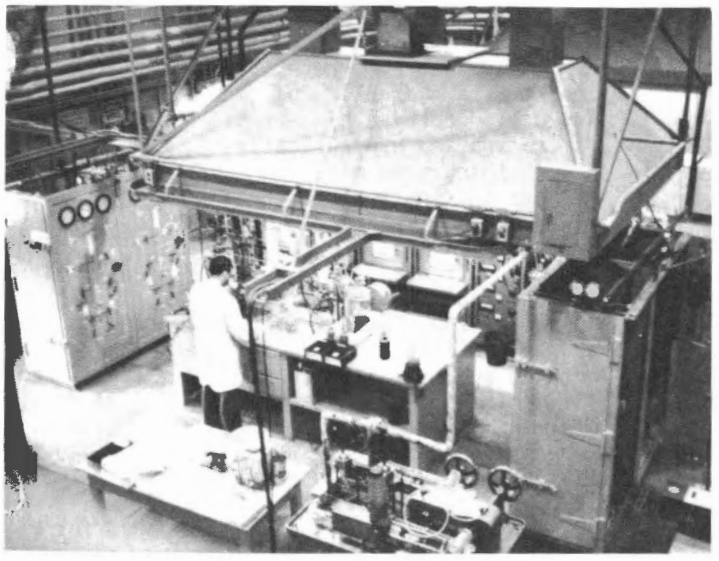
Hydrocracking of Bitumen and Heavy Oils

In 1976-77, in cooperation with other agencies, CANMET continued to develop processes for refining bitumen from Alberta's oil sands, and from heavy crude oil by high-pressure thermal and catalytic hydrocracking to produce synthetic liquid fuels. Present methods of refining bitumen and heavy oils produce a high-sulphur coke that can be burned in only limited quantities without violating environmental regulations. CANMET has developed a hydrocracking process known as Extendoil, in which the bitumen or heavy oil is hydrogenated so that coke production can be reduced or eliminated altogether. This process increases the liquid yield from the bitumen or heavy oil by up to 15%, and most of the sulphur is retained in the pitch fraction. Research efforts over the past year were concentrated on the development of operating techniques in the one-barrel per day hydrocracker to reduce operating pressure, and thus capital costs, without reactor fouling. The pilot plant is being run on a 24-hour basis with much success. Construction of a 200-barrel per day pilot plant is being considered.

The effects of additives were tested as a means of reducing reactor deposits during thermal hydrocracking. Addition of subbituminous coal to feed was particularly successful and prompted further research into the mechanism of deposit formation to determine whether the reduction is due to a catalytic effect or to scaveneger effects of the coal. Coal-based slurry catalysts were also tested for their effect on reactor fouling at reduced pressures. Two runs using iron sulphate catalyst produced results that were considered to represent a breakthrough; consequently, this technique will be thoroughly expoloited before other catalysts are tried.

In another study, two-stage treatment of bitumen using hydrocracking and hydrotreating in series was evaluated. It was shown that the sulphur and nitrogen specifications for naptha and gas oils could be met by treating the combined distillate. The conventional method is to condense the distillate, separate the three products by distillation, treat each product separately, and then recombine them. The proposed treatment would eliminate several steps and hence improve the economics of the process.

CANMET's bench scale catalysis research program has been directed almost entirely towards the development of catalytic systems for hydrocracking Athabasca bitumen. Coal used as a "getter" or catalyst support can be classed as a short-life throw-away additive. Despite



Bench scale high-pressure facilities for catalyst evaluation.

the fact that the coal passes through the reactor and has to be removed continously, this system is still considered economically viable because the coal is inexpensive. The work on long-life catalysts involves optimizing catalyst porosity so that the entire catalyst structure will be accessible to reactant molecules. An inexpensive system for regenerating hydrotreating catalysts was developed during the year and a patent applied for.

Solution of some of the material problems associated with development of Canada's oil sands and heavy oils has been undertaken at CANMET. Digging teeth and other components used in mining the Alberta oil sands have shown excessive wear, and abrasives have likewise shown up in bitumen distillates, leading to shortened lives for valve needles and seats. Research is under way to develop a single-step process for producing abrasion-resistant surfaces on steel castings as a substitute for the two-stage process now used. Initial results have been promising, particularly with cobalt-based alloys. Also, different valve materials and coating systems are being evaluated.

Another project is concerned with the selection of materials for a 10,000-barrel per day (8.51×10^4 m^3/hr) thermal hydrocracking demonstration plant. A study is being made of the most suitable materials and methods of manufacture for the pressure vessel. So far, the type 316 stainless steel used in the pilot plant has proven satisfactory, and this would be a candidate material either for the vessel itself or for a lining.

Coal Mining Technology

In Canada and elsewhere, there is great interest in hydraulic coal mining whereby coal is dislodged by a high-pressure water jet and is transported hydraulically to the surface. At a thick-seam mine in British Columbia, methods and instrumentation are being developed to study strata behaviour. Measurements to date have indicated that the area of influence is much greater than would be expected from conventional mining in relatively thin seams. However, the overall displacements and load changes within the vicinity of the active working sublevel are surprisingly small. Instruments have also been installed to determine the effects of strata behaviour with different roof support systems. Further studies will examine the effect of planned extraction in a different direction and at a different gradient. Methods have been developed for remote monitoring of surface movements caused by this thick-seam mining in rugged and steep terrain.

Safety in Coal Mines

The presence of methane, carbon monoxide, and fine dust and the risk of spontaneous combustion are serious hazards in coal mining. CANMET scientists are studying ways to reduce these hazards.

A method has been developed to identify gaseous products of low-temperature coal oxidation and thus reduce the likelihood of spontaneous combustion. For early detection of heating, the absolute level of carbon monoxide (CO) in the mine air, whether high or low, is not of great significance, but a steady increase in the CO concentration is indicative of unusual oxidation. A sophisticated four-point CO monitoring system has been installed and successfully operated in an hydraulic mine, marking an important innovation in coal mining in Canada. In addition to its research aspects, the monitoring system provides the mine with a valuable safety control by indicating CO concentration in various sections of the mine long before it reaches toxic levels. In areas where carbon monoxide monitoring is not possible or practical, infra-red technology can detect sources of high rates of oxidation or hidden fire before it spreads. Field surveys using an infra-red scanner and an infra-red thermometer were carried out during the year, with encouraging results.

CANMET is also looking at ways of controlling methane emission in coal mines through such methods as methane drainage and ventilation. The work includes participation in a multi-company feasibility study on methane production from coal beds. Of particular interest in this study is the development of a computer model to simulate methane emission.

Because of the explosive nature of methane/air mixtures in coal mines, mining equipment must be designed to eliminate risks of igniting these mixtures. In addition to studies of spark ignition from electricl equipment, scientists are looking at the properties of exhaust flame arresters for diesel equipment and reasons for the occurrence of high explosion pressures in diesel exhaust scrubbers. A cooperative project with the National Research Council has demonstrated that a high-compression diesel engine can continue to run after the fuel has been shut off if a methane/air mixture is present in the mine.

Certification of mining equipment continues to be an important task of CANMET mining personnel. A change in policy by provincial mine inspectors to require Canadian certification of all equipment led to an increase during the year in the number of applications for certification from overseas. New programs for certification of combustible gas detection equipment and non-combustible hydraulic fluids also were initiated in 1976-77.

Coal Cleaning and Pollution Control

Coal-cleaning techniques are being investigated to make coals containing large amounts of ash or other impurities suitable for steelmaking or thermal power generation. A pilot plant to test the capabilities of the "EMR Process" based on compound water cyclones commenced operations in 1976-77. To date, the system has proven to be easy to control and, because of its ability to tolerate slimes, viable as a bulk cleaning system. Tests with coals that are difficult to clean by other methods have demonstrated that the process can handle a broad range of washing requirements. Use of CANMET's patented Auto Medium Cyclone as a scalper ahead of a more expensive cleaning process was shown to reduce the capacity requirements, and thus the costs, of the latter.

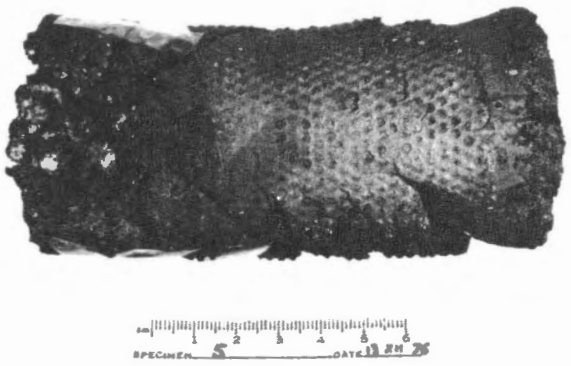
A 45 x 12-foot (13.7 x 3.7-m) trailer has been purchased which is to be fitted for field testing of a 300-gallon per minute (22.73-L/s) prototype of the CANMET process water recovery system. The mobile unit will include a flocculant preparation feeding section, a bottom-feed thickener, and a solid-bowl centrifuge for dewatering of the thickener sludge. It will permit a reliable evaluation, not obtainable in the pilot plant, of some site-specific aspects of water recovery

operations. It will also be capable of rigorously testing principles derived from laboratory flocculation research and pilot plant development work.

In flocculation research, an atomizing device developed in-house was found to be generally superior to conventional mechanical stirring systems in dissolving polymers of high molecular weight in water. It promises to effect savings in time, space, and costs for a wide variety of mixing applications in industry.

Coke from Canadian Coals

CANMET's applied research on coal carbonization is formulated in collaboration with the Canadian Carbonization Research Association through regular meetings of the Association's Technical Committee. This excellent example of industry-government cooperation has been successfully maintained for the past 12 years. Priority projects sponsored by the Association include self-reliance in terms of coking coals and methods of increasing the range of coals for use in conventional coke-making. Meetings between Canadian and Japanese experts were begun in 1976-77, with a view to fostering technological growth in coke-making to the potential benefit of both countries. At present, more than 13 million tons (11.8×10^6 t) of Canadian coking coal are exported each year to Japan.



Evaluation of small amounts of metallurgical coals. Cannister sample of half oven piece of coke.

Coke is produced almost exclusively from the carbonization of coking coals in conventional slot-type coke ovens. Innovations such as formed coke, which are not necessarily restricted to coking coals but produce a high-carbon product suitable for blast furnaces, are not expected to have a serious impact on the market for many years. Conventional coke-making studies carried out during the year included research on selective pulverization and partial briquetting to increase coke strength and to broaden the range of usable coals. More intensive investigations are scheduled for 1977-78, particularly in areas related to national self-sufficiency.

Formed coke has many advantages over the conventional method, including better control of air pollution, use of marginal and non-coking coals, production of desired product shapes, and the installation of small production units with the ability to start up and shut down when required. Progress was made during the year on development of a hot briquetting formed-coke pilot development unit. A ball mill capable of simultaneous grinding and screening of coal or char was designed and fabricated to provide a means of quickly and efficiently preparing materials for the unit. A sand-bed coker was designed, fabricated, and shown to operate at a temperature of 1000°C. The unit was operated successfully and produced hot-formed briquettes made with an eastern Canadian high-volatile coking coal as binder and a char from a western Canadian semi-anthracite coal. Tests in a counter-current reactor that simulates conditions in the blast furnace have indicated that the resultant coke from hot briquettes is similar in reactivity to conventional metallurgical coke.

Research related to the physical and chemical properties of coals and cokes included studies on the extent of coal oxidation, the effects of depth of cover on coal properties, and the influence of generation and decomposition of petroleum-like substances in coal seams.

Improved Uranium Extraction Methods

Because a substantial proportion of Canada's total uranium resources is either of low grade or of a complex nature, further research is needed to process such ores economically. Work is being done on new methods and on innovations in the conventional sulphuric-acid leach process. Along with new process methods, problems of analysis must be resolved. Mineralogical examination of new and difficult ores is required. The environmental burden caused by uranium-processing effluents

has received much attention recently, and work is being done to reduce pollutants by improving the extraction process.

A flowsheet has been proposed for a nitric-acid leaching process, and promising results have been obtained with tests on chloride leaching. CANMET researchers have also developed a deep, single-stage, fluidized ion-exchange column for uranium extraction. The process allows the treatment of unclarified colutions or of dilute slurries at reduced cost and also permits recovery of thorium, which is a potential feed for reactors for electrical energy production. Peat is also being examined as a source of humic acid for the recovery of trace amounts of uranium that would otherwise be discharged to the environment.

Nuclear Material

In the manufacture of heavy water for Canada's nuclear reactors, processing steps include containment of deuterium oxide/hydrogen sulphide mixtures in pressurized towers at temperatures from 30 to 130°C. Uncertainties have arisen regarding the integrity of steels for use in pressure vessels under such corrosive and potentially hydrogen-embrittling conditions. Initial laboratory tests have indicated that the ASTM A516 Grade 70 steel used in the towers can suffer hydrogen-induced delamination damage. Testing is continuing.

Materials for Electrical Energy Production

One limitation to efficient energy use lies in the cyclical nature of demand on electrical utilities. Improved efficiency can, however, be realized through load-levelling by the storage of power during off-peak hours. Such a system requires a high-energy density battery such as the sodium-sulphur cell. This type of battery is also of interest for electrically powered vehicles. CANMET scientists have succeeded in producing a powder of single phase β alumina, which is used as the solid electrolyte for the cell. It is hoped that this material will form the basis for producing improved cells for the batteries.

In the magnetohydrodynamic generation of electricity from fossil fuels, such components as electrodes are subject to severe abrasion, corrosion, and thermal shock. Studies are under way to find materials that will withstand these conditions. Such materials may also prove valuable in the development of fuel cells.

Materials for Energy Transportation

A project is under way to acquire the necessary technological knowledge base to ensure integrity of structures and equipment for transporting oil and gas. The research has special reference to Arctic and offshore

The temperature of a bath of molten alloy pipeline steel is being measured in a direct arc electric furnace in the experimental foundry.

regions, where technology is not well established, and involves evaluating materials and developing related testing and specification criteria.

The Charpy test is a simple standard test commonly used to measure toughness, but there is considerable doubt as to how Charpy measurements correlate with the true service fracture toughness of line-pipe steels. To provide a more reliable measure of fracture toughness, an instrumented drop-weight test was successfully developed during the year for measuring dynamic stress and ductility characteristics of fracture through a line-pipe wall. This, for the first time, has made possible an assessment of the Charpy energy level required to eliminate brittle behaviour in X-65 grade line pipe. This work has aroused considerable interest, and an evaluation of X-70 grade steel has subsequently been undertaken.

To investigate further the problems of maintaining high toughness in high-strength line-pipe steels as yield strength is increased, three experimental low-carbon manganese-molybdenum-niobium steels have been studied. In the direct-quenched condition, the required impact toughness has been obtained at a yield strength of 100 kpsi (690 MPa). Work aimed at optimizing composition is under way.

Data obtained on the corrosion fatigue of an X-64 line-pipe steel have been applied to a crude-oil pipeline that experienced four service failures during a five-year operating period. The service pressure fluctuation spectrum of the failed line, coupled with laboratory data, has provided a calculation that agrees well with the observed life to failure. Since the fatigue life depends largely upon the initial defect size, the calculation provides important inspection criteria.

MINERAL AND ENERGY TECHNOLOGY INFORMATION

J.E. Kanasy, Chief

The Mineral and Energy Technology Information Program is a natural extension of CANMET's research and development activities, and of its close ties with industry. The program is implemented through the provision of advice and consultative services by Branch research personnel and, more formally, through the work of information specialists and editorial and publications staff assigned to the Technology Information Division.

As well as meeting the information needs of CANMET research staff, the Division directly serves scientific and technical personnel throughout Canada by answering inquiries, publishing and disseminating the results of CANMET research, and bringing together Branch research staff and other members of the scientific community. Through these services, the Division plays an important role in developing a national network for the dissemination of scientific and technical information.

DISSEMINATION OF INFORMATION

A significant development in 1976-77 was the growth in size and scope of the Technical Inquiries Section. The staff now includes professionals specializing in technology information relating to energy, mining, metallurgy, and mineral processing. Much effort was devoted to establishing interaction with CANMET research personnel and with the industrial clientele that the Division aims to serve. Mailing compaigns, notices in journals, exhibits, presentations, and personal contacts were used as the initial elements of a plan to inform Canadians of CANMET's extensive information capabilities. During the year, the Division handled more than 600 requests for technical information, many involving extensive literature searches, and more than 1,000 requests for advice and consultation, which were dealt with directly by individual researchers.

In responding to technical inquiries, the Division's information specialists now routinely employ on-line access to about 40 large computer-stored data bases. Of particular value are the METADEX file of the American Society for Metals; COMPENDEX, the machine-readable form of Engineering Index; and files generated by the U.S. Energy Research and Development Administration and the American Petroleum Institute. These sources are supplemented by in-house files developed over many years, library holdings, and the expertise of CANMET's research staff. A current awareness service is also offered in collaboration with the Canadian Selective Dissemination of Information Network (CAN/SDI) of the National Research Council.

The energy information service covers conventional oil and natural gas, oil from tar sands, heavy oils, coal, and peat. It relies on several computerized data bases, on relevant reports issued by the U.S. Energy Research and Development Administration, and on a growing collection of journals, monographs, and reports published around the world.

During the year, a subunit was established within the Technical Inquiries Section to fulfill obligations assumed through the Department's membership in coal projects of the International Energy Agency — notably, the Technical Information Service, and the Mining Technology Clearing House. Staff of the subunit have completed a questionnaire on Canadian research and development related to mechanized drivage of roads, slopes, and shafts for the Mining Technology Clearing House, and they are routinely submitting abstracts of Canadian, Australian, and South African literature to the Coal Technical Information Service of the International Energy Agency. Information officers are also available to answer technical inquiries on coal originating both within and outside CANMET.

In 1976-77, more than 2,500 new abstracts were added to the mining technology information data base, an in-house computerized bibliographic file established by CANMET in 1968. This file now holds about 15,000 abstracts covering all aspects of the mining of metallic and non-metallic minerals, construction materials, and solid fuels. In addition to file-building, the mining technology information unit responded to nearly 400 inquiries during the year and produced a number of technical and statistical summaries on various aspects of Canadian mining.

In metallurgy, the Division offers a CAN/SDI current awareness service based on the METADEX tapes of the American Society for Metals, and answers technical inquiries by using computerized and conventional bibliographic files. Current awareness services are also available in CANMET's other subject fields.

The mineral processing information service is based on an in-house file in which items are indexed and retrieved as numerically coded titles. The file now holds almost 10,000 entries. In a move to strengthen this service, an information officer and an abstractor were appointed during the year. Abstracts of reports selected from the world's mineral processing literature are being prepared as first input to an expanded computerized reference file.

The Division's Slavic Language Specialist conducts background studies of Soviet and Polish technical literature and assists Department officials involved in exchanges with these countries. The work also includes regular translation and dissemination of the tables of contents of Russian journals, to keep departmental personnel aware of new developments in mineral and energy-related fields in the U.S.S.R.

The Division provides a referral service to ensure that callers reach the best source of information without delay. Since 1973, the Division has also participated in a structured referral service — "ASK" — organized as a pilot project by the National Research Council in the Toronto-Hamilton industrial area to test the technical information needs of a community. A detailed profile of CANMET expertise is registered in the ASK knowledge base, and the Technical Inquiries Section has been receiving a steady flow of referrals from the service.

LIBRARY SERVICES

With well over 100,000 volumes, the CANMET Library is Canada's best single collection of literature on mining and mineral processing. To meet the responsibilities implicit in this status, it has participated in recent years in the national system of interlibrary lending. This participation includes coordinated collection development and other forms of cooperation with the Canada Institute for Scientific and Technical Information of the National Research Council and with other information centres. The Library also operates satellite libraries in the Physical Metallurgy Research Laboratories and at other CANMET laboratories in Elliot Lake, Ontario, and in Edmonton and Calgary, Alberta.

In 1976-77, the collection grew by more than 6,000 volumes. It now comprises 35,000 books, 85,000 volumes of serials, and over 15,000 technical reports. The film and microfiche collections also experienced significant growth, mainly through the addition of approximately 12,000 reports on microfiche from the U.S. Energy Research and Development Administration.

In the past, the Library's acquisition policy has relied heavily on the recommendations of CANMET staff. In 1976-77, as the basis for systematic collection-building, staff recommendations were supplemented by acquisitions based on an interest profile for current awareness of new publications. Special arrangements were also made with a large book-jobbing firm to ensure comprehensive and rapid acquisition of materials of interest.

Loans of books, serials, and reports to CANMET staff totalled 61,432 in 1976-77, and loans to other libraries totalled 4,474. The Library borrowed 2,226 items on behalf of CANMET's research staff, mostly in disciplines peripheral to CANMET's central concerns. Library staff also answered 882 major reference inquiries.

PUBLISHING SERVICES

The Publications Section of the Technology Information Division, in collaboration with laboratory editors and other support staff, is responsible for the technical production and dissemination of research results achieved by CANMET scientists. The principal activities include technical and literary editing of CANMET Reports; printing, physical processing, and dissemination of all reports; translations in the two official languages; and maintenance of files of photographs and slides for illustrative purposes.

During the past year, word processing equipment was acquired to accelerate the production process and reduce costs and manpower requirements. Initially used for the production of CANMET's Pit Slope Manual, this type of equipment will be phased in gradually, as resources permit, to handle production of all reports prepared by CANMET staff.

In 1975-76, the Division issued two categories of senior reports directed to the public. Subsequently, the two categories have been consolidated into a single series, collectively titled CANMET Reports, which is sold to the public through the Department of Supply and Services and by CANMET's own distribution facilities.

In 1976-77, more than 900 new reports and papers were produced by CANMET staff, including 50 CANMET Reports, 180 presentations and journal submissions, 380 unclassified papers for limited external distribution, 145 unclassified papers for internal distribution, and 160 confidential documents. In addition, 115 reports, previously classified as confidential, were placed on open file in the CANMET Library.

LIST OF PUBLICATIONS

CANMET Reports

76-3
Faye, G.H. Certified and provisional reference materials available from the Canada Centre for Mineral and Energy Technology as of 1976.

76-5
Faye, G.H., Bowman, W.S. and Sutarno, R. Tungsten ores CT-1, and TLG-1: their characterization and preparation for use as certified reference materials.

76-9
Ternan, M. and Whalley, M.J. Catalysts for hydrocracking and refining heavy oils and tars, part 3: the effect of presulphiding conditions on catalyst performance.

76-10
MacKinnon, D.J. and Lakshmanan, V.I. Recent advances in copper electrowinning.

76-11
Zimmerman, J.B. and Armstrong, V.C. The termination of radium-226 in uranium ores and mill products by alpha energy spectrometry.

76-12
Wilson, H.S. Lightweight aggregates for structural concrete.

76-13
Wheat, T.A. Development of a zirconia electrolyte for use in a steelmaking oxygen probe.

76-14
Estimation of upper bounds to rock slopes by analysis of existing slope data — wall stability in the South Roberts Pit — an example of the use of previous slopes.

76-15
Ranganathan, R., Ternan, M. and Parsons, B.I. Competing reactions in hydrotreating coker distillates from Athabasca bitumen on unpromoted and promoted catalysts.

76-16
Dames and Moore. A digest of environmental regulations pertinent to open pit mining in Canada (current at Apr. 1975).

76-17
Wyman, R. The floatability of eleven non-metallic minerals and three metallic oxides (sequel to TB 108 and TB 186).

76-18
Malhotra, V.M. Use of recycled concrete as a new aggregate.

76-20
Coates, D.F. The director-general's annual review/revue annuel du directeur general.

76-22
Sage, R. Editor. Pit slope manual — Chapter 1 — Summary.

76-23
Williams, R.J., Ternan, M. and Parsons, B.I. Catalysts for hydrocracking and refining heavy oils and tars, part 2: the effects of molybdenum concentration and of zinc to molybdenum ratio on desulphurization and denitrogenation.

76-24
Mines memo 1976.

76-25
Berry, E.E. Fly ash for use in concrete, part 1 — a critical review of the chemical, physical, and possulamic properties of fly ash.

76-29
Welwood, R.J.R. Mining technology in 1974.

76-30
Pruden, B.B. and Denis, J.M. Heat of reaction and vaporization of feed and product in the thermal hydrocracking of Athabasca bitumen.

76-31
1976 Catalogue of CANMET publications.

76-32
George, A.E., Banerjee, R.C., Smiley, G.T. and Sawatzky, H. Effect of thermal hydrocracking on the distribution of compound-types in Athabasca bitumen.

76-33
Pruden, B.B., Logie, R.B., Denis, J.M. and Merrill, W.H. Thermal hydrocracking of Athabasca bitumen — reduction of reactor fouling.

76-34
Raicevic, D. A technical review of ore dressing investigations on Canadian titaniferous ores conducted at CANMET from 1950 to 1975.

76-35
Ranganathan, R., Denis, J.M. and Parsons, B.I. Preliminary studies on the denitrogenation of distillates obtained from thermally-hydrocracked bitumen.

76-36
Sydney Abbey. SY-2, SY-3 and MRG-1 — Report on the collaborative analysis of three Canadian rock samples for use as certified reference materials — Supplement 1.

76-39
Raicevic, D. Technical review of ore dressing investigations on Canadian chromite ores conducted at CANMET from 1918 to 1976.

76-40
Tibbetts, T.E. and Montgomery, W.J. Evaluation of Canadian commercial coals: Nova Scotia and New Brunswick — 1975.

76-41
Tibbetts, T.E. Evaluation of Canadian commercial coals: Saskatchewan, Alberta and British Columbia — 1975.

76-42
Tibbetts, T.E. Evaluation of peat samples as part of a peat fuel inventory in the province of Newfoundland.

77-1
Coates, D.F. and Yu, Y.S., Editors. Pit slope manual — Chapter 9 — Waste embankments.

77-2
Whitby-Costescu, L., Shillabeer, J. and Coates, D.F. Pit slope manual — Chapter 10 — Environmental planning.

77-3
Sage, R. Pit slope manual — Chapter 6 — Mechanical support.

77-5
Coates, D.F. Pit slope manual — Chapter 5 — Design.

77-6
Kim, Y.C., Cassun, W.C. and Hall, T.E. Pit slope manual — Supplement 5-3 — Financial computer programs.

77-7
Faye, G.H., Bowman, W.J. and Sutarno, R. Zinc-copper ore RU-1: its characterization and preparation for use as a certified reference material.

Director's Services Reports

DS 75-10(INFO)
Mines memo 1975.

DS 76-13(ADM)
CANMET Staff. CANMET seminar on resource assessment.

DS 76-20(INFO)
Job, A.L. Statistical information on Canadian coal mines — 1975.

DS 76-21(INFO)
Job, A.L. Annotated bibliography of underground coal mines — 1975.

TECHNOLOGY INFORMATION DIVISION

Periodicals

Dixon, C.F. A pipeline for the Arctic. GEOS, spring 1976.

Skelly, H.M. and Dixon, C.F. The effect of Cr, Co and Sr additions on the strength of an Al-35% Si powder alloy. Powder Metall., 4, 1976.

Weidmark, P.E. Bibliography of Canadian contributions in the field of rock mechanics (12th supplement). CIM Bull., June 1976.

MINERAL SCIENCES LABORATORIES

Available Laboratory Reports

MRP/MSL 76-10(IR)
Lakshmanan, V.I. and MacKinnon, D.J. The feasibility of the bisulphite process in zinc metallurgy.

MRP/MSL 76-28(IR)
Dutrizac, J.E. Ammoniacal percolation leaching of a bornite chalcopyrite ore from Valley Copper Mines, B.C.

MRP/MSL 76-29(IR)
Petruk, W. Quantitative mineralogical analysis of a copper rougher concentrate for Selco Mining Co. Ltd.

MRP/MSL 76-31(IR)
Rolia, E. Silicate precipitation and co-precipitation as potential metal removal processes.

MRP/MSL 76-38(IR)
Petruk, W. Mineralogical analysis of samples from Test 147 — Peace River iron ore.

MRP/MSL 76-39(IR)
Sutarno, R. and Bowman, W.S. Statistical analysis of analytical data resulting from an international trial conducted by ISO/TC 102/SC 2/WG 4 — "Method for the determination of sulphur in iron ore" — combustion method — third draft proposal from the United Kingdom. ISO/TC 102/SC 2 (U.K.-17) 381E.

MRP/MSL 76-53(IR)
Sutarno, R. and Bowman, W.S. Statistical analysis of analytical data resulting from an international trial conducted by ISO/TC 102/SC 2/WG 3 "Method for the determination of sulphur in iron ores" — by gravimetric method — third draft proposal. ISO/TC 102/SC 2 (Japan-47) 346E.

MRP/MSL 76-67(IR)
Soles, J.A. Petrographic studies of potential concrete aggregate: waste rock from Marmoraton and Hilton Iron Mines.

MRP/MSL 76-91(IR)
Smith, C.W. Investigation of methods for the determination of trace amounts of arsenic in copper and copper-base alloys: application of a solvent extraction/spectrophotometric procedure to spectrographic copper standards.

MRP/MSL 76-126(IR)
Smith, C.W. Application of an ultra-violet on-stream monitor for chlorine in uncondensed exhaust gas from a sulphide ore chlorinator: preliminary investigation of the problem.

MRP/MSL 76-139(IR)
Eaton, N.S. and Sutarno, R. Sampling of iron ores from conveyors.

MRP/MSL 76-141(IR)
Petruk, W. and Pinard, R.G. Mineralogy of a zinc concentrate from mill tails of Brunswick Mining and Smelting Ltd.

MRP/MSL 76-147(IR)
Hamer, C.A. Acid extraction and recovery of alumina from melted and quenched anorthosite.

MRP/MSL 76-148(IR)
Hughson, M.R. Mineralogical studies of low-grade Santa Lucia ore samples.

MRP/MSL 76-152(IR)
Sutarno, R. Procedure for statistical evaluation of analytical data resulting from internal tests (second draft proposal).

MRP/MSL 76-157(IR)(R)
Raicevic, D. Technical review and evaluation of concentration investigation on Canadian titaniferous ores conducted by the Mines Branch from 1950 to 1975.

MRP/MSL 76-160(IR)
Petruk, W. and Pinard, R.G. Mineralogy of tailings from the mill of Brunswick Mining and Smelting Limited, New Brunswick, Canada.

MRP/MSL 76-170(IR)
Carette, C. Investigation of freeze-thaw durability of concrete for Miron Company, Montreal, P.Q.

MRP/MSL 76-171(IR)
Petruk, W. and Pinard, R.G. Mineralogical investigation of residues from chlorination leaching of bulk flotation zinc concentrate from Brunswick Mining and Smelting Limited.

MRP/MSL 76-193(IR)
Collings, R.K. and Brown, G.A. An evaluation of gold mill tailings as raw material for dry pressed building brick.

MRP/MSL 76-194(IR)
Quon, D.H.H., Bowman, W.S. and Farrell, D.M. Characterization of products from the lime-soda sinter process for alumina extraction from anorthosite.

MRP/MSL 76-270(IR)
Parsons, H.W. Chlorination of bulk zinc concentrate.

MRP/MSL 76-275(IR)
MacDonald, R.J.C., Haque, K.E. and Dutrizac, J.E. Peat moss — a new source of copper?

MRP/MSL 76-284(IR)
Pinard, R.G. and Petruk, W. Mineralogical examination and Quantimet analysis of a zinc-copper ore from Geco Mine.

MRP/MSL 76-299(IR)
Ripley, L.G. Extraction of alumina from Canadian anorthosite by the lime-sinter process.

MRP/MSL 76-356(IR)
Ripley, L.G. Recrystallization of fine-grained sulphide ore by chemical transport.

MRP/MSL 76-86(LS)
Parsons, H.W. Chlorination of uranium ores — literature review.

ERP/MSL 76-102(LS)
Lucas, B.H. Literature survey for the uranium program "Chloride metallurgy of uranium" — period 1950-1954 (inclusive).

ERP/MSL 76-112(LS)
Parsons, H.W. Chloride metallurgy of uranium — literature survey.

ERP/MSL 76-113(LS)
Gilmore, A.J. and Skeaff, J.M. Chloride metallurgy of uranium and thorium — a review.

MRP/MSL 76-115(LS)
Ritcey, G.M. DCOM deep ocean mining study: review of the state of the art of processing manganese nodules.

ERP/MSL 76-121(LS)
Saint-Martin, N. Literature survey on chloride metallurgy of uranium.

MRP/MSL 76-185(LS)
Parsons, H.W. A discussion of the disposal of sulphur monochloride produced on the chlorination of mineral sulphides.

MRP/MSL 76-208(LS)
Hitchen, A. and Smith, C.W. A review of analytical methods for the determination of polythionates, thiosulphate, sulphate and sulphides in mining effluents.

MRP/MSL 76-223(LS)
Smith, C.W. and Hitchen, A. Aqueous solution chemistry of polythionates and thiosulphate: a review of formation and degradation pathways.

MRP/MSL 76-271(LS)
Parsons, H.W. Dechlorination of $FeCl_3$.

MRP/MSL 76-340(LS)
Rolia, E. Calculating the interdependence between pH and the optimum adsorption of reagents on non-sulphide minerals.

Periodicals

Ahmed, S.M. Measurement of the galvanic currents related to the catalytic reduction of oxygen and oxidation of xanthate on galena. Extended abstract: International conference on modern electrometric techniques for investigating chemical systems. Carleton Univ., Ottawa, 1976.

Berry, E.E. and MacDonald, L.P. Experimental burning of used automotive crankcase oil in a dry-process cement kiln. J. Hazard. Mater., 73, 33-36, 1976.

Bruce, R.W. Determining the nature and association of gold in mill tailings. Proc. 8th Ann. Meet. Can. Min. Proc., 1, 311-325, 1976.

Bruce, R.W. and Petruk, W. Grinding media can have significant effect on selective floatation of copper-zinc ore. North. Min.,Ann. Rev., 62, 37, C28-29, Nov. 25, 1976.

Cabri, L.J. Glossary of platinum-group minerals. Econ. Geol., 71, 1476-1480, 1976.

Cabri, L.J., Chen, T.T., Stewart, J.M. and Laflamme, J.H.G. Two new palladium-arsenic bismuth minerals from the Stillwater complex, Montana. Can. Mineral., 14, 410-413, 1976.

Cabri, L.J. and Laflamme, J.H.G. Ore microscopy of some samples from Lac des Isles. GAC-MAC Program with abstracts. 1, 56, 1976.

Carson, D.J., Jambor, J.L., Ogryzlo, P. and Richards, T.A. Bell Copper: geology, geochemistry and genesis of a supergene-enriched, biotitized porphyry copper deposit with a superimposed phyllic zone. CIM Special, Vol. 15, 245-263, 1976.

Dean, R.S. and Ross, G.J. Anomalous gypsum in clays and shales. Clays and Clay Mineral, 24, 103-104, 1976.

Faye, G.H. and Sutarno, R. Certified reference materials for the earth sciences. Can. Mineral., 14, 164-171, 1976.

Faye, G.H. and Sutarno, R. CCRMP ores and related materials (1976). Geo-standards Newsletter, 1, 31-34, 1977.

Fleischer, M. and Cabri, L.J. New mineral names. Amer. Mineral., 61, 502-504, 1976.

Fleischer, M., Pabst, A. and Cabri, L.J. New mineral names. Amer. Mineral., 61, 1053-1056, 1976.

Fleischer, M., Pabst, A., Mandarino, J.A. Chao, G.Y. and Cabri, J.L. New mineral names. Amer. Mineral., 61, 174-186, 1976.

Gosselin, J.R., Townsend, M.G., Tremblay, R.J. and Webster, A.H. Mossbauer effect in single-crystal $Fe_{1-x}S$. J. Solid State Chem., 17, 43-48, 1976.

Gosselin, J.R., Townsend, M.G. and Tremblay, R.J. Electric anomalies at the phase transition in FeS. J. Solid State Chem., 19, 799-803, 1976.

Harris, D.C. and Chen, T.T. Crystal chemistry and re-examination of nomenclature of sulfosalts in the aikinite-bismuthinite series. Can. Mineral., 14, 194-205, 1976.

Hoey, G.R. and Lui, A.W. Reply to comments of Dr. P.J. Lloyd. Can. Metall. Quart., 15, 2, 191 (discussion, P.J. Lloyd, Can. Metall. Quart., 15, 2, 189), 1976.

Horwood, J.L., Townsend, M.G. and Webster, A.H. Magnetic susceptibility of single-crystal $Fe_{1-x}S$. J. Solid State Chem., 17, 35-42, 1976.

Jambor, J.L. New occurrences of the hybrid sulphide tochilinite. Geol. Surv. Can., Paper 76-1B, 6569, 1976.

Jambor, J.L. Studies of basic copper and zinc carbonates: 3. Powder x-ray data for zincian malachite, rosasite and cobalt analogues. Geol. Surv. Can., Paper 76-1C, 97105, 1976.

Jambor, J.L. A possible unit cell for glaucosphalerite. Can. Mineral., 14, 574-576, 1976.

Jambor, J.L. and McMillan, W.J. Distribution and origin of the "Gypsum Line" in the Valley Copper porphyry deposit, Highland Valley, B.C. Geol. Surv. Can., Paper 76-1B, 335-341, 1976.

Jambor, J.L., Plant, A.G. and Steacy, H.R. A dawsonite-bearing silicocarbonatite sill from Montreal Island, Quebec. Geol. Surv. Can., Paper 76-1B, 357-362, 1976.

Joe, E.G. Some recent trends in Canadian mineral processing. CIM Bull., 69, 776, 110-113, 1976.

Kaiman, S. Studies of radioactive ore minerals and uranium extraction. North. Min., Ann. Rev., 62, 37, D9, 1976.

Kaiman, S. and Horwood, J.L. An unusual thucolite from Elliot Lake, Ontario. Can. Mineral., 14, 422-428, 1976.

Kawatra, S.K. and Dalton, J.L. The on-line measurements of ash in coal slurries. Can. J. Spectrosc., 21, 58-60, 1976.

Kawatra, S.K. and Dalton, J.L. The use of gel-153 gamma-ray density gauge for coal slurries in an on-line x-ray fluorescence system. Can. J. Spectrosc., 21, 97-100, 1976.

Kodama, H., McKeague, J.A., Tremblay, R.J., Gosselin, J.R. and Townsend, M.G. Characterization of iron oxide compounds in soils by Mossbauer and other methods. Can. J. Earth Sci., 14, 1-15, 1977.

Lui, A.W. and Hoey, G.R. Corrosion inhibitors for the reduction of wear in iron ore grinding. Mat. Performance, 15, 9:13, 1976.

MacDonald, R.J.C., Haque, K.E. and Dutrizac, J.E. Peat moss – A new source of copper? North. Min. Ann. Rev., 62, 37, D10, 1976.

MacKinnon, D.J. Fluidized-bed anodic dissolution of covellite. Hydrometallurgy, 2, 65-76, 1976.

MacKinnon, D.J. Copper recovery by solvent extraction and electrowinning. North. Min., Ann. Rev., 62, 37, D5, 1976.

Malhotra, V.M. Hardened concrete: Nondestructive testing. (Book) Iowa State University Press and American Concrete Institute, 1976.

Malhotra, V.M. Are 4 x 8-inch concrete cylinders as good as 6 x 12-inch for quality control of concrete? J. Amer. Conc. Inst. Proc. 73, 1, 33-36, 1976.

Malhotra, V.M. Reply to discussions of a paper entitled "Development of a sulphur-in filtrated high-strength concrete". J. Amer. Conc. Inst. Proc., 73, 3, 168, 1976.

Malhotra, V.M. Reply to discussions. J. Amer. Conc. Inst. Proc., 73, 7, 43, 1976.

Malhotra, V.M. Discussion of a paper, "How soon is soon enough?" J. Amer. Conc. Inst. Proc., 73, 9, 528-529, 1976.

Malhotra, V.M. Discussion of a paper entitled, "Is high-alumina cement a satisfactory structural material?" Can. J. of Civil Eng., 3, 3, 474-475, 1976.

Malhotra, V.M. Chapters — The new A.C.I. frontier. J. Amer. Conc. Inst. Proc., 73, 7, N14, 1976.

Malhotra, V.M. No-fines concrete — Its properties and applications. J. Amer. Conc. Inst. Proc., 73, 11, 628-643, 1976.

Malhotra, V.M., Painter, K.E. and Soles, J.A. Development of high-strength concrete at early stages using a sulphur infiltration technique. Proc., 1st Int. Cong. on Polymer Concretes, 276-281, 329-330, 1976.

Malhotra, V.M. and Winer, A.A. The use of asbestos fibre in portland cement and sulphur concretes. CIM Bull., 69, 767, 1-7, 1976.

Mirkovich, V.V. Thermal diffusivity of solids and methods of its measurement. J. Can. Ceramic Soc., 45, 27-31, 1976.

Naldrett, A.J. and Cabri, L.J. Ultramafic and related rocks: their classification and genesis with special reference to the concentration of nickel sulfides and platinum-group elements. Econ. Geol., 71, 1131-1158, 1976.

Petruk, W. Application of Quantimet to the analysis of ore minerals for mineral dressing. Microsc. Soc. Can. Proc. 3rd Ann. Meet., 76-77, 1976.

Petruk, W. The application of quantitative mineralogical analysis of ores to predicting optimum grind. Proc. 8th Ann. Meet. Can. Min. Proc., 72-85, 1976.

Quon, D.H.H., Wei, J. and Malanka, D.P. Growth of $LiNbO_3$ and $LiTaO_3$ and the fabrication of thin-film optical waveguiding layers. J. Can. Ceramic Soc., 45, 39-45, 1976.

Raicevic, D. and Bruce, R.W. How to make $235,000,000. GEOS, summer 1976.

Raicevic, D. and Bruce, R.W. Gold recovery from a refractory carbonaceous gold ore. Can. Min. J., 97, 3, 40-45, 1976.

Raicevic, D. and Cabri, L.J. Mineralogy and concentration of Au- and Pt-bearing placers from the Tulameen River area in British Columbia. CIM Bull., 69, 770, 111-119, 1976.

Reed, A.J. and Jambor, J.L. Highmont: linearly-zoned copper-molybdenum porphyry deposits and their significance in the genesis of the Highland Valley ores. CIM Special Vol. 15, Porphyry Deposits of the Canadian Cordillera, 163-181, 1976.

Ritcey, G.M. Hydrometallurgy at CANMET: Technology transfer between government-university-industry. North. Min., Ann. Rev., 62, 37, D13-14, 1976.

Sastri, V.S. Reverse osmosis treatment of metal waste solutions. J. Sci. Indus. Res., 35, 64, 1976.

Sastri, V.S. Selective leaching of metals from ores with organic solvents and chelating agents. J. Sci. Indus. Res., 34, 663, 1976.

Sastri, V.S. and Ashbrook, A.W. Reverse osmosis performance of cellulose acetate membranes in the separation of uranium from dilute solutions. Separation Sci., 11, 361-376, 1976.

Stemerowicz, A., Bruce, R.W., Sirianni, G.V. and Viens, G.E. Recovery of vanadium and nickel from Athabasca tar sands fly-ash. CIM Bull., 69, 768, 102-108, 1976.

Szymanski, J.T. The crystal structure of mawsonite, $Cu_6Fe_2SnS_8$. Can. Mineral., 14, 529-535, 1976.

Washington, R.A. and Horwood, J.L. Problems in area monitoring for radon daughters. Proc. OECD/NEA Specialists Meet. on Personal Dosimetry and Area Monitoring Suitable for Radon and Daughter Products, Elliot Lake, Ont., 1976.

Wheat, T.A. Pilot plant testing of a zirconia-based oxygen probe. J. Can. Ceramic Soc., 45, 5-13, 1976.

Yoon, R.H. Heats of adsorption of anionic surfactants on $Cu(OH)_2$ and $Co(OH)_2$. Proc. CIC, Symp. on Polymers at Interfaces: Focus on Adhesion, 239-262, 1976.

Presentations

Ahmed, S.M. Measurement of the galvanic currents related to the catalytic reduction of oxygen and oxidation of xanthate on galena. Presented at the Int. Conf. on Modern Electrometric Techniques for Investigating Chemical Systems, Carleton Univ., Ottawa, July 13-16, 1976.

Ahmed, S.M. Measurement of the electrocatalytic activity of metal sulphides for oxygen reduction in relation to xanthate adsorption and flotation. Abstract presented at Amer. Chem. Soc., San Francisco, Aug. 29-Sept. 3, 1976.

Bell, K.E. Development of porosity during firing of high-lime clays and shales. Presented at the fall meeting of Structural Clay Products, Div. of Amer. Ceramic Soc., Toronto, Sept. 22-24, 1976.

Bell, K.E. The firing behaviour of clays. Invited lecture to Ottawa Guild of Potters, Ottawa, March 1976.

Bell, K.E. Summary of Canadian clay and shale resources as sources of Al_2O_3. 2nd Seminar on Resource Evaluation for Non-Bauxite Sources of Alumina, CANMET, Ottawa, July 1976.

Bell, K.E. and Brady, J.G. A summary of Canadian clays and shale resources as sources of alumina. Presented at Seminar on Resource Evaluation P-6, Ottawa, May 27, 1976.

Berry, E.E. Current availability of fly ash and its use in concrete in Canada. Presented at CANMET Seminar (Energy and Resource Conservation in the Cement and Concrete Industry), Nov. 8-9, 1976.

Boyd, J.D., Hoey, G.R. and Buhr, R.K. Wear problems in the mining and minerals industry. Presented at the Tribology Seminar, Arnprior, Ont., June 10, 1976.

Bruce, R.W. Determining the nature and association of gold in a mill tailing. Presented to Can. Min. Proc. Ann. Meet., Ottawa, Jan. 1976.

Bruce, R.W. The effect of grinding media on the selective flotation of Cu-Pb-Zn ore. Presented at Ann. Western Meet. of AIME, Denver, Colo., Sept. 2, 1976.

Cabri, L.J. Ore microscopy of some samples from Lac des Isles, Ontario. Presented at the Ann. Meet. of GAC-MAC, Edmonton, May 19-21, 1976.

Collings, R.K. and Brown, G.A. Alumina resources in Canada: nepheline, syenite and kyanite. Presented at Alumina Resource Seminar P-6, CANMET, Ottawa, May 27, 1976.

Dean, R.S. Clay minerals investigation in the Atlantic Provinces, Canada. Presented at Clay Minerals Conf., Corvallis, Oregon, Aug. 1-6, 1976.

Dutrizac, J.E. The reaction of titanium with sulphur vapour. Presented at the Conf. of Metall., Ottawa, Aug. 23-26, 1976.

Flengas, S.N. and Dutrizac, J.E. A new process for the separation of hafnium from zirconium. Presented at the Conf. of Metall., Ottawa, Aug. 1976.

Faye, G.H. and Sutarno, R. The Canadian Certified Reference Materials Project: how reference ores are certified. Presented at the Can. Min. Anal. Meet., Timmins, Ont., Sept. 21, 1976.

Francis, D.J. Determination of the identity and concentration of chloraquairon (III) complexes in aqueous hydrochloric acid solution by UV-VIS absorption spectroscopy. Presented at 1st Chem. Cong. of North American Continent, Mexico, Nov. 30-Dec. 5, 1976.

Francis, D.J. A tetrachloroferrate (III) selective liquid ion exchange electrode. Presented at Int. Conf. on Modern Electroanalytical Methods, Ottawa, July 1976.

Gilmore, A.J. The recovery of zinc from a mine water containing amounts of alkali and heavy metals. Presented to 15th Ann. Conf. of Metall., Ottawa, Aug. 25, 1976.

Gosselin, J.R., Townsend, M.G. and Tremblay, R.J. Electric anomolies at the phase transition in FeS. Abstract presented at CAP-APS-SMF, Laval Univ., June 1976.

Gosselin, J.R., Tremblay, R.J. and Townsend, M.G. Electric and magnetic properties at the phase transition in FeS. Abstract presented at Int. Conf. on Metal-Insulator Transition, Grenoble, France, June 1976.

Green, D.J. Particle-crack interaction in brittle composites. Presented at Ann. Meet. Amer. Ceramic Soc., Toronto, Feb. 1976.

Green, D.J. Crack-particle interactions in brittle particulate composites. 6th Int. Materials Symp., Univ. of California, Berkeley, Calif., Aug. 1976.

Harris, D.C. Application of the electron microprobe in exploration, evaluation, development and genetic aspects of ore deposits. Lecture sponsored by Mineral. Assoc. of Can., Univ. of Alberta, Edmonton, May 16-18,1976.

Hoey, G.R., Dingley, W. and Lui, A.W. Corrosion control methods for reduction of steel consumption in ore grinding. Presented at Corrosion/76, Houston, Tex., March 23, 1976.

Hutchings, M., Parisot, L. and Townsend, M. Neutron inelastic scattering measurement of spin-waves in iron sulphide. Presented at Int. Conf. on Magnetism and Magnetic Materials, Amsterdam, Sept. 1976.

Joe, E.G. Some recent trends in Canadian mineral processing. Presented at 78th Ann. Meet. of CIM, Quebec City, Apr. 27, 1976.

Kaiman, S. and Horwood, J.L. An unusual "thucholite" from Elliot Lake, Ontario. Presented at MAC-GAC, Alta., May 1976.

Kaiman, S. Mineralogical support. Presented at MRP Seminar on P-1 Projects. Apr. 1976.

MacDonald, R.J.C. and Dutrizac, J.E. Percolation leaching of pyritic Zn-Pb-Cu ores using ferric ion. Presented at Conf. of Metall., Ottawa, Aug. 23-26, 1976.

Malhotra, V.M. Use of recycled concrete as a new aggregate. Energy and resource conservation in the cement and concrete industry — seminar arranged by CANMET and the Office of Energy Conservation, Ottawa, Nov. 7-8, 1976.

Malhotra, V.M. Sulphur infiltration of concrete. Lecture at Dept. of Civil Eng., Univ. of Illinois, Chicago Circle, Chicago, Ill., March 9, 1976.

Malhotra, V.M. In situ testing of concrete. Lecture to Conc. Mater. Group, Nat.Bureau of Stand., Wash., D.C., Apr. 26, 1976.

Malhotra, V.M. Non-destructive testing of concrete. Seminar organized by the Mid-South Chapter, Amer. Conc. Inst., Memphis, Tenn., Apr. 27, 1976.

Malhotra, V.M. In situ testing of concrete. Luncheon speaker at Ann. Meet. Can. Testing Assoc., Ottawa, June 11, 1976.

Malhotra, V.M. Current research in concrete technology at CANMET. Summer school of the Cement and Conc. Assoc. of Colombia, Bogota, Colombia, July 1976.

Malhotra, V.M. Accelerated strength testing. Seminar organized by the Amer. Conc. Inst., Pittsburgh, Pa., Oct. 15, 1976.

Malhotra, V.M. Guest speaker (2 lectures) at 3rd Int. Symp. on Conc. Tech. of the Cement and Conc. Assoc. of Venezuela, Caracas, Venezuela, Nov. 1976.

Malhotra, V.M. Quality control of concrete. Seminar organized by Amer. Conc. Inst., Valley Forge, Pa., Dec. 15, 1976.

Malhotra, V.M., Soles, J.A. and Carette, G.G. Research and development of sulphurinfiltrated concrete at CANMET, Canada. Presented at Int. Symp. "New uses of sulphur", Madrid, May 18-20, 1976.

Malhotra, V.M., Carette, G.G. and Soles, J.A. Long-term strength and durability of sulphurinfiltrated concrete. Presented at Int. Symp. on "Polymers in concrete", Mexico City, Oct. 25-29, 1976.

Malhotra, V.M. An accelerated method of estimating the 28-day splitting tensile and flectural strength of concrete. Presented at the Int. Symp. on Accelerated Strength Testing of the Amer. Conc. Inst., Mexico City, Oct. 1976.

McCreedy, H.H. Bacterial leaching to be applied to a new Canadian uranium mine. Presented at IAEA, Coventry, England, Dec. 13-15, 1976.

Mirkovich, V.V. Thermal diffusivity of solids and methods of its measurement. Presented at Ann. Meet. of Can. Ceramic Soc., Toronto, Feb. 1976.

Mirkovich, V.V. Thermal diffusivity of yttria-stabilized zirconia. Presented at 5th European Conf. on Thermophys. Prop. at High Temperature, Moscow, U.S.S.R., May 18-21, 1976.

Petruk, W. The application of quantitative mineralogical analysis of ores to predicting optimum grind. Presented at 8th Ann. Meet., Min. Proc., Ottawa, Jan. 22, 1976.

Petruk, W. The state of the art of the application of mineralogical analysis to ore dressing. Presented at Brandon Univ., Brandon, Oct. 25; Univ. of Manitoba, Winnipeg, Oct. 26; Regina Univ., Regina, Oct. 27; Univ. of Saskatchewan, Saskatoon, Oct. 28, 1976.

Petruk, W. Characteristics of the silver deposits in the Cobalt ores, Ontario. Presented at Univ. of Manitoba, Winnipeg, Oct. 26; Regina Univ., Regina, Oct. 27; Univ. of Saskatchewan, Saskatoon, Oct. 28, 1976.

Petruk, W. Characteristics of oolitic iron deposits, Peace River district, Alberta. Presented at Brandon Univ., Brandon, Oct. 25; Univ. of Saskatchewan, Saskatoon, Oct. 29, 1976.

Petruk, W. Amorphous minerals from the Peace River oolitic iron deposits, Alberta. Presented at MAC, Edmonton, May 1976.

Petruk, W. Application of Quantimet to the analysis of ore minerals for mineral dressing. Presented at Microsc. Soc. of Can., June 20, 1976.

Quon, D.H.H. Growth of $LiNbO_3$ and $LiTaO_3$ and the fabrication of thin film optical waveguiding layers. Ann. Meet., Can. Ceramic Soc., Toronto, Feb. 1976.

Quon, D.H.H. Outline of extraction of alumina from anorthosite by the lime-soda-sinter method. First CANMET Seminar on Resource Evaluation for Non-Bauxitic Sources of Alumina, Ottawa, Jan. 1976.

Quon, D.H.H. Degradation of high-alumina cement. Joint seminar of Mineral Sciences Laboratories and Div. of Building Research, NRC, Ottawa, Jan. 1976.

Raicevic, D. and Cabri, L.J. Mineralogy and concentration of Au- and Pt-bearing placers from the Tulameen River area in B.C. Presented at CIM Ann. Meet., Quebec City, 1976.

Ritcey, G.M. Solvent extraction. Seminar at McMaster Univ., Hamilton, Feb. 8, 1976.

Ritcey, G.M. Extraction in metallurgy. Seminar at Univ. of British Columbia, March 2, 1976.

Ritcey, G.M. Hydrometallurgy. Seminar, Dept. of Chem. Eng., Univ. Newcastle, Australia, Nov. 10, 1976.

Ritcey, G. M. Uranium processing in North America. Seminar, Aust. Atomic Energy, Australia, Nov. 11, 1976.

Ritcey, G.M. Matrix management at CANMET and chemical and metallurgical research. CSIRO, Melbourne, Nov. 14, 1976.

Ritcey, G.M. Solvent extraction in hydrometallurgy. Dept. Chemistry, Murdock Univ., Perth, Australia, Dec. 7, 1976.

Ritcey, G.M. Aspects of solvent extraction and ion exchange application to ammoniacal solutions. Seminar, Western Mining, Perth, Australia, Dec. 8, 1976.

Ritcey, G.M. Solvent extraction technology. Presented in Adelaide, Australia at the Australian Min. Found., 1976.

Saiddington, J.C. Effect of plating interruptions on surface morphology of electrodeposited chromium. Presented as an invited paper at a joint meeting of Electrochem. Soc. and Amer. Electroplaters' Soc., Detroit, Mich., Jan. 12, 1976.

Soles, J.A. Instability problems with sulphur concrete and sulphur-infiltrated concrete. Invited lecture at Univ. of Calgary, Calgary, May 1976.

Sutarno, R. and Faye, G.H. A case for a standardized approach for certifying reference materials. Presented at ASTM Symp., Ottawa, Sept. 29, 1976.

Szymanski, J.T., Hall, S.R. and Stewart, J.M. Stannite, $Cu_2(Fe,Zn)SnS_4$, Kesterite, $Cu_2(Zn,Fe)SnS_4$ and unnamed $Cu_2(Cd,Zn,Fe)SnS_4$; structurally similar but distinct mineral. Abstract submitted for the Amer. Crystall. Assoc. Winter Meet., Feb. 21-25, 1977.

Townsend, M.G. Electric anomalies at the phase transition in FeS. Presented at Can. Assoc. of Physicists Ann. Meet., Laval Univ., Quebec, June 1976.

Townsend, M.G. Metal-semiconductor transition in FeS. Presented at International Meet. on Metal-Insulator Transition, Grenoble, France, July 1976.

Townsend, M.G. Neutron-inelastic scattering of spin-waves in FeS. Presented at Int. Meet. on Metal-Insulator Transition, Grenoble, France, July 1976.

Weston, T.B. The effect of some processing variables on the dielectric properties of $BaTi_4O_9$ and $Ba_2Ti_9O_{20}$ ceramics. Presented at Ann. Meet. Can. Ceram. Soc., Feb. 23, 1976.

Wheat, T.A. Pilot plant testing of a zirconia based oxygen probe. Presented at Can. Ceram. Soc. Meet., Toronto, Feb. 23, 1976.

Wheat, T.A. Ceramics. Talk to visiting groups of students on four occasions, March to Sept. 1976.

Winer, A.A. Comments on revised notice of proposed rulemaking occupational exposure to asbestos (Feb. 1976). Presentation and defence before Exec. of Comm. E 34, ASTM, St. Louis, Miss., May 2, 1976.

Winer, A.A. Basic factors in mineral wool production with particular reference to waste asbestos tailings. Seminar on Cement, Ceramics and Insulating Materials for Resource Conservation, Ottawa, Feb. 1976.

Winer, A.A. and Tibbetts, T.E. Shales and coal refuse for alumina production. Presented at Seminar on Resource Evaluation, Ottawa, May 27, 1976.

Yoon, R.H. and Salman, L. Heats of adsorption of anionic surfactants on $Cu(OH)_2$ and $Co(OH)_2$. Presented at Chem. Eng., Montreal, Sept. 19, 1976.

ENERGY RESEARCH LABORATORIES

Periodicals

CCRL Staff. Comparative performance characteristics of typical oil-fired domestic space and water heating appliances. Book based on reports: ERL IR-7332, 33, 70; ERL IR-74-43, 45; ERL IR-75-1, 4; Ont. Pet. Assoc., Toronto.

Brown, T.D. and Lee, G.K. The effects of external flue-gas recirculation on emissions from liquid and solid fuel combustion. Proc., 4th Members Conf., Int. Flame Res. Foundation, Ijmuiden, The Netherlands, 1976.

Brown, T.D. and Lee, G.K. Liquid and colloidal alternatives to conventional liquid fuels. Proc., 4th Members Conf., Int. Flame Res. Found., Ijmuiden, The Netherlands, 1976.

Whaley, H., Lee, G.K. and Gainer, J. Plume dispersion from a natural gas sulphur extraction plant under a persistent elevated inversion. Paper IGU/BIO-76, 13th World Gas Conf. of the Int. Gas Union, London, 1976.

Friedrich, F.D. Present and future combustion systems. ERP/ERL 76-13(OP), Energy Management Seminar on Steam Generation and Utilization, Province of Ontario, Brockville, Ont., 1976 and Can. Lime Inst., Toronto, Ont., 1976.

Lee, G.K. and Brown, T.D. Coal-in-oil: a substitute boiler fuel. Paper No. 76-WA/Fu-2, ASME Winter Ann. Meet., New York, 1976.

Hayden, A.C.S., Braaten, R.W. and Brown, T.D. Oil conservation in home heating. Paper No. 76-WA/Fu-8, ASME Winter Ann. Meet., New York, 1976.

Whaley, H. and Lee, G.K. Plume dispersion from a lignite-fired power station in flat, rural terrain. Paper No. 76-WA/APC-7, ASME Winter Ann. Meet., New York, 1976.

Qayyum, M.A. and Reeve, D.A. Reduction of chromites to sponge ferrochromium in methane-hydrogen mixtures. Can. Metall. Quart., Jan. 1977.

Qayyum, M.A. and Reeve, D.A. Hydrogenation of carbon to methane in reduced sponge iron, chromium and ferrochromium. Carbon, 14, 199-202, 1976.

Price, J.T. and Reeve, D.A. (CANMET) co-authored with Charlier, P. and Ajersh, F. (Ecole Polytechnique, Montreal). Reducibility and mechanical properties of iron oxide pellets with zinc and alkali additions. Trans., Second Int. Symp. on Agglom., AIME, Atlanta, Ga., 1977.

Nandi, B.N., Brown, T.D. and Lee, G.K. Inert coal macerals in combustion. Fuel, 56, Apr. 1977.

Nandi, B.N., Ciavaglia, L. and Montgomery, D.S. Variation of microhardness and reflectance of coal under conditions of oxidation simulating weathering. J. Microsc., 109; 1, 1977.

Nandi, B.N., Belinko, K. and Denis, J.M. Microscopic studies of the structure of coke formed during thermal hydrocracking of Athabasca bitumen. Preprint of Amer. Chem. Soc. Meet., New Orleans, Div. of Pet. Chem, 22, 2, 733, March 1977.

Belinko, K., Nandi, B.N. and Denis, J.M. Distribution of coke precursors in the reactor during thermal hydrocracking of Athabasca bitumen, Canada. Venezuela Oil Sands Symp., Feb. 1977.

Botham, J.C., Leeder, W.R. and Reeve, D.A. The evaluation of coke quality. Symp. on Coal Evaluation, Info. Series 76, 90-105, Alberta Research Council.

Botham, J.C. and Donaldson, J.R. Coking coals of Eastern Canada differ from those of the West. Trends in Mining issue of the North. Min., A5-A7, Apr., 1976.

Botham, J.C. Full potential of Canadian coking coals still to be realized – growing demand in world and domestic markets. North. Min., Ann. Rev., C23-C30, Nov. 1976.

Botham, J.C. and Donaldson, J.R. Die kokshohlen Ostkanadas. Gluckauf, 113, 1, 6, 26-29, Jan. 1977.

Tibbetts, T.E. An overview of coal preparation in Canada. World Coal, 1976.

Tibbetts, T.E. Elements of briquetting and agglomeration. Univ. of Waterloo, Inst. of Briquetting and Agglomeration, 1976.

Botham, J.C. Cokemaking. 60-page manuscript submitted to McMaster Univ. as part of an intensive course on blast furnace iron-making, Hamilton, Ont., March 1977.

Ternan, M. and Whalley, M.J. Presulphiding of catalysts for hydrodesulphurization and hydrodenitrogenation in a bottom feed liquid phase reactor. Can. J. of Chem. Eng., 54, 642, 1976.

Kriz, J.F. and Gray, I.D. Carbon-13 N.M.R. observations of butenes. J. Phys. Chem., 80, 2951, 1976.

Hardin, A.H. and Davis, A.R. Molecules adsorbed at oxide surfaces. Light Scattering in Solids, 3, 527, 1976.

Egerton, T.A., Hardin, A.H. and Sheppard, N. Pyridine adsorbed on a series of Y zeolites. Can. J. of Chem., 54, 586, 1976.

Hardin, A.H., Klemes, M. and Morrow, B.A. Pyridine adsorption on a series of X zeolites. Raman Scattering, 5, 1976.

Hardin, A.H. and Davis, A.R. Organic molecules adsorbed at model sediment surfaces. Can. J. of Spectrosc., 21, 139, 1976.

Sawatzky, H., George, A.E., Smiley, G.T. and Montgomery, D.S. Hydrocarbon-type separation of heavy petroleum fractions. Fuel, 55, 16-20, 1976.

Sawatzky, H., George, A.E., Smiley, G.T. and Montgomery, D.S. Gas-solid chromatographic separation of petroleum compounds and distillates on lithium chloride-coated silica. Fuel, 55, 329-333, 1976.

Clugston, D.M., George, A.E., Montgomery, D.S., Smiley, G.T. and Sawatzky, H. Sulphur compounds in oils from the Western Canada tar belt. Chem. Series, Shale Oil, Tar Sands and Related Fuel Sources, 151, 11-27, 1976.

George, A.E., Banerjee, R.C., Smiley, G.T. and Sawatzky, H. Effects of thermal hydrocracking on the compound-type distribution in Athabasca bitumen. Preprint, Div. of Fuel Chem., Amer. Chem. Soc. Nat. Meet., 21, 6, 176-189, 1976.

Presentations

Reeve, D.A. Reducibility and mechanical properties of iron oxide pellets with zinc and alkali additions. Presented at two seminars to the staff of the Central Research Laboratories (BHP), Australia, 1976.

Reeve, D.A. The requirements of raw materials for ironmaking, their assessment and methods available to tailor burden feed to desirable properties. Lectures, Univ. of Newcastle, N.S.W., 1976.

Nandi, B.N. Variation of microhardness and reflectance of coal under conditions of oxidation simulating weathering. Presented at Oxford, England, Apr. 5-6, 1976.

Nandi, B.N. Microscopic studies of the structure of coke formed during thermal hydrocracking of Athabasca bitumen. Presented at New Orleans, La., March 1977.

Price, J.T. Reducibility and mechanical properties of iron oxide pellets with zinc and alkali additions. Presented at Atlanta, Ga., 1977.

Leeder, W.R. Formed coking with the CMFRL fluidized-bed pilot facility. 26th Can. Chem. Eng. Conf., Toronto, Oct. 5, 1976.

Leeder, W.R. Introduction to energy. Presented at Carleton Univ., March 1976.

Leeder, W.R. Coal — the forgotten resource? Presented at Carleton Univ., March 9, 1976.

Leeder, W.R. Energy technology. Weekly graduate student course (Chem. 590) at Carleton Univ., spring 1976.

Nandi, B.N. Selected as a sessional lecturer for 1976-77 in the Geology Department, Carleton Univ. to organize a coal course and also to give lectures on coal science and coal petrology.

Botham, J.C. Cokemaking in relation to Canadian coking coals. Presented at Metals, Minerals and Energy consultations (Dept.Industry. Trade and Commerce) with commercial and other foreign officers during the annual Ottawa briefing visit, May 31, 1976.

Botham, J.C. Cokemaking. Presented talk and answered questions pertaining to the metallurgical use of the various coal seams of the Fording operation at a special meeting of senior officials of the Fording Coal Ltd., Calgary, Alta., Nov. 1976.

Botham, J.C. Chaired the first session of a joint meeting of the Canadian Coal Petrographers Group and the North American Coal Petrologists in Ottawa, and gave a brief talk on the formation of the group, its objectives and affiliation with the Can. Carb. Res. Assoc., Sept. 1976.

Nandi, B.N. Inert coal macerals in combustion. Joint meet. of the Can. Coal Pet. and the Amer. Coal Pet., Ottawa, Sept. 1976.

Reeve, D.A. Reduction of chromites and iron oxides in methane and hydrogen. CIM Conf. of Metall., Ottawa, Aug. 22, 1976.

Reeve, D.A. The future of coking coals in Canada. Presented at Newcastle (Australia) Branch of the Australasian Inst. of Min. and Metall., Apr. 9, 1976.

Reeve, D.A. Coking coal in Canada and its future. Presented to the Queensland Coal Preparation Soc., Brisbane, May 18, 1976.

Kelly, J.F. Surfactant sorption phenomena. Presented at the 8th Ann. Research Sem. of the Pet. Recovery Inst., Calgary, Alta., June 11, 1976.

Hardin, A.H., Klemes, M. and Morrow, B.A. Reactions of metal halides with catalyst surfaces. Joint Spectroscopy Soc./CIC Conf., London, June 1976.

Hardin, A.H., Klemes, M. and Morrow, B.A. Raman scattering from MX_4 modified oxide surfaces. 50th ACS Colloid Conf., Puerto Rico, June 1976.

Hardin, A.H., Klemes, M. and Morrow, B.A. Adsorption sites on ten cation exchanged X-zeolites. 5th Int. Conf. on Raman Spectroscopy, Freiburg, Germany, Sept. 1976.

Hardin, A.H. Studies of adsorption at modified catalyst surfaces. School of Chem. Sci., Univ. of East Anglia, Norwich, England, Sept. 1976.

Ternan, M. Natural gas and petroleum processing. Lecture at Carleton Univ., Ottawa, Feb. 15, 1976.

Ternan, M. The catalytic hydrocracking of bitumen derived from the Athabasca oil sands. Presented to the Eastern Canada Catalysis Discussion Group at Ottawa, May 14, 1976.

Parsons, B.I. and Ternan, M. The hydrodesulphurization and hydrocracking activity of some supported binary metal oxide catalysts. Presented at the 6th Int. Cong. on Catalysis sponsored by the Int. Union of Pure and Applied Chem., London, July 12-16, 1976.

Packwood, R.H., Ternan, M. and Parsons, B.I. A preliminary investigation of the fouling of catalyst pellets by residual oils and tars. Joint meetings of the Microbeam Anal. Soc. and Electron Microsc. Soc. of North America, Miami, Fla., Aug. 9-13, 1976.

Ranganathan, R., Ternan, M. and Parsons, B.I. Competing reactions in hydrotreating coker distillates from Athabasca bitumen on unpromoted and promoted catalysts. Centennial Meet. of the Amer. Chem. Soc., San Francisco, Calif., Aug. 29-Sept. 3, 1976.

Ternan, M. Hydrocracking bitumen from the Canadian oil sands. Presented to the Dept. of Chem. and Chem. Eng., Univ. of Saskatchewan, Saskatoon, Feb. 22, 1976.

Ternan, M. Coal gasification and coal liquefaction. Presented to the Nat. Advisory Comm. on Min. and Metall., Ottawa, March 17, 1977.

Sawatzky, H. Maturation studies of oils from the Alberta Tar Belt. Coal Pet. Meet., Hamilton, Ont., Jan. 1976.

George, A.E., Banerjee, R.C., Montgomery, D.S., Smiley, G.T. and Sawatzky, H. Simulated geochemical maturation of Athabasca bitumen. Assoc. of Amer. Pet. Geol. Meet., New Orleans, La., May 1976.

Sawatzky, H., George, A.E., Smiley, G.T. and Montgomery, D.S. Gas-solid chromatography on lithium chloride coated silica of petroleum compounds and distillates. ERDA Symp. on the Chem. of Fossil Fuel, Laramie, Wyoming, July 1976.

George, A.E., Banerjee, R.C., Smiley, G.T. and Sawatzky, H. Effects of thermal hydrocracking on the compound-type distribution in Athabasca bitumen. Amer. Chem. Soc., Fuel Div. Symp., San Francisco, Calif., Sept. 1976.

Pruden, B.B., Denis, J.M., Logie, R.B. and Merrill, W.H. Thermal hydrocracking of Athabasca bitumen: reduction of reactor fouling. 26th Can. Soc. Chem. Eng. Conf., Toronto, Oct. 1976.

Ranganathan, R. Hydrodenitrogenation of kerosene and gas-oil distillates from Athabasca bitumen. Catalysis Discussion Group Fall 1976 Meet., Defence Research Board, Ottawa, Oct. 1976.

Belinko, K., Nandi, B.N., Pruden, B.B. and Denis, J.M. Microscopic studies of the structure of coke formed during thermal hydrocracking of Athabasca bitumen. ACS Meet., New Orleans, La., March 1977.

Mikhail, M. and Visman, J. Sulphur reduction of coking coal from Cape Breton. Presented at 7th Int. Coal Prep. Cong., Sydney, Australia, 1976.

Visman, J. A general theory of sampling — its objectives and application. Presented at Sampling Seminar, Univ. of Wisconsin, Madison, Wisc., Oct. 12-13, 1976.

MINING RESEARCH LABORATORIES

Periodicals

Stewart, D.B., D'Aoust, A., Dainty, E.D. and Mogan, J.P. The determination of diesel engine parameters underground for a load-haul-dump vehicle. MRL 76-3, CIM Bull., June 1976.

Stewart, D.B. and Mogan, J.P. Modifications to improve L.H.D. type vehicles. MRL 76-82, CIM Bull., March 1977.

Gangal, M.K. and Aggarwala, B.D. Heat transfer in rectangular ducts with fins from opposite walls. Z. Angew. Math. Mech., 56, 253-266, 1976.

Gangal, M.K. and Aggarwala, B.D. Combined free and forced laminar convection in internally finned square ducts. Z. Angew. Math. Phys., in press.

Herget, G. and Pahl, A. Spannungsmessungen in der umgebung von felsholhlraumen (Stress determinations in the vicinity of rock excavations). 2nd Nat. Rock Mech. Conf., Aachen, West Germany, Apr. 1-2, 1976.

Herget, G. Review of handbook on mechanical properties of rocks, vol. 1 by Vutukuri, Lama and Saluja. Can. Geotech. J., 13, 93, 1976.

Herget, G. Some comments on the papers or statements made at ICASP, Aachen. Proc. ICASP, 3, 255, 1976.

Herget, G. and Unrug, K. In situ rock strength from laboratory tests. Geomech. Abstract, Int. J. Rock Mech. and Min. Sci., 1976.

Moffett, D. Review of waste disposal at Canadian uranium mines. Can. Min. J., Jan. 1977.

Moffett, D., Gillespie, R., Spekkens, P. and Milne, J. A reinvestigation of the vibrational spectrum of $SeOF_2$ — and the preparation and Raman spectrum of SeO_2F_2. J. of Fluor. Chem., 7, 43-54, 1976.

Moffett, D. Oxfluoro complex anion equilibria in aqueous hydrofluoric acid. 3 iodate (V) in concentrated hydrofluoric acid. Inorganic Chem., 15, 9, 2165-2169, 1976.

Savich, M. Noise monitor hat. Sound and Vibration J., Jan. 1976.

McFarlane, D.W., Godfrey, T.J.R., Bielenstein, H.U. and McCurdy, R.M. Field trip A-3 guide book — Coal deposits of west central Alberta. Geol. Assoc. of Can., 69 p., 1976.

Presentations

Barron, K. Some engineering constraints related to coal mining in Western Canada. Updated version of 74-1 (IR). Presented to the Soc. of Sigma XI, Univ. of Calgary, Sept. 1976.

Bielenstein, H.U. Thrust faults — a problem in Western Canadian mines. ERP/MRL 76-101(OP). Presented at Univ. of British Columbia, Vancouver, March 15, 1977.

Fisekci, M.Y. Strata control instrumentation for coal mine design with special reference to hydraulic mining. ERP/MRL 76-1(OP). Presented at 17th U.S. Symp. on Rock Mech., Snowbird, Utah, Aug. 25-27, 1977.

Knight, G. Airborne contaminants and ventilation in mines. MRP/MRL 76-05(OP). Presented at CIM-sponsored Underground Operators Conf., Val d'Or, Que., Feb. 25, 1976.

Barron, K. Revised costs for the mining of thick seams using a longwall bottom slice with caving and drawing. MRP/MRL 76-12(TR). Presented at CIM Calgary Branch, April 14, 1976.

Moffett, D. Acidity and pH: useful indicators of water pollution? MRP/MRL 76-34(OP). Presented at Algoma Branch Meet., CIM, March 31, 1976.

Sabourin, R. Application de la geostatistique aux gisements d'uranium du Canada. MRP/MRL 76-53(OP). Presented at Ann. Gen. Meet., CIM, Quebec City, April 28, 1976.

Moffett, D. Rapid analysis of uranium mill effluents using specific-ion electrodes. MRP/MRL 76-60(OP). Presented at Can. Uran. Producers' Metall. Comm., Elliot Lake, Ont., May 20-21, 1976.

Yu, Y.S. Finite element modelling at Kidd Creek Mine, Timmins, Ontario. MRP/MRL 76-70 (OP). Presented at 3rd Symp. on Eng. App. of Solid Mech., Univ. of Toronto, June 7 and 8, 1976.

Knight, G. Calibration of respirable fraction sampling equipment and quartz analysis of airborne dust samples. MRP/MRL 76-95(OP). Presented at Conf. on Occup. Health, Johnson State College, Vermont, July 7, 1976.

Hedley, D.G.F. A case history of monitoring at the Kidd Creek Mine of Texasgulf Canada Ltd. MRP/MRL 76-120(OP). Presented at 11th Can. Rock Mech. Symp., Vancouver, Oct. 1976.

Knight, G., Washington, R.A. and Gray, W.M. A combined personal sampler for dust and radon-daughter exposure in mines. MRP/MRL 76-122 (OP). Presented at OECD Spec. Meet. on Personal Dosimetry and Area Monitoring Suitable for Radon and Daughter Products, Elliot Lake, Ont., Oct. 4-8, 1976.

Washington, R.A. and Horwood, J.L. Problems in area monitoring for radon daughters. MRP/MRL 76-140(OP). Presented at Spec. Meet. on Personal Dosimetry and Area Monitoring Suitable for Radon and Daughter Products, Elliot Lake, Ont., Oct. 4-8, 1976.

Dainty, E.D. Report of investigation of the October 26, 1976 explosion at Sudbury Metals. MRP/MRL 76-156(OP). Presented in précis form to coroner's inquest, Sudbury, Ont., Jan. 31, 1977.

Stewart, D.B., Mogan, J.P. and Dainty, E.D. Diesel engines and the mine environment. MRP/MRL 76-163(R). Presented to the Prov. Mech./Elect. Inspect. Meet., Quebec City, and to Queen's Univ. Mine Vent. Class, Kingston, Ont., March 1977.

Murray, D.R. Reclamation by vegetation. MRP/MRL 76-166(OP). Presented at Coal Indus. Reclam. Symp., Banff, Alta., Feb. 13, 1977.

Moffett, D. Research on tailings disposal at Elliot Lake. MRP/MRL 76-167(OP). Presented at Can. Min. Proc. Conf., Ottawa, Jan. 25-27, 1977.

Stewart, D.B., Dainty, E.D. and Mogan, J.P. Diesel emissions with respect to the mine environment. Presented to McGill Univ. Prof. Dev. Seminar, Montreal, Oct. 1976.

PHYSICAL METALLURGY RESEARCH LABORATORIES

Available Laboratory Reports

MRP/PMRL 76-2(J)
Jubb, J.T., Laufer, E.E. The beam tilt device of an electron microscope as an internal diffraction standard.

MRP/PMRL 76-3(J)
Stewart, M.J. Metal forming and processing at the Physical Metallurgy Research Laboratories, CANMET.

MRP/PMRL 76-4(J)
Lagowski, B. Gravity segregation and its effects on tensile properties of magnesium casting alloys.

MRP/PMRL 76-5(J)
Jeglic, F.S. Mechanical damage and its effect on fracture initiation in line pipe.

MRP/PMRL 76-6(J)
Davis, K.G. The filling of gates during casting.

MRP/PMRL 76-7(J)
McDonald, R.D. Galvanizing of welded high-strength structural steel. Part I: occlusion of hydrogen in heavy sections during pickling and its effects at hard weld heat-affected zones.

MRP/PMRL 76-8(J)
McDonald, R.D. Galvanizing of welded high-strength structural steel. Part II: effects of simulated hard welds in association with severe corrosion and hydrogen.

MRP/PMRL 76-12(J)
Vosikovsky, O. Environmental acceleration of crack growth in an X65 line-pipe steel under cyclic loading.

MRP/PMRL 76-14(J)
Tyson, W. Atomistic simulation of the ductile/brittle transition.

MRP/PMRL 76-18(J)
Bonnet, R. and Cousineau, E. Computation of coincident and near-coincident cells for any pair of lattices — related DSC-1 and DSC-2 lattices.

MRP/PMRL 76-19(J)
Lagowski, B. The effect of composition and heat treatment on tensile properties of ZE41 (Mg-4Zn-IRE-0.7Zr) casting alloy.

MRP/PMRL 76-20(J)
Bonnet, R. and Laufer, E.E. Precise determination of the relative orientation of two crystals from the analysis of spot diffraction patterns.

MRP/PMRL 76-21(J)
Heikkinen, V. and Boyd, D. The microstructure and properties of quenched and tempered HSLA V and V-N steels.

MRP/PMRL 76-22(J)
Davis, K.G. and Magny, J.G. The effect of hydrogen-charging on the nodularizing efficiency of a rare-earth alloy used in treating cast iron.

MRP/PMRL 76-23(J)
Edwards, J.O., Hamilton, R.I. and Gilmour, J.B. Short-term corrosion failures in copper heat exchanger tubing.

MRP/PMRL 76-24(J)
Thomson, R. The mechanical behaviour of electrodes in the I.E.C. cadmium breakflash apparatus.

MRP/PMRL 76-25(J)
Vosikovsky, O. and Cooke, R.J. An analysis of crack extension by corrosion fatigue in a crude oil pipeline.

MRP/PMRL 76-26(J)
Thomson, R. and Edwards, J.O. The effect of composition and process variables on the tensile properties of nickel-aluminum bronze.

MRP/PMRL 77-1(J)
Edwards, J.O. and Dixon, C. Bronze plaque casting by the V process.

MRP/PMRL 77-3(J)
Gordine, J. The weldability of some Arctic grade line-pipe steels.

MRP/PMRL 77-4(J)
Pollard, W.A. and Edwards, J.O. Combined effects of Pb and Sn additions on the corrosion of Zn-12 pct Cu-0.02 pct Mg sand cast alloys in wet steam.

MRP/PMRL 77-5(J)
Tobe, Y. and Tyson, W.R. Hydrogen embrittlement of a boron steel.

Periodicals

Lagowski, B. and Crawley, A.F. The effect of prior cold work on the precipitation and mechanical properties of a heat-treated Mg-9Al-2Zn(AZ92) alloy. Met. Trans., 7A, 5, 773-775, 1976.

Buhr, R.K. Hot, dirty gas is cleaned by HITEC. Can. Chem. Proc., 60, 26-29, Feb. 1976.

Tyson, W.R. Estimation of surface energies from phonon frequencies for bcc and fcc metals. J. Applied Phys., 47, 2, 459-465, Feb. 1976.

Thomson, R. Hydraulic modelling of closedhead continuous casting systems. Brit. Foundryman, 69, 3, 62-71, March 1976.

Stewart, M.J. Superplasticity in lowalloy steels. Met. Trans., 8A, 399-406, March 1976.

Packwood, R.H., Ternan, M. and Parsons, B.I. A preliminary investigation of the fouling of catalyst pellets by residual oils and tars. Microbeam Anal. Soc. 11th Ann. Conf., 1976.

Tyson, W.R., Cerkirge, H.M. and Krausz, A.S. Thermally activated fracture of glass. J. Mater. Sci., 11, 4, 780, Apr. 1976.

Szabo, E.I. Two rapid methods of preparing investment shell moulds. Foundry Trade J., 140, 386, March 18, 1976.

Vosikovsky, O. Fatigue-crack growth in an X65 line-pipe steel at low cyclic frequencies in aqueous environments. Closed Loop, 6, 3-12, April 1976.

Murton, A.E. and Buhr, R.K. An evaluation of the vacuum moulding process. AFS Trans., 1976.

Campbell, W.P. Some experiences with HAZ cold cracking testing of a C-Mn structural steel. Welding J. (U.S.), 55, 5, 135s-143s, May 1976.

Thomson, R. and Crawley, A.F. Precipitation hardening in Cu-Zn-Be alloys. Met. Trans., 7A:865-8, June 1976.

Thomson, R. Notes on heat transfer and solidification rates in the continuous casting of cast iron. British Foundryman, 70, 1-7, Jan. 1977.

Boyd, J.D., Embury, J.D. and Sargent, C.M. On the analysis of dislocation substructures in deformed and recovered niobium single-crystals. Scripta Met., 10, 901-903, Oct. 1976.

Biefer, G.J. Sulphide stress cracking in some "Big-inch" line-pipe steels. Corrosion, 32, 378, Sept. 1976.

Winterton, K. Welding progress in the last two decades. Can. Welder and Fabricator, 67, 10, 6-9, Oct. 1976.

Mitchell, C.M. A dual detector diffractometer for measurement of residual stress. Advances in x-ray Analysis, 20, Plenum Press, N.Y., 1976.

Vosikovsky, O. Fatigue-crack growth in an X65 line-pipe steel in sour crude oil. Corrosion, 32, 472-475, 1976.

Shulson, E.M. and Stewart, M.J. The forming of Zr_3Al base alloy. Met. Trans., 7B, 363-368, Sept. 1976.

Winterton, K. Thirty years of welding research at PMRL. Can. Welder and Fabricator, 68, 3, March 1977.

Pollard, W.A. and Edwards, J.O. Effects of Cu, Mg, Pb, and Sn on the corrosion of sand-cast Zn-12 pct Al alloy in wet steam. Met. Trans., 8B, 157-167, March 1977.

Godden, M.J. Precipitation and strengthening effects in some Ti-45 pct V alloys containing silicon. Mater. Sci. and Eng., 28, 2, 257-262, 1977.

Tyson, W.R. and Miller, W.A. Surface free energies of solid metals: estimation from liquid surface tension measurements. Surf. Sci., 62, 267-276, 1977.

Couture, A. and Edwards, J.O. Analyses of two prehistoric copper artifacts from the Cloverleaf Bastion of the Fort at Coteau-du-Lac, Quebec. History and Archaeology (Dept. of Indian and Northern Affairs), 12, 101-110, 1977.

Ruddle, G.E., Sebisty, J.J., Packwood, R.H. and Pickwick, K.M. Analysis of the distribution and form of silicon in the steel surface as related to the galvanizing reaction. Proc. of the 2nd Int. ILZRO Galvanizing Seminar (St. Louis, Missouri, June 9-10, 1976), Inter. Lead Zinc Res. Org., Inc., New York, 5.1-5.37, 1976.

Wilsdorf, H.G.F. and Ruddle, G.E. The influence of surface films on mechanical properties; surface effects in crystal plasticity. NATO Advanced Study Inst. (Hohegeiss, F.R. Germany, Sept. 5-14, 1975), Noordhoff, Leyden, 565-591, 1977.

Presentations

Beifer, G.J. Review of current research at PMRL on line-pipe corrosion. Presented to Corr. Con. Comm., Calgary, Feb. 17, 1976.

Winterton, K. What's new in steel welding. Presented at the ASM Seminar at Univ. of Toronto, Toronto, March 17, 1976.

Gordine, J. Weldment microstructure in structural steels, HSLA steels and quenched-and-tempered steels. Presented to ASM Sem. at Univ. of Toronto, Toronto, March 17, 1976.

Biefer, G.J. and Gilmour, J.B. Environmental cracking of candidate hydrofoil alloys. Presented at 5th Internaval Corr. Conf.,Auckland, N.Z., Apr. 5-9, 1976.

Lagowski, B. Metallography of hydrided ZE63 magnesium casting alloy. Presented to 80th AFS Casting Cong., Chicago, Ill., Apr. 26, 1976.

Couture, A. Effect of impurity elements on microstructure of copper-base casting alloys. Presented to 80th AFS Casting Cong., Chicago, Ill., Apr. 27, 1976.

Murton, A.E. and Buhr, R.K. An evaluation of the vacuum moulding process. Presented at AFS Convention, Chicago, Ill., Apr. 1976.

Stewart, M.J. Third symposium on engineering applications of solid mechanics. Presented at Univ. of Toronto, Toronto, June 7-8, 1976.

McDonald, R.D. Galvanizing of structural steels in large welded section — a review. Presented at 2nd Ann. ILZRO Galvanizing Sem ., St. Louis, Mo., June 10, 1976.

Jubb, J.T. and Laufer, E.E. An internal standard for electron diffraction. Presented at 3rd Ann. Meet., Microsc. Soc. of Can., Univ. of Ottawa, Ottawa, June 20-23, 1976.

Jubb, J.T. and Laufer, E.E. Utilisation des taches de diffraction pour mésurer de manière précise l'orientation relative de deux cristaux. Presented at 3rd Ann. Meet., Microsc. Soc. of Canada, Univ. of Ottawa, Ottawa, June 20-23, 1976.

Couture, A. and Edwards, J.O. Examination of Indian copper artifacts from the B.C. coast. Presented at CIM Conf. of Metall., Ottawa, Aug. 25, 1976.

Edwards, J.O. and Couture, A. Evaluation of the French test bar design, U.S. keel block and a reduced keel block for ISO standardization of cast copper alloys. Presented at ISO/TC26, WAG (Cast Copper Alloys Meet.), Berlin, W. Germany, Sept. 22, 1976.

Vosikovsky, O. Fatigue crack growth of X65 line-pipe steel in aqueous and crude oil environments. Presented at CIM Ann. Conf. of Metall., Ottawa, Aug. 23-25, 1976.

Jeglic, F.S. Mechanical damage of line pipe. Presented at CIM Ann. Conf. of Metall., Ottawa, Aug. 23-25, 1976.

Heikkinen, V.K. On the occurrence of Fe-NbC eutectic in niobium-bearing mild steel. Presented at Conf. of Metall., Ottawa, Aug. 24, 1976.

McDonald, R.D. Galvanizing of structural steels. Presented at Conf. of Metall., Ottawa, Aug. 23, 1976.

Packwood, R.H., Ternan, M. and Parsons, B.I. A preliminary investigation of the fouling of catalyst pellets by residual oils and tars. Presented to Microbeam Anal. Soc., 11th Ann. Conf., Miami, Fla., Aug. 9-14, 1976.

Mitchell, C.M. A dual detector diffractometer for the measurement of residual stress. Presented at 25th Ann. Denver x-ray Conf., Univ. of Denver, Denver, Colo., Aug. 4-6, 1976.

Tyson, W.R. Atomistic simulation of the ductile/brittle transition. Presented at TMS-AIME Fall Meet., Niagara Falls, N.Y., Sept. 20, 1976.

Boyd, J.D. Effects of thermomechanical treatment on a controlled-rolled Mn-Mo-Nb steel. Presented at TMS-AIME Fall Meet., Niagara Falls, N.Y., Sept. 22, 1976.

Boyd, J.D. High-strength steel for Arctic pipelines. Presented at Conf. on Mater. Eng. in the Arctic, St. Jovite, Que., Sept. 29, 1976.

Vosikovsky, O. Environmental acceleration of crack growth in an X65 line-pipe steel under cyclic loading. Presented at Conf. on Mater. Eng. in the Arctic, St. Jovite, Que., Sept. 27-Oct. 1, 1976.

Jeglic, F.S. Mechanical damage and its effects on fracture initiation in linepipe. Presented at Conf. on Mater. Eng. in the Arctic, St. Jovite, Que., Sept. 27, 1976.

Trudeau, L.P. Dynamic toughness. Presented at Conf. "UP-DATE 76", Toronto, Sept. 22, 1976.

Ogle, I.C.G. Environmental cracking of linepipe steel microstructures under hydrogen embrittling conditions. Presented at Conf. on Mater. Eng. in the Arctic, St. Jovite, Que., Sept. 30, 1976.

Warda, R.D. CANMET's new packed-bed filter system. Presented at seminar on Technology Transfer in Air Pollution Control, Toronto, Dec. 1, 1976.

Fegredo, D.M. Work in the Tribology Section at the Railway Technical Centre (British Rail) with notes on the curving behaviour of railway vehicles. Presented at PMRL Sem., Jan. 7, 1977.

Trudeau, L.P. Fast fracture in structural and pipeline steels. Presented at PMRL Sem., Feb. 25, 1977.

Vosikovsky, O. and Cooke, R.J. An analysis of crack extension by corrosion fatigue. Presented at NACE Can. Reg. West. Conf., Edmonton, Feb. 16-18, 1977.

Ogle, I.C.G. Sulphide stress cracking and hydrogen induced step-wise cracking of linepipe steels. Presented at NACE Can. Reg. West. Conf., Edmonton, Feb. 16-18, 1977.

Mitchell, C.M. and Laufer, E.E. A study of surface damage in titanium by x-ray diffraction and transmission electron microscopy. Presented at Amer. Crystall. Assoc. Meet., Pacific Grove, Calif., Feb. 21-25, 1977.

Laufer, E.E. Circumferential variation of notch toughness in a sample of line pipe. Presented at the 106th AIME Ann. Meet., Atlanta, Ga., March 6-10, 1977.

Garner, A. (Endako Mines). Chloride pitting of ferrite-containing austenitic stainless steel weld metal. Presented at Ann. Meet. Nat. Assoc. of Corr. Eng. (NACE) "Corrosion 77", San Francisco, Calif., March 15, 1977.

Heikkinen, V.H. and Packwood, R.H. On the occurrence of Fe-NbC eutectic in niobium-bearing mild steel. Presented at 14th Conf. of Metall., Ottawa, Aug. 24, 1976.

Buhr, R.K. Internal defects in castings. Presented to Ottawa Valley Chapter of Can. Soc. for Nondestructive Testing, Oct. 12, 1976.

Buhr, R.K. Current foundry research in Ottawa. Presented to AFS Prairie Conf., Winnipeg, Oct. 23, 1976.

Edwards, J.O. The foundry of the future. Presented at AFS Manitoba Chapter 10th Ann. Prairie Conf., 1976.

Warda, R.D. CANMET's new packed-bed filter system. Presented at seminar sponsored by Environment Canada and Air Pollution Control Assoc., Toronto, Dec. 1, 1976.

MINERALS RESEARCH PROGRAM

Available Program Reports

MRP 76-6
Gow, W.A., Sirois, L.L. and Winer, A. The assurance of mineral supplies for Canadian industry.

MRP 76-12
Boyd, J.D., Hoey, G.R. and Buhr, R.K. Wear problems in the mining and minerals industry.

MRP 77-1
Hedley, D.G.F., Sirois, L.L. and White, D.W.G. Outline of the Minerals Research Program for 1977-78.

ENERGY RESEARCH PROGRAM

Available Program Reports

ERP 76-2
Dainty, E.D., Faurschou, D.K., Smith, E. and Ashbrook, A.W. Summary of CANMET Energy Research Program at the project level.

ERP 76-6
Smith, E., Faurschou, D.K., Dainty, E.D. and Ashbrook, A.W. CANMET research and development in relation to Canada's energy commodity resources.

ERP 76-7
Dainty, E.D. CANMET Energy Processing Activity status report, Oct. 1976.

ERP 76-8
Ashbrook, A.W. Reports, presentations and publications issued in the energy research and development field, Apr. 1 – Sept. 30, 1976.

ERP 76-10
Faurschou, D.K., Smith, E., White, D.W.G., Dainty, E.D. and Montgomery, D.S. CANMET rationale for energy development and funding projected to 1985.

PATENTS

Patents Issued

Lucas, B.H. and Ritcey, G.M. Solvent-pulp extraction. U.S. Patent 3,969,476, July 13, 1976.

Mitchell, E.R., Brown, T.D. and Post, B.C. Oil burner assembly. Can. Patent 999,812, Nov. 16, 1976.

Szabo, E.I. Method of electrophoretically forming foundry moulds. Can. Patent 796,363, 1976.

Visman, J. and Hamza, H.A. Method and apparatus for centrifugally separating finely divided solids from aqueous suspensions thereof. Can. Patent 995,148, Aug. 17, 1976.

Patents Filed

Slater, M.J., Lucas, B.H. and Ritcey, G.M. The single-stage deep fluidized bed ion exchange column. A British Provisional Patent has been taken out to cover the design and concept of this column and the accompanying elution column.

Patents Applied For

Hamza, H.A. and Visman, J. Dual atomizer for flocculant preparation. CPDL Case No. 265-6261-1.

Wyman, R.A. and Cameron, W.H. Separation of asbestos fibre from rock. Sept. 3, 1976.

Mitchell, E.R., Brown, T.D. and Post, B.C. Oil burner assembly. U.S. Patent Application 692461, June 3, 1976; West German Patent Application P26.26846.2, June 15, 1976; U.K. Patent Application 26246, June 24, 1976; Japanese Patent Application 75400-76, June 25, 1976.

EARTH PHYSICS BRANCH

K. WHITHAM, DIRECTOR-GENERAL

The Earth Physics Branch is responsible for providing geophysical information (data, knowledge, and expertise) on the configuration, structure, evolution, and dynamic processes of the solid earth and on the hazards associated with natural and induced geophysical phenomena, with specific reference to the Canadian landmass. This responsibility has been translated into four principal missions:

To maintain and augment geophysical data bases with appropriate technology in the fields of seismology, geothermics, geomagnetism, gravity, and geodynamics

To provide new concepts and understanding of the basic geophysical framework of Canada for the wise use of the Canadian landmass and its resources

To assess geological hazards in Canada, including earthquakes and permafrost, and to contribute to the understanding of current earth dynamics related to such hazards, such as sea floor spreading, vertical motion, rotation, and axial wobble of the earth

To apply the Branch's expertise and knowledge in solving specific national problems.

In carrying out these objectives, the Branch operates networks of seismological, earth motion, and magnetic observatories; conducts field surveys to identify Canada's magnetic and gravity fields, to map the country's geothermal regime, and to obtain paleomagnetic and seismological data for particular regions or areas of activity; and initiates prediction research related to geophysical phenomena. Since many of the earth studies have global relevance, the Branch participates in the exchange of geoscientific data with a variety of international organizations. In addition, cooperative projects are carried out with other federal and provincial government organizations, research groups, and universities in Canada and the United States.

The work of the Branch is performed by three scientific divisions: Seismology and Geothermal Studies, Geomagnetism, and Gravity and Geodynamics. A fourth, administration division provides central administrative and technical support services such as budgeting, accounting, record and property management, stores, drafting, photography, and library services; it also maintains carpentry and machine shop facilities for use by the scientific divisions.

In 1976-77, expenditures by the Branch under the Earth Sciences Program amounted to $6.5 million. More that 175 staff were employed, of whom 87 were classified as scientific and professional. Approximately 85% of the staff were based in Ottawa and the remainder located on the west coast and at various observation stations across Canada.

DIVISION OF SEISMOLOGY AND GEOTHERMAL STUDIES

M.J. Berry, Director

The Division of Seismology and Geothermal Studies is responsible for carrying out a range of seismological and geothermal activities through two Services. The Seismological Service monitors seismic ground motion in Canada by operating a number of seismograph networks throughout the country. Data from the various stations are used to determine Canadian seismicity and to estimate seismic risk, particularly in areas around urban centres and regions of industrial development located in zones that are earthquake prone. These data also provide information on the structure of the Canadian landmass and the nature of the earth's mantle and core. Extensive theoretical studies and special field experiments are undertaken to supplement the records from seismic observatories.

The Geothermal Service conducts research into the thermal regime of the earth in all parts of Canada. This research is applied in three main directions: the distribution and character of permafrost are examined in order to provide information appropriate to the needs of resource industries and regulatory agencies; geothermal energy resources in Canada are evaluated to assist in research and development related to renewable energy resources; and tectonic processes are investigated to increase our understanding of crustal evolution and resource emplacement.

SEISMOLOGICAL SERVICE

Monitoring Seismic Ground Motion

The Seismological Service is responsible for the operation of seismograph stations throughout Canada, the development and calibration of seismic instruments, quality control, and the collection and dissemination of seismic data. Throughout 1976-77, observations were recorded at 20 standard and 14 regional stations. Two of the regional stations were opened during the past year. The Eastern Canadian Telemetered Network provided telephone line transmission to Ottawa from outstations at Maniwaki, Montreal, and near the Manicouagan reservoir; and the Western Canadian Telemetered Network similarly served the Victoria Geophysical Observatory from Alberni, Haney and Pender Island.

The Yellowknife seismological array has continued operation in a stable configuration. Automatic telephone dialing and data transfer facilities are employed to transmit the array event detection log from Yellowknife to an Ottawa computer on a daily basis. During the year a sensitive broadband seismometer was installed in a 100-m borehole near Ottawa, and development work was undertaken to transmit the seismic signals to the Division's data laboratory for recording and analysis.

The network of 94 strong-motion seismographs continued operation in Western Canada. Seven of the accelerographs in the Georgia Strait region were triggered during the Pender Island earthquake (magnitude 5.3) on May 16, 1976, producing accelerations in the range of 2-4% gravity.

Seismological Data Management

Information on approximately 30,000 P phases is reported annually by the standard stations and relayed through Ottawa to international centres for world-wide earthquake determinations. To meet the demands of national and international research institutions for original Canadian data, seismograph records are microfilmed and deposited in the files of the World Data Centres.

Specialized seismological data, from the Yellowknife array, from field projects, and from temporary special stations, are managed within the seismic data processing laboratory in Ottawa. This laboratory is used as the recording centre for the Eastern Canadian Telemetered Network, for special interactive research analysis, and for copying and disseminating data requested by outside agencies. The data laboratory makes extensive use of the Department's computing centre.

Both the Eastern and the Western Canadian Telemetered Network recording systems have automatic detectors that are triggered by, and store digital data for, detected seismic events. Special event library tapes of both local and distant earthquakes are generated for later research analysis.

Seismological Studies of Earth Dynamics

In 1976-77, the Service continued its study of Canadian earthquakes in three general time frames: rapid determination of epicentral parameters, within about 48 hours, of earthquakes of interest or concern to the general public; preparation of preliminary bi-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 risk, and to contribute to general geophysical studies of the tectonic forces acting within the Canadian landmass.

During the year, numerous damaging earthquakes were experienced around the globe, and Service personnel responded to many inquiries from the press and the general public concerning these events. Approximately two dozen earthquakes were reported to be felt in Canada during 1976-77. The May 16 Pender Island earthquake was felt widely in southwestern British Columbia; an earthquake occurring on October 23, 1976 near St. Simeon, Quebec, was felt throughout the lower St. Lawrence valley and in Maine and New Brunswick. Minor reports of earthquakes were received from such widespread locations as Leamington, Ontario; Radville, Saskatchewan; Baffin Island and the Yukon-Alaska border: the

last of these caused an avalanche on Mt. Logan. The largest recorded Canadian earthquake during the time period occurred December 20, 1976, at magnitude 6 centred west of Vancouver Island; it was not reported to be felt.

In 1976 a temporary seismograph array was installed near Windsor, Ontario. This array is being used to analyze seismic disturbances in the region and to attempt to establish the origin(s) of earth tremors felt in the Windsor area in recent years.

The Service has agreements with Hydro-Québec, Société d'énergie de la Baie James, and B.C. Hydro to monitor seismic activity in the vicinity of the Manicouagan (Manic), La Grande 2, and Mica damsites, respectively. The purpose of the seismograph operations is to detect any seismicity that may be related to reservoir loading or, in the case of La Grande, preloading activity. The induced seismicity at the Manic 3 reservoir, which commenced in the autumn of 1975, has been monitored since September 1976 with a six-element telemetered seismic array. By the spring of 1977, the activity had decreased to a very low level. An analysis of the results obtained to date from Branch field activities in the Manic 3 region has been completed, and the special array monitoring will be discontinued in August 1977, unless there is a significant renewal of activity.

Special investigations of significant Canadian earthquakes have continued. Reassessment of data available on twentieth century earthquakes in the Charlevoix region of the lower St. Lawrence has indicated that the historical seismicity may be confined to a smaller zone than that which was previously identified. An analysis of four earthquakes in the Byam Martin Channel in the Arctic Archipelago has revealed shallow depths of occurrence and provided some of the first evidence for an understanding of the seismotectonics of this region. An earthquake of magnitude 5.3 recorded in the Beaufort Sea in June 1975 is being analyzed in detail to provide a better understanding of seismicity in this important resource exploration area. As a result of re-evaluation and analysis of information on the magnitude 7 earthquake occurring on Vancouver Island in 1946, the location of the event has been revised, and further understanding has been attained concerning the relationship of this important earthquake to current west coast tectonics. The Pender Island earthquake, which had a focal depth of about 60 km, is also being analyzed in the light of recent hypotheses of continuous subduction beneath Georgia Strait and Puget Sound.

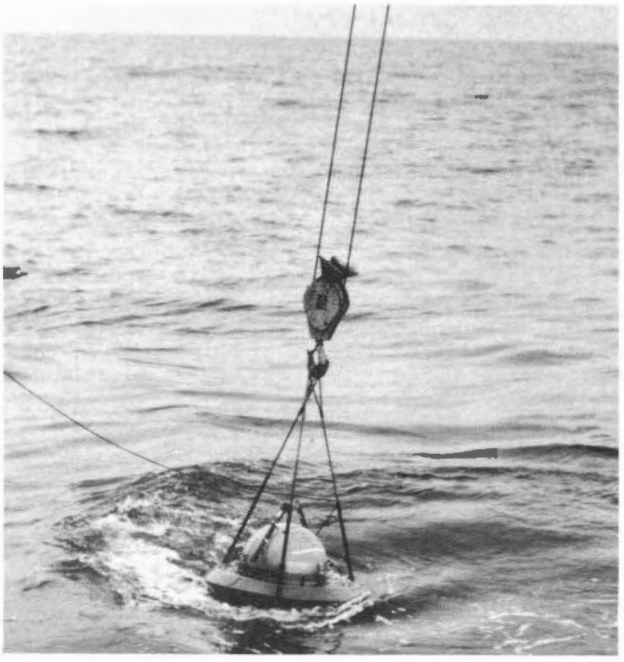
The Seismological Service responds to numerous requests for information on seismic risk from engineers, various government agencies, and the general public. Special studies have been undertaken to establish methods of estimating seismic risk at sites of critical structures. In addition, research staff are continuing to develop procedures for establishing seismic risk at nuclear power plant sites in Eastern Canada. This work is being carried out in cooperation with the Atomic Energy Control Board, Atomic Energy of Canada Limited, and provincial power utilities, and in conjunction with other members of a code committee whose task is to establish a new standard of seismic design requirements for CANDU nuclear power plants.

Seismological Studies of Earth Structure

The Service studies the dynamic processes, materials, and structure of the earth underlying Canada, using a wide variety of techniques. All these techniques are 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.

Methods and techniques are being evaluated for studying the stress field and stress changes within the earth's crust. Special emphasis is being placed on methods that may be applicable in regions such as Eastern Canada, where few earthquake focal mechanisms are available to delineate the stress field.

In August 1976, the first Canadian experiments were conducted with ocean-bottom seismometers when three were deployed off the coast of southwestern British Columbia near the Explorer Ridge, an active sea-floor spreading feature. In one configuration, the seismometers were used as recorders for a 75-km reversed refraction profile perpendicular to the Explorer Ridge; these data are being analyzed to determine the oceanic crustal structure. In another configuration, the seismometers were employed to record earthquake activity. Approximately 1,000 earthquakes were detected, of which about 100 could be accurately located on and near the spreading centre. During the experiment, a magnitude 4.5 earthquake was recorded, located about 3 km from one seismometer. This earthquake is being used as a calibration event for the relocation of other offshore earthquakes, using data from the land-based stations.



An ocean-bottom seismometer is lowered into the Pacific over the Explorer Spreading Ridge.

Seismological studies of the Charlevoix region in the lower St. Lawrence have continued as part of a broad range of geophysical studies of this active zone. Calibration explosions have been employed to monitor velocity changes that may precede a large earthquake. Between 1974 and the end of 1976, eight explosions were set off in the region, five in an abandoned mine on the north shore and three in 50-m drill holes on the south shore. These explosions were recorded by up to 15 temporary stations distributed throughout and beyond the active zone. The identification of velocity changes with time requires very precise timing of the arrivals of the seismic signals, and extensive analyses have been undertaken to assess potential timing errors. It is concluded that to the end of 1976 no velocity changes have been detected. Further explosions will be set off periodically in future years; the next is scheduled for September 1977. During the year, a seismograph station was installed at the Charlevoix Observatory for continuous monitoring of low-level earthquake activity. On the basis of the first six months of recording, current activity appears to be lower than in recent years.

A seismic refraction survey was conducted on the Beaufort Sea ice during April and May 1976, in conjunction with the Arctic Ice Dynamics Joint Experiment (AIDJEX) and with the support of the Polar Continental Shelf Project. The data are being analyzed to provide an estimate of the structure and the velocity anisotropy of the oceanic crust. Another study of the upper mantle of southern British Columbia has used surface wave inversion data to identify significant low-velocity zones in the central and eastern areas of the region. Theoretical studies of the effects of a finely layered crust-mantle transition zone have been applied to the interpretation of a 1975 vibroseis survey in British Columbia.

A technique that makes use of the properties of interfering P wave arrivals to detect the presence of small triplications in travel-time curves has been used to identify regions of high-velocity gradients in the lower mantle at depths of 1,250, 2,350 and 2,700 km.

Geoscience of Nuclear Explosions

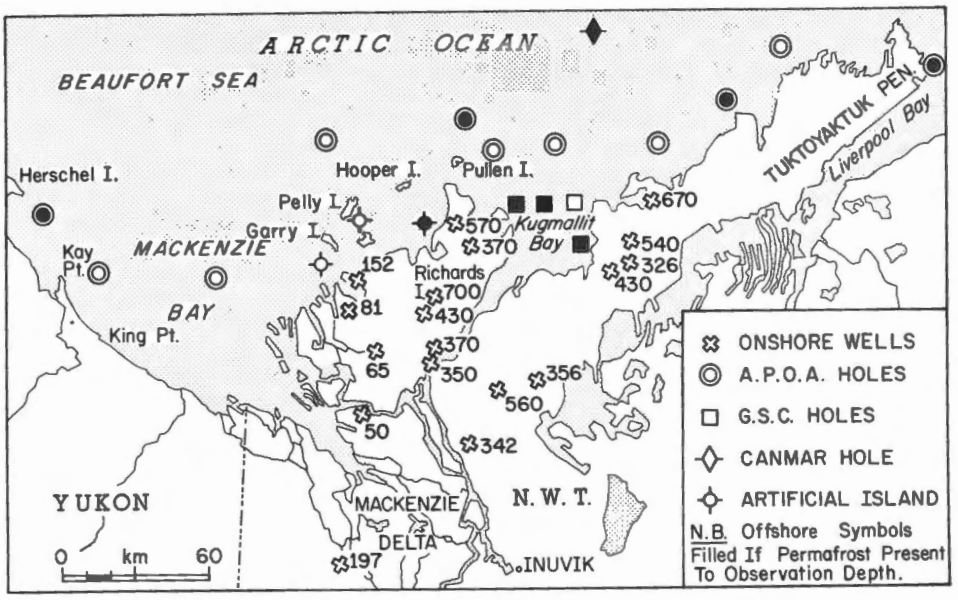
The Service is responsible for basic and applied research into the use of seismology; in particular, it conducts investigations and provides advice to the Department of External Affairs on all matters pertaining to seismological verification of underground nuclear explosions. Analyses of a number of seismic events, predominantly underground nuclear explosions, were performed in 1976-77, often in cooperation with seismological research groups in the United Kingdom and Sweden. The Service has arranged to make the Yellowknife array event detection bulletin available to research groups in these two countries and the United States.

In April 1976, the Conference of the Committee on Disarmament in Geneva established an Ad Hoc Group of scientific experts to consider international cooperative measures for the detection and identification of seismic events. Officers of the Service are representing Canada in the meetings of this Group.

GEOTHERMAL SERVICE

Permafrost Studies

The Geothermal Service has measured thermal profiles at over 90 locations in the Arctic Islands, the Mackenzie Valley, and other northern regions of Canada. The measured and calculated equilibrium temperatures of all wells north of 60°N are published annually. Individual wells are logged several times after completion, as the rate of decay of the drilling disturbance reveals the physical properties of the surrounding rocks and the thickness of the permafrost. Measurements at



Permafrost observations in the Beaufort Sea and Mackenzie Delta.

33 locations in the Mackenzie Delta show great variability in the thickness and character of the permafrost.

In support of environmental-social studies related to potential northern development, the Service has undertaken thermal studies of the near-surface regime in the Arctic channels, using temperature gradiometers developed originally to measure heat flow through the ocean floor. Shallow thermal measurements have also been made along the shorelines of Byam Martin and Little Cornwallis islands, in eastern Melville Island, and in regions of the Keewatin.

In cooperation with the Geological Survey of Canada, seismic techniques and thermal studies of permafrost have been extended to the offshore areas of the Beaufort Sea. In addition, in an attempt to avoid the high cost of conventional drilling techniques, a hydraulic jet-drill has been developed, which is both convenient and economical for drilling shallow holes. These techniques have been used in studies of the relationship between the distribution pattern of permafrost and the combined histories of water and ice-cover.

The thermal data from deep northern wells are valuable in outlining possible zones of occurrence of gas hydrates – ice-like combinations of water and natural gas – which currently present a hazard to northern drilling operations but which may in the future be an additional producible source of natural gas.

Geothermal Energy Resource Studies

The Geothermal Service coordinates the research and development activities of the federal government in the field of geothermal energy. Continued field observations of thermal parameters by the Earth Physics Branch and of volcanic features by the Geological Survey of Canada yield information that is essential to the delineation of areas of geothermal potential. Surveys have been performed by universities and consultants under contract to the Department.

During 1976, a reconnaissance geochemical survey of hot-spring water in the Yukon and adjacent Northwest Territories was undertaken. In the Meager Creek area of southwestern British Columbia, several surveys of a possible reservoir area have been carried out, including detailed geological mapping, age measurement of volcanic rocks, and hydrologic and magnetotelluric observations.

The geothermal potential of the deep sedimentary basins of Western Canada has been the subject of a second contracted study. Calculations based on the first study have shown that the total heat energy contained in hot water in porous formations amounts to the equivalent of about 8×10^{12} barrels of oil. This water is widely and unevenly distributed, and some of it is capable of production through deep wells, although conditions at any individual location may not be known. Problems may occur related to requirements for pumping from great depths and to very high

levels of salinity in some areas. Any water produced must be used close to its source, since transmission of energy in this form is expensive; also, its value lies in direct use, since the temperature is not high enough for economical electrical generation. This source of energy is not renewable, and the thickness and permeability of reservoir rocks will impose limits on the duration of exploitation. The University of Regina has expressed interest in using natural hot water for space heating of a large building, and a feasibility study will be carried out at the university in the coming year.

Geothermal Studies of Deep Earth Structure

In 1976-77, the Branch published the third catalogue of world heat flow data, listing 5,417 measurements from all parts of the globe. This work, a contribution to the activities of the International Heat Flow Commission, combines continental data assembled by the Branch with oceanic data that are compiled elsewhere.

A study of the thermal nature of the crust beneath the Maritime Provinces, conducted in cooperation with Dalhousie University, has shown that temperature gradients and heat flow are high in areas of granitic intrusion and low in the sedimentary terrain of the Cumberland Basin. Although data are sparse and limited to a thin surface veneer, the results suggest that the Cumberland Basin does not have the same potential for geothermal exploitation that the Western Canadian Basin has.

Another study has examined the heat generated by radioactivity in rocks of the Coast Range Complex and other parts of British Columbia. Heat generation in the Coast Range Complex is low compared with that in southeastern British Columbia — a finding which is consistent with observed patterns of heat flow and suggests that coastal temperature is correspondingly higher. Recent volcanic activity has penetrated the Coast Range, and thermal patterns are probably complex. The regional assessment of geothermal resources depends upon a thorough understanding of the nature of the crust beneath the western mountain belt.

The science of geothermics is a discipline with considerable value in the field of applied research. Knowledge of the history and nature of the earth's crust, as revealed by geothermal and other geophysical research, yields an understanding of the distribution and origin of mineral resources including geothermal energy and ore deposits. Analyses of thermal events in the North indicate the presence of permafrost and the probable impact of man-made disturbances. Such information is clearly important to the development and exploitation of Canada's resources.

DIVISION OF GEOMAGNETISM

P.H. Serson, Director

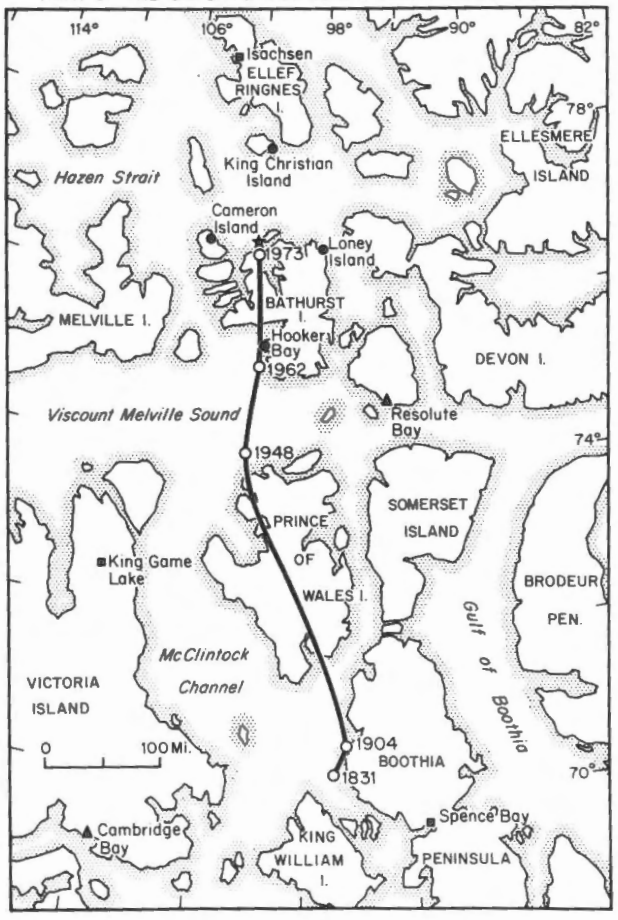
The Division of Geomagnetism is responsible for providing up-to-date information on the magnetic field of the earth to users in many fields, including navigation, telecommunications, and geophysical exploration. The Geomagnetic Service responds to over 2,000 requests per year for values of the magnetic declination and its secular variation, for use in maps and manuals published by other federal, provincial, and international organizations. Every five years, the Service publishes revised magnetic charts of Canada and the adjacent ocean areas. In addition, data are provided, in analogue and digital form, on the daily variation of the magnetic field and on magnetic storms; and regular forecasts of magnetic activity are issued, in print, by telephone, and by radio broadcast.

The Geomagnetic Service maintains the data base necessary to carry out its various functions by conducting systematic surveys, on the ground and in the air, and by operating the Canadian Magnetic Observatory Network. The Network consists of 11 fixed observatories, which continuously record the intensity and direction of the varying magnetic field.

The Division's research program includes paleomagnetism, interpretation of aeromagnetic anomalies, electromagnetic induction in the earth, and studies of geomagnetic time variations and pulsations. Canada provides a particularly favourable environment for research on these aspects of geomagnetism. Its landmass contains the north magnetic pole and is bisected by the auroral zone. It is the only major landmass in the world in which magnetic disturbances and related upper atmospheric phenomena are accessible for study from polar regions to subauroral latitudes. Large anomalies in electromagnetic induction indicative of highly conducting zones in the crust or upper mantle are found in the Arctic Islands and in the Cordillera. Canadian geological history, extending from Archean time to the present, provides an opportunity for studies of paleomagnetism and continental evolution over a time span exceeding two billion years.

Other work of the Division includes the use of magnetic and magnetotelluric methods to

PATH OF THE UNPERTURBED NORTH MAGNETIC DIP POLE



The peregrination of the north magnetic dip pole, the place where a magnetized needle would point straight down. The pole moved little from the visit of Ross in 1831 to that of Amundsen in 1904; but it has since moved rapidly northwards and is still doing so, at a speed of 10 kilometres per year. The 1973 position was determined from observations at the points indicated. The star indicates the position shown on the 1975 magnetic charts, which was extrapolated with the aid of data from magnetic observatories such as those at Resolute Bay and Cambridge Bay.

study and locate geothermal resources in Western Canada. The usefulness of these techniques for earthquake prediction is being assessed in a seismically active region on the north shore of the St. Lawrence River.

GEOMAGNETIC SERVICE

Magnetic Observatories

The 11 magnetic observatories that operated throughout 1976-77 were located at Mould Bay, Resolute Bay, Cambridge Bay, and Baker Lake in the Arctic; at Yellowknife, Churchill, and Great Whale River in the auroral zone; and at Victoria, Meanook, Ottawa and St. John's in southern regions. Magnetic field data also were collected by a variation station at Whiteshell, Manitoba.

At all stations except the one at Mould Bay, an Automatic Magnetic Observatory System (AMOS) records the northward, eastward and vertically downward components of the magnetic field, and its total intensity, once per minute in digital form on magnetic tape. The tapes are sent to Ottawa at the end of the month for editing by computer. The operation of AMOS installations is checked daily by telephone from Ottawa.

The prototype of an improved AMOS has been built and tested. The new version is based on a microprocessor which is now programmed to duplicate the functions of the existing AMOS; with further development, the system will be self-checking for instrumental integrity and statistical consistency. It will also compute mean hourly values and hourly ranges, and store them together with status information, until interrogated by telephone.

During the year, the AMOS at St. John's was moved to a new building away from encroaching roadways and vehicle parking. A new AMOS building was also put into service at Victoria.

The magnetic observatories at Meanook, Ottawa, and Victoria have been equipped with newly-developed photographic recording variometers. These instruments do not require daily servicing but will operate unattended for weeks, if necessary.

Magnetic Surveys

A three-component airborne magnetometer survey of Quebec, the Atlantic Provinces, and the Atlantic continental shelf was carried out in September and October 1976 at an altitude of 3-5 km. The flight lines ran approximately north-south with a line spacing of about 75 km, for a total of 85,400 line-kilometres. This survey completes the present phase of high-level airborne vector coverage of Canada.

As part of a continuing multi-disciplinary survey of Hudson Bay conducted in cooperation with the Ministry of Transport, a total magnetic field survey was carried out aboard the C.C.G.S. NARWHAL. Approximately 12,800 line-kilometres were covered between July 17 and August 26, 1976.

Management of Geomagnetic Data Base

Observatory Data

During the year, final magnetic tapes storing geomagnetic data for 1975 and about one-half of 1976 were completed for all observatories. The tapes contained one-minute values of all recorded components (except for Mould Bay), mean hourly values, hourly ranges, and summary tables. Observatory yearbooks for 1973 and 1974 were submitted for publication. Microfilm copies of magnetograms for all observatories are sent monthly to World Data Centre A in Boulder, Colorado, with edited versions of the digital magnetic tapes.

Forecasts of Geomagnetic Activity

As a service to geophysical exploration companies, electrical power companies, and pipeline companies, the Ottawa Magnetic Observatory issues two types of forecasts of geomagnetic activity: a 27-day forecast, issued at three to four-week intervals and distributed by mail, and a 72-hour forecast, prepared twice a week and available by telephone. In 1976-77, the Canadian Broadcasting Corporation broadcast the 72-hour forecast twice a week over the 46 stations of its northern radio network.

Magnetic Charts

During the year, tests were carried out on the mathemetical model used to derive the 1975 magnetic charts of Canada. The model is in the form of a sixth-order polynomial function of latitude and longitude, and a cubic function of time. Data from North American magnetic observatories were used to test the model's predictive capabilities, and comparisons showed a significant decrease in accuracy over a few years. A study of other predictive methods indicates that only graphical techniques are sensitive to sudden changes in secular variation.

The secular variation pattern in Canada is greatly influenced by four isoporic foci, or centres of rapid change. An examination of the movements of these foci indicates that the horizontal component will continue to increase rapidly in Eastern Canada; the declination will change more rapidly over most of the country, especially in Eastern Canada; and the vertical component will begin to decrease in parts of Northern Canada and will decrease more rapidly in southeastern regions.

A comparison of the International Geomagnetic Reference Field (1975) with annual mean values extrapolated to 1977 for 130 magnetic observatories, indicates many large departures in secular variation throughout the world. Departures in the vertical component were particularly prominent, exceeding 40 nT per year over parts of North America. These large time-term errors, coupled with the known main field errors, provide a compelling argument for adopting a completely new model for the international reference field.

Paleomagnetic Data

The listing and appraisal of world-wide paleomagnetic data are now complete. The results have been published in five issues of the Geomagnetic Series, as follows: Issue 1, Results up to 1971; Issue 2, Precambrian results 1957-1974; Issue 3, Paleozoic results; Issue 4, Mesozoic results and results from seamounts; Issue 5, Cenozoic results.

Geomagnetic Studies of Earth Structure

Magnetic Anomalies

A study of broad-scale magnetic anomalies, magnetic properties of rocks and geology in the southern Coast Mountains of British Columbia is being carried out jointly with personnel of the Geological Survey office in Vancouver. Although a long intense magnetic anomaly correlates with high magnetizations found at the surface, the evidence shows that there is a deeper more magnetic zone in the crust. The cause of this highly magnetic region has been attributed to subduction, since Cretaceous time, of oceanic crust beneath Vancouver Island and the mainland. Partial melting of the downgoing slab under hydrous conditions, with subsequent recrystallization of material advected upwards, results in increased magnetite content in the crust near the volcanic front.

A joint project with personnel of the Goddard Space Flight Centre at NASA has continued. During the year, a revised airborne data set was continued upward to an altitude of 500 km, the mean altitude for the satellite data set. Good agreement exists between magnetic anomalies observed in these airborne data and those seen in the revised satellite data set, over Western Canada and the Arctic regions, except in a small area still under

investigation. This project has been instrumental in encouraging international plans for the initiation of world-wide magnetic surveys by satellite, beginning in 1980.

Detailed model interpretations of the prominent magnetic anomaly at the centre of the Manicouagan Impact Structure, Quebec, indicate a body approximately 8 x 12 km in lateral extent, from near-surface to a depth of about 3 km. The direction of magnetization agrees with paleomagnetic directions obtained previously from melt rocks in the crater. Shock remanent magnetization at the time of impact is a likely explanation for the origin of the anomaly.

Paleomagnetism

Several Precambrian and Archean rock units have been studied during the year. Results from the following rock units have been published or submitted for publication: the Abitibi dikes, the Matachewan dikes, the Kamiskotia complex, the Dundonald sill, the Rapitan Group, the Michikamau Intrusion, rocks from the Central Labrador Trough, the Harp Lake Anorthositic Complex, the Seton Formation, the Douglas Peninsula Formation, the Takiyuak Formation, the Pearson Formation, and the Jacobsville sandstones.

The Archean results have been used to sketch an Archean polar path (Track 6). Aphebian results indicate that an event of folding and subsequent remagnetization may have affected a wide area extending from Quebec to Minnesota, before intrusion of the Nipissing diabase (≈2,150 Ma). Results from these different studies indicate that Laurentia has remained intact for at least the last 2.2 Ba. Data from the Jacobsville sandstones and the Rapitan Group have led to a reinterpretation of the Hadrynian Polar Track. These data also support the hypothesis of an integral single plate unit for Laurentia and Grenvillia.

Several studies of Paleozoic rocks have been completed. A paper has been published on the occurrence of a transcurrent motion in the Northern Appalachians and Caledonides during the Lower Paleozoic. Results of a study on the Botwood Group and the Mount Peyton Batholith, and a review of Lower Paleozoic paleomagnetic data have been submitted for publication. In addition, a paper has been prepared on the Lower Ordovician Connemara Suite in Western Ireland, and studies of other rock units are in progress.

Results of an extensive study of the magnetization of the red sandstones of Minudie Point, Nova Scotia, are in press. This investigation has permitted the more precise determination of the stratigraphic position of the Carboniferous reference horizon. This reference point can be used with confidence in the study of the tectonic history of the ancient Carboniferous basin of Eastern Canada. Moreover, its determination in other Carboniferous sequences will provide a simple and effective basis for world-wide correlations.

Research has continued on the evolution of the Arctic Ocean as part of a branch-wide study of Arctic geophysics.

Fifteen global maps have been prepared, summarizing the drift of the major continental blocks since the Devonian period. These maps indicate that, at the end of the Paleozoic era, a redistribution of the major continents occurred without the formation of a new ocean. This episode of continental drift appears to coincide with the world-wide extinctions of species and the development of oil-rich structures around the North Atlantic.

During the year, much effort has been directed towards the improvement of magnetic cleaning techniques, and several new techniques and instruments have been developed. Chemical leaching is proving to be the most efficacious treatment to separate the various phases of magnetization of sediments.

Electromagnetic Induction

The magnetotelluric method is being used to investigate changes in earth resistivity that might be associated with the build-up of stress in crustal layers before the onset of an earthquake. For this purpose, magnetotelluric fields have been monitored for the past two years near the centre of seismicity in a tectonically active region on the north shore of the St. Lawrence River. The results indicate that electrical properties of upper crustal layers are strongly time-dependent in this area, with changes of more than 30% in the impedance tensor occurring over periods of a few months. There have been only two earthquakes greater than magnitude 3.0 in the area since recording began in 1974; and so far, it has not been possible to develop a clear association between seismic activity and resistivity changes. Seasonal changes in the temperature and salinity of the nearby St. Lawrence River may be an important factor. Much less variation in impedance was observed at similar recording stations located less than 100 km to the west of La Malbaie and in the Manicouagan region, 265 km to the northeast. Magnetotelluric recording is continuing in an effort to assess the usefulness of the method as a means of earthquake prediction.

Study of the large conductivity anomaly in the crust or upper mantle beneath the western Arctic Islands (the Mould Bay anomaly) continued in the spring of 1976, when a profile of 11 three-component fluxgate magnetometers was operated for one month on a 500-km line extending from north-central Banks Island to south-central Victoria Island. The magnetic components were digitally recorded on cassettes. The Polar Continental Shelf Project provided logistical support and air transport for establishment and removal of the stations.

During the year, the Mineral Exploration Research Institute, under contract, completed an audio magnetotelluric reconnaissance survey at three locations in the Lillooet Valley. Though geothermal effects were not found at shallow depths, many of the recording sites showed strong anisotropy with low resistivity in the north-south direction and high resistivity east-west. The anisotropy may be caused by fracture zones associated with geologically recent rifting and volcanism. A highly conducting layer was found at depth of 20 km, suggesting the existence of high temperatures at this depth.

In cooperation with the University of Washington, geomagnetic variation stations were temporarily established across western British Columbia and Washington State. Preliminary interpretation indicates high electrical conductivity at depth under all of the region and an anomaly probably associated with the Cascade line of volcanics.

An ocean-bottom magnetometer was designed to measure and record variations in the geomagnetic vector on the sea floor for induction studies west of Vancouver Island in active tectonic areas. Construction of the prototype has begun.

Geomagnetic Disturbances

Bays and Pulsations

In 1976-77, pulsations in the period range 150-600 seconds (Pc5) recorded in 1967 at Resolute Bay, Baker Lake, Churchill, Great Whale River, Meanook, Victoria and Agincourt were further analyzed to investigate the movement of the cleft region. To assess the solar cycle influence on this group of pulsations, 11 years (1962-1972) of Pc5 scaled hourly values were analyzed. Annual and semi-annual variations and a previously suspected 27-day recurrence tendency have been clearly demonstrated.

The quiet-time Pc5 event (designated Spacequake) of March 18, 1974 has been studied in detail, and long-term characteristics of these rare events have been investigated by using nearly 45 years of data from Resolute Bay, Churchill, Great Whale River, and Meanook. Such events seem to originate close to the magnetopause, possibly by Kelvin-Helmholtz instability related to internal convection of the magnetosphere.

During the year, single-component induction magnetometers were put into operation at Ottawa and Resolute Bay to record short-period pulsations north and south of the auroral zone. Similar measurements are being recorded in the central region, near Churchill, by the University of Alberta.

Solar and Lunar Variations

The development of the Chapman-Miller program, which computes solar and lunar harmonic coefficients associated with geomagnetic variations, was completed in 1976-77 and the documentation prepared. The program is capable of handling large volumes of magnetic observatory data and regrouping them according to the constraints imposed by a particular problem or study. Results are presented as harmonic coefficients and in various graphical representations.

Auroral and Cleft Region Current Systems

Models of the electric current system in the magnetospheric cleft have been constructed for Los Alamos Scientific Laboratories rocket campaigns. (The cleft is the day-side extension of the auroral oval.) The Black Brant rockets were launched from Cape Parry, Northwest Territories, on November 25, and 28, 1975. Cleft region currents were found to be similar to auroral currents but flowing at an altitude of 200 km instead of the usual 100 km of auroral and diurnal current systems. Intense field-aligned currents were flowing outwards above the arcs and downwards at the edges of the cleft region.

International Magnetospheric Study

The Geomagnetic Service is operating a north-south line of eight magnetic variation stations as a contribution to the International Magnetospheric Study (IMS), 1976-1979, and to support IMS auroral and rocket compaigns. These variation stations are located at Island Lake, Thompson, Ft. Severn, Gillam, Back, Eskimo Point, Rankin Inlet, and Alert. Permanent stations also along the line include those at Whiteshell, Churchill, Baker Lake, and Resolute Bay. All the temporary variation stations except Alert were upgraded by October 1976 with newly developed low power digital

Making a gravity observation at a station in the Cordillera, British Columbia.

tape recorders. The three components of the magnetic field are sampled and recorded every 10 seconds. Edited copies of the tapes and auxiliary analogue records are sent to the World Data Center at Boulder, Colorado.

GRAVITY AND GEODYNAMICS DIVISION

J.G. Tanner, Director

The Gravity and Geodynamics Division is responsible for operating the Gravity Service and the Geodynamics Service of Canada. The Gravity Service maintains and augments annually the National Gravity Data Base, maintains national gravity standards, publishes gravity maps and reports, and provides gravity and related information to users in the public and private sectors, both nationally and internationally. The data base is also used for in-house geodetic studies and studies that contribute to an understanding of local geologic features and regional geologic frameworks in Canada. The Geodynamics Service is responsible for studies of the earth's rotation, polar motion, and earth tides and for investigations of crustal strain and tilt related to tectonic movements, groundwater levels, and earthquake prediction.

GRAVITY SERVICE

Gravity Mapping

In 1976-77, approximately 15,000 line kilometres of dynamic gravity data were observed during two shipborne surveys; an additional 4,600 static gravity measurements were taken on land and on ice-covered coastal regions. Shipborne surveys were carried out in cooperation with the Canadian Hydrographic Service off the northwestern shores of Vancouver Island to a distance of 100 km and in Hudson Bay. The Hudson Bay survey was designed to interline the 45-km track spacing completed in 1975. Using helicopter support, gravity and bathymetric data were collected from the ice-covered surfaces of Amundsen Gulf and the Beaufort Sea. This survey also was a cooperative effort with the Canadian Hydrographic Service and was supported by the Polar Continental Shelf Project of the Department of Energy, Mines and Resources. Reconnaissance survey data in the general area of the Beaufort Sea and Amundsen Gulf are now complete.

The Division's policy of contracting surveys to industry was extended in 1976-77. Three surveys were carried out under contract.

An underwater gravity survey, in which gravity readings were made on the sea floor by lowering a specially adapted gravity meter, was completed off the west coast of Vancouver Island and the Queen Charlotte Islands in British Columbia. A second survey was commenced over the ice-covered surface of Hudson Bay north and east of the Belcher Islands. A conventional helicopter-supported land survey covering much of Nova Scotia also was undertaken. Average station spacing in these surveys was 6 km.

Systems Maintenance and Updating

Efforts throughout the year have been concentrated on refining the reduction and editing systems for field observations in order to reduce the time interval between the gathering and the dissemination of data. Significant improvements in software, particularly in relation to the processing of offshore gravity data, have been made in the past year. Introduction of the open file system contributed to a more timely release of data.

Systems Development

Research in both marine and aerial dynamic gravimetry continued. Analysis of data collected using the precise gyro installed in 1975 revealed a hitherto undiscovered platform azimuth oscillation in marine data and large azimuth wanderings in aerial applications. Consequently, the assumption that platform aximuth errors are small was proven invalid, and techniques were developed to determine the platform orientation from azimuth gyro data. Previously analyzed marine and aerial data are being re-evaluated in the light of this discovery.

Map Production

Three Open Files comprising gravity anomaly maps and related digital files were released in 1976: 76-1 Queen Charlotte Sound (2,700 observations), 76-2 La Perouse Bank (2,100 observations), and 76-3 James Bay (2,300 observations).

Gravity Standards and Gravity Data Base

The systematic inspection and updating of control stations of the National Gravity Net were continued by contract in northern Ontario and southern Quebec. A total of 369 stations was visited, and 88 were replaced. Updated gravity values and base station descriptions for this area are now available on request.

All necessary modifications to the data base required to implement the maintenance service for the International Gravity Standardization Net 1971 (IGSN71) have now been made. Information for updating approximately 800 IGSN71 station descriptions has now been received from 47 countries, and compilation of new descriptions, to be distributed through the International Gravimetric Bureau in Paris, is now under way.

Compilation and adjustment of a 1,000-station reference network spanning 21 countries in Latin America are now essentially complete. During the next three years, the data base and the expertise necessary to sustain the on-going maintenance program will be transferred to a Latin American agency. The Brazilian national net, not presently included in the Latin American Gravity Standardization Network, is currently being observed by Brazilian government agencies. The Gravity Service has assisted in the planning of this net and has provided six weeks of training to a Brazilian geodesist.

During the year, advice and assistance were provided to the Ontario Ministry of Natural Resources in the processing of data from a gravity survey in the Red Lake area. Similar assistance, including the production of a 1:250,000 gravity map of the Notre Dame Bay area, was given to Memorial University, Newfoundland.

The National Gravity Data Base incorporates gravity and related data obtained by departmental surveys or contributed by provincial government agencies, universities, and industry. In response to 125 requests received over the past year from exploration companies, government agencies, and universities, the Gravity Data Centre retrieved and distributed 104 million characters of information, mostly in the form of magnetic tapes. About 15% of the requests required preparation of digital anomaly maps. In addition, 1,040 descriptions for reference stations were requested. In support of in-house field and research programs, an additional 232 requests were processed, involving the retrieval of 54 million characters of information, 1.5 million of which were also plotted.

Gravity Studies of Earth Structure

Studies of gravity anomalies, usually in conjunction with other geophysical and geological data, provide information about the size, shape, and depth of bodies with contrasting densities below the earth's surface. Short wavelength anomalies usually have their sources within the crust; long wavelength anomalies may result from deeper density discontinuities in the mantle and even at the core-mantle boundary.

As a contribution to a branch-wide study of geophysical data available in the Arctic, the Division undertook the compilation of free-air and bathymetric maps north of 60°N at a scale of 1:7,500,000. This work has led to significant improvements over previously published maps of the region. The compilation of Phanerozoic vertical motion data from Arctic regions is virtually complete. Interpretations of these and other compilations, along with the maps themselves, will be published in the near future. In studies of other offshore regions, the evidence for subduction processes during the last 10 million years off Vancouver Island was reviewed, and calculations were made to determine the extent and thickness of the lithospheric slab that has been subducted; in Amundsen Gulf, a joint study with the Geological Survey of Canada of gravity and magnetic anomalies confirmed geological estimates of the thickness of sedimentary strata. The surveys also revealed a large local anomaly in the Gulf similar to the anomaly at Darnley Bay (the largest local gravity anomaly in Canada). The investigations suggest that a basic or ultrabasic intrusive body is the source of this anomaly.

Studies of gravity anomalies at several structural boundaries in the Shield suggest that density discontinuities penetrate the entire crust in these localities. These discontinuities have been interpreted as sutures between collided continental fragments, suggesting that plate tectonic processes operated during formation of the Shield in Precambrian time. If this hypothesis is correct, the ancient plate boundaries may be compared with modern examples where new concepts of metallogeny are currently evolving. During the year, local investigations in the Shield of the Moran anorthosite and Gow Lake and Manicouagan impact crater sites were completed.

A continuing study of global gravity and magnetic anomalies suggests that there may be a fairly close relationship between fluid motions at the surface of the core and lithospheric plate motions at the surface of the earth. Research in physical geodesy continued in 1976-77 with development of a computer program to facilitate the representation of the gravity field over portions of the globe by spherical harmonics up to order 200 — a limit set only by computer memory size.

As part of the investigations into the physical and chemical state of rocks subjected to high pressures and temperatures, studies of the mechanism of crustal melting at the Manicouagan structure, Quebec, were completed in collaboration with scientists of the U.S. National Aeronautics and Space Administration (NASA). A study of the rate of shock wave decay, as recorded in rocks at several Canadian impact sites, was also completed and the results incorporated into theoretical models based on comparisons between meteorite impact and nuclear explosion sites. The Manicouagan results were also applied to lunar studies directed at determining the composition of the crust at major lunar basins.

Studies continued in collaboration with other branches on the suitability of rocks in the Canadian Shield for storage of nuclear wastes. These studies included an assessment of sites for thermal experiments to be carried out by the Canada Centre for Mineral and Energy Technology and an evaluation of geophysical techniques to be used in site selection surveys.

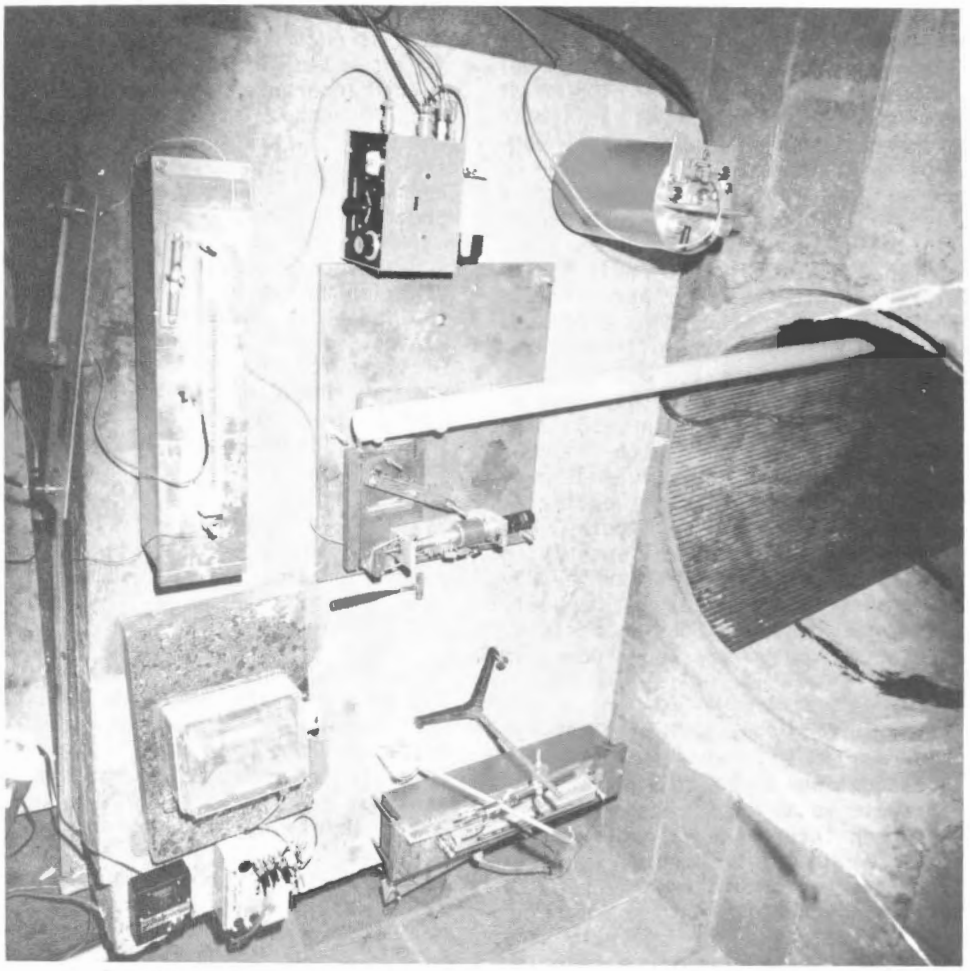
GEODYNAMICS SERVICE

Generation and Management of Geodynamics Data

Polar Motion

Polar motion and earth rotation have been monitored from the Polar Motion Observatories near Ottawa and Calgary using astronomic (PZT) and satellite Doppler techniques. Astronomic data are transmitted regularly to the International Time Service (BIH) and International Polar Motion Service, which are responsible for obtaining the combined global solution. Satellite Doppler observations are transmitted daily and routinely processed, together with data from a world-wide satellite tracking network, by the Polar Monitoring Service of the U.S. Defense Mapping Agency Topographic Centre. In 1976, the routine operations and data communication of the Ottawa Tranet Satellite tracking station were fully automated, and the equipment moved to the Shirley's Bay site alongside the astronomical instrument. The Canadian PZT's received the two highest combined weights for time and latitude observations among 75 instruments from around the world contributing to the BIH system in 1976. An analysis of simultaneous satellite and astronomical observations shows approximately the same dispersion of the mean daily coordinates. The satellite results do not indicate apparent seasonal variations, which are characteristic for the astronomical results; however, the latter support the satellite system by providing the necessary information on the earth's rate of rotation.

Detailed comparison and analysis of polar motion as determined by the astronomical and satellite techniques at co-located stations are necessary for understanding their differences and for analyzing sources of error and the related effects.



Quartz rod and invar wire strainmeters, tiltmeters, and a seismometer in the underground vault at the Charlevoix Observatory, Quebec.

Earth Tides

During 1976, earth tide data were collected at Glen Almond and Charlevoix, Quebec, and Fredericton, New Brunswick, in support of various research projects. At Glen Almond, improvements were made to the automatic calibration system of the hydrostatic tiltmeter, and a new digital recording system went into operation. Strain and tilt tides were recorded at Charlevoix, in an experiment to monitor the elastic properties of the crust in a seismically active area. Where these data meet certain minimum quality standards, they are transmitted to the Commission Permanente des Marées Terrestres, Association International de Géodésie in Brussels, which acts as a collecting and distributing centre for world-wide earth tide data. Recording of gravity tides was commenced at Fredericton during the latter part of the year to provide data on the gravity tide anomaly thought to be due to anomalous ocean tides in the western Atlantic.

Dynamics of the Earth

In 1976, precise gravity networks for the measurement of crustal deformation were established in four locations: at the Manic 3 dam in Quebec, where seismicity was induced by the filling of the reservoir; in the Charlevoix region of Quebec, where there is a concentration of natural seismicity; along the first order level line from Quebec City to Laurentide Park, where there is anomalous vertical crustal movement; and across Vancouver Island, where there have been large earthquakes in the past. The network at Manic 3 consisted of 11 stations and 150 ties made with each of two LaCoste and Romberg model D gravimeters. This survey is the first in which a precise gravity

network has been established by helicopter using these instruments. At Charlevoix, a new 15 station network was established by road, involving over 200 gravity ties made with each of two instruments. This new network replaces one established in 1974. The precise gravity profile from south of Quebec City to Laurentide Park was established to provide a basis for a long term study of gravitational effects associated with vertical movements in the area. Two profiles were established across Vancouver Island, consisting of 13 and 9 Stations each and following existing and proposed special order level lines.

Over the past few years, the Earth Physics Branch has been developing techniques for the measurement and analysis of changes in tilt, strain, and gravity to assist tidal studies. These techniques are now being applied to the study of crustal movements associated with earthquakes. Strain and tilt data recorded at the Charlevoix Observatory near La Malbaie, Quebec are now being analyzed routinely from month to month. A quartz rod strainmeter and an invar wire strainmeter are operating in parallel in the vault, as are three mercury-level tilt meters. All instruments are operating at earth tide sensitivity, and good tidal records have been obtained, permitting analysis for possible changes in tidal amplitudes. Permanent and simultaneous offsets in both strain and tilt have been identified, and these are being studied with respect to local seismicity. Variations in crustal dimensions are being studied in conjunction with continuous measurements of tidal gravity, resistivity, seismic velocity, changes in levels, and gravity networks.

Studies of water level variations in a well near Ottawa have demonstrated that a 200- to 300-m thick surface layer is decoupled from the normal crustal variations in volumetric strain. Whether this is a general result for the area is being tested by measurements in other wells.

Analysis of laser ranging data to the GEOS-3 satellite has continued during the year, with the objective of determining the feasibility of sensing the tidal displacements of the earth's surface. Results have shown that the dynamic force model for the satellite is the limiting factor in the determination of real station movements when a single laser station is used to define the reference arc. Apparent station movements of 5 to 10 m are perceived to be due to the inadequacies of the existing model.

Gravity, magnetic field, ocean depth, and ocean and ice tilt measurements were made throughout 1976-77 from a floe station in the Beaufort Sea. During an unusually calm 20-day period in February, when the ice floe remained stationary, the gravimeter records clearly showed the variations caused by the ocean and earth tides. From these records, it has been possible to determine the amplitude and phase of the three main ocean tide constituents in that part of the Beaufort Sea. Ocean tilt measurements showed fluctuations of the slope of the ocean surface in the 15-microradian range, while on the average the ocean tilted down to the northwest by about 10 microradians. Ice tilt measurements showed that tilt changes over a short period (30 microradians) are related to the drift velocity of the ice, whereas changes over a long period (100 microradians) are due to the shifting of the snow load.

Gravitational, inertial, and toroidal oscillations of the outer core are being studied for earth models with a uniformly stable, neutral, and unstable outer core, in an effort to determine the structure of the outer core of the earth. During the past year, the particular case of the fundamental toroidal core oscillation, which gives rise to the "nearly diurnal wobble", was studied in detail. The present results show that the internationally adopted nutation constant of $9''.210$ is incompatible with the theoretical amplitude of $9''.1966$. This result is significant for the modelling of the polar motion data collected at the Earth Physics Branch and at other stations throughout the world.

LIST OF PUBLICATIONS

OFFICE OF THE DIRECTOR-GENERAL

Farquhar, R.M. Canadian Geophysical Bulletin for 1975, v. 28, 1976.

DIVISION OF SEISMOLOGY AND GEOTHERMAL STUDIES

Buchbinder, G.G.R. A test of new earth models against PcP and PmKP travel times. Phys. Earth and Planet. Interiors, 11, 13-17, 1976.

Green, A.G. Ray paths and relative intensities in one- and two-dimensional velocity models. Bull. Seis. Soc. Am., 66, 1581-1607, 1976.

Halliday, R.J., Shannon, W.E., Lombardo, F. and Compton, B. Canadian seismograph operations — 1975. Seis. Series Earth Phys. Br. No. 75, 1977.

Heidebrecht, A.C., Whitham, K., Berry, M.J., Kanasewich, E.R. and Milne, W.G. Canadian engineers study Chinese earthquake technology. Eng. J., 59, 35-38, 1976.

Horner, R.B., Milne, W.G. and McMechan, G.A. Canadian earthquakes — 1971. Seis. Series Earth Phys. Br. No. 74, 1976.

Hyndman, R.D. and Drury, M.J. The physical properties of oceanic basement rocks from deep drilling on the Mid-Atlantic Ridge. J. Geophys. Res., 81, 4042-4052, 1976.

Hyndman, R.D., Von Herzen, R.P., Erickson, A.J. and Jolivet, J. Heat flow measurements in deep crustal holes on the Mid-Atlantic Ridge. J. Geophys. Res., 81, 4053-4060, 1976.

Jessop, A.M., Hobart, M.A. and Sclater, J.G. The world heat flow data collection — 1975. Geothermal Series Earth Phys. Br. No. 5, 1976.

Jessop, A.M. Geothermal energy from sedimentary basins. Geothermal Series Earth Phys. Br. No. 8, 1976.

Judge, A.S., MacAulay, H.A. and Hunter, J.A. An application of hydraulic jet drilling techniques to mapping of sub-seabottom permafrost. Geol. Surv. Can., Paper 76-1C, 75-78, 1976.

Keith, C.M. and Crampin, S. Seismic body waves in anisotropic media-synthetic seismograms. Geophys. J. Roy. Astr. Soc., 49, 225-243, 1977.

Lewis, J.F. and Hyndman, R.D. Oceanic heat flow measurements over the continental margins of Eastern Canada. Can. J. Earth Sci., 13, 1031-1038, 1976.

Lewis, T.J. Heat generation in the Coast Range Complex and other areas of British Columbia. Can. J. Earth Sci., 13, 1634-1642, 1976.

Lewis, C.F.M., Blasco, S.M., Bornhold, B.D., Hunter, J.A.M., Judge, A.S., Kerr, J.Wm., McLaren, P. and Pelletier, B.R. Marine geological and geophysical activities in Lancaster Sound and adjacent fiords. In Report of Activities, Part A; Geol. Surv. Can., Paper 77-1A, 495-506, 1977.

Mair, J.A. and Lyons, J.A. Seismic reflection techniques for crustal structure. Geophys., 41, 1272-1290, 1976.

McMechan, George A. Generalized p-curves. Geophys. J. Roy. Astr. Soc., 47, 9-18, 1976.

McMechan, George A. and Dey-Sarkar, Samir K. Quantized ray theory for non-zero focal depths. Geophys. J. Roy. Astr. Soc., 46, 235-246, 1976.

McMechan, George A. and Sinclair, Judith J. Upper mantle P-wave model catalogue. Can. J. Earth Sci., 13, 1481-1486, 1976.

Milne, W.G. Earthquake — Studies of the seismic risk in British Columbia. GEOS, Summer 1976, 5-7, 1976.

Milne, W.G. and Berry, M.J. Induced seismicity in Canada. Eng. Geol., 10, 219-226, 1977.

Rogers, Garry C. A microearthquake survey in northwest British Columbia and southeast Alaska. Bull. Seis. Soc. Am., 66, 1643-1655, 1976.

Stevens, A.E. Some twentieth-century Canadian earthquakes. Geosci. Canada, 4, 41-45, 1977.

Taylor, A.E. and Judge, A.S. Permafrost studies provide data for future Arctic developments. Oilweek, 1976.

Taylor, A.E. and Judge, A.S. Canadian geothermal data collection — northern wells, 1975. Geothermal Series Earth Phys. Br. No. 6, 1976.

Taylor, A.E. and Judge, A.S. Permafrost distribution in the far north is subject of ongoing research. Northern Miner, 1976.

Weichert, D.H. Earthquake reconnaissance: Guatemala, February 1976. Geosci. Canada, 3, 208-214, 1976.

Weichert, D.H. and Henger, M. The Canadian seismic array monitor processing system (CANSAM). Bull. Seis. Soc. Am., 55, 1381-1403, 1976.

Whitham, K., Berry, M.J., Heidebrecht, A.C., Kanasewich, E.R. and Milne, W.G. Earthquake prediction in China. Geosci. Canada, 3, 263-268, 1976.

DIVISION OF GEOMAGNETISM

Coles, R.L., Haines, G.V. and Hannaford, W. Large scale magnetic anomalies over Western Canada and the Arctic. Can. J. Earth Sci., 13, 790-802, 1976.

Donaldson, J.A., Irving, E., Tanner, J. and McGlynn, J. Stockwell symposium on the Hudsonian orogeny and plate tectonics. Geosci. Canada, 3, 285-291, 1976.

Emslie, R.F., Irving, E. and Park, J.K. Further paleomagnetic results from the Michikamau Intrusion, Labrador. Can. J. Earth Sci., 13, 1052-1057, 1976.

Gupta, Jagdish Chandra. Pc5 pulsations and the movement of the cleft. Ann. Geophys., 32, 29-38, 1976.

Gupta, Jagdish Chandra. Some characteristics of large amplitude Pc5 pulsations. Australian J. Phys., 29, 67-87, 1976.

Haines, G.V. and Hannaford, W. A three-component aeromagnetic survey of Saskatchewan, Alberta, Yukon, and the District of Mackenzie. Geomag. Series Earth Phys. Br. No. 8, 1976.

Honkura, Y., Kurtz, R.D. and Niblett, E.R. Geomagnetic depth sounding and magnetotelluric results from a seismically active region northeast of Quebec City. Can. J. Earth Sci., 14, 256-267, 1977.

Honkura, Y., Niblett, E.R. and Kurtz, R.D. Changes in magnetic and telluric fields in a seismically active region of Eastern Canada: preliminary results of earthquake prediction studies. Tectonophys., 34, 219-230, 1976.

Irving, E. and Naldrett, A.J. Paleomagnetism in Abitibi Greenstone Belt and Abitibi and Matachewan Diabase Dikes: evidence of the Archean geomagnetic field. J. Geology, 85, 157-176, 1977.

Irving, E., Tanczyk, E. and Hastie, J. Catalogue of paleomagnetic directions and poles, third issue, Paleozoic results 1949-1975. Geomag. Series Earth Phys. Br. No. 5, 1976.

Irving, E., Tanczyk, E. and Hastie, J. Catalogue of paleomagnetic directions and poles, fourth issue, Mesozoic results 1954-1975 and results from seamounts. Geomag. Series Earth Phys. Br. No. 6, 1976.

Irving, E., Tanczyk, E. and Hastie, J. Catalogue of paleomagnetic directions and poles, fifth issue, Cenozoic results 1927-1975. Geomag. Series Earth Phys. Br. No. 10, 1976.

Loomer, E.I. Annual report for magnetic observatories — 1971. Geomag. Series Earth Phys. Br. No. 4, 1976.

Loomer, E.I. Annual report for magnetic observatories — 1972. Geomag. Series Earth Phys. Br. No. 7, 1976.

Loomer, E.I. Annual report for magnetic observatories — 1973. Geomag. Series Earth Phys. Br. No. 9, 1976.

Morris, W.A. Transcurrent motion determined paleomagnetically in the Northern Appalachians and Caledonides and the Acadian orogeny. Can. J. Earth Sci., 13, 1236-1243, 1976.

Nienaber, W., Dosso, H.W., Law, L.K., Jones, F.W. and Ramaswamy, V. An analogue model study of electromagnetic induction for island-continent ocean channels. Phys. Earth and Planet. Interiors, 13, 169-183, 1976.

Park, J.K. A reconnaissance paleomagnetic survey of the Central Labrador Trough, Quebec. Can. J. Earth Sci., 14, 159-174, 1977.

Roy, J.L. Problems in determining paleointensities from very old rocks. Phys. Earth and Planet. Interiors, 13, 319-324, 1977.

Roy, J.L. and Lapoint, P.L. The paleomagnetism of Huronian red beds and Nipissing diabase; Post-Huronian igneous events and apparent polar path for the interval -2300 to -1500 Ma for Laurentia. Can. J. Earth Sci., 13, 749-773, 1976.

Ueno, H. and Irving, E. Paleomagnetism of the Chibougamau Greenstone Belt, Quebec, and the effects of Grenvillian post-orogenic uplift. Precambrian Res., 3, 303-315, 1976.

GRAVITY AND GEODYNAMICS DIVISION

Berger, J. and Beaumont, C. An analysis of tidal strain observations from the United States of America: II. The inhomogeneous tide. Bull. Seism. Soc. Am., 66, 1821-1846, 1976.

Bower, D.R. Geos-C and measurement of the earth tide. In Satellite geodesy and geodynamics, P. Vanicek, ed. Earth Phys. Br., 45 (3), 1976.

Dence, M.R., Grieve, R.A.F. and Plant, A.G. Apollo 17 grey breccias and crustal composition in the Serenitatis Basin region. Proc. Lunar Sci. Conf. 7th, 1831-1832, 1976.

Donaldson, J.A., Irving, E., Tanner, J.G. and McGlynn, J. Stockwell symposium on the Hudsonian orogeny and plate tectonics. Geosci. Can., 3, 285-291, 1976.

Dragert, H. and Clarke, G.K.C. A detailed investigation of the Canadian Cordillera geomagnetic transition anomaly. J. Geophys., 42, 373-390, 1977.

Ellis, R.M., Dragert, H. and Ozard, J.M. Seismic activity in the McNaughton Lake area, Canada. Eng. Geol., 10, 227-238, 1976.

Floran, R.J. and Dence, M.R. Morphology of the Manicouagan ring-structure, Quebec, and some comparisons with lunar basins and craters. Proc. Lunar Sci. Conf. 7th, 2845-2865, 1976.

Fulton, R.J. and Walcott, R.I. Lithospheric flexure as shown by deformation of glacial lake shorelines in southern British Columbia. Geol. Soc. Am., Mem. 142, 163-173, 1975.

Gibb, R.A. and Thomas, M.D. Gravity signature of fossil plate boundaries in the Canadian Shield. Nature, 262, 199-200, 1976.

Gibb, R.A. and Thomas, M.D. The Thelon Front: a cryptic suture in the Canadian Shield? Tectonophys., 38, 211-222, 1977.

Gibb, R.A. and Thomas, M.D. A question of gravity. GEOS, Winter 1977, 5-8, 1977.

Grieve, R.A.F. and Robertson, P.B. Variations in shock deformation at the Slate Islands impact structure, Lake Superior. Contrib. Min. Petrol., 58, 37-49, 1976.

Halls, H.C. and Grieve, R.A.F. The Slate Islands: a probable complex structure in Lake Superior. Can. J. Earth Sci., 13, 1301-1309, 1976.

Kearey, P. A gravity survey of the central Labrador Trough, northern Quebec. Can. J. Earth Sci., 14, 45-55, 1977.

Kearey, P. and Halliday, D.W. The gravity field of the central Labrador Trough, northern Quebec. Grav. Map. Series Earth Phys. Br. No. 162, 1976.

Lambert, A. and Beaumont, C. Nano variations in gravity due to seasonal groundwater movements: implications for the gravitational detection of tectonic movements. J. Geophys. Res., 82, 297-306, 1977.

Mak, E.K., York, D., Grieve, R.A.F. and Dence, M.R. The age of the Mistastin Lake crater, Labrador, Canada. Earth Planet, Sci. Lett., 31, 345-357, 1976.

Nagy, D. On gravimetric geoid computations. Acta Geodaet. Geophys. et Montanist., Acad. Sci. Hung., 10, 321-328, 1975.

Paul, M.K. The gravity effect of a homogenous polyhedron for three-dimensional interpretation. Pageoph., 112, 553-561, 1974.

Popelar, J. Polar motion program of the Earth Physics Branch, Department of Energy, Mines and Resources. In Satellite geodesy and geodynamics, P. Vanicek, ed. Earth Phys. Br., 45 (3), 1976.

Popelar, J., Sim, S.B. and Wheeler, M.O. PZT observations of time and latitude, Ottawa and Calgary, 1975. Geodyn. Series Earth Phys. Br., Bull. 68, 1976.

Riddihough, R.P. A model for recent plate interactions off Canada's west coast. Can. J. Earth Sci., 14, 384-396, 1977.

Riddihough, R.P. and Hyndman, R.D. Canada's active western margin — the case for subduction. Geosci. Can., 3, 269-278, 1976.

Sobczak, L.W. Ice movements in the Beaufort Sea 1973-1975: determination by ERTS imagery. J. Geophys. Res., 82, 1413-1418, 1977.

Stacey, R.A. Deep structure of porphyry ore deposits in the Canadian Cordillera. Geol. Assoc. Can., Spec. Paper 14, 393-412, 1976.

Stacey, R.A. Structure of the Queen Charlotte Basin. Can. Soc. Petr. Geol., Mem. 4, 723-741, 1976.

Sweeney, J.F. Subsidence of the Sverdrup Basin, Canadian Arctic Islands. Bull. Geol. Soc. Am., 88, 41-48, 1977.

Sweeney, J.F. Evolution of the Sverdrup Basin, Arctic Canada. In Sedimentary basins of continental margins and cratons, M.H.P. Bott, ed. Tectonophys., 36, 181-196, 1976.

Thomas, M.D. and Gibb, R.A. Gravity anomalies and deep structure of the Cape Smith foldbelt, northern Ungava, Quebec. Geology, 5, 169-172, 1977.

Thomas, M.D., Gibb, R.A. and Quince, J.R. New evidence from offset aeromagnetic anomalies for transcurrent faulting associated with the Bathurst and McDonald faults, Northwest Territories. Can. J. Earth Sci., 13, 1244-1250, 1976.

Tiffin, D.L. and Riddihough, R.P. Gravity and magnetic survey off Vancouver Island, 1975. In Report of Activities, Part A, Geol. Surv. Can., Paper 77-1A, 311-314, 1977.

Valliant, H.D. and LaCoste, L.J.B. Theory and evaluation of the LaCoste and Romberg, three-axis inertial platform for marine gravimetry. Geophys., 41, 459-467, 1976.

Valliant, H.D., Halpenny, J., Beach, R. and Cooper, R.V. Sea gravimeter trials on the Halifax test range aboard C.S.S. HUDSON, 1972. Geophys., 41, 700-711, 1976.

Zurn, W., Beaumont, C. and Slichter, L.B. Gravity tides and ocean loading in southern Alberta. J. Geophys. Res., 81, 4923-4932, 1976.

SURVEYS AND MAPPING BRANCH

R.E. MOORE, DIRECTOR-GENERAL

The Surveys and Mapping Branch is responsible for the fundamental surveying and mapping of Canada's landmass. This broad responsibility has been defined in terms of five specific objectives:

To ensure the availability of geodetic information on the Canadian landmass, with emphasis on the development and maintenance of a national network of monumented points of known latitude, longitude, and elevation

To ensure the availability of information on the topographical features of the Canadian landmass, through the production of new and revised maps in the National Topographic Series

To ensure the availability of geographic information for Canada as a whole, through the production and distribution of the National Atlas of Canada, aeronautical charts, gazetteers of place names, aerial photographs, and thematic maps

To ensure that national, provincial, and territorial boundaries and the boundaries of Canada Crown Lands are correctly positioned, marked and maintained

To provide effective scientific and technical support to other federal and provincial government departments and agencies

In meeting these objectives, the Branch supports a wide range of activities carried out by the federal and provincial governments, educational institutions, external aid organizations, industry, and the general public.

The Branch cooperates closely with provincial government agencies in coordinating activities and resolving common problems. Through the Canadian Council on Surveying and Mapping, federal and provincial programs are coordinated, and information is exchanged that is of benefit to all parties. The National Advisory Committee on Control Surveys and Mapping advises the Minister of Energy, Mines and Resources on requirements for federal surveying and mapping programs. The Branch chairs two interdepartmental committees of the federal government — Air Surveys and Aeronautical Charting — and it provides the Secretariat for the Canadian Council on Surveying and Mapping and the Canadian Permanent Committee on Geographical Names. In addition, training, monitoring, and consultant services related to mapping programs in other countries are provided through the Canadian International Development Agency. These programs are implemented under contract to Canadian industry.

The work of the Branch is carried out by five main divisions: Geodetic Survey, Legal Surveys, the International Boundary Commission, the Topographical Survey Directorate, and the Directorate of Map Production. About 1,000 staff were employed in 1976-77, many of them involved in field work in various parts of the country. The budget for the past fiscal year was approximately $26 million, of which $2.1 million were spent on contracts with private sector organizations.

GEODETIC SURVEY DIVISION

L.J. O'Brien, Dominion Geodesist

All surveying and mapping activities depend upon primary surveys of great accuracy. These "control surveys" establish the reference points of latitude, longitude, and elevation which comprise the framework for measuring landmass. The fixing of these basic reference points is the special concern of the geodetic surveyor.

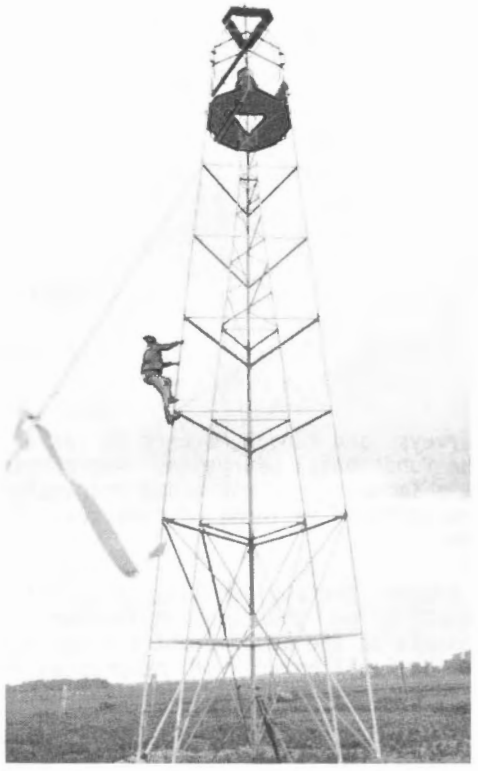
In the course of a survey, reference points are identified on the ground by permanent markers called monuments; then, on the

basis of current knowledge concerning the dimensions and shape of the earth, they are brought into conformity with larger survey networks embracing entire continents. Through this process, it is possible to determine the configuration of a particular landmass.

The objectives of the geodesist are achieved in three main ways: (1) by establishing and maintaining primary and secondary systems of monument control, based upon internationally accepted standards of accuracy; (2) by maintaining a control data file from which survey information is provided to government agencies, private industry, and the general public; and (3) by promoting research to advance geodetic knowledge and techniques. These three sets of activities define the range of functions carried out by the Geodetic Survey Division. To carry out its function, the Division is organized into two units: Surveys, which is responsible for primary horizontal control surveys, primary vertical control surveys, and supplementary surveys; and Geodesy, which is responsible for geodetic data management, processing of geodetic and geophysical mathematical data, computations and adjustments and technological developments.

PRIMARY HORIZONTAL CONTROL

To develop the primary system of horizontal control and to provide a basis for locating network stations, first-order and second-order Laplace azimuths are established. In recent years, first-order horizontal control field work carried out by the Geodetic Survey has concentrated on the acquisition of data for a proposed adjustment of the Canadian geodetic network. This work has consisted of the development of a Doppler "anchoring" network. The program, which was commenced in 1974, was completed in 1976-77 with the positioning of the final 42 stations of the total of 170. Activities covered parts of the Northwest Territories, Manitoba, Quebec, New Brunswick, Nova Scotia, Labrador and Newfoundland. In addition, selected lengths in old geodetic networks were remeasured by means of modern electronic distance-measuring equipment; 109 lines were measured in existing networks at scattered locations in British Columbia, Saskatchewan, Manitoba, Quebec, New Brunswick, Nova Scotia, Newfoundland (including Labrador), and in the Northwest Territories. Twenty-three first-order and eight second-order Laplace azimuths and ten deflection determinations were observed in British Columbia, Saskatchewan, Manitoba, Quebec, and Newfoundland.



The Bilby tower, a highly portable yet completely stable steel platform used by the Geodetic Survey Division for making observations.

The existing first-order horizontal control network was extended in southern Saskatchewan by means of a north-south traverse from Estevan to Kamsack (290 km). From a point on this traverse just north of Wapella, reconnaissance was commenced for a traverse which will follow the Qu'Appelle River Valley westwards north of Regina and connect with the existing Geodetic control near Empress, Alberta. Another first-order traverse was extended across the southern part of Newfoundland, following the southerly coast from Fortune Bay to Port-aux-Basques, a distance of about 270 km.

A very accurate network of 13 stations, with average spacing of about 10 km, was established upstream from the Manic 3 Dam on the Manicouagan River in Quebec to monitor earth movements. Remeasurement of this network will occur periodically.

Reconnaissance was completed for an urban first-order densification network in Edmonton and suburbs.

Plans and studies culminating in the complete readjustment of the horizontal control system of Canada and North America have been continued in cooperation with the United States, Mexico, and Denmark (Greenland). A preliminary readjustment of the Canadian primary geodetic network is scheduled for completion in 1977, followed by integration of secondary networks by regions; the continental readjustment is planned for 1983.

Data preparation and assessment for the Canadian primary network have been completed, and the established files are being kept up to date. The first preliminary test adjustment, including both terrestrial and satellite Doppler data, is proceeding according to plan. Assessment of the secondary networks is continuing, so that they can be improved and strengthened before they are integrated with the primary control network.

PRIMARY VERTICAL CONTROL

Primary vertical control surveys involve the establishment of permanent monuments of known elevation (bench marks) to which levels in a given locality may be referred. Such survey operations – known as levelling – are essential to the planning and execution of any large construction project. The Geodetic Survey Division is responsible for carrying out primary vertical control surveys throughout Canada.

In 1976-77, the primary vertical control network was extended by 3,014 km, bringing the total to 104,019 km of first-order control. The level line continued down the Mackenzie River as far as Arctic Red River, terminating a five-year cooperative program with the federal Department of Public Works. In response to a request from the Department of Public Works of the Northwest Territories, about 65 km of levelling were completed on roads near Yellowknife. Relevelling of the Alaska Highway continued with work between Fort St. John and Fort Nelson, British Columbia, and northwesterly towards Watson Lake, Yukon Territory, a total distance of 670 km.

Cooperative levelling with the Province of Newfoundland was undertaken. By the end of 1976 about 145 km had been completed between Bishop's Falls and Harbour Breton, and another 1,100 km, chiefly along the Trans Canada Highway between Corner Brook and St. John's. Another cooperative venture, first-order levelling in the regional municipality of

A geodetic surveyor takes precise measurements with a geodimeter.

Hamilton-Wentworth, Ontario, begun in 1975-76, was completed. More than 200 bench marks were established during the two- year period, and 350 km of levelling were completed.

A further 77 km were surveyed in support of the Manic test for the detection of vertical crustal movements. Also associated with crustal movements is the relevelling of a line in the vicinity of the Mica Dam in British Columbia, which was completed for B.C. Hydro in 1976-77. A start was made on the program of systematically monitoring earth movements, to be carried out in cooperation with Earth Physics Branch: special-order levelling was undertaken between Campbell River and Gold River on Vancouver Island, a distance of 110 km.

In the summer of 1976, an important levelling project was completed by the Division, in cooperation with the Société d'énergie de la Baie James. This work resulted in the establishment of a line of levels 800 km long from Schefferville to Fort George on James Bay.

About 45 deep bench marks were established in Calgary, Creston, and Vancouver in preparation for the levelling to be done in these areas in 1977. The first contract to private industry for geodetic levelling was awarded in October 1976. The work, which was completed by the end of that year, consisted of levelling and relevelling 293 km of terrain in eastern Prince Edward Island. During the same period, a geodetic party carried out 430 km of levelling in the western part of the island. This group also monitored the contract operation.

SECONDARY CONTROL

The first major production use of the Inertial Survey System (ISS), in both motor vehicle and helicopter modes, was undertaken in 1976. The ISS, mounted in a ground vehicle, was used to establish vertical control for 1:50,000 mapping of Vancouver Island, covering 2,750 km and establishing elevations of 210 vertical control points in 11 weeks. Later the system was mounted in a Hughes 500 helicopter (marking the first production use of the ISS in this mode) and employed in photomapping and boundary resurveying of the Sarcee Indian Reserve. Horizontal and vertical control was provided for an area of approximately 48,000 km^2 southwest of Calgary. Within this area, 455 stations were established. The ISS was used to establish further boundary and photomapping control on 10 other Indian Reserves in Alberta. In northern Saskatchewan, 470 km of airborne ISS traverse were run to establish 25 third-order control points between 13 Doppler stations established previously on the road from North Battleford to Turnor Lake, a distance of about 500 km This project was carried out in cooperation with the provincial Department of Highways.

During the year, the Doppler receivers were used for other purposes, namely, for marine navigation in Senegal in West Africa (three stations); for hydrographic control in the Michipicoten area of Lake Superior (two stations); and for increasing the density of existing first-order control in the Calgary-Medicine Hat area of Alberta (four stations).

Conventional methods of establishing second-order multi-purpose control continued in Northern Canada. A 128,000 km^2 area in the Mackenzie Mountains of the Yukon and Northwest Territories was covered with stations established by electronic distance measuring traversing; and 3,400 km of traverse were completed to provide control for 1:50,000 mapping and to increase the density of existing control.

Lower-order control was also established by conventional methods on Vancouver Island and in the Queen Charlotte Islands, for mapping and offshore positioning. In the Ungava region of northern Quebec, 8,000 km of altimetric traversing were completed to provide vertical control for 1:50,000 mapping (133 sheets). The Ground Elevation Meter was used to provide vertical control for the 36 map sheets at a scale of 1:50,000 in the Lac St. Jean area of Quebec and northern New Brunswick. The Mekometer was used to remeasure baselines at Chicoutimi and Montreal, to measure new baselines in Calgary and Edmonton, and to establish measurements between four stations of the Manic Strain Polygon. This instrument also was employed for precise measurements along the test track off-set baseline at Holoman Airforce Base, White Sands, New Mexico.

GEODETIC DATA

Data File

Approximately 3,400 requests for control survey data were received during the year. Over 415,000 pages of survey information were issued, providing data on geographic location, descriptions and elevations for bench marks, and horizontal control stations.

The program to automate the National Positional Control Survey Data File was continued, and at the end of 1976, the file contained information on 76,000 stations. The

Helicopters are the preferred mode of transportation for survey parties.

computerized file will provide positional control data to government agencies, industry, and the general public in the fields of geodesy, surveying, and mapping.

Satellite Geodesy

As noted earlier, during 1976, the basic network of 170 satellite Doppler positions, covering the Canadian landmass, was completed. Of these, 115 are coincident with, or tied to, primary triangulation stations. Both the broadcast satellite ephemeris and the precise ephemeris supplied by the U.S. Defense Mapping Agency were used for the multi-station solutions. Sixteen additional satellite control points were established in support of ISS control work, using only broadcast ephemerides.

GEOS-3 observations were made at five other sites in Canada, along with observation of the regular U.S. Navy Navigation Satellite System satellites. Reduction of the latter data set at Geodetic Survey will provide known tracking station positions for refinements to the GEOS-3 orbits.

1977 Adjustment

To verify programs and procedures, a test adjustment of the Canadian primary horizontal control network was carried out, using an in-house modified version of Geographic Adjustment of Networks of the U.S. Defense Mapping Agency's program Horizontal Adjustment by Variation of Coordinates.

Geoid undulations and deflections of the vertical were derived from GEM8 after an appropriate transformation to the geodetic datum. Research continued towards improving the accuracy of predicted undulations and deflections of GEM8, observed deflections, and observed gravity data, using a collocation technique.

Inventory of secondary horizontal control continued as part of the preparation for the evaluation phase. An estimate was made of the field work required to increase the density of the existing secondary fabric and to strengthen and properly integrate it.

LEGAL SURVEYS DIVISION

D.R. Slessor, Surveyor General

The Legal Surveys Division carries out and supervises the performance of legal or land surveys respecting federal lands within provinces (that is, national parks and Indian Reserves) and lands in the Yukon and Northwest

Territories. It also fulfills federal government obligations regarding the definition, survey, and maintenance of provincial and territorial boundaries in Canada and ensures the competence of property surveys, land descriptions, and plans made under the Canada Lands Surveys and other Acts and Regulations.

The functions of the Division include regulating the surveys of Indian Reserves and lands, national parks, territorial lands, lands under water in the offshore areas, and other Crown lands; qualifying Dominion Land Surveyors; regulating the surveys of subsurface rights and of subdivisions of private lands in the Territories; and 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. The Division also surveys and maintains specified provincial boundaries jointly with the corresponding provincial agencies, under commission of the Governor General in Council; establishes Coordinated Surveys Areas; and establishes standards, issues instructions, examines survey returns and inspects field work for surveys of Crown Canada Lands. Surveying services are provided on request to federal departments and agencies and to territorial governments, relating to the provision of professional advice, the administration, monitoring, and inspection of surveying contracts and the execution of surveys. The Division is further responsible for ratification, custody, and maintenance of legal survey records, and for the preparation and verification of legal descriptions of Crown Canada Lands and also ensures the adequacy of descriptions used to define federal electoral districts.

FIELD AND OFFICE OPERATIONS

Twenty-two field parties completed 104 separate projects in 1976-77. These assignments included 79 projects in Indian Reserves and national parks in all provinces except Newfoundland, 16 projects in the Yukon, and 9 projects in the Northwest Territories. Three Coordinated Survey Areas were surveyed, including one new area at Rankin Inlet. In order to complete as many as possible of the projects required for federal government departments, 259 additional surveys were carried out under contract.

The nine Regional Offices continued to demonstrate 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.

Under severe winter conditions a surveyor uses a theodolite to make observations.

Technical instructions were issued for 597 surveys in Crown Canada Lands.

Of the 951 survey plans examined in 1976-77, 391 were for federal government departments, 301 were for outside organizations and individuals, 100 were Legal Surveys Division Quad Sheets, and 59 were Regional Surveyor Plans.

The Surveyor General of Canada is a member of two federally established commissions that were active during the year. The Manitoba-Saskatchewan Boundary Commission completed the editing of its report and the drafting of the boundary atlas sheets. The British Columbia-Yukon-Northwest Territories Boundary Commission continued with its monument restoration program and carried out maintenance on 20 miles (32.2 km) of boundary.

BOARD OF EXAMINERS FOR DOMINION LAND SURVEYORS

The Board of Examiners for Dominion Land Surveyors met five times during the year. Twenty-four candidates wrote the 1977 annual examinations, and six qualified for a Commission as a Dominion Land Surveyor.

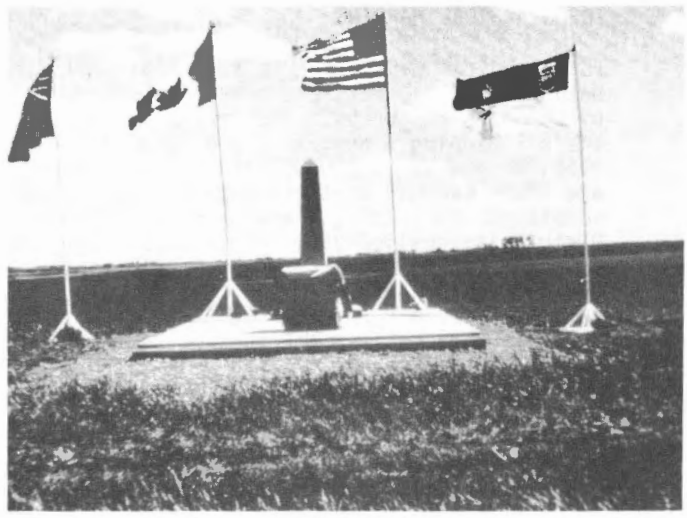
INTERNATIONAL BOUNDARY COMMISSION

A.C. McEwen, Commissioner

The International Boundary Commission is empowered to maintain an effective boundary line between Canada and the United States under the terms defined by the Treaty of 1925 and other previous or future treaties. The primary task of the Commission is to maintain a well-defined boundary and to determine the location of any point on the boundary line, as required to settle any question that may arise between the two governments. In carrying out this task, the Commission inspects the various sections of the international boundary when deemed necessary; carries out the surveys required to maintain the system of boundary monuments, including repairing and relocating existing monuments and establishing new ones; keeps the boundary vistas open; regulates all work within 3 m of the international boundary, in both Canada and the United States; and reports annually to the respective governments upon the work of the Commission, including provision of lists of the geodetic positions of all new or moved monuments and any revisions of the official boundary maps. In addition, the Commission undertakes studies on the historic, technical and legal aspects of boundary development. These studies are intended to provide information that may be used in formulating Canadian government policy on international boundaries. For operational purposes, the Canadian section of the Commission is included in the Surveys and Mapping Branch.

Canadian field parties operated in two areas during 1976-77. On the Quebec-Maine and Quebec-New York boundaries, 117 monuments were inspected, six of which were found to be in need of repair. Maintenance was also completed on 69 km of 20-ft (6.1-m) boundary vista by the retardation of woody growths, using an application of approved herbicides. In addition, clearing was completed on 21 km of vista to maintain the 20-ft (6.1-m) width clear of overhanging growths. Replacement of two monuments on the Quebec-New York boundary completed the restoration of the entire 45th parallel boundary to an effective state of demarcation.

On the British Columbia-Washington boundary, the program to inspect monuments and reclear the 20-ft (6.1-m) boundary vista through the rugged Cascade Mountains was completed. Sixty kilometres were cleared over this heavily timbered and mountainous section. In addition, 41 monuments were inspected, two of which required repairs. Day marks were replaced and maintenance completed on the east and west towers at Point Roberts to improve ranging of the boundary across Boundary Bay and westwards into the Strait of Georgia.



The International Boundary meets the Saskatchewan-Manitoba Boundary at the point marked by this monument. The State of North Dakota, identified by the U.S. Flag and the State Flag, is on the right of the monument.

TOPOGRAPHICAL SURVEY DIRECTORATE

J.M. Zarzycki, Director

The Topographical Survey Directorate is responsible for ensuring that topographical information concerning the Canadian landmass is available for use by federal government departments and agencies, provincial governments, private sector organizations, and the general public. On the basis of information gathered from field surveys carried out on the ground and/or from the air, maps are compiled and published for use in resource development and management, environmental protection, administration, security, education, recreation, and scientific investigation. The Directorate also issues aerial photographs, photomaps, and mosaics produced from data obtained by satellite, and it maintains the National Air Photo Library.

To carry out its various functions, the Directorate is organized into two main units: Engineering and Planning, which comprises the Mapping Program Section and the Research and Development Section; and Production Operations, which includes the Canada Map Office, the Topographical Mapping Division, and the Aerial Photography Division.

TOPOGRAPHICAL MAPPING

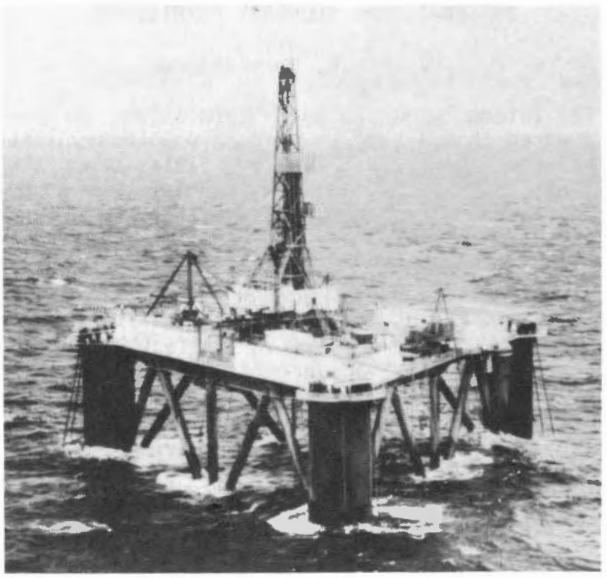
Topographical maps are an essential tool for national development and effective management of Canada's resources. The backbone of Canada's mapping program are the standard 1:50,000 and the 1:250,000 scale maps. Coverage for Canada at the 1:250,000 scale was completed in 1970, and in 1976-77 the Directorate revised 35 of these maps. For the 1:50,000 scale, for which coverage is not yet complete, 319 new map sheets were compiled, of which 231 were prepared in-house and 88 on contract; 304 of these sheets were printed as monochromes and 15 in colour. In addition, 383 existing map sheets were revised or updated.

Work carried out during the year continued to be influenced by the federal government's policy to encourage energy production. New maps were produced for a number of northern areas of high natural resource potential. Hydroelectric power development was the major focus in Quebec and Labrador; in Ontario, both hydroelectric power and forest products were emphasized; and in Western Canada, efforts were concentrated on the search for oil and gas and the future development of pipeline routes.

Photomaps were prepared for the Department of Indian Affairs and Northern Development to assist in the administration of territorial lands. Seventy-four photomaps were produced at a scale of 1:30,000, in order to show such features as mining claims, road allowances, and cadastral survey lines. Another 26 were issued at a scale of 1:50,000.

The Directorate continued to provide photogrammetric and cartographic services, on request, to federal and provincial departments and agencies. These services include administration, monitoring, and inspection of mapping contracts, as well as professional advice. In 1976-77, medium and large-scale mapping projects worth approximately $1,238,000 were monitored for various federal and provincial organizations. The work was carried out by the Canadian aerial survey industry.

The Topographical Map Planning Section continued to plan and maintain the national mapping program. It also was responsible for the acquisition of all survey data and aerial photography for both new and revised mapping. In order to establish and maintain priorities for mapping, provincial survey and mapping agencies and other mapping and map-using organizations were visited during the year and consulted on their mapping requirements.



The positioning of offshore drilling platforms is aided by the use of aerial photographs and LANDSAT imagery provided by the National Air Library Reproduction Centre.

To aid private and provincial mapping agencies in producing maps, a sophisticated computer program, SPACE-M, has been made available. The program, which provides for the adjustment of blocks of 1,000 or more aerial photographs used in aerotriangulation, has been set up in five major cities in Canada, with multi-access facilities that extend the service to many other centres across the country.

In 1976-77, the Research and Development Section of the Directorate concentrated most of its efforts on the acquisition of digital data and the automated drafting of maps. Under current procedures, topographical data are entered into a mini-computer via direct links with several stereo-plotters or digitizing tables. Input data are displayed in real time on graphic cathode ray tubes. The same computer system is used for the cartographic editing of data for 1:50,000 scale mapping. A Gestalt Photomapper 11 (GPM-2) was acquired during the year and its installation started. The unit constitutes a highly automated photogrammetric system which is designed to produce digital terrain models, orthophotos, and contours, using electronic image correlation to measure parallaxes. The Directorate has now developed most of the software necessary for the treatment of GMP-2 data.

A technician assembles a mosaic of remote sensing images taken by the LANDSAT satellite.

LANDSAT imagery was used to position shoals in Ungava Bay, an isolated island in Lake Athabasca, and a shoal in the high Arctic which is the home of a drilling rig. It also discovered an unmapped small island off the coast of Labrador.

In order to keep abreast of changes in photogrammetry and cartography, the Directorate has continued a number of research and development contracts with universities, private consultants, and firms. The staff also attended various conferences during the year, including the Pan-American Institute of Geography and History in Colombia, the American Congress on Surveying and Mapping, the Canadian Institute of Surveying, and the International Society of Photogrammetry in Finland. At the latter conference, J.M. Zarzycki was elected president of Commission IV, Topographic and Cartographic Applications of Photogrammetry. This is one of seven technical commissions of the Society; each commission president is from a different country.

AERIAL PHOTOGRAPHY

Up-to-date aerial photography is a prerequisite of the Branch's topographic mapping program and also of the mapping needs of many other federal, provincial, and private mapping agencies and scientific research organizations. The Topographical Survey Directorate is responsible for the development and maintenance of an aerial survey data base, the operation of the Interdepartmental Committee on Air Surveys (ICAS) Secretariat, the maintenance of an aerial photograph and remote sensing image reproduction service, and the operation of the National Air Photo Library.

The aerial survey data base acquired 9,024 models of data in 1976-77, providing sufficient information for the compilation of 500 map sheets at 1:50,000 scale. The data base consists of marked aerial photographs (including diapositives) showing the precise position of four points per stereoscope model and magnetic tape on which the X, Y, and Z coordinates of these four points are recorded. The position of these points is obtained by aerotriangulation, which is a method of supplementing ground control by photogrammetric means. The data base makes it possible to begin mapping of any area as soon as data are available. While these points are not located by survey monuments on the ground, they can be used for projects such as the planning of transmission lines and pipelines, eliminating the need to carry out expensive ground control surveys.

The ICAS Secretariat is the focal point for the provision of aerial photographic services required by federal government departments and agencies. It receives and coordinates requests, prepares specifications and contract documents, receives funds from requesting departments, approves payments, and ensures that work is carried out in accordance with specifications and contract terms. During the year, the Secretariat received requests from nine federal departments other than Energy, Mines and Resources, altogether covering 128,077 km of aerial photography. Approximately 37,800 exposures of black-and-white film and 570 exposures of colour were added to the national collection.

The National Air Photo Library and its Reproduction Centre operate and maintain a national reference library of aerial photography and remote sensing data, and reproduce and distribute aerial photographs and remote sensing imagery. Through the use of the Library's microfiche and microfilm services, a second centre, at the Institute of Sedimentary and Petroleum Geology at Calgary, Alberta, also provides full photographic coverage of Canada.

During 1976-77, the Library received requests for information worth $1,532,166 in materials issued. At year-end, the Library inventory comprised 4,421,721 reference prints and 11,340 index maps. The General Coverage System catalogues were updated to include the

By using the National Air Photo Library's microfilm services members of the public can gain easy access to the millions of aerial photographs available from the library.

1976 aerial photography coverage, and microfilming of the 1976 coverage and index maps was completed.

A total of 6,090 LANDSAT photomaps and mosaics was sold during the year. The mosaics are available for each province and territory and also provide a complete image of Canada.

At the National Air Photo Library Reproduction Centre, in response to 10,236 customer requisitions, 900,034 photographic items were produced in support of departmental airborne and satellite programs. Of these items, 664,230 were produced by aerial survey, 99,573 by airborne remote sensing, and 136,231 by LANDSAT. There was a 43.8% decrease in the reproduction of LANDSAT imagery from the previous year, primarily resulting from the contracting out of black-and-white work to Integrated Satellite Information Services Ltd. of Prince Albert, Saskatchewan. The Reproduction Centre completed the Canada mosaic project in July, which consists of 70 photomaps at a scale of 1:1,000,000 for the National Topographic Series.

As part of the in-house research and development program, an improved printing process of LANDSAT colour contact prints and transparencies was developed, to a stage where colour repeatability in successive reproductions of colour negatives can be guaranteed. These procedures have aided in efforts to improve and enhance the quality of Brazilian LANDSAT images, acquired from NASA, for interpretation by a Canadian consultant. Also devised was a colour internegative procedure to enhance infra-red data from false-colour positive imagery for the Nova Scotia Department of Lands and Forests.

CANADA MAP OFFICE

The Canada Map Office is responsible for bulk distribution of maps and of the Canada Air Pilot and related publications. The network of dealers across Canada includes 421 topographical map dealers, 282 aeronautical chart dealers, seven consignment dealers, and 146 depositories.

The Office's current inventory of maps, charts, and publications is 13,501 titles, representing 22,804,323 items. In 1976-77, 3,270,767 maps and charts were distributed.

In addition, displays were arranged at several conventions and sportsmen shows in Quebec, Ontario and Manitoba.

DIRECTORATE OF MAP PRODUCTION

T.H. Kihl, Director (to December 31, 1976)

R. Groot, Director (from January 1, 1977)

The Directorate of Map Production is responsible for providing services in national geographic mapping, toponymy (geographical names), aeronautical charting, and cartographic support. These services are made available through six divisions: Map Reproduction, Cartography, Aeronautical Charts, Geography, Toponymy, and Automated Cartography. The Directorate also staffs and maintains the departmental Map Library.

MAP REPRODUCTION

The Map Reproduction Division operates several large, overhead suspension cameras and uses contact and plate-making devices, as well as film processing equipment. A computerized typesetting system is employed to prepare cartographic text and geographical names for maps and charts, and automated trimming and folding equipment is used in the final stages of production. In the lithographic plant, one- and two-colour rotary offset presses provide rapid printing of high-colour cartographic products. An increasing percentage of printing work is being contracted out to private industry.

During 1976-77, 3,101 maps and charts were printed, for a total of 5,945,754 copies. This figure includes 552 reprints to maintain stock inventory, primarily of topographic maps, and 475,800 copies printed under contract by private industry.

TOPOGRAPHIC MAP DRAFTING AND REPRODUCTION

Topographic map drafting is undertaken by the

Maps such as this detailed relief map of Canada flow from the Directorate of Map Production to be distributed to the public by the Canada Map Office and its network of associated dealers.

Cartography Division and includes the selection and verification of geographical names to be used. During the year, drafting was completed for 366 new and revised topographic maps. Topographic maps printed in 1976-77 included 12 new multi-colour maps, 406 revised multi-colour maps, 297 new monochrome maps, and 23 photomaps.

AERONAUTICAL CHARTING

The Aeronautical Charts Division is responsible for the provision of aeronautical charts and related air information for the regulation, safety, and development of Canadian civil and military aviation. The availability of these publications is ensured by the maintenance of up-to-date aeronautical chart coverage of Canada at scales of 1:500,000 and 1:1,000,000. International schedules and standards are carefully observed. The availability factor is also ensured by the production of enroute navigation and instruction procedure charts and related publications, and of special aeronautical charts required for air traffic control, military flight operations, training, and other air navigation requirements.

In 1976-77, 277 new and revised visual pilotage charts were issued. Enroute navigation charts were revised for a total output of 1,277,450 charts for the year. Pilot's handbooks were updated with the publication of 126 new and 1,610 revised charts. Seven air information publications were published on a revision cycle ranging from 56 days to annual, for a total of 171,740 copies. In support of air traffic control for the Ministry of Transport, 423 new and revised controller charts and 312 new and revised video charts were produced. In addition, a "Canada Plotting Chart" at a scale of 1:3,000,000 was produced to support navigation training exercises for the Department of National Defence.

THE NATIONAL ATLAS OF CANADA

Compilation of the National Atlas of Canada is the responsibility of the Geography Division.

The periodic issuance of this publication is based on a cycle phased to the decennial and quinquennial censuses.

After a thorough assessment and review of the Fourth Edition of the National Atlas of Canada published in 1974, work is now well under way towards preparation of the next edition. It is intended that the new edition will contain an authoritative Gazetteer section.

Parallel to the research and design of maps for the Atlas is the production of maps for the new Geographical Map Series. The Series will provide geographical information in a map form for rapid assimilation and use in the fields of planning, administration, research, and education. Topics will include energy, transportation, population distribution, and tourism. The Relief Map of Canada is the first map in this new series. This map, released in the spring of 1977, is the first Canadian-produced map to show in detail the complete topography of the nation and its surrounding seabed.

GENERAL AND SMALL-SCALE MAPPING

In the Cartography Division, work continued on the International Map of the World (IMW), 1:1,000,000 scale series in Northern Canada. During the year, compilation and drafting were completed for six maps. Current status of the series is now as follows: of 69 maps, 52 have been published, 11 are in production, and 6 have not yet been started.

Other work carried out in 1976-77 included the revision and printing of the following maps: National Capital Region Map (MCR 17), Status Map (MCR 104, 105, and 106), Wilderness Canoeing (MCR 107 and 107F), and Yukon Territory Map (MCR 47).

CARTOGRAPHIC SERVICES

Cartographic services are provided by the Cartography and the Map Reproduction divisions. They include the statutory obligation to provide cartographic support in the production of electoral maps and bilingual district maps, as well as the provision of cartographic and reproduction services and advice to federal departments and agencies, provincial governments, educational institutions, and industry.

Cartographic support to the Office of the Representation Commissioner entailed the preparation and printing of 320 federal electoral riding maps and 124 municipality maps, after the latest redistribution. As support to the Bilingual Districts Advisory Board studying proposals on bilingual districts, the Directorate produced a total of 43 illustrative maps.

Other major cartographic services included the production of 11 Royal Tour Maps for the Secretary of State; 7 Administrative Maps for the Department of Manpower and Immigration; 1 Metric Edition of the Canada Vacation Planning Map for the Canadian Government Office of Tourism; 2,635 duplicates of reproduction material, primarily topographic maps for use as bases by federal departments and provincial agencies; printing of 86 geological maps; 232 hydrographic charts; 150 land-use maps; and 141 miscellaneous maps for other departments and agencies.

TOPONYMIC SERVICES

The Toponymy Division provides a Secretariat for the Canadian Permanent Committee on Geographical Names, as well as a wide variety of toponymic services. These include field research on geographical names, studies and reports on the history of geographical names, production of gazetteers, and advice to mapping agencies, other government agencies, and the general public on official geographical names.

During 1976-77, field research on geographical names continued in Manitoba, in cooperation with the provincial Department of Renewable Resources and Transportation Services. A new Yukon volume of the Gazetteer of Canada was produced, and the compilation of data for the revision of the Nova Scotia volume was completed. A third set of cumulative supplements was produced and distributed through the Canada Map Office.

Work continued on toponymy studies of Nova Scotia and the Northwest Territories, as did research on the bibliography of Canadian toponymy. The Division responded to more than 1,200 inquiries on a variety of subjects and reviewed approximately 30,000 names.

DEPARTMENTAL MAP LIBRARY

The Map Library provides a map reference service for the Department and other agencies. Along with departmental maps and charts, it maintains an extensive collection of other Canadian and foreign maps. During the year, the Library acquired 9,270 maps and charts, and 55 atlases and gazetteers, to bring the total holding to about 280,000 items. Loans during the year amounted to 703. About 2,120 persons used the Library reference facilities.

AUTOMATED CARTOGRAPHY

In the Automated Cartography Division, continuing emphasis was placed on the development of software for a total cartographic monitoring package, including input, storage, and retrieval. The XCM system installation was completed in March 1977, and operational testing has now commenced. Hardware enhancement to meet the demand for increased production included the purchase of a Kongsberg 1216 plotter.

In topographic mapping, the automated cartography facilities were used for the production of 414 control plots for 1:500,000 mapping and for 258 miscellaneous jobs, including rejoins, border plots, and cartographic editing plots. An on-line service was provided for the processing and storage of geological map data digitized by the Geological Survey of Canada. Plotting and scribing services also were provided and included the production of 126 photo plots of geological symbols.

LIST OF PUBLICATIONS

ADMINISTRATION

Collected papers: geodetic survey 1976, 215 p.

Surveying offshore Canada Lands for mineral resources development. 2nd edition, 1976, 106 p. Stock no. SMP-1212E.

Morse, E. Maps and wilderness canoeing. 1976. Stock no. SMP-1218E.

Morse, E. Les cartes et le canotage en pleine nature. 1976. N° de série SMP-1218F.

Tremblay, J.D. Notre héritage cartographique. GEOS, printemps 1976.

Tremblay, J.D. Traits du Glacier Peyto. GEOS, automne 1976.

Wray, T. Mathematics in the context of surveying and cartography. Can. Surv., 30, 157-159, 1976.

Wray, T. Letter. Can. Surv., 31, 84-85, 1977.

Wray, T. Letter. Can. Surv., 31, 86-87, 1977.

Wray, T. Mathematics in the context of surveying and cartography. Feb. 13, 1976.

Wray, T. The legacy of Gauss to geodesy and cartography. Feb. 25, 1977.

Wray, T. Foreword to L.P. Lee's Conformal projections based on elliptic functions. Cartographica Monograph, 16, Bernard V. Gutsell, Toronto, iii, 1976.

GEODETIC SURVEY DIVISION

Blais, J.A.R. Space-M spatial photogrammetric adjustment for control extensions using independence models. Paper presented at ISP, July 1976.

Blais, J.A.R. Error analysis of least-squares adjustments internal report. Dec. 1976.

Kouba, J. A proposed geodetic reference system for the Canadian adjustment. Paper presented at the 69th Annual Convention of the CIS, May 1976.

Kouba, J. Doppler levelling. Can. Surv., 30, 1, 1976.

Kouba, J. and Boal, J.D. The Canadian Doppler satellite network. Paper prepared for International Geodetic Symposium on Satellite Doppler Positioning, New Mexico State University, Las Cruces, New Mexico, Oct. 1976.

Kouba, J. and Boal, J.D. Program GEODOP. 1976. 190 p. Stock no. SMP-1213E.

Kouba, J. and Wells, D.E. Semi-dynamical Doppler satellite positioning. Bull. Geod., 50, 1, 1976.

Lachapelle, G. Prediction of deviations of the vertical using heterogeneous data. Paper presented at the XVIth General Assembly of the International Association of Geodesy, Grenoble, France, Aug. 1975. Can. Surv., 30, 2, June 1976.

Lachapelle, G. Research in physical geodesy at Geodetic Survey of Canada. Paper presented at 69th Annual Convention of the CIS, May 1976.

Lachapelle, G. Determination of geoid undulations and deviations of the vertical using a combined integral formulae and collocation approach. Paper presented at the Annual Canadian Geophysical Union Meeting, Quebec City, June 1976.

Lachapelle, G. Physical geodesy at the Geodetic Survey. Paper presented at the Pan-American Institute of Geography and History Symposium on Solid Earth Geophysics in the Americas, Ottawa, Sept. 1976.

Lachapelle, G. A spherical harmonic expansion of the isostatic reduction potential. Paper presented at the 6th Symposium on Mathematical Geodesy, Siena, Italy, Apr. 1975. Boll. Geod. Sci. Affini, XXXV, 3, 1976.

Lawnikanis, P. Program PREDOP. 1976. 215 p. Stock no. SMP-1214E.

Lawnikanis, P. GEODOP utilities program. 1976. 190 p. Stock no. SMP-1215E.

Lawnikanis, P. Program PREPAR. 1976. 110 p. Stock no. SMP-1216E.

McLellan, C.D. The Canadian adjustment. Can. Surv., 30, 5, Dec. 1976.

O'Brien, L.J. The inertial survey. Paper presented at the 68th Annual Meeting of CIS, Winnipeg, May 1976. Can. Surv., 30, 5, Dec. 1976.

Selley, A.D. A trigonometric level crossing of the Strait of Belle Isle internal report. Dec. 1976. 16 p.

Swanson, M.T. A geodetic network for crustal deformation studies at Manic 3, Quebec internal report. Dec. 1976. 22 p.

Vigneault, C. Les levés astronomique sous le soleil de minuit. GEOS, été 1976.

TOPOGRAPHICAL SURVEY DIRECTORATE

Allam, M.M. The estimation of fractures and slope stability of rock faces using analytical photogrammetry. Paper presented at ISP, July 1976. 13 p.

Allam, M.M. Photogrammetric deformation of lake surfaces caused by air temperature differential over water bodies. Paper presented at ISP, July 1976. 13 p.

Allam, M.M. and Wong, C. Gridding topographical surfaces. Paper presented at ISP, July 1976. 9 p.

Allam, M.M., Chaly, C.K. and Wong, C. Geometrical distribution of vertical control and the simultaneous adjustment of auxiliary data in independent model triangulation. Paper presented at ISP, July 1976. 9 p.

Fleming, E.A. The use of satellite photography in the national topographic mapping program of Canada. Paper presented at ISP, July 1976. 13 p.

Fleming, E.A. Positioning off-shore features with the aid of LANDSAT imagery. Photogramm. Eng. and Remote Sensing J., 43, 1, 53-59, 1977.

Fleming, E.A. and LeLievre, D.D. The use of LANDSAT imagery to locate uncharted coastal features. Paper presented at the 16th Canadian Hydrographic Conference, Burlington, Mar. 1977.

O'Donnell, J.H. Canada National Report 1972-1976 for the XIII International Congress for Photogrammetry. Prepared for ISP, July 1976. 21 p.

Sebert, L.M. Designing Canadian topographic maps for the next decade. Paper presented at 1976 meeting of The Association of Canadian Map Libraries in London, Ontario.

Sebert, L.M. The one inch to one mile series of the national mapping program. Can. Cartog., 13, 2, 123-131, 1976.

Zarzycki, J.M. Experience with the automated contouring by gestalt photomapper GPM-2 for production of 1:50,000 maps. Paper presented at ISP, July 1976. 8 p.

Zarzycki, J.M. and Allam, M.M. Block triangulation by bundles and stereounits. Paper presented at the ISP, 1976. Joint publication with G.W. Marks and E.M. Mikhail of Purdue University, U.S.A.

DIRECTORATE OF MAP PRODUCTION

MacKay, D. Kingston Mills 1783-1830. Hist. Kingston, 25, Mar. 1977.

Marshall, I. Soil capability for agriculture in Gloucester and Nepean townships, Carleton County, Ontario. Joint publication with the Soils Research Institute, Agriculture Canada, 1977.

Marshall, I. Soils of Gloucester and Nepean townships, Carleton County, Ontario. Joint publication with the Soils Research Institute, Agriculture Canada, 1977.

LEGAL SURVEYS DIVISION

Bonnel, C.F. Photomapping and its application to legal surveys. Paper presented at the 69th Annual Convention of the CIS, May 1976.

CANADA CENTRE FOR REMOTE SENSING

L.W. MORLEY, DIRECTOR-GENERAL

E.A. GODBY, ASSOCIATE DIRECTOR-GENERAL

The Canada Centre for Remote Sensing is responsible for developing remote sensing technology and introducing it into various organizations across Canada that are involved in resource management and environmental monitoring. Specifically, the Centre is concerned with developing and demonstrating systems, methods, and instruments for acquiring, analyzing, and disseminating remote sensing data obtained by aircraft and satellite.

Remote sensing techniques are applicable to a variety of fields and scientific disciplines, including agriculture, forestry, geosciences, oceanography, engineering, atmospheric sciences, water resource management, ice reconnaissance and glaciology, and geography. The data produced by remote sensing equipment contribute to the development of effective resource management and information systems relating to Canada's terrain and ocean environment.

Under the guidance of the federal government's Inter-Agency Committee on Remote Sensing, the Centre serves federal and provincial government departments and agencies, universities, regional organizations, industry, and the general public. In addition, through the Canadian Advisory Committee on Remote Sensing, the Centre coordinates remote sensing activities on a national scale. The latter committee includes provincial government representatives and about 200 scientists and resource managers in 13 working groups covering fields of application. The Centre also fosters international cooperation in the peaceful use of space technology.

Remote sensing activities are carried out be three scientific divisions within the branch: Data Acquisition, Data Processing, and Applications. The facilities of the Centre include satellite ground receiving stations at Prince Albert, Saskatchewan, and Shoe Cove, Newfoundland; a fleet of four aircraft equipped with a variety of sensors and navigating instruments; 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.

The Centre employed a total staff of 106 in 1976-77, including 55 professionals. The budget for the year was about $10 million.

DATA ACQUISITION DIVISION

R.C. Baker, Chief

Until very recently, airborne remote sensing has been limited to aerial photography, using a variety of cameras and films, and thermal mapping. These techniques produce photographic products from which information can be obtained visually by trained photo-interpreters. The Canada Centre for Remote Sensing provides conventional photo-analysis services to users across Canada, but efforts are also being concentrated on the development of new techniques for data collection and interpretation. These activities are the concern of the Data Acquisition Division.

New electronic sensors are being developed and flight tested as part of an integrated multi-sensor system. Data produced by these sensors will be 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. The Division is also continuing to develop long-term sensor capability, particularly in the laser, microwave, and imaging multi-spectral systems, to collect information which will complement resource satellite data. To an increasing extent, the Division's experimental capabilities are being used in programs initiated by other organizations to

The Convair 580 aircraft is used for remote sensing investigations in the Arctic and offshore. It is now being used in an aerial hydrography project and is being outfitted with a synthetic aperture radar (SAR) for participation in the SURSAT project the objective of which is to determine how best to meet Canada's surveillance needs in the 1980's.

which the Centre can make a valuable contribution.

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. A Convair-580 turboprop aircraft has just been reconfigured to fill both an operational and test-bed role. Its long range and good payload capability make it ideally suited to work over the oceans and in the Arctic, and to use in cooperative programs with countries outside North America. In the 1976-77 flying season, 197 flights were completed, covering 14,921 sensor line miles (23,900 km) and producing data for 80 projects.

In the Convair-580, a number of holes, ports, and attachment points have been provided which, in addition to accepting sensors in current use, will allow the aircraft to carry the new sensors under development – specifically, a complement of microwave sensors for all-weather sensing in the Arctic and over the oceans. The modified aircraft will carry a full data acquisition system and have sufficient space and power to allow multi-sensor experiments to be performed in flight.

Production sensors used in airborne operations consist of Daedalus infra-red line scanners, 9 x 9-inch (228.6-mm) metric cameras, multi-spectral camera packs, consisting of four 70 millimetre vinten cameras, PRT-5 radiometers, and the Miller four-channel filter photometer. Sensor packages are fitted to meet the requirements of individual investigators and may be operated singly or simultaneously. In addition, the production sensors undergo regular maintenance, calibration, improvement, and modification to fit the requirements of users. This work is carried out in a calibration and testing laboratory, which has been established to ensure that sensors meet required specifications and tolerances.

Scanner and PRT-5 data are recorded throughout all flights on Mincom tape recorders. Data are replayed and converted into imagery, with a PRT-5 profile overlay, on two separate systems. The first replay system produces black and white imagery on 5-inch (127-mm) film in continuous tone or level sliced form. Imagery is S-bend corrected. Alternative presentations include bi-format, in which continuous tone and level sliced data from the same channel are displayed side by side. The second system has been commissioned by the Centre's Data Processing Division. It produces imagery in colour level sliced form, S-bend corrected, on 9-inch (228.6-mm) film.

AIRBORNE SYSTEMS

The Centre has a continuous program of improving aircraft facilities; installing, maintaining, and upgrading navigation systems; and integrating sensors into coordinated data acquisition and track recovery systems. The Airborne Data Acquisition System (ADAS), 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. At present, the system interfaces with three navigation systems (LTN-51, Doppler, and Global VLF), an RC-10 camera, a multi-spectral photometer, a barometric altimeter, and a push broom multi-band imager. These navigation systems and sensors not only provide improved navigation and track recovery capabilities (when used together with Kalman filtering techniques), but also have the potential to resolve navigating problems in the Arctic and over the ocean, where the Convair-580 will operate much of the time.

SENSORS

New sensing capabilities are developed through a combination of in-house work and major contracts with industry. New sensors and sensing techniques are evaluated and flight tested in cooperation with users in various scientific disciplines. In 1976-77, important advances were made in the development of techniques for use in lidar hydrography and in the identification of environmental hazards.

Lidar Hydrography

In the past year, a number of flights were carried out using the Centre's profiling lidar bathymeter. The data collected on these flights were subsequently used to construct a 6-mile (9.6-km) profile of the bottom of the harbour at Kingston, Ontario. This profile, in which the bathymeter penetrated 25 feet (7.6 m) of water, corresponds almost exactly to a profile extracted from the published hydrographic chart of the area.

The bathymeter has now been retired, to be replaced by a new Mark II profiling system. The new system, which is being developed by Optech Inc. in Toronto and will be delivered for flight testing in 1977, is designed to demonstrate the performance required for an operational scanning system. The depth-penetrating capability will be vastly superior to that of the older system, and the data will be automatically acquired in digital form for later processing.

Identification of Oil Spills, Chlorophyll, and Water Pollution

Laser Fluorosensing

The construction of the Mark III Remote Sensing Laser Fluorometer has almost been completed. The new profiling sensor, being developed by Barringer Research Limited in Toronto, uses a pulsed laser emitting light in the ultra violet to excite fluorescence. Fluorescence emission is measured in 16 spectral channels, and there are two additional channels for measurement of the fluorescence lifetime. The sensor is designed to operate at altitudes of up to 2,500 feet (762 m) under both day and night flying conditions. Data are recorded either on a computer-compatible magnetic tape or an ADAS.

A contract laboratory study to measure the fluorescence emission spectra and fluorescence lifetime of oils has been completed, and an atlas has been compiled showing the fluorescence characteristics of the 40 samples. The study, which simulated the performance of the Mark III fluorosensor, showed that the airborne sensor should be able to classify oils into three broad categories: crude, bunker, and light refined products. The instrument also has the potential to measure chlorophyll concentration in water. Other possible uses include crop identification, forest surveys, mapping of the distribution of insecticides in aerial spraying operations, and identification and mapping of selected geological anomalies.

During the year, the old laser fluorosensor was used in a number of test flights, including emergency flights over the Thousand Island oil spill in June 1976. Initial studies were begun on the variation in amplitude and pulse width of the laser backscatter as it passes over different terrain surfaces. This information is necessary for an understanding of the fluorescence lifetime measurement which will be made by the Mark III fluorosensor.

Spectroscopic-based Techniques

Multi-spectral Scanner

An 11-channel Daedalus/MDA Multi-Spectral Scanner (MSS) was delivered in 1976. Offering 10 channels in the visible and near infra-red and an eleventh in the thermal infra-red, this MSS has its data recorded digitally during flight, with optional correction for S-bend distortion. The spectral channels can be mixed to match LANDSAT passbands. Histograms of the data in the 11 channels can be displayed. The scanner is under test and evaluation and will be used in 1977-78 on special pilot projects.

Multi-spectral Electro-optical Imaging System

In 1977, a new generation two-channel prototype "solid state" multi-spectral scanner, developed by MDA Limited, was delivered to the Centre. The Multi-Spectral Electro-Optical Imaging System (MEIS) consists of two identical units, each containing a 512-element silicon detector linear array in the focal plane of an imaging lens. The units are bore-sighted, and each has a different easily interchanged filter in front of the lens to define its spectral channel. In flight, the system will look vertically down with the arrays aligned across the line of flight. For ease of reduction, the data are digitized and recorded in the Daedalus MSS format.

This system is now under testing in the laboratory and will shortly be evaluated during flight. It has application to both airborne and satellite remote sensing.

Atmospheric Pollutant Monitor

During the year, delivery was taken of a new spectroscopic non-dispersive gas sensor of the "Gaspec" family developed by Barringer Research Limited. The incoming radiation to the sensor is detected in a dual-beam manner. One arm of the sensor directly detects the incoming radiation, and the other detects the radiation after spectral filtering by a cell containing a sample of the gas to be quantified. The sensor is set up for carbon monoxide monitoring and has undergone initial flight trials to evaluate its performance.

MAJOR PROJECTS

Aerial Hydrography

The aerial hydrography and airborne bathymetry projects have recently been combined under the aerial hydrography project, a joint project being carried out by the centre and the Department of Fisheries and the Environment (Victoria and Ottawa). The ultimate goal of the project is to form an integrated photo/lidar hydrographic system for charting shallow coastal waters. The two projects have been renamed, respectively, photo hydrography and lidar hydrography.

Developments in lidar hydrography have been described in the preceding section. The photo hydrography project is investigating the use of stereo photography for contouring the sea bottom in shallow areas. An inertial navigation system is required to align the stereo pairs correctly in the analytical plotters.

The photo hydrography system includes both airborne and ground-based equipment. The airborne component comprises an RC-10 aerial survey camera, and LTN-51 Inertial Navigation System, and the Centre's Airborne Data Acquisition System. The ground segment is made up of the computer-controlled analytical plotter at the University of New Brunswick and the PDP-10 computer facility at the Centre. Airborne equipment is used to gather photographic and navigational data over the waters to be charted, and these data are processed post-flight on the PDP-10 computer and analytical plotter to provide the required hydrographic charts.

At present, all hardware for the photo hydrography system is operational. The Centre is now concentrating on system software development, which should be completed by early summer 1977. Flight trials of the navigation system hardware/software and the fully integrated system are scheduled for April and September of 1977 respectively.

Energy Loss

In the winter of 1976-77, an extended program was mounted to measure, by remote sensing, energy loss from buildings. This program, which was carried out in cooperation with the Office of Energy Conservation, involved many flights over industrial and school building complexes in Prince Edward Island. Further flights were carried out over Ottawa test sites with a view to determining the nature and value of the information that can be acquired by remote sensing under various weather and flight conditions.

Mapping of Ice Distribution and Thickness

During the year, work continued on the identification of sea ice from the air, using the Centre's 13.3 GHz scatterometer. Data were acquired over first-year sea ice (floating and shore-fast) in the Bay of Chaleur in spring 1976. Analysis of these data has shown that it is possible to distinguish between new, young, and first-year ice on the basis of spatial detail and backscatter amplitude at the incident angles commonly associated with satellite-borne radar. This finding complements the previous analysis of multi-year Arctic ice, which showed that cross-polarized data greatly facilitated the differentiation of Arctic ice categories on the basis of backscatter. In the case of the 1976 study, it was found that the polarization was essentially immaterial. It apperas at this stage that an imaging radar for the classification of sea ice should preferably have both like and cross-polarized channels (and particularly

the latter) and should operate at the steeper incident angles appropriate to a satellite-borne system.

Further work was carried out with the Communications Research Centre of the Dept. of Communications to evaluate the use of X-band impulse radar on the Centre's experimental aircraft. Flights over the Ottawa River demonstrated the ability of the quipment to measure the thickness of fresh, water ice, to produce real time hard copy results in the air, and to record the data for further post-flight processing.

ACTIVE MICROWAVE AIRBORNE SENSOR PLANS

Substantial progress was made in 1976 towards obtaining high-quality fine resolution multi-band imaging radar for use aboard the Centre's Convair-580 aircraft. The aircraft radar program is one element of the Microwave Surveillance Satellite initiative, for which approval in principle was granted by Cabinet early in 1977. The radar, belonging to the Environmental Research Institute of Michigan, will be leased and operated through Intera Environmental Consultants of Calgary and Innotech Aviation Limited of Montreal. It will be used in Canada in scientific and application experiments to produce data required by federal government departments and other users.

The radar operates at wavelengths of 25 cm and 3 cm with dual polarization available on both. The imagery will be the best now available for civilian purposes anywhere in the world. It will provide Canada with a unique and critical data base for evaluating the 25-cm imaging radar of SEASAT-A (an oceanographic satellite to be launched by the United States in May 1978) and for placing in context the various imaging microwave requirements of users. These results are expected to affect Canada's future sensor requirements for both satellite and aircraft systems.

INDUSTRIAL INVOLVEMENT PROGRAM

The Centre's Industrial Involvement Program, commenced in 1975-76, is aimed at promoting the development of a viable Canadian industrial capability in remote sensing. Early in 1976, a transfer plan report was completed which outlines in detail all the necessary elements of building the industrial operational capability. As a result of subsequent reviews of the plan, it has been decided that the contract let in the previous year to Innotech Aviation Limited (and the primary subcontractor, Intera Environmental Consultants) should be modified to allow implementation of the reports recommendations.

When the Industrial Involvement Program is fully implemented, the Centre's airborne remote sensing program will have two visibly separate identities: the government-supported program, primarily concerned with research and development in remote sensing technology and with remote sensing applications development and demonstrations (or, more concisely, all the steps necessary to demonstrate the feasibility of remote sensing to solve a particular problem); and the industrially managed element, which will meet market requirements for operational remote sensing applications and pursue, through an active marketing program, new uses and users for remote sensing. These two activities will be coordinated to ensure full responsiveness to remote sensing requirements, so that both the research community and the end user will derive full benefits from the airborne sensing program.

DATA PROCESSING DIVISION

E.Shaw, Chief

OVERVIEW

Recording and processing of data from the LANDSAT and NOAA series of satellites continued throughout the year. On the airborne side an operational capability for the recording and processing of infra-red sensed data was completed and development work took place on other sensors. Of particular interest was the placing into a production status of a continuous strip film recorder. This low cost computer controlled unit was developed in house using commercially available equipment and enables a user to have a reasonable quality colour image strip of his data within a short turnaround time. It has been used on a regular basis for airborne infra-red, the U.S. National Oceanographic and Atmospheric Administration (NOAA) satellite and LANDSAT data, as well as for output from the Image 100 and Multispectral Analyser & Display units.

PRINCE ALBERT SATELLITE STATION

The Prince Albert station records LANDSAT multi-spectral (MSS) data and NOAA very high resolution radiometer (VHRR) data. Bands 5 and 6 of the MSS and the thermal and visible bands of the VHRR are recorded on the quick-look system to produce master film images for rapid distribution to users. Regular tracking of NOAA orbits covering the Arctic, Hudson Bay and the east coast areas continues on a non-interference basis with LANDSAT. First priority is given to LANDSAT, followed by coverage of sea-ice areas from NOAA. Routine production of LANDSAT black and white quality imagery was transferred to a commercial firm located at Prince Albert.

Shoe Cove Satellite Receiving Station.

SEA ICE FAX

LANDSAT and NOAA images continued to be sent in near real time from Prince Albert to ships in the Arctic via Ice Forecast Central in Ottawa, using a satellite link. LANDSAT images are found to be more useful for ice forecasting while the daily coverage of NOAA images is useful in planning ship operations for geophysical exploration.

EAST COAST STATION

A portable satellite ground station for receiving and processing LANDSAT and NOAA data developed by a Canadian firm in Vancouver, was delivered to Shoe Cove, Newfoundland during the fall. It will produce quick-look images and computer tapes from LANDSAT MSS or NOAA VHRR data beginning early in 1977. The portable station, fairly innovative in its field, was tested experimentally in Vancouver prior to shipment to Newfoundland.

SATELLITE IMAGE PRODUCTION

At the end of 1976 the current image inventory consisted of 67,548 black and white and 17,036 colour scenes. Mosaics of LANDSAT images are also part of the product line. These mosaics cover specific regions of Canada and also include a mosaic of the entire Canadian landmass.

IMAGE INVENTORY AND CATALOGUE SERVICE

Summary information of LANDSAT data is available in catalogue form, now produced on an annual basis, with interim supplements, and also on transparent overlays. These overlays are useful in studies of imagery availability and seasonal variation of quality. Users are also able to do a direct search of the LANDSAT data base via remote computer terminals, providing immediate information on image availability.

DATA COLLECTION PLATFORM (DCP) SUPPORT

During the year, CCRS continued to receive Data Collection Platform data from NASA, converting it to engineering units and providing it to users through a teletype or telex link once a day. DCP reception at Prince Albert from the LANDSAT and U.S. Geostationary Operational Environmental Satellite (GOES) satellites using a Canadian development, will be implemented in 1977.

DIGITAL IMAGE CORRECTION SYSTEM

Work has begun during the year on a production system for geometrically correcting satellite data. This will enable data taken from satellites on different passes to be overlain for comparison purposes, and will enable data to be precisely matched with existing maps.

The system is based on a mini computer delivered during the year, and on some special purpose computer hardware for the precision processing algorithms developed by a Canadian firm in Toronto, to be delivered in January 1977. Production of geometrically corrected scenes on a request basis will commence in the summer of 1977.

AIRBORNE PROCESSING

A production facility for processing infra-red data sensed by aircraft, was established during the year. This enables a user to overfly a particular area of interest with a Daedelus infra-red scanner. The resulting output can then be replayed on a "quick-look" device or converted to computer compatible tape (CCT). These CCT's, as a user option, can have their data converted to temperature for the production of a thermal image, in which different colours represent different temperature ranges. Such an option is useful in heat loss studies of buildings, evaluation of frost prone agricultural areas, etc. Developed to a quasi-operational stage during the year was a capability to develop images from flights in which a multi spectral scanner or a York-Miller photometer sensor, was used. These should become fully operational during 1977.

APPLICATIONS DIVISION

W.M. Strome, Chief

Continued technological development in remote sensing is of great importance to assist in the planning and management of the environment and natural resources of Canada. To be of real value, these new technologies must be broadly and effectively transferred through the development of viable operational applications. Such development and transfer are the main responsibilities of the Applications Division.

In most cases, the transfer to technology requires more than a demonstration of operational capability and potential benefit. For transfer to be complete, the eventual benefactors must be prepared to accept and use the technology effectively within their own administrative and disciplinary frames of reference. Technology transfer thus requires the establishment and maintenance of close liaison with the user community, to ensure that user feedback is integrated at as early a stage as possible in technology development and application.

To carry out its responsibilities, the Division is organized into three sections: Applications Development, Methodology, and the Technological Information Service. The Applications Development Section holds the prime responsibility for direct user liaison. Effort is concentrated on the development and transfer of discipline-oriented applications, in cooperation with interested organizations and individuals. The Applications Development Section holds the prime responsibility for direct user liaison. Effort is concentrated on the development and transfer of discipline-oriented applications, in cooperation with interested organizations and individuals.

Although much useful exchange can be effected through ad hoc communication among colleagues, more formal avenues also are essential. In 1976-77, Section scientists have maintained continuing liaison with various provincial organizations, in an attempt to encourage provincial participation in remote sensing projects. In addition, to facilitate communication between disciplines, staff have served as official Centre representatives to each discipline working group of the Canadian Advisory Committee on Remote Sensing.

A major area of interest in the Division is the use of digital techniques for image analysis. Until recently, the users of the Centre's digital image analysis system were relatively limited in number and were often experienced in the applicable techniques. In view of the broadening interest in these techniques, the Section has established an Image Analysis Utilization Committee to assist new users in appreciating the capabilities of present technology and to enable them to obtain maximum benefit from its use.

In 1976-77, projects were carried out in response to a variety of current and anticipated discipline requirements. Areas receiving particular emphasis included: Agriculture and Land Use, Energy Conservation, Technology Transfer, Water Resources, and the Geosciences.

Agriculture and Land Use

During the year, an evaluation was completed of remote sensing techniques for acreage measurement of certain specialty crops in Ontario and New Brunswick. Related work was carried out on the determination of field sizes, rates of harvest, idle land, and woodlot distribution.

Energy Conservation

Heat loss from residential and industrial structures is a major concern of agencies involved in energy conservation. Airborne thermal imagery (Thermography) is proving, in

current projects, to be an effective tool for the detection and quantitative evaluation of such heat loss conditions.

Technology Transfer

Management of a major CIDA-sponsored project on behalf of Peru has permitted the practical testing and assessment of several innovating concepts in operational technology transfer. This cooperative effort is yielding significant practical benefits to all parties involved.

Water Resources

Projects carried out during the past year have produced important progress towards quantitative assessment of suspended sediment content and other factors affecting water quality, using techniques which rely heavily on remotely sensed data.

Geosciences

Successful integration of LANDSAT image data in operational surficial geologic mapping and mineral exploration programs has been demonstrated during the past year. Emphasis in the coming year will be placed on the standardization of requirements and methodologies to facilitate broader access to the techniques being developed.

METHODOLOGY

As remote sensing systems become more varied and complex, the demand for machine-assisted image analysis increases. The Methodology Section is responsible for providing the automated image analysis capabilities necessary to facilitate the continued development of certain applications. Both the limited resources available and practicality dictate that systems and methodologies be made available which combine needed capabilities with economy. The same constraints require that any system developed be broadly flexible, so as to permit its use in a number of programs and to provide insurance against early obsolescence. The Methodology Section is responsible for provision of the methodologies and related capabilities necessary to maximize the potential information value of remote sensing data, and for encouraging related research in Canada. Currently, a major effort is being directed towards the automated digital processing of data from satellite and airborne sensors.

Literature and documentation on remote sensing are often difficult to obtain and evaluate because of the wide range of activities involved in the technology. The organization and dissemination of information are the functions of the Technical Information Service. The Service provides document-library and LANDSAT image search services to the public, as well as support services to other sections of the Division.

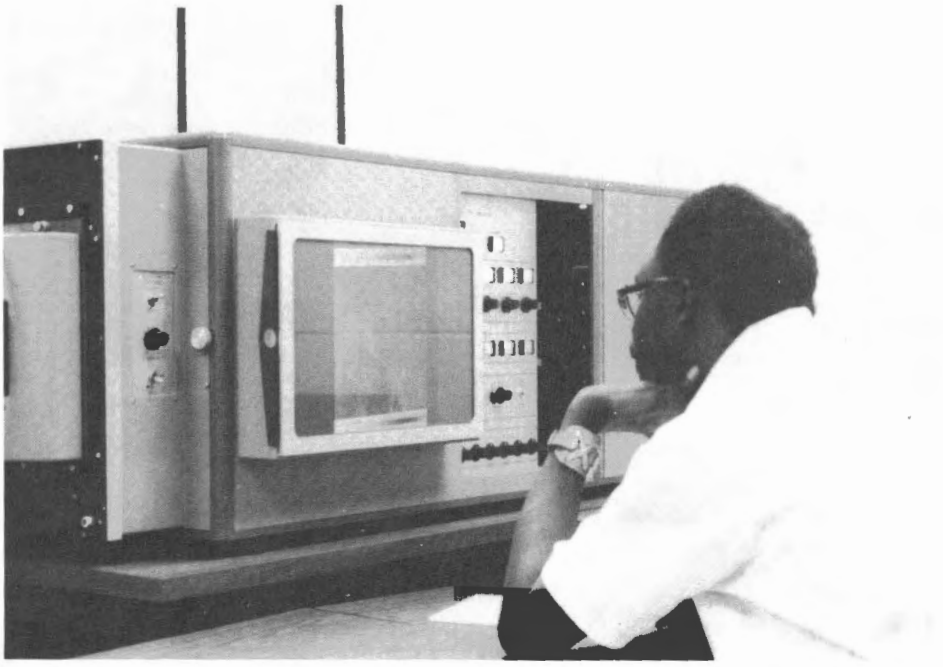
To keep the remote sensing community informed of development in Canada and abroad, the Division, with the cooperation and assistance of the Information Group of the Department of Energy, Mines and Resources, undertakes the publication of the quarterly CCRS Newsletter. The newsletter has a current circulation of over 3,600 and is sent to any individual who expresses specific interest in the Canadian remote sensing program. The Division also organizes and hosts a regular scientific series for the purpose of encouraging scientific exchange and discussion.

APPLICATIONS DEVELOPMENT

The Applications Development Section maintains an active research program directed at the identification and advancement of applications with operational potential. As noted earlier, the effective transfer of applications requires a major involvement with users or potential users of remote sensing. Consequently, scientific staff are concerned with developing and maintaining continuous channels of communication with other individuals and organizations, and with participating in cooperative research endeavours.

In 1976-77, a significant proportion of the Section's effort was devoted to the consolidation and functional integration of the Division's digital image analysis facities in a single CCRS Image Analysis System (CIAS). The new system combines the impressive image analysis capabilities of the CCRS Image 100 and its dedicated PDP 11/70 computer with the colour read/write capabilities of a precision PDS Microdensitometer and its dedicated PDP 11/40 computer. The CIAS will provide valuable assistance in the development of applications of remote sensing in the immediate future. Furthermore, the system has been designed to accommodate future demands for precision, volume, and a variety of image analysis capabilities.

Through the expertise of Section scientists, the Division supports the Modular Interactive Classification Analyser (MICA) and the MADCON Image enhancement package. While the CIAS is a hardware-based system, the MICA and MADCON systems are software based, on-line to the CCRS PDP-10 time-sharing computer.



Scientist analyzing multispectral LANDSAT data on the Colour Additive Viewer.

Hardware systems offer the advantages of speed and efficiency for operational use; software systems, because of their flexibility and large memory access capabilities, facilitate flexible methodological research and development. The two digital image analysis systems are designed and operated in a manner which best utilizes their relative capabilities. Outside users routinely obtain access to both of these facilities in support of their remote sensing applications research.

In addition to the development of digital multi-spectral image analysis capabilites, Section scientists are concerned with a variety of other tasks, including the provision of methodologies for analysis in cooperation with sensor development programs. The Section is also involved in advanced planning for participation in future satellite-borne and airborne programs of applications interest. Current activities are directed towards the development of methodologies required for effective use of the outputs from advanced sensing systems operating in the visible, infra-red, and microwave portions of the electromagnetic spectrum. Also, in recognition of the critical role of accurate ground-based measurements as calibration for airborne and satellite-borne sensors, the Section is involved in the design and implementation of systems to facilitate the collection and improve the accuracy of such calibration data.

In addition to the activities described above, the Methodology Section carried out projects in the following areas in 1976-77: a) the development of radiometric and geometric algorithms for synthetic aperture radar imagery which would allow application of techniques developed for LANDSAT analysis; b) an investigation into sea ice as viewed from aircraft from laser and microwave sensors; c) research on methods for automatically correcting satellite data for the effects of atmosphere; d) the development of a visible and infra-red spectroscopy laboratory for the investigation of the remotely sensed properties of surface features; and e) methods for generating approximate map products from satellite data.

TECHNICAL INFORMATION

The role of the Technical Information Service is to acquire and disseminate documentation related to the Centre's activities and programs. In recent years, the section has become the focus of remote sensing documentation in Canada, within the national network of scientific and technical information services.

Professional staff maintain a large collection of remote sensing and related literature and slides, and an extensive LANDSAT satellite image library, as well as selected NOAA and Skylab imagery. The Section also

Applications scientists using the CCRS Image-100 System.

distributes reports of the Centre, prepares displays, exchanges information with other remote sensing facilities in Canada and internationally, and handles many initial user contacts and requests.

The Technical Information Service has acquired an extensive collection of publications on remote sensing and has catalogued their subject content in machine-readable form, so that they may be quickly located by the user. A remote sensing on-line retrieval system (RESORS) has been developed, which is equally accessible from all parts of Canada, and reference and loan services are provided to scientists and other interested organizations and individuals.

LIST OF PUBLICATIONS

Information Bulletin, Airborne Operation, 1976, Canada Centre for Remote Sensing.

Ahern, F.J., Gray, A.L. and Lowry, R.T. Coherent speckle and coherent microwave sensor data analysis. CASI Remote Sensing Symposium, Ottawa, February 1977.

Campbell, W.J., Gray, A.L., et al. Microwave remote sensing of sea ice in the main AIDJEX experiment. IUCRM Colloquium on Radio-Oceanography, Hamburg, Fall 1976.

Davies, J.H. and Zwick, H.H. New progress in correlation spectroscopy and its applications. CASI Aerospace Electronics Symposium, Banff, February 1976.

Gower, J.F.R. and Nevill, R.A. A method for the remote measurement of the vertical distribution of phytoplankton in seawater. Fourth Canadian Symposium on Remote Sensing, Quebec City, May 1977.

Gray, A.L. Active microwave remote sensing spectral requirements, 1976; Document for preparations for the 1979 World Administrative Radio Conference.

Gray, A.L., Cihlar, J., Parashar, S. and Worsfold, R. Scatterometer results from shorefast and floating sea ice. Eleventh International Symposium on the Remote Sensing of the Environment, Ann Arbor, Michigan, April 1977.

Gray, A.L., Rasmeier, R.O. and Campbell, W.J. Scatterometer and SLAR results obtained over Arctic sea ice and their relevance to the problems of Arctic sea ice reconnaissance. Fourth Canadian Symposium on Remote Sensing, Quebec City, May 1977.

Hesketh, W.D., Reichle, H.G., Massey, W.A., Ward, T.V. and Zwick, H.H. A gas filter correlation instrument for atmospheric tract constituent monitoring. Fifth Annual Remote Sensing of Earth Resources Conference, Tullahoma, Tennessee, 1976.

Livingstone, C.E. An instrument for real time measurement of the decaying edge of transient signals. IEE Transactions on Instrumentation and Measurement, vol. IM 25, #2, June 1976, 120-125.

Neville, R.A. Null-plane quantum electrodynamics in an external radiation field. Can. J. Phys., 54, 1976, p. 2246.

Peleato, J.M. and Livingstone, C.E. A distribution transformer impulse test analyser. IEE Conference on Communications and Power, Montreal, October 1976.

Raney, R.K. Alternative statistics for quantitative radar image interpretation. CASI Remote Sensing Symposium, Ottawa, February 1977.

Raney, R.K. A solution to the range curvature problem. Eleventh International Symposium on the Remote Sensing of the Environment, Ann Arbor, Michigan, April 1977.

Zwick, H.H. Passive electro-optical remote sensors at CCRS. CASI Remote Sensing Symposium, Ottawa, February 1977.

Ahern, F.J. and Goodenough, D.G. Optical and microwave crop identification, a comparison experiment. Canada Centre for Remote Sensing Seminar Series, Ottawa, 1977.

Ahern, F.J., Fitzgerald, M.P., March, K.H., and Purton, O.R. A single star model for V1016 cygni. Astronomy and Astrophysics, 58, 35, 1977.

Ahern, F.J., Goldberg, M.J., Goodenough, D.G., Gray, S.I., Ryerson, R.A., and Vilbikaitis, R.J. Low altitude microwave and visual measurements of agricultural targets. Aerospace Electronics Symposium, Canadian Aeronautics and Space Institute, Banff, Alberta, 1976.

Ahern, F.J. and Goodenough, D.G. Atmospheric correction of LANDSAT data. Workshop on Atmospheric Effects in Remote Sensing Data, Atmospheric Environment Service, Downsview, Ontario, 1976.

Ahern, F.J., Goodenough, D.G., Gray, A.L., Ryerson, R.A., Vilbikaitis, R.J. and Goldbert, M. Simultaneous microwave and visual wavelength observations of agricultural targets. Can. J. Remote Sensing (in press 1977).

Ahern, F.J., Goodenough, D.G., Jain, S.O., Rad, V.R., and Rochon, G. LANDSAT atmospheric corrections at CCRS. Fourth Canadian Symposium on Remote Sensing, Canadian Aeronautics and Space Institute, Quebec City, 1977.

Ahern, F.J., Goodenough, D.G., Jain, S.O., Rad, V.R., and Rochon, G. Use of clear lakes as standard reflectors for atmospheric measurements. Eleventh International Symposium on Remote Sensing of Environment, Environmental Research Institute of Michigan, Ann Arbor, 1977.

Ahern, F.J. and Guertin, F.E. JSC format specification for CCRS — SMD tapes. CCRS Internal Report, 1976.

Ahern, F.J. and Vilbikaitis, R.J. MTF evaluation of the PASS quick-look imaging system. CCRS Internal Report, 1976.

Alfoldi, T.T. Digital analysis of LANDSAT MSS imagery for snow mapping applications; a report to the Atmospheric Environment Service. Dept. of Fisheries and the Environment, August 1976.

Alfoldi, T.T. The use of satellite imagery for an inventory of coastal resources in the Atlantic Provinces. Canada Centre for Remote Sensing, Research Report 75-5, 1977.

Alfoldi, T.T. User recommended improvements for the next generation of digital image processing machines. CCRS Internal Report, 1976.

Alfoldi, T.T. and Munday, J.C., Jr. Progress toward a LANDSAT water quality monitoring system. Fourth Canadian Symposium on Remote Sensing, May 1977.

Alfoldi, T.T. and Thomson, K.P.B. Snow mapping from LANDSAT digital data. Proceedings of the 17th International Scientific Technical Meeting on Space, Rome, March 1977.

Alfoldi, T.T. and Ryerson, R.A. Satellite imagery interpretation; suggestions for laboratory design. COSPAR Technique Manual Series, Manual No. 5, May 1976.

Brown, R.J. Infrared scanner technology applied to building heat loss determination. Remote Sensing Science and Technology Symposium, Quebec City, February 1977.

Bruce, W.D. Signals from space. GEOS, Information, Dept. of Energy, Mines and Resources, Spring 1976.

Cihlar, J. Remote sensing of soil moisture. Presented at the Remote Sensing Workshop, McGill University, Montreal, Quebec, May 13-14, 1976.

Cihlar, J. Soil moisture determination by thermal infrared remote sensing. Proceedings, Soil Moisture Workshop. Canadian Aeronautics and Space Institute, CACRS Hydrology Working Group, Toronto, November 8-10, 1976.

Cihlar, J. Thermal infrared remote sensing: a bibliography. Research Report 76-1, Canada Centre for Remote Sensing, 46 p., 1976.

Cihlar, J., Brown, R.J., Lawrence, G., Barry, J.N. and James, R.B. Use of aerial thermography in Canadian energy conservation programs. Proceedings of the Eleventh International Symposium on Remote Sensing of the Environment, Ann Arbor, Michigan, April 25-29, 1977.

Cihlar, J. and Thomson, K.P.B. Diurnal temperature variations and their usefulness in mapping sea ice from thermal infrared imagery. Fourth Canadian Symposium on Remote Sensing, Quebec City, 1977.

Dixon, R.G. Colour additive views users' manual. Unpublished report, Canada Centre for Remote Sensing, 18 p., 1975.

Goldberg, M. and Goodenough, D.G. Analysis of a spatial filter for LANDSAT imagery. Proc. SPSE Conference on Image Processing and Evaluation (Editor: R. Shaw), Waverley Press, 1976.

Goldberg, M., Goodenough, D.G. and Shlien, S. Classification methods and error estimation for multispectral scanner data. Proc. of the Third Canadian Symposium on Remote Sensing, 125-141, 1976.

Goldberg, M. and Shlien, S. Computer implementation of a four-dimensional clustering algorithm. CCRS External Technical Report, 1976.

Goldberg, M. and Shlien, S. A four-dimensional histogram approach to the clustering of LANDSAT data. Can. J. Remote Sensing, 2, 1, 1-11, 1976.

Goldberg, M. and Shlien, S. A four-dimensional histogram approach to the clustering of LANDSAT data. Proc. Fourth Symposium Machine Processing of Remotely Sensed Data, 250-258, 1977. (Extracts from publication 20).

Goodenough, D.G. The Canada Centre for Remote Sensing's image analysis system (CIAS). Proc. Fourth Canadian Symposium on Remote Sensing (in press 1977).

Goodenough, D.G. A hybrid system for image processing and pattern recognition in remote sensing. IEE Trans. on Comp. (in press 1977).

Goodenough, D.G. Image 100 classification methods. Can. J. Remote Sensing, 2, 18-29, 1976.

Goodenough, D.G. Remote sensing science and technology in Canada. Eng. J. (in press 1977).

Goodenough, D.G. and Narendra, P.M. Feature subset selection in remote sensing. IEE Milwaukee Symposium on Automatic Computation and Control, 1976.

Holmes, Q.A., Goodenough, D.G. and Erickson, J.D. Remote sensing data processing two years ago, today, and two years from today. Proc. Eleventh International Symposium on Remote Sensing of the Environment, Ann Arbor, Michigan, 1977.

Holyer, I., Wadhams, P. and Lowry, R.T. An interactive graphic system for the reduction of airborne laser profiles of sea ice. Scott Polar Research Institute, Cambridge. Technical Report 77-1, 1977.

King, G., Ryerson, R.A. and Mosher, P. Can remote sensing technology provide what specialty crop inventories require? Aerospace Electronics Symposium, Canadian Remote Sensing Society of the Canadian Aeronautics and Space Institute, Ottawa, 1977.

Lowry, R.T. and Brochu, G. An interactive correction and analysis system for laser profiles of sea ice. Presented at the Aerospace Electronics Symposium, Banff, Alberta, 1976.

Lowry, R.T. and Goodenough, D.G. On the analysis of airborne synthetic aperture radar imagery of the ocean. Proc. Fourth Canadian Symposium on Remote Sensing, Quebec City, 1977.

Lowry, R.T., Gray, A.L. and Ahern, F.J. Coherent speckle and coherent microwave sensor data analysis. Remote Sensing Science and Technology Symposium, Canadian Aeronautics and Space Institute, Ottawa, 1977.

Lowry, R.T. and Wadhams, P. On the statistical distribution of pressure ridges in sea ice. Submitted to J. Glaciology.

McGurrin, B. and Silcoff, B. The Remote Sensing Information Centre: a national information network and mode. Canadian Association for Information Science, Fourth Annual Meeting, London, 1976.

McNeil, W.R., Thomson, K.P.B. and Jerome, J. The application of remote spectral measurements to water quality monitoring. Can. J. Remote Sensing, 2, 1, 1976.

Odenyo, V.A.O. and Pettry, D.E. Land use mapping of rapidly changing area by machine processing of LANDSAT-1 data. Photogramm. Eng. and Remote Sensing J. (in press 1977).

Schubert, J.S., Chagarlamudi, P., Moore, H., Goodfellow, C. and Mack, A.R. Global agricultural productivity estimation from LANDSAT data. Fourth Canadian Symposium on Remote Sensing, 1977.

Shuchman, R.A. and Lowry, R.T. Vegetation classification with digital X-band and L-band dual polarized SAR imagery. Fourth Canadian Symposium on Remote Sensing, Quebec City, 1977.

Singhroy, V. and Bruce, W. Surficial geology in The Pas area of Manitoba: an application of digital LANDSAT data. Fourth Canadian Symposium on Remote Sensing, Quebec City, 1977.

Thomson, K.P. Position paper on remote sensing of water resources. Annual Report of the Canadian Advisory Committee on Remote Sensing, Canada Centre for Remote Sensing, 1976.

Thomson, K.P.B., Abiodun, A.A., Kirby, M., Ayles, H. and Heckey, R. The applications of LANDSAT multispectral radiance data to environmental impact studies on large lakes. Proceedings of the Symposium on Radiation in the Atmosphere, Garmisch-Partenkirchen, FDR, 1976.

Wadhams, P. and Lowry, R.T. A joint topside – bottomside remote sensing experiment on Arctic sea ice. Fourth Canadian Symposium on Remote Sensing, Quebec City, 1977.

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. Activities are aimed at achieving four main objectives:

To obtain fundamental information on the geological, geophysical, and oceanographic characteristics of Arctic Canada and the Arctic Ocean, to facilitate the evaluation and management of mineral and other resources; and to provide knowledge of the problems to be resolved in developing and exploiting resources, establishing transportation and communications facilities, and carrying out other economic, strategic, and social or administrative activities in the region

To obtain information on the Arctic environment and on the actual or possible impact of economic, sociological, or military activities

To devise equipment and techniques that will permit the efficient and economical fulfilment of federal government responsibilities in the polar regions

To provide factual information and evidence concerning national activities in the Arctic region and to demonstrate Canada's occupation, authority, and administrative presence in Arctic lands and waters

The Project comprised 102 separate investigations in 1976-77. Twenty full-time staff were employed, including two research scientists and two technicians. An additional 11 employees provided casual or term assistance on various studies.

About 93% of the Project's budget of $3.5 million for the year was expended on studies in the earth sciences or on technical surveys conducted by the Department of Energy, Mines and Resources and the Department of Fisheries and the Environment. The balance of the funds was allocated to support of investigations initiated by other government departments and agencies and by universities and research organizations. The following organizations participated in or received assistance from the Project in 1976-77:

Arctic Institute of North America
Defence Research Establishment Pacific
Department of Indian Affairs and Northern Development
Environment Canada, Arctic Biological Station
Environment Canada, Canadian Hydrographic Service
Environment Canada, Canadian Wildlife Service
Environment Canada, Fisheries and Marine Service
Environment Canada, Frozen Sea Research Group
Environment Canada, Inland Waters Directorate
National Museums of Canada
Carnegie Museum of Natural History
Milwaukee Public Museum
Swiss Federal Institute of Technology
University of Alberta
University of Bristol
University of British Columbia
University of Calgary
Laurentian University
McGill University
McMaster University
University of Massachusetts
Memorial University
University of Ottawa
University of Toronto
Tubingen University, West Germany
University of Washington
University of Western Ontario
University of Wisconsin

ARCHAEOLOGY

In 1976-77, field work to trace the history of human occupation in the central Arctic was continued. Twelve sites were located at Porden Point, representing occupations in the Independence I, Independence II, Late Dorset, and Thule Inuit periods.

On the Thule Archaeology Conservation Project, excavations were carried out by archaeological teams at Cape Garry and Creswell Bay. At Cape Garry, where three houses were selected for excavation, the site is estimated to have been occupied at approximately A.D. 1100-1300; the Creswell Bay site indicates an approximate age of A.D. 1300-1500.

Archaeological research was also conducted to investigate the nature and extent of Thule Eskimo occupations along the south coast of Banks Island. Data are being sought that might throw light upon cultural interactions between the eastern and western Arctic.

Continued ethnological and ethnohistoric studies in the Sachs Harbour area have revealed that a large part of that population comes from the Mackenzie Delta and a small part from the Copper Eskimo region. Two distinct traditions and cultures can still be observed in these two groups.

BIOLOGY

During the year, many services within the Department of Fisheries and the Environment, as well as the National Museum of Natural Sciences and McGill University, received considerable logistical support from the Project in the conduct of biological studies. The following description is a very brief summary of activities in this area.

Research continued at the National Museum's High Arctic Research Station on Bathurst Island, established in 1968, to investigate the relationships between species of Arctic animals and the behavioural adaptations that enable them to survive in high Arctic environments.

Populations of five species of seabird on the cliffs of Prince Leopold Island were studied to obtain data that can be used in resource management policy and in the identification of ways to protect and maintain endangered species.

An aerial survey in the Mackenzie Delta and Franklin Bay in early July counted approximately 3,250 white whales, of which more than half were immediately outside Shallow Bay. Studies were made of Inuit hunts of narwhal at Pond Inlet and Arctic Bay, to acquire new information on feeding and hunting loss rates; and studies of anadromous Arctic char at Stanwell-Fletcher Lake were carried out to determine the effects of sediment addition on the biota and chemistry of a tundra pond. Balloon trawling in Tuktoyaktuk Harbour and Kugmallit Bay confirmed the existence of large numbers of smelt, and trawling in Liverpool Bay revealed the presence of abundant fish occurring as large itinerant schools.

Field studies have continued on polar bears captured by researchers and those killed by Inuit hunters. Attention is being focused on the possible effects of proposed pipeline channel crossings and staging areas on important bear denning and feeding areas, and on the cultural and economic value of polar bears to Inuit hunters. These studies will be used to assess the impact of a proposed pipeline from the high Arctic Islands to Southern Canada, to determine the status of polar bear populations in the Canadian Arctic, and to increase our understanding of the marked decline in numbers, productivity, and survival of young polar bears and seals in the western Canadian Arctic.

Grizzly bears were captured, tagged, and equipped with radio location telemetry collars in order to obtain data on population, reproduction, recruitment, and movement. Also, ecological studies of Peary caribou continued, concentrating on reproduction. More data are needed on the relationship between physical condition and reproduction.

Studies of caribou and muskoxen are being conducted to describe and delineate some of their habitats along the proposed route of the Arctic Island Pipeline Project and to assess the importance of these habitats to the wildlife populations. Studies on Somerset Island suggest that the Stanwell-Fletcher Lowlands are a key breeding and wintering ground for caribou and for the re-establishment of muskoxen.

Studies of Arctic hare provide information on seasonal changes in numbers and distribution. An aerial survey revealed that hare were not abundant in the Fosheim Peninsula area.

Helicopter flights were made over Prince of Wales Island, simulating the type of flying activity that would likely be associated with the construction and maintenance of a pipeline, to gain insight into the problem of helicopter harassment of Peary caribou and muskoxen. The reactions of individual animals and

herds were observed to vary with the altitude of the flight and the duration of harassment.

Work continued at Holman Island on the population dynamics and birth habitat of the ringed seal. There were a few surprising recoveries of seals, the furthest coming from eastern Siberia.

Studies continued in the vicinity of the Nanisivik Mine to determine the abundance and species composition of aquatic biota in the waters adjacent to the development area. In addition, an extensive aerial survey of marine mammal resources was conducted in the Admiralty and Navy Board Inlet areas, to determine the migration patterns and abundance of narwhal and to assess their use of Strathcona Sound. Environmental studies were conducted to evaluate the impact of disposal tailings from the proposed Arvik Mine.

BOTANY

Lichens from various vegetation communities have been used as indicators of sensitivity to atmospheric pollutants. The sensitivity of lichens depends upon such environmental factors as temperature and atmospheric humidity. A large sampling program was carried out of the grasses growing in fumigated areas in the vicinity of the Smoking Hills on Cape Bathurst, and those occurring in zones of heavy SO_2 fumigation and on heavy metal-contaminated, highly acidic soils. The purpose of the study was to select and develop vegetation capable of growing on highly acidic tailings and mine wastes in the Yukon and Northwest Territories.

CLIMATOLOGY

The Polar Continental Shelf Project continued to provide equipment and considerable logistical support to the Northwater Project as part of the Canadian effort to study this polynia in northern Baffin Bay. It has been deemed essential that the meteorological history be unbroken until a decision is made regarding wintering of a scientific vessel in the Northwater area. Six unmanned OTT automatic weather stations were left operating through the winter in the area, and further measurements were taken of Northwater sea-ice dynamics.

As part of the national weather-forecasting network, twice-daily transmissions of aviation weather reports received from field camps were passed from Resolute to Edmonton Arctic Weather Central during the field season.

A study of the relationship between mass balance and climate on the Devon Island ice cap revealed three basic synoptic types whose frequencies explain very negative and very positive balance years. The weather behind the unusually warm summers of 1969 and 1962 was examined; the 1969 circulation appears to have given very local summer conditions to Devon Island ice cap, whereas 1962 was a summer of very negative mass balances over all the ice caps of the Queen Elizabeth Islands.

GEOLOGY

In 1976-77, 13 different geological investigations, conducted by various organizations (the Geological Survey of Canada, the universities of Western Ontario, Alberta, Ottawa, British Columbia, and Massachusetts, and the Milwaukee Public Museum), were supported in the field by logistical expertise and aircraft supplied by the Polar Continental Shelf Project.

Mapping was completed on Lougheed and Mackenzie King Islands and at Sabine Peninsula on Melville Island. The structural style indicates the presence of a high domain offshore from the southwestern and southern coast of Lougheed Island. Mapping of Somerset Island and the northern half of Boothia Pensinsula was completed also.

Studies of the Brock Inlier of the Melville Hills, Northwest Territories, confirmed the earlier proposed assignation of these rocks to the Shaler Group of Victoria Island. Another study of the stratigraphy and paleoecology of the Upper Silurian rocks along the southeastern coast of Somerset Island revealed several new facts on the Leopold, Read Bay, and Peel Sound Formations.

Basic data necessary for land management were studied on King Christian Island and both onshore and offshore southwestern Ellef Ringnes Island, to determine the susceptibility of the terrain to man-induced disturbance.

Field work of a stratigraphic nature continued to investigate pingos of southwestern Banks Island. From C-14 dates on willow, it is possible to calculate maximum age for the growth of the features and the age of cessation of pingo growth.

Coastal process studies in Barrow Strait ended a three-year investigation of seasonal beach profile change and near-shore characteristics and coastal processes. Repeated resurveying of beach profiles to document shoreline stability has produced a quantitative analysis of shoreline change.

Field studies continued in the Mackenzie Valley and Delta on the genesis of permafrost, with specific reference to ground ice and patterned ground.

Eight terrain disturbance sites on Banks Island were visited under the ALUR (Arctic Land Use Regulations) program. The major component of summer field work was terrain sensitivity mapping on eastern Melville Island, and a survey of well sumps both in the high Arctic Islands and the Mackenzie Delta.

Field work continued on eastern Judge Daly Promontory, Ellesmere Island, to study the former interaction of the Ellesmere Island and Greenland ice sheets.

A substantial collection of vertebrate fossils was collected from a series of localities in the Eureka Sound Formation near Strathcona Fiord, Ellesmere Island. These vertebrates are apparently representative of a warm temperate climate and show an assemblage far more diverse than that which lives in the same region today.

GEOPHYSICS

Eight geophysical projects were supported by the Project during the year. A brief description of these activities follows.

Electromagnetic sounding of ice and permafrost was undertaken near Tuktoyaktuk at the Involuted Hill Test Site and over sea and lake ice.

Three-component fluxgate magnetometers were operated simultaneously by the Earth Physics Branch of the Department of Energy, Mines and Resources, extending from north-central Banks Island to south-central Victoria Island. This work was designed to contribute further to studies of the Mould Bay induction anomaly, to locate its eastern boundary, and to examine the inductive response of Victoria Island, in particular the Precambrian Minto Arch.

Eight new permafrost thickness determinations based on deep temperature measurements in northern drillholes were made in the Mackenzie Delta, again by the Earth Physics Branch. Numerical models have been developed to determine the physical parameters of the surrounding formation, and gas hydrates are being investigated with current emphasis on prediction and detection. Combined seismic and thermal studies of permafrost and hydrates beneath the Beaufort Sea are being continued to map a distribution pattern.

Seven hundred and thirteen stations were observed to complete the regional gravity coverage in the Beaufort Sea and Amundsen Gulf area. The Project's Decca Lambda chain was used for navigation.

Experimental studies using radar sounding and time-domain reflectometry were carried out at various Arctic locations by geophysicists of the Geological Survey of Canada, to delineate the extent of buried massive ice bodies. Radar can be used to map lithology. Ice thickness of freshwater lakes and water depths of shallow lakes and rivers can be determined. The electromagnetic wave velocities of frozen soil and ice are, however, so similar that ice content cannot be inferred from velocity measurements alone.

Research continued by Geological Survey geophysicists on the seismic properties of ice-bonded permafrost and sub-sea-bottom permafrost in the Beaufort Sea. Several oil companies are supporting and participating in this project.

Sonic velocity measurements were carried out in the 1971 and 1972 drillholes to the base of the Devon Island ice cap. A completely unexpected result was that at depths greater than 210 metres velocities decreased rapidly downwards.

The Geological Survey of Canada, in cooperation with the Polar Continental Shelf Project, has developed a portable meterological satellite receiver. The stretched infra-red visible infra-red spin scan radiometer (VISSR) data from a geostationary satellite provided a coarse but timely (every half-hour) view of weather conditions affecting a survey area at Lynn Lake, Manitoba, and complemented the more detailed imagery received from the Polar orbiting satellite operated by the U.S. Naval Oceanographic and Atmospheric Agency (NOAA). At Resolute Bay, only data from the NOAA satellite were received. The images were used by the Project to coordinate airborne support of scientific parties working in the Arctic Islands and by the weather office as an adjunct to the isobaric and forecast maps.

GLACIER PHYSICS AND GLACIOLOGY

In May and June 1976, radio echo soundings were taken on Devon Island ice cap, central Ellesmere Island ice cap, Mer de Glace Agassiz in northern Ellesmere Island, and the main ice cap of Axel Heiberg Island, in search of a borehole site to be drilled in the spring of 1977. Low-order accuracy mass balance networks were set up across the central Ellesmere

ice cap and down the east side of the Axel Heiberg ice cap to provide background data for any future boreholes; and the mass balance of Devon Island ice cap and Meighen ice cap were measured. Final sets of inclinometer measurements were made in the 1971 and 1972 boreholes on the Devon Island ice cap.

Measurements of the amplitude and phase of radio echoes returned from the bed of the Devon Island ice cap were carried out successfully with new phase-sensitive radio echo sounding equipment, in the vicinity of a borehole located near the crest of the ice cap. It was noted that one can detect echoes using a receiving antenna oriented at right angles to the transmitting antenna. These observations were made by a team from Bristol University.

Temperature measurements were taken to the glacier bed at three sites in the ablation area of White Glacier, using an open system hot-water drill developed by scientists from the Swiss Federal Institute of Technology. Work continued on the mass balance measurements of White and Baby glaciers with stake readings and a resurvey of the stake network.

HYDROGRAPHY

A bathymetric survey of Belcher Channel and northern Penny Strait was conducted in the spring of 1976. In conjunction with this program, closely spaced soundings were taken in a corridor through Belcher Channel and along two proposed pipeline crossings. In total, 8,705 spot soundings were taken. Studies of currents were carried out in Belcher Channel and Penny Strait in addition to regular survey operations, and successful field tests were conducted using a vehicle to deploy through-the-ice continuous sounding instruments. The Polar Continental Shelf Project provided aircraft and logistical support to these investigations.

In 1976, the Canadian Hydrographic Service initiated an aerial photography study of 17 artificial islands built by oil companies in the Beaufort Sea, to monitor the construction of these islands and, more specifically, their status after they have been abandoned. Photographs of the islands were taken on July 15, shortly after ice break-up, and again on September 28, shortly before freeze-up. One island disappeared between July and September, and two more are showing signs of rapid disintegration.

Hydrographic surveys continued of the Athabasca-Mackenzie waterway. A survey of Hay River was completed, extending the sounding coverage upstream to the new townsite. An annual revisory survey of the Mackenzie River from Tuktoyaktuk to Mile 0 was conducted. A survey of a proposed shipping route through Eskimo Lakes from Liverpool Bay to Hans Bay revealed that an acceptable route exists throughout the lakes.

HYDROLOGY

Hydrologic studies were carried out in a drainage basin near Resolute Bay to determine accurately the snow storage and rainfall in the basin. Initial results indicate that Atmospheric Environment Service data from Resolute underestimate basin snow storage by 200%, and rainfall data show great variability within the basin.

Studies continued to provide hydrologic information for the construction of highways in the Mackenzie Valley. Data were collected and analyzed for peak discharge, channel velocity, and precipitation at or near selected river crossing points on proposed or present highway routes.

LIMNOLOGY

Solar radiation lake-ice interaction studies took place on several lakes in the Mackenzie Delta area. Considerable background data on chemical and biological water quality were accumulated for these studies. Light penetration measurements were obtained during the crucial late spring period of intense phytobiological activity in the lakes.

OCEANOGRAPHY

Several oceanographic studies were carried out in the Beaufort Sea and the Arctic Archipelago by various agencies, with the support of the Polar Continental Shelf Project. These investigations included winter oceanographic, meteorological, ice movement, and reconnaissance surveys of the shear zone of the southern Beaufort Sea; ice movement studies, using NOAA and LANDSAT satellite imagery to identify patterns of timing of open-water formation; ice movements by radar tracking in Byam Martin and Austin Channels; and a review of compiled data on oceanography of the Arctic Archipelago.

A transect from Grinnell Peninsula to Bathurst Island was surveyed to examine near-surface currents and related physical parameters with a view to determining geostrophic transport through Penny Strait. Also, during April and early May 1976, 20 recording current meters were deployed in Byam and Martin Channels. The meters were located on the sea

floor and just beneath the sea ice. Data were transmitted acoustically to a remote data recording system on Byam Island.

In 1976-77, a continuing study of physical oceanography in d'Iberville Fiord emphasized water structure and its modification by floating glacial ice. A study designed to determine spatial aspects of brine drainage events in and just beneath the sea ice was carried out.

Marine geoscience research was carried out in the eastern Arctic from C.S.S. HUDSON, aimed at studying the margins of Baffin Bay and the crustal structure of central Baffin Bay, and obtaining bedrock geology data on the southeastern Baffin Island shelf. Some diapiric-like structures were observed on traverses off Greenland. A thick sedimentary basin in Home Bay was surveyed. Magnetic and gravity lineations were identified in central Baffin Bay. High-quality seismic data provided good sediment and crustal velocity data. Also, two chemical oceanographical sections and some geophysical data were acquired in Lancaster Sound.

PHOTOGRAPHY

Aerial photography studies were undertaken to examine hydrological and geomorphical conditions associated with proposed engineering projects along the Mackenzie Valley and along the route of the Eastern Arctic Pipeline; to support basic research on mechanical aspects of ice-jamming in the Mackenzie River; and to investigate such diverse matters as historical sites, ice caps, and hydrologic basins.

SEA ICE

The systematic airborne sea-ice reconnaissance surveys conducted by the Polar Continental Shelf Project from April to October 1976 marked the sixteenth consecutive year for this program. Observations of sea-ice conditions were made in the channels of the Arctic Archipelago between Alert and Tuktoyaktuk and from Baffin Bay to the Arctic Ocean eight times during the season.

The Arctic Ice Dynamics Joint Experiment (AIDJEX), a program launched in 1975 in cooperation with the U.S. National Science Foundation, was completed in May 1976. This operation, which was described in the Project's annual report for 1975-76, involved the participation of eight Canadian scientific parties and is judged to have been a success.

LIST OF PUBLICATIONS

Doake, C.S.M., Gorman, M. and Paterson, W.S.B. A further comparison of glacier velocities measured by radio-echo and survey methods. J. Glaciology, 17, 75, 35-38, 1976.

Hobson, G.D., Neave, K.G., MacAulay, H.A. and Hunter, J.A. Permafrost distribution in the southern Beaufort Sea as determined from seismic measurements. Paper presented at NRC Permafrost Symposium, Vancouver, October 1976.

Hunter, J.A., MacAulay, H.A., Neave, K.G. and Hobson, G.D. Seismic mapping of sub-seabottom permafrost in the Beaufort Sea: Recent interpretations. Paper presented at GAC, Vancouver, April 1977.

Koerner, R.M. Distribution of micro-particles in a 299-m core through the Devon Island ice cap, Northwest Territories, Canada. Paper read at the IUGG Conference (IASH) in Grenoble, France, August 1975.

Koerner, R.M., Taniguchi, M. Artificial radioactivity layers in the Devon Island ice cap, Northwest Territories. Can. J. Earth Sci., 13, 9, 1251-1255, 1976.

Koerner, R.M. Climatic interpretations from glacier ice cores. Paper given October 9, 1976 to the Fourth Biennial Meeting of the American Quaternary Association.

Neave, K.G., Hunter, J.A., and Hobson, G.D. Some methods of estimating thickness of ice-bonded sub-seabottom permafrost in the Beaufort Sea. Paper presented at C.S.E.G. Convention, May 1976.

Paterson, W.S.B. Thermal core drilling in ice caps in Arctic Canada. In Ice Core Drilling, 113-116, Univ. Nebraska Press, J.F. Splettstoesser, ed., 1976.

Paterson, W.S.B. Temperatures in the Devon Island ice cap, Arctic Canada. J. Glaciology, 16, 74, 277, 1976.

Paterson, W.S.B. Vertical strain rate measurements in an Arctic ice cap and deductions from them. J. Glaciology, 17, 75, 3-12, 1976.

Paterson, W.S.B. Climatic interpretations from glacier ice cores. American Quaternary Association, Abstr. of Fourth Biennial Meeting, Tempe, Arizona, 16-19, 1976.

Paterson, W.S.B. Radioactive waste disposal in Antarctica: some glaciological aspects. Mod. Geol., 6, 37-42, 1976.

Paterson, W.S.B. Secondary and tertiary creep of ice as measured by borehole closure rates. Rev. Geophys. and Space Phys., 15, 1, 47-55, 1977.

Paterson, W.S.B., Koerner, R.M., Fisher, D., Johnsen, J.J., Clausen, H.B., Dansgaard, W., Bucher, P., and Oeschger, H. An oxygen-isotope climatic record from the Devon Island ice cap, Arctic Canada. Nature, 266, 508-511, 1977.

EXPLOSIVES BRANCH

B.P. McHugh, Director

The Explosives Branch is responsible for the administration of the Canada Explosives Act and related activities in the explosives field. Such responsibility includes control over all factories that produce commercial blasting explosives, military explosives, blasting accessories, sporting ammunition, fireworks, and other pyrotechnics, and control of the quality and safety of these products. The Branch also monitors road transportation, storage, sale, and importation of explosives.

Control is exercised by a system of licensing, supported by inspections carried out by Branch staff. In 1976-77, the Branch had a total staff of 25, including 10 professionals, of whom 60% were based in headquarters and regional offices in Ottawa and the remainder spread among four other regional offices in Halifax, Nova Scotia; Sillery, Quebec; Calgary, Alberta; and Vancouver, British Columbia. The budget for the past fiscal year totalled $583,000.

In 1976-77, 74 licensed factories produced about 258,853,000 kilograms of commercial explosives, as compared with 70 factories manufacturing 238,714,000 kilograms in the previous year. In addition, 21,615,000 kilograms of mixed ammonium nitrate and fuel oil were produced by on-site users. More than 4,000 licences and permits were issued by the Ottawa headquarters, and 1,645 inspections of factories and storage facilities were carried out. There were no major accidents during the year.

Members of the Branch participated in the following committee activities supported by various national and international organizations:

The United Nations Group of Experts on Explosives

The federal government's Interdepartmental Technical Committee on Transportation of Dangerous Goods

The Department of Transport Policy Council and the Executive Committee on the Transport of Dangerous Goods

The Canadian Transport Commission's Task Force on Dangerous Goods

Various advisory committees on explosives safety and training

The Branch continued to provide courses to qualify candidates as licensed Fireworks Supervisors, and 588 persons received this training at centres across Canada in 1976-77. In addition, safety literature was produced and distributed to organizations and individuals concerned about the storage, handling, and transportation of explosives.

CANADA CENTRE FOR GEOSCIENCE DATA

C.F. BURK, JR., DIRECTOR

The Canada Centre for Geoscience Data is responsible for the development and operation of national scientific and technical information systems for Canadian geoscience. During the year, a new policy framework was established for the Centre, identifying the following role and functions:

> The Centre operates within the context of a national scientific and technical information (STI) system in collaboration with interested Canadian agencies and users.
>
> The principal function of the Centre is to provide a national referral service for the benefit of government bodies, industry, and the academic community. This is based primarily on the national inventory of sources of geoscience data managed by the Centre.
>
> Subject matter covered by the Centre is limited to the geosciences dealing with the Canadian landmass and its offshore regions, emphasizing non-renewable energy and mineral resources.
>
> The Centre's referral functions direct users to sources of "data" – that is, to observations, measurements, statistics, and other essentially factual information and not to geoscience literature and documentation in general.
>
> The Centre deals operationally with "secondary" information only – that is, with information on information, typically in the form of bibliographic or other references to "primary" information.

The national STI system within which the Centre operates, designated as the Canadian Geoscience Data Referral System, has replaced the Earth Resources Data System described in reports of previous years. The latter system was cancelled in August 1976.

Within the framework of the Canadian Geoscience Data Referral System, the Centre coordinates a national data inventory program, manages the national referral files, and offers services based on these and other sources of secondary information. In addition, it coordinates certain departmental information activities and contributes to programs of international non-governmental organizations dealing with scientific and technical information.

Expenditures by the Centre for 1976/77 were $177,000, up $44,000 from the previous year, reflecting the additional cost of service-related operations. The branch had a total staff of five, including three professionals, all based in Ottawa.

DATA REFERRAL SERVICE

The Canadian Index to Geoscience Data, the Centre's major computer-based referral file, grew throughout the year to a total of 56,500 entries. Each entry describes a document which contains geoscience data on the Canadian landmass or its offshore regions, and which is published or held by one of the 13 organizations contributing to the Index. The following contributors were active in 1976-77:

Alberta Research Council
Canadian Society of Petroleum Geologists
Department of Energy, Mines and Resources,
  Earth Physics Branch
  Mineral Development Sector
Department of Indian Affairs and Northern Development
  Exploration and Geological Services Unit
New Brunswick Department of Natural Resources
Newfoundland Department of Mines and Energy
Nova Scotia Department of Mines
Ontario Ministry of Natural Resources
Quebec Ministry of Natural Resources
Saskatchewan Department of Mineral Resources

The Geological Survey of Canada and the Department of Indian Affairs and Northern Development, Oil and Gas Division, which normally provide entries to the Index, were temporarily inactive during the year.

The Centre continued to investigate and apply advancements in computer-based information processing and publishing, and to provide advice and assistance in these areas to the contributing agencies and to other groups within the Department of Energy, Mines and Resources. Fifty-eight custom indexes were prepared for users in industry, universities and federal and provincial governments; they were provided in the form of high-speed printouts, photocomposed copy ready for publication, microfiche, and magnetic tape. Indexes were published by four contributing agencies, using the national file and the Centre's processing facilities.

The Geoscience Index Advisory Committee, through which the contributing agencies advise the Centre of their own requirements and those of their users, met in September in Quebec City. Work is nearly complete on revision of The Thesaurus of the Canadian Index to Geoscience Data, to make it compatible with international standards established by the Abstracting Board of the International Council of Scientific Unions.

SYSTEMS PLANNING AND DEVELOPMENT

Early in 1977, responsibilities for file management software were transferred to the Canada Centre for Geoscience Data from the Department's Computer Science Centre. At the time of the transfer, the system was renamed PRIM-1 (Package for Reference Index Management-version 1). Procedures for software management were established, permitting the controlled implementation of a number of additions, including an online text-scanning facility. A computer-processable library of computer programs was established to maintain rigid software control. Also, among the procedures was a formal means of requesting and subsequently documenting activities, such as revisions, to be carried out on the software. A standard for the documentation of each program was implemented.

During the year, a systems and procedures manual was developed for the Canadian Index to Geoscience Data file. The purpose of the manual is to provide concise and accurate documentation on all aspects of the system, and it is the first handbook of this type to be prepared by the Centre.

A study was initiated to determine the feasibility of a change in the Centre's data management systems. In parallel to this activity, a detailed definition and analysis of branch and user requirements will be conducted. This study may result in a decision to develop and implement a new data management system for use within the Canadian Geoscience Data Referral System by the latter part of 1977-78 or early 1978-79.

INTERNATIONAL ACTIVITIES

Until October 1976, the Centre continued to serve as secretariat for the Committee on Storage, Automatic Processing and Retrieval of Geological Data (COGEODATA) of the International Union of Geological Sciences (IUGS), at which time this function was transferred to the Federal Institute for Geosciences and Natural Resources of the Federal Republic of Germany. Four issues of COGEODATA NEWSLETTER were edited and published on behalf of the IUGS.

In the United States, the Centre contributed to a national study on "data indexing" carried out by Informatics Inc. for the National Science Foundation. Preliminary discussions were held with the American Geological Institute on the exchange of bibliographic data between their GEO.REF file and the Canadian Index to Geoscience Data.

PUBLISHED INDEXES

Technical Reports 1976: Department of Indian and Northern Affairs, Exploration and Geological Services Unit, 1976, 280 p.

Index to Uranium Assessment Reports for Quartz Mineral Exploration Permits, by M. Poruks and W.N. Hamilton: Alberta Research Council, Report 76-6, 1976, 81 p.

Open File Rept. 5210 (Index to assessment work and reports on Mineral Exploration Assistance Program 1946-76): Ontario Division of Mines, 1976, 9 p., 60 microfiche.

Index to Mineral Assessment Reports to 1976, by D.J. Gregory: Dept. Mines, Report 77-2, 1977, 380 p.

GEOLOGICAL SURVEY OF CANADA

NAME	DEGREES	CLASS TITLE
OFFICE OF THE DIRECTOR-GENERAL		
D.J. McLaren	M.A. (Cantab.), Ph.D. (Michigan), F.R.S.C.	Director General
J.O. Wheeler	B.A.Sc., Ph.D. (Columbia), F.R.S.C.	Deputy Director General
J.G. Fyles	B.A.Sc., M.A.Sc. (British Columbia), Ph.D. (Ohio State), F.R.S.C.	Res. Man.
E. Hall	B.Sc. (McGill)	Phys. Sci.
SPECIAL PROJECTS		
R.J.W. Douglas	B.Sc. (Queen's), Ph.D. (Columbia), F.R.S.C.	Res. Sci.
T.E. Bolton	M.A., Ph.D. (Toronto)	Res. Sci.
DATA MANAGEMENT SYSTEMS GROUP		
W.W. Hutchison	B.Sc. (Aberdeen), M.A. (Toronto), Ph.D. (Toronto)	Res. Sci.
G. Martin	B.Sc. (Leeds)	Phys. Sci.
T. Scaga		D.A.
D.D. Picklyk	B.Sc. (Carleton), D.I.C. (Imperial), Ph.D. (Queen's)	Res. Sci.
PROGRAM OFFICE		
J.E. Brindle	B.Sc. (Manchester), Ph.D. (Glasgow)	Phys. Sci.
D.W. Stalker	B.Sc. (Queen's)	Phys. Sci.
M.A. Petre	B.A. (Carleton)	Phys. Sci.
ATLANTIC GEOSCIENCE CENTRE		
B.D. Loncarevic,	B.A.Sc., M.A. (Toronto), Ph.D. (Cantab.)	Res. Man.
Environmental Marine Geology Subdivision		
D.E. Buckley, Head	B.Sc. (Acadia), M.Sc. (Western Ontario)	Phys. Sci.
Sediment Dynamics		
S.B. McCann	B.Sc. (Wales), Ph.D. (Cambridge)	Res. Sci.
G. Reinson	B.A.Sc. (Saskatchewan), Ph.D. (Aust. National Univ.)	Res. Sci.
D.H. Frobel	B.Sc. (Carleton)	Tech.
Marine Geochemistry		
MA. Rashid	B.Sc. (India), M.Sc. (Oklahoma), Ph.D. (Utah)	Res. Sci.
R.E. Cranston	B.Sc. (Alberta), M.Sc. (Dalhousie)	Phys. Sci.
G.V. Winters	B.Sc. (St. Mary's)	Phys. Sci.
G.H.E. Joice	B.Sc. (Guelph), M.Sc. (Toronto)	Phys. Sci.
R.A. Fitzgerald	B.Sc. (St. Mary's)	Tech.

Paleoecology

C.T. Schafer	B.Sc. M.Sc. Ph.D. (New York)	Res. Sci.
G. Vilks	B.Sc. (McMaster), M.Sc., Ph.D. (Dalhousie)	Res. Sci.
F.J.E. Wagner	B.A., M.A. (Toronto), M.Sc., Ph.D. (Stanford)	Res. Sci.
D.A. Walker	B.Sc. (Dalhousie)	Phys. Sci.
F. Cole	B.A. (Queen's)	Tech.

Eastern Petroleum Geology Subdivision

L.P. Purcell, Head	B.Sc. (Alberta)	Res. Man.
P.A. Hacquebard	B.Sc. M.Sc. (Leiden), Ph.D. (Groningen) F.R.S.C.	Res. Sci.
P. Ascoli	B.A., Mc., Ph.D. (Milano)	Res. Sci.
F.M. Gradstein	B.Sc., M.Sc., Ph.D. (Utrecht)	Res. Sci.
I.M. Harris	B.A. (Acadia), B.Sc. (Alberta), 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. (University College, London), Ph.D. (Sheffield)	Res. Sci.
A.C. Grant	B.A. (Acadia), B.Sc. (Dalhousie), M.Sc. (New Brunswick)	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.
J.P. Bujak	B.Sc. (Sheffield), Ph.D. (Sheffield)	Res. Sci.

Regional Reconnaissance Subdivision

D.I. Ross, Head	B.Sc. (Victoria), M.Sc., Ph.D. (New Zealand)	Res. Man.

Surficial and Bedrock Geology

L.H. King	B.Sc. (Acadia), Ph.D. (M.I.T.)	Res. Sci.
B. MacLean	B.A. (Acadia)	Phys. Sci.
G. Fader	B.Sc. (St. Mary's)	Phys. Sci.
W.H. Josenhans	B.Sc. (Dalhousie)	Phys. Sci.

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. Folinsbee	B.Sc. (Alberta), M.Sc., Ph.D. (M.I.T.)	Phys. Sci.
J.M. Woodside	B.Sc. (Queen's), M.Sc. (M.I.T.), Ph.D. (Cambridge)	Phys. Sci.

Eastern Arctic Group

R.K.H. Falconer	B.Sc., Ph.D. (Victoria, N.Z.)	Res. Sci.

Labrador Sea Studies

S.P. Srivastava	B.Sc., M.Sc. (Kharagpur, India), Ph.D. (British Columbia)	Res. Sci.
R.H. Fillon	B.Sc. (Pennsylvania), M.Sc. (Vermont), Ph.D.	Res. Sci.
D.B. Livingstone	B.Sc. (British Columbia)	Tech.

Program Support Subdivision

K.S. Manchester, Head	M.Sc. (Dalhousie)	Phys. Sci.
Instrument Operation and Maintenance		
T.J. Corbett		Tech.
Systems Development		
D.E. Heffler	B.Sc. (Dalhousie), M.Sc. (Saskatchewan)	Eng.
Postdoctorate Fellows		
C.L. Amos	B.Sc. (Wales), Ph.D. (Imperial)	
B.J.N. Long	B.Sc. (Nantes), M.Sc. (Nantes), Ph.D. (Toulouse)	
S. Hada	B.Sc., M.Sc., D.Sc. (Osaka City)	
J.D. Willey	B.Sc. (Duke), Ph.D. (Dalhousie)	
P. Rosen		

CENTRAL LABORATORIES AND ADMINISTRATIVE SERVICES DIVISION

J.A. Maxwell, Director	B.Sc., M.Sc. (McMaster), Ph.D. (Minnesota), 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), C.Chem., F.R.I.C.	Chem.
G.R. Lachance	B.Sc. (Carleton)	Res. Sci.
R. Rousseau	B.Sc., Ph.D. (Laval)	Tech.
J.L. Bouvier	B.Sc., Ph.D. (Laval)	Tech.
Spectrographic Laboratories		
W.H. Champ	B.A. (McMaster)	Chem.
K.A. Church		Tech.

Mineralogy Section

R.J. Traill	B.Sc., M.Sc., Ph.D. (Queen's)	Phys. Sci.
Mineralogical Studies		
A.G. Plant	B.Sc., Ph.D. (Bristol)	Phys. Sci.
A.P. Stenson	B.Sc. (Manitoba)	Phys. Sci.
G.J. Pringle	B.Sc., M.Sc. (New Brunswick)	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.
D.A. Walker	B.Sc. (Dalhousie)	Phys. Sci.
D.M. Watson	B.Sc. (Carleton)	Phys. Sci.
Mineral Separation and Sample Preparation		
J.C. Paris		Tech.

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.

Technical Services Section

G.A. Meilleur		Tech.

GEOLOGICAL INFORMATION DIVISION

P. Harker, Director	B.Sc. (London), M.A. (Cantab.), Ph.D. (Michigan)	Phys. Sci.
R.G. Blackadar, Asst. Director	B.A., MA., Ph.D. (Toronto)	Phys. Sci.
P.J. Griffin	B.Sc. (Ottawa)	Phys. Sci.
L.E. Vincent	B.Sc. (Laval)	Phys. Sci.

Production, Editing and Layout

L.R. Mahoney

Publications Information and Publications Distribution

J.L. Touchette

Photographic Services

J.W. Kempt

Library Services

D.M. Sutherland, Head	B.A. (Saskatchewan), B.L.S. (Toronto)	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.
A. Solyma	B.A., B.L.S. (Alberta)	Lib.

Cartography

J.G. Roberts

INSTITUTE OF SEDIMENTARY AND PETROLEUM GEOLOGY

D.F. Stott, Director	B.Sc., M.Sc. (Manitoba), M.A., Ph.D. (Princeton)	Res. Man.

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. (Saskatchewan), M.A. (Toronto), Ph.D. (Kansas), F.R.S.C.	Res. Sci.
R.L. Christie	B.A. (British Columbia), M.Sc., Ph.D. (Toronto)	Res. Sci.
J.W. Kerr	B.Sc. (Alberta), Ph.D. (Columbia)	Res. Sci.
H.P. Trettin	Dr. Phil. (Hamburg), M.Sc., Ph.D. (British Columbia)	Res. Sci.
A.D. Miall	B.Sc. (London), Ph.D. (Ottawa)	Res. Sci.
U. Mayr	Ph.D. (Ottawa)	Res. Sci.

Mainland Section

D.G. Cook	B.Sc., M.Sc., Ph.D. (Queen's)	Res. Sci.
J.D. Aitken	B.Sc. (British Columbia), Ph.D. (California)	Res. Sci.
M.P. Cecile	B.A. (Waterloo), Ph.D. (Carleton)	Res. Sci.
D.C. Pugh	B.Sc. (London), Ph.D. (Paris)	Res. Sci.
N.C. Meijer-Drees	B.Sc., M.Sc. (Utrecht)	Phys. Sci.
G.K. Williams	B.Sc. (Alberta)	Phys. Sci.
R.I. Thompson	B.Sc. (Queen's), Ph.D. (Queen's)	Res. Sci.
D.W. Morrow	B.Sc. (British Columbia), Ph.D. (Texas)	Res. Sci.
E.R.W. Neale	B.Sc. (McGill), Ph.D. (Yale), F.R.S.C.	Res. Sci.

Sverdrup-Mackenzie Section

H.R. Balkwill	B.Sc. (Queen's), M.Sc. (S. Carolina), Ph.D. (Texas)	Res. Sci.
F.G. Young	B.Sc., M.Sc., Ph.D. (Queen's)	Res. Sci.
R. Rahmani	B.Sc. (Bagdad), M.Sc. (British Columbia), Ph.D. (Alberta)	Res. Sci.
A.F. Embry	B.Sc. (Manitoba), Ph.D. (Calgary)	Res. Sci.

Curation and Technical Services

L.L. Price	B.Sc. (Manitoba)	Phys. Sci.
M.A. MacKenzie	B.A. (Calgary)	Tech.
R.J. Broadfield	B.Ed. (Calgary)	Tech.

Coal Geology Subdivision

D.K. Norris, Head	B.A., M.A. (Toronto), Ph.D. (C.I.T.)	Res. Sci.

Coal Technology Section

A.R. Cameron	B.Sc. (St. Francis Xavier), M.Sc., Ph.D. (Penn. State)	Res. Sci.
P.R. Gunther	M.Sc. (Calgary)	Phys. Sci.

Resource Evaluation Section

B.A. Latour	B.A. (Saskatchewan)	Phys. Sci.
J.A. Irvine	B.Sc. (British Columbia)	Phys. Sci.
P.S. Graham	B.Sc. (Calgary)	Phys. Sci.
C.F. Stevens	B.Sc. (Dalhousie)	Phys. Sci.
J.D. Hughes	B.Sc., M.Sc.(Alberta)	Phys. Sci.

Coal Geology Section

J.R. McLean	B.Sc. (Saskatchewan), Ph.D. (Saskatchean)	Res. Sci.
N.C. Ollerenshaw	B.Sc. (Wales), M.A., Ph.D. (Toronto)	Res. Sci.
D.W. Gibson	B.Sc. (Queen's), Ph.D. (Toronto)	Res. Sci.
D.G.F. Long	B.Sc. (Leicester), Ph.D. (Western Ontario)	Res. Sci.

Paleontology Subdivision

B.S. Norford	M.A. (Cantab.), M.Sc., Ph.D. (Yale)	Res. Man.

Macropaleontology Section

A.W. Norris	B.Sc., M.Sc. (Alberta), Ph.D. (Toronto)	Res. Sci.
E.W. Bamber	B.Sc. (Alberta), M.A., Ph.D. (Princeton)	Res. Sci.
W.W. Nassichuk	B.Sc. (British Columbia), M.Sc., Ph.D. (Iowa)	Res. Sci.
A.E.H. Pedder	B.A., M.A. (Cantab.), Ph.D. (New Eng., Australia)	Res. Sci.

Micropaleontology Section

J.H. Wall	B.Sc. (New Brunswick), M.Sc. (Alberta) Ph.D. (Missouri)	Res. Sci.
W.S. Hopkins, Jr.	B.Sc. (Washington), M.Sc., Ph.D. (British Columbia)	Res. Sci.
A.R. Sweet	B.Sc. (Alberta), Ph.D. (Calgary)	Res. Sci.
W.A.M. Jenkins	B.Sc. (Duneln, Diploma College, London), Ph.D. (Sheffield)	Res. Sci.
S.A. Pickering	B.Ed. (Calgary)	Tech.

Ottawa Paleontology Section

E.T. Tozer	M.A. (Cantab.), Ph.D. (Toronto), 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.

Energy Subdivision

R.G. McCrossan, Head	B.A. (British Columbia), M.Sc., Ph.D. (Chicago)	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.
R.A. Davidson	B.A., B.Sc. (Calgary)	Tech.

Petroleum Resources Section

E.C. Dahlberg	A.B. (Williams), Ph.D. (Penn. State)	Phys. Sci.
R.M. Procter	B.Sc., M.Sc. (Manitoba), Ph.D. (Kansas)	Res. Man.
N.E. Haimila	B.A., Sc. (British Columbia), Ph.D. (Mich. State)	Phys. Sci.
A.A. Densmore	B.A. (Queen's), M.Sc. (McGill)	Phys. Sci.
N.G. Wilson	B.Sc. (British Columbia)	Phys. Sci.
R.L. Baird	B.A., B.Sc. (Saskatchewan)	Phys. Sci.

Data Management

K.N. Nairn	B.Sc. (Saskatchewan), M.A.Sc. (Toronto)	Phys. Sci.

Geological Information Subdivision

E.J.W. Irish	M.A. (British Columbia), Ph.D. (Illinois)	Phys. Sci.
C.E. Findlay	B.A. (Sir George Williams)	

Cartography

L. MacLachlan		

Library

M. Jones		Lib.
J.C. Graff	B.A., B.L.S. (Alberta)	Lib.

Photography

D.G. Lawrence		

REGIONAL AND ECONOMIC GEOLOGY DIVISION

J.E. Reesor, Director	B.A.Sc. (British Columbia), Ph.D. (Princeton)	Res. Man.
I.M. Stevenson, Assistant Director	B.Sc., M.Sc., Ph.D. (McGill)	Res. Man.

Cordillera and Pacific Margin Subdivision

H. Gabrielse, Head	B.A.Sc., M.Sc. (British Columbia), Ph.D. (Columbia), F.R.S.C.	Res. Man.

Information Services

M.K. Akehurst	B.A., M.L.S. (British Columbia)	L.S.
J.W. Hinchliffe	B.A. (Waterloo)	S.I.

Micropaleontology

B.E.B. Cameron	B.Sc., M.Sc. (Alberta), Ph.D. (Stanford)	Phys. Sci.
S.E. Banninger	B.A. (British Columbia)	Tech.

Geological Research

J.G. Souther	B.A.Sc. (British Columbia), Ph.D. (Princeton)	Res. Sci.
J.A. Roddick	B.A.Sc. (British Columbia), M.Sc. (C.I.T.), Ph.D. (Washington)	Res. Sci.
S.L. Blusson	B.A.Sc. (British Columbia), Ph.D. (Berkeley)	Res. Sci.
J.W.H. Monger	B.Sc. (Reading), M.Sc. (Kansas), Ph.D. (British Columbia)	Res. Sci.
H.W. Tipper	B.Sc. (Western Ontario), Ph.D. (State College of Wash.)	Res. Sci.
R.B. Campbell	B.A.Sc. (British Columbia), M.Sc., Ph.D. (C.I.T.)	Res. Sci.
J.E. Muller	B.Sc. (Groningen), M.Sc. (Leiden), Ph.D. (Groningen)	Res. Sci.
G.H. Eisbacher	Dr. Phil. (Innsbruck), M.A., Ph.D. (Princeton)	Res. Sci.
D.J. Tempelman-Kluit	B.Sc., M.A.Sc. (British Columbia), Ph.D. (McGill)	Res. Sci.
T.A. Richards	B.Sc., Ph.D. (British Columbia)	Res. Sci.
C.J. Dodds	B.Sc. (London), M.Sc. (Alberta)	Phys. Sci.
S.F. Leaming	B.A. (Brandon), M.A. (Toronto)	Phys. Sci.
G.J. Woodsworth	B.Sc. (British Columbia), Ph.D. (Princeton)	Res. Sci.

Marine Geology

D.L. Tiffin	B.A.Sc., Ph.D. (British Columbia)	Res. Sci.
C.J. Yorath	B.Sc. (British Columbia), M.Sc. (Alberta), Ph.D. (Queen's)	Res. Sci. Res. Sci.
R.G. Currie	B.Sc., M.Sc. (British Columbia)	Phys. Sci.
D.A. Seeman	B.Sc. (British Columbia)	Tech.
I.I. Frydecky	B.A.Sc. (British Columbia)	Tech.

Precambrian Subdivision

W.F. Fahrig	B.Sc. (Manitoba), M.Sc., Ph.D. (Chicago)	Res. Man.
R. Skinner	B.A.Sc., (British Columbia), M.Sc., Ph.D. (McGill)	Res Sci.
J.H. Maley	B.Sc. (Queen's)	Phys. Sci.
W.N. Houston	B.Sc., M.Sc. (McMaster)	Phys. Sci.
R.K. Herd	B.Sc. (Toronto), D.I.C. (London), Ph.D. (London)	Res. Sci.

Special Projects

W.R.A. Baragar	B.A.Sc. (British Columbia), M.Sc. (Queen's), Ph.D. (Columbia)	Res. Sci.
M.J. Frarey	B.Sc. (Western Ontario), M.Sc., Ph.D. (Michigan)	Res. Sci.
F.C. Taylor	B.Sc. (Western Ontario), M.Sc., Ph.D. (McGill)	Res. Sci.

Bear-Slave Section

J.C. McGlynn	B.Sc., M.Sc. (Queen's), Ph.D. (Chicago)	Res. Sci.
F.H.A. Campbell	B.Sc., M.Sc. (Dalhousie), Ph.D. (Manitoba)	Res. Sci.
R.A. Frith	B.Sc. (Mt. Allison), Ph.D. (McGill)	Res. Sci.
J.B. Henderson	B.Sc. (Queen's), M.Sc., Ph.D. (Johns Hopkins)	Res. Sci.
P.F. Hoffman	B.Sc. (McMaster), M.A., Ph.D. (Johns Hopkins)	Res. Sci.
M.B. Lambert	B.Sc., M.Sc. (British Columbia) Ph.D. (Carleton)	Res. Sci.

Northern Churchill Section

K.E. Eade	B.Sc. (Queen's), M.Sc., Ph.D. (McGill)	Res. Sci.
J.A. Fraser	B.A.Sc. (Toronto), M.A. (British Columbia), Ph.D. (Minnesota)	
T. Frisch	B.Sc. (Queen's), Ph.D. (California)	Res. Sci.
W.W. Heywood	B.A.Sc. (British Columbia), M.Sc., Ph.D. (Washington)	Res. Sci.
G.D. Jackson	B.Sc., M.Sc., Ph.D. (McGill)	Res. Sci.
A.N. LeCheminant	B.Sc. (Carleton), Ph.D. (British Columbia)	Res. Sci.
W.C. Morgan	B.Sc., M.Sc., Ph.D. (Aberdeen)	Res. Sci.
M.P. Schau	B.Sc., Ph.D. (British Columbia)	Res. Sci.

Superior-Grenville Section

R.H. Ridler	B.A. Sc., M.A.Sc. (Toronto), Ph.D. (Wisconsin)	Res. Sci.
J.H. Bourne	B.Sc. (McGill), M.Sc., Ph.D. (Queen's)	Res. Sci.
A. Davidson	B.Sc., M.Sc., Ph.D. (British Columbia)	Res. Sci.
W.L. Davison	B.Sc., M.Sc. (Dalhousie)	Res. Sci.
I.F. Ermanovics	B.Sc. (Carleton), M.Sc. (Western Ontario), Ph.D. (Queen's)	Res. Sci.

Paleomagnetic 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	B.A.Sc. (British Columbia), M.Sc. (Queen's), Ph.D. (Princeton) F.R.S.C.	Res. Man.
F.D. Anderson	B.Sc. (New Brunswick), M.Sc., Ph.D. (McGill)	Res. Sci.

Mineral Commodity Reviewer

P. Moyd	B.A. (Columbia), M.A. (Bryn Mawr)	Phys. Sci.

Mineral Resources Liaison Officer and NREP Coordinator

D.C. Findlay	B.Sc., M.Sc. (McGill), Ph.D. (Queen's)	Res. Sci.

Special Projects

G.A. Gross	B.A., M.A. (Queen's), Ph.D. (Wisconsin)	Res. Sci.

Mineral Deposits Geology Section

D.F. Sangster	B.Sc. (Bishop's), B.Sc., M.Sc. (McGill), Ph.D. (British Columbia)	Res. Sci.
J.J. Carrière	B.Sc. (Laurentian)	Phys. Sci.
K.R. Dawson	B.Sc. (New Brunswick), M.A., Ph.D. (Toronto)	Res. Sci.
O.R. Eckstrand	B.Sc., M.Sc. (Saskatchewan), Ph.D. (Harvard)	Res. Sci.
R.V. Kirkham	B.Sc., M.Sc. (British Columbia), Ph.D. (Wisconsin)	Res. Sci.
C.R. McLeod	B.A. (Acadia)	Phys. Sci.
R. Mulligan	B.Sc. (Alberta), M.Sc., Ph.D. (McGill)	Res. Sci.
E.R. Rose	B.A. (Western Ontario), M.A., Ph.D. (Queen's)	Res. Sci.
R.I. Thorpe	B.Sc. (Acadia), M.Sc. (Queen's), Ph.D. (Wisconsin)	Res. Sci.
R.L. Lancaster	B.Sc. (St. Francis Xavier)	Res. Sci.
F.M. Vokes	B.Sc., M.Sc. (Leeds), Ph.D. (Oslo)	Res. Sci.
K.M. Dawson	B.Sc., Ph.D. (British Columbia)	Res. Sci.
D. Watson	B.Sc. (Carleton)	Phys. Sci.
J.M. Duke	B.Sc., M.Sc. (McGill), Ph.D. (Connecticut)	Res. Sci.
J.M. Franklin	B.Sc., M.Sc., Ph.D. (Carleton)	Res. Sci.
A. Soregaroli	B.Sc. (Iowa State), M.Sc. (Idaho), Ph.D. (British Columbia)	Res. Sci.

Geomathematics Section

F.P. Agterberg	B.A., M.Sc., Ph.D. (Utrecht)	Res. Sci.
C.F. Chung	B.Sc. (Sogang, Korea), M.Sc. (Carleton)	Comp. Sci.
A.G. Fabbri	B.A., M.A. (Bologna)	Phys. Sci.
R.M. Laramée	B.Sc. (Montreal)	Phys. Sci.
R. Divi	B.Sc., M.Sc. (Andhra, India), Ph.D. (Ottawa)	Phys. Sci.

Uranium Resource Evaluation Section

V. Ruzicka	Abs., Dr. R. Nat. (Charles, Czech.)	Res. Sci.
S.S. Gandhi	B.Sc. (Bombay), M.Sc. (Karnatak), M.Sc., Ph.D. (McGill)	Res. Sci.
J.Y.H. Rimsaite	B.Sc. (Kaunas, Lithuania), M.A. (Queen's) Ph.D. (George August, Germany)	Res. Sci.
L.P. Tremblay	B.A., B.Sc., M.Sc. (Laval), Ph.D. (Toronto)	Res. Sci.
H.E. Dunsmore	B.A., B.Sc. (Queen's), M.Sc. (Calgary) Ph.D. (London)	Res. Sci.
R.T. Bell	B.A., M.A. (Toronto), Ph.D. (Princeton)	Res. Sci.
A. Boyer	B.Sc. (Montreal)	Phys. Sci.
A. Miller	B.Sc. (Carleton) M.Sc. (Western Ontario)	Phys. Sci.
J. Kerswill	B.Sc. (McGill), M.Sc. (Western Ontario)	Phys. Sci.
L.D. Jones	B.Sc. (Carleton)	Phys. Sci.
N. Prasad	B.Sc., M.Sc. (Lucknow), M.Sc. (McMaster)	Phys. Sci.
M. Turay	Licence Sc. (U. Cath. Louvain, Belgium)	Phys. Sci.

Mineral Data Bank

K.W. Shewbridge	B.Sc. (McMaster)	Phys. Sci.
D.G. Rose	B.Sc. (New Brunswick)	Phys. Sci.
R. Telewiak	B.Sc. (Carleton)	Phys. Sci.

Correlation and Standards Subdivision

W.H. Poole	B.A.Sc. (British Columbia), Ph.D. (Princeton)	Res. Man.
J. MacManus	B.A. (Lancaster, England)	Phys. Sci.

Petrography-Paleontological Service Section

B.J. Botte		Tech.
D.C. Brown	B.Sc. (Dalhousie)	Tech.

Petrology Section

K.L. Currie	B.Sc. (Queen's), M.Sc., Ph.D. (Chicago)	Res. Sci.
E. Froese	B.Sc., M.Sc. (Saskatchewan), Ph.D. (Queen's)	Res. Sci.
T.M. Gordon	B.A.Sc. (British Columbia), M.A., Ph.D. (Princeton)	Res. Sci.
R.F. Emslie	B.Sc., M.Sc. (Manitoba), Ph.D. (Northwestern)	Res. Sci.
A.V. Okulitch	B.A.Sc., Ph.D. (British Columbia)	Res. Sci.

Geochronology Section

R.K. Wanless	B.Sc., M.Sc., Ph.D. (McMaster)	Res. Sci.
W.D. Loveridge	B.Sc., M.Sc. (Manitoba)	Phys. Sci.
J.L. MacRae	B.Sc. (Carleton)	Phys. Sci.
R.D. Stevens	B.Sc., M.Sc. (Sydney)	Phys. Sci.
R.W. Sullivan	B.Sc. (Carleton)	Chem.

Eastern Paleontology Section

M.J. Copeland	B.A., M.A. (Toronto), Ph.D. (Michigan)	Res. Sci.
W.T. Dean	B.Sc. (Leeds), Ph.D. (Bristol), D.Sc. (Leeds)	Res. Sci.
W.H. Fritz	B.Sc., M.Sc., Ph.D. (Washington)	Res. Sci.
D.C. McGregor	B.A., M.Sc., Ph.D. (McMaster)	Res. Sci.

Appalachian Section

D.G. Benson	B.Sc., M.Sc. (New Brunswick), (M.I.T.), Ph.D. (McGill)	Res. Sci.
H.H. Bostock	B.Sc. (Queen's), M.A.Sc. (British Columbia) Ph.D. (Wisconsin)	Res. Sci.
F.W. Chandler	B.Sc. (London), Ph.D. (Western Ontario)	Res. Sci.
L.M. Cumming	B.Sc., M.Sc. (New Brunswick) Ph.D. (Wisconsin)	Res. Sci.
H.H.J. Geldsetzer	B.Sc. (Washington), M.S. (Seattle), Ph.D. (Queen's)	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.
A. Larochelle, Assist. Director	B.A., B.A.Sc. (Laval), M.Sc. (St. Louis), Ph.D. (McGill)	Res. Man.

Special Projects

R.W. Boyle	B.Sc., M.Sc., Ph.D. (Toronto), F.R.S.C.	Res. Sci.
B.E. Manistre	B.A., M.A. (Cantab.)	Phys. Sci.

Electrical Methods

L.S. Collett	B.Sc. (McMaster), M.A. (Toronto)	Res. Sci.
A.P. Annan	B.A.Sc., M.Sc. (Toronto), Ph.D. (Memorial)	Res. Sci.
J.L. Davis	B.Sc. (Loyola), M.Sc. (Cantab.)	Phys. Sci.
A.V. Dyck	B.Sc. (Waterloo), M.Sc. (Toronto)	Phys. Sci.
T.J. Katsube	B. Eng., M. Eng., Dr. Eng. (Tokyo)	Res. Sci.
W.J. Scott	B.A., M.A. (Toronto), Ph.D. (McGill)	Res. Sci.
A.K. Sinha	B.Sc. (Ranchi, India), M. Tech., Ph.D. (India Inst. of Tech.)	Res. Sci.

Seismic Methods

J.A.M. Hunter	B.Sc., M.Sc. Ph.D. (Western Ontario)	Res. Sci.
A. Overton	B.Sc. (British Columbia)	Res. Sci.

Magnetic Methods

P.J. Hood	B.Sc. (London), M.A., Ph.D. (Toronto)	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. (Western Ontario)	Phys. Sci.

Radiation Methods

K.A. Richardson	B.A. (Toronto), M.A., Ph.D. (Rice Inst., Houston)	Res. Sci.
G.R. Bernius	B.A. (Colorado)	Phys. Sci.
G.W. Cameron	B.Sc. (Carleton)	Phys. Sci.
J.M. Carson	B.Sc. (Queen's), M.Sc. (Western Ontario)	Phys. Sci.
B.W. Charbonneau	B.Sc. (Carleton)	Phys. Sci.
B.E. Elliott	B. Math (Waterloo)	Comp. Sci.
K.L. Ford	B.Sc. (Carleton)	Tech.
R.L. Grasty	B.Sc., Ph.D. (Imperial)	Res. Sci.
P.B. Holman	B.Sc. (Carleton)	Phys. Sci.
P.G. Killeen	B.Sc. (Montreal), M.Sc., Ph.D. (Western Ontario)	Res. Sci.
V.R. Slaney	B.Sc. (U. College of Wales), M.Sc. (Delft)	Res. Sci.

Experimental Airborne Operations

P. Sawatzky	B.Sc. (Toronto)	Res. Sci.

Digital Compilation

M.T. Holroyd	B.Sc. (Manchester), M.Sc. (Durham)	Comp. Sci.

Contract Surveys

E.E. Ready		Tech.

Geochemistry

E.M. Cameron	B.Sc., Ph.D. (Manchester)	Res. Sci.
S.B. Ballantyne	B.Sc. (Guelph)	Phys. Sci.
G. Aslin	B.Sc. (Exeter), M.Sc. (Imperial)	Chem.
W.B. Coker	B.Sc. (Carleton), Ph.D. (New Brunswick)	Phys. Sci.
W. Dyck	B.A., M.Sc. (Saskatchewan)	Res. Sci.
D.J. Elwood	B.A. (Western Ontario)	Phys. Sci.
R. Garrett	B.Sc., Ph.D. (London)	Res. Sci.
W.D. Goodfellow	B.Sc. (Mt. Allison), Ph.D. (New Brunswick)	Phys. 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.
N.G. Lund	B.Sc. (Carleton)	Phys. Sci.
J.J. Lynch	B.Sc. (Ottawa)	Chem.
Y.T. Maurice	B.A., Sc. (Laval), Ph.D. (Imperial)	Phys. Sci.
E. Ruzgaitis	B.Sc. (Carleton)	Tech.
B.W. Smee	B.Sc. (Alberta)	Phys. Sci.

Analytical and Nuclear Instrumentation

Q. Bristow	B.Sc. (London)	Phys. Sci.

TERRAIN SCIENCES DIVISION

J.S. Scott, Director	B.Sc. (McMaster), Ph.D. (Illinois)	Res. Man.
B.G. Craig, Asst. Dir.	B.Sc. (Western Ontario), M.Sc., Ph.D. (Michigan)	Res. Man.

Scientific and Technical Services

H. Dumych	B.A. (Saskatchewan)	Phys. Sci.
G. Mizerovsky	B.A., M.A. (Ottawa)	Phys. Sci.
D.A. Proudfoot	B.Sc. (New Brunswick)	Phys. Sci.

Special Projects

O.L. Hughes	B.Sc. (British Columbia), Ph.D. (Kansas)	Res. Sci.
B.R. Pelletier	B.Sc. (McGill), M.Sc. (McMaster) Ph.D. (Johns Hopkins) (Toronto)	Res. Sci.
V.K. Prest	B.Sc., M.Sc. (Manitoba), Ph.D. (Toronto) F.R.S.C.	Res. Sci.
A.M. Stalker	B.A., M.Sc., Ph.D. (McGill)	Res. Sci.

Regional Projects Section

R.J. Fulton	B.Sc. (Manitoba), Ph.D. (Northwestern)	Res. Sci.
D.M. Barnett	B.Sc. (London), M.Sc. (McGill)	Phys. Sci.
J.J. Clague	A.B. (Occidental College), M.A. (California), Ph.D. (British Columbia)	Res. Sci.
S.A. Edlund	B.A. (Case Western Reserve), Ph.D. (Chicago)	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. (Alberta), Ph.D. (Saskatchewan)	Res. Sci.
M.F. Nixon	B.A. (Brock)	Tech.
S.H. Richard	B.A., B.Sc. (Laval), M.A. (Sarbonne)	Phys. Sci.
R.D. Thomas	B.Sc., M.Sc. (McGill)	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., Fi. Dr. (Stockholm)	Res. Sci.
T.W. Anderson	B.Sc. (Dalhousie), M.Sc., Ph.D. (Waterloo)	Res. Sci.
S. Federovich	B.Sc., M.Sc. (Manitoba), Ph.D. (Trent)	Res. Sci.
J.V. Matthews, Jr.	B.Sc., M.Sc. (Alaska), Ph.D. (Alberta)	Res. Sci.
R.J. Richardson	B.Sc. (Brock), M.Sc. (Auckland)	Phys. Sci.

Paleoecology Laboratory

R.J. Mott	B.Sc. (Carleton)	Phys. Sci.
L.D. Gill		Tech.

Radiocarbon Laboratory

J.A. Lowdon	B.Sc. (Carleton)	Phys. Sci.
I.M. Robertson		Tech.

Marine and Coastal Section

C.F.M. Lewis	B.A., M.A., Ph.D. (Toronto)	Res. Sci.
S.M. Blasco	B.Sc. (Queen's), M.Sc. (Brock)	Phys. Sci.
B.D. Bornhold	B.Sc. (Waterloo), A.M. (Duke), Ph.D. (M.I.T.)	Res. Sci.
T.J. Day	B.A., M.A. (British Columbia), Ph.D. (Canterbury)	Res. Sci.
J.L. Luternauer	B.A. (Colby), M.A. (Duke), Ph.D. (British Columbia)	Res. Sci.
P. McLaren	B.Sc., M.Sc. (Calgary)	Phys. Sci.
R.B. Taylor	B.A., M.Sc. (McMaster)	Phys. Sci.

Sedimentology and Mineral Tracing Section

W.W. Shilts	B.A. (Depaw), M.Sc. (Miami), Ph.D. (Syracuse)	Res. Sci.
J.D. Adshead	B.Sc., M.Sc. (Alberta), Ph.D. (Missouri)	Res. Sci.
R.N.W. DiLabio	B.Sc. (Carleton), Ph.D. (Western Ontario)	Res. Sci.
P.A. Egginton	B.A. (McMaster)	Phys. Sci.
R.A. Klassen	B.Sc., M.Sc. (Queen's)	Phys. Sci.

Sedimentology-Engineering Geology Laboratories

W.E. Podolak	B.Sc. (Brock)	Phys. Sci.
C.M. McFarlane		Tech.
R.G. Kelly		Tech.
D.E. Field		Tech.
P.J. Higgins		Tech.

Engineering and Environmental Geology Section

E.B. Owen	B.A. (Western Ontario)	Phys. Sci.
J.R. Bélanger	B.A., M.A. (Ottawa)	Phys. Sci.
J.G. Bisson		Tech.
P.B. Fransham	B.Sc. (Sir George Williams), M.Sc. (McGill)	Phys. Sci.
J.A. Heginbottom	B.Sc. (London), M.Sc. (McGill)	Phys. Sci.
P.J. Kurfurst	B.Sc., M.Sc., Ph.D. (Prague)	Res. Sci.
F. Morin	B.Sc. (Loyola), M.Sc. (McGill)	Phys. Sci.

CANADA CENTRE FOR MINERAL AND ENERGY TECHNOLOGY

NAME	DEGREES	CLASS TITLE
OFFICE OF THE DIRECTOR-GENERAL		
D.F. Coates	B.Eng., M.Eng., Ph.D. (McGill) B.A., M.A. (Oxford)	Director-General
V.A. Haw	B.S., M.S. (Queen's)	Deputy Director General
RESEARCH PROGRAM OFFICE		
W.A. Gow	B.A.Sc. (Toronto), P.Eng.	Director, Minerals
D.A. Reeve	B.Sc., Ph.D. (Birmingham)	Director, Energy
L.L. Sirois	B.A., B.Eng., M.Eng. (McGill), P.Eng.	Act.Ldr. MRP
D.G.F. Hedley	B.Sc., Ph.D. (Newcastle), P. Eng	Act.Ldr. MRP
D.W.G. White	M.Sc., D.Sc. (M.I.T.)	Act.Ldr. MRP
G.S. Bartlett	B.Sc., B.A. (Memorial)	Econ.
R. Sage	B.Sc. (Bristol), M.A.Sc. (Ottawa)	Eng.
E.D. Dainty	B.Sc., M.Sc. (Toronto), P. Eng.	Act.Ldr. ERP
D.K. Faurschou	B.A.Sc. (Toronto)	Act.Ldr. ERP
E. Smith	M.A., Ph.D. (Cambridge)	Act.Ldr. ERP
TECHNOLOGY INFORMATION DIVISION		
J.E. Kanasy	B.Sc., B.A. (Windsor), M.A. (Michigan), Ph.D. (Pittsburgh)	Chief
Library		
G. Peckham	B.A., B.L.S. (McGill)	Chief Lib.
J. Ho	B.A., B.L.S. (Ottawa)	Lib.
A. Hobson	B.A., B.L.S. (Toronto)	Lib.
K. Nagy	B.A., B.L.S. (McGill)	Lib.
Technical Inquiries		
A.S. Romaniuk	B.Sc. (Queen's), P.Eng.	Phys. Sci
G.M. Blondeau	B.A. (Queen's), M.A. (Guelph)	Min. Abst.
C.F. Dixon	B.Eng. (N.S.T.C.), P.Eng.	Phys. Sci.
A.L. Job	A.C.S.M. (Camborne School of Mines, U.K.) C.Eng.	Phys. Sci.
C. Lafkas	B.Eng. (McGill), M.Sc. (Queen's)	Phys. Sci.
B.E. Lawton	B.Sc. (Queen's), P.Eng.	Phys. Sci.
R.J.C. MacDonald	B.Sc. (St. Francis Xavier)	Phys. Sci.
T.J. Patel	B.Sc. (Oregon State), M.Sc. (Washington State)	Min. Proc. Abst.
I. Slowikowski	M.A. (Ottawa), D.D.S. (Beirut)	Slavic Lang. Spec.
G.W. Taylor	B.Sc. (Queen's)	Phys. Sci.
Publications		
C. Mamen	B.Eng. (McGill), Eng. (Que.)	Phys. Sci.
L. Carreau	B.A. (Ottawa)	French Tech. Sp.

TECHNICAL SERVICES DIVISION

E.K. Swimmings	B.Sc. (Queen's), P.Eng.	Chief
D.M. Norman	M.I.Mech. Eng. (Borough Polytechnique, U.K.)	Eng.

ENERGY RESEARCH LABORATORIES

B.I. Parsons	B.Sc., Ph.D., D.Phil. (Oxford)	Chief

Engineering, Design, and Construction Group

R.E. Carson	B.Sc. (Queen's), P.Eng.	Eng.
L.P. Mysak	B.A.Sc. (Ottawa), P.Eng.	Eng.

Special Studies

B.J.P. Whalley	B.Sc., Ph.D. (McGill)	Res. Sci.
I. Lau	M.A.Sc. (Ottawa)	Eng.
D. Desai	M.A.Sc. (Ottawa)	Eng.
J. Beshai	B.Sc. (McMaster)	Eng. Support

Canadian Synthetic Fuels Research Laboratory

W.H. Merrill	B.A.Sc. (Ottawa), P.Eng.	Manager

Petroleum Process Engineering

J.M. Denis	B.A.Sc. (Ottawa), P.Eng.	Res. Sci.
B.B. Pruden	B.Eng. (Saskatchewan), M.A.Sc.(British Columbia), Ph.D. (McGill), P.Eng.	Res. Sci.
R. Ranganathan	B.E. (Anamalai, India), M.E. (Indian Institute of Science), Ph.D. (Saskatchewan)	Res. Sci.
R.B. Logie	B.Sc. (New Brunswick)	Res. Sci.
C.P. Khulbe	B.Sc., M.Sc. (Agra, India), M.A.Sc., Ph.D. (Ottawa)	Res. Sci.
A.M. Shah	B.Sc. (St. Xavier's, India), B.A.Sc., M.A.Sc., Ph.D. (Ottawa)	Res. Sci.
K. Belinko	B.Sc., Ph.D. (Carleton)	Res. Sci.

Catalysis Research

M. Ternan	B.A.Sc., (British Columbia), Ph.D. (McGill), P.Eng.	Res. Sci.
A.H. Hardin	B.Sc., Ph.D. (British Columbia)	Res. Sci.
J.F. Kriz	Dipl. Eng.-M.Eng. (Prague), Ph.D. (Dalhousie), P.Eng.	Res. Sci.
J.F. Kelly	B.Eng., Ph.D. (McGill), P.Eng.	Res. Sci.
L.E. Galbraith	B.A. (Carleton)	Eng. Support
J.B. Aarts	B.Sc., M.Sc. (Eindhoven), Ph.D. (New Brunswick)	Eng. Support

Research on Bituminous Substances

H. Sawatzky	B.S.A., M.S.A., Ph.D. (Toronto)	Res. Sci.
A. George	B.Sc., M.Sc., Ph.D. (Cairo)	Res. Sci.
S.M. Ahmed	B.Sc., M.Sc. (Osmania, India)	Chem.
R.C. Banerjee	B.Sc., M.Sc., D.Phil. (Calcutta)	Chem.
B. Nunn	B.Sc. (Carleton)	Eng. Support

Petroleum and Gas Laboratory

R. Draper	B.Sc. (Saskatchewan)	Chem.
E. Furimsky	Dipl. Eng. (Prague), Ph.D. (Ottawa)	Chem.
D.M. Clugston	B.Sc., Ph.D. (McMaster)	Chem.
A. Yates	B.Sc. (Manitoba)	Chem.
R.E. Gill	B.Sc. (St. Francis Xavier)	Chem.

Canadian Combustion Research Laboratory

E.R. Mitchell	B.Sc. (Queen's), P.Eng., C.Eng.	Manager
G.K. Lee	B.Sc., M.Sc. (Queen's), P.Eng., C.Eng.	Res. Sci.
F.D. Friedrich	B.Sc., (Saskatchewan), M.Sc. (Queen's), P. Eng.	Res. Sci.
T.D. Brown	B.Sc. (Durham), Ph.D. (Sheffield), C.Eng.	Res. Sci.
H. Whaley	B.Sc., Ph.D. (Sheffield), P.Eng., C.Eng.	Res. Sci.
A.C.S. Hayden	B.Eng., M.Eng. (Carleton), P.Eng.	Res. Sci.
T.J. Cyr	B.Sc., M.Sc., Ph.D. (British Columbia)	Chem.
S.I. Steindl	Dipl. Eng. (Budapest), M.Sc. (Oueen's), P.Eng.	Eng.
R.G. Fouhse	B.Sc. (Saskatchewan), P.Eng.	Eng.
R.W. Braaten	B.Sc. (Carleton)	Eng. Support
G.D. Sergeant	B.Sc., Ph.D. (Cardiff)	Visiting Sci.

Coal Resource and Processing Laboratory

J.C. Botham	B.Sc. (Queen's), P.Eng.	Res. Sci.
T.A. Lloyd	B.Sc. (Carleton)	Phys. Sci.
J.G. Jorgensen	B.Sc. (Carleton)	Phys. Sci.
W.R. Leeder	B.Sc. Ph.D. (British Columbia)	Res. Sci.
W. Gardiner	C.Chem., E.Eng. (Heriot-Watt, U.K.)	Eng. Support
A.B. Fung	B.Sc., Eng. (Waterloo)	Eng.
R. Zrobock	B.Sc. (Alberta)	Eng. Support
T.E. Tibbetts	B.Sc., B.Ed. (Dalhousie)	Res. Sci.
B.N. Nandi	B.Sc., M.Sc. (Calcutta), Dr. Ing. (Karlsruhe)	Res. Sci.
L. Ciavaglia	B.Eng. (Carleton)	Phys. Sci.
J.R. Donaldson	B.A. (Acadia)	Phys. Sci.
W.J. Montgomery	B.S.A. (Toronto)	Phys. Sci.
J.Z. Skulski	Chem. Eng. (Wroclaw)	Chem.
J.F. Gransden	B.Sc. (London), A.R.S.M., Ph.D. (Western Ontario)	Res. Sci.
J.T. Price	B.Sc., M.Sc. (Calgary), Ph.D. (Western Ontario)	Res. Sci.
K. Belinko	B.Sc., Ph.D. (Carleton)	Res. Sci.
R.H. Lomas	B.Sc. (Queen's)	Eng. Support
L.C.G. Janke	B.Sc. (Wilfrid Laurier), B.Ed. (Queen's)	Eng. Support

Pyrometallurgy Research Laboratory

G.E. Viens	B.A. (McMaster)	Res. Sci.
R.A. Campbell	B.Sc., M.Sc. (Queen's)	Res. Sci.
G.N. Banks	B.A. (British Columbia)	Res. Sci.
G.V. Sirianni	B.Sc. (Ottawa)	Res. Sci.
E.W. Montgomery	B.Eng. (McGill), P.Eng.	Res.Sci.

Western Research Laboratory (Edmonton)

J. Visman	M.I.Dr. T.W. (Delft), P.Eng.	Manager
H.A. Hamza	B.Sc. (Cairo), Ph.D. (Newcastle-on-Tyne)	Res. Sci.
M.W. Mikhail	B.Sc. (Assiut), M.Sc. (Alberta), P.Eng.	Eng.
J.L. Picard	B.Sc. (Alberta)	Phys. Sci.

C.F. Rozenhart	Chem. Eng. (Heerlen M.T.S.)	Eng. Support
A. Mo	B.Sc. (Alberta)	Eng. Support
G. Potter	B.Sc. (McMaster)	Eng. Support
R. Santos	B.Sc. (Mapua I.T.)	Eng. Support

MINING RESEARCH LABORATORIES

T.S. Cochrane	B.A.Sc., M.Sc. (Washington), P.Eng.	Chief
W.M. Gray	B.A., M.A., Ph.D. (Toronto)	Res. Sci.
F.L. Casey	B.Sc. (Queen's)	Sr. Sci. Adv. Eng.

Rock Mechanics Laboratory

G.E. Larocque	B.Sc. (Carleton)	Res. Sci.
A. Boyer	B.Sc. (Montreal)	Phys. Sci.
A. Fustos	B.S.F./F.E., B.Sc. (British Columbia), P.Eng.	Eng.
L. Geller	Dipl. Mech. Eng. (Budapest), B.Sc. (Eng.) (London), M.A.Sc. (Toronto)	Phys. Sci.
M. Gyenge	Dipl. Eng. (Budapest), P. Eng.	Res. Sci.
R.L. Sabourin	B.Sc., M.Eng. (Ecole Polytechnique), P.Eng.	Eng.
N.A. Toews	B.Sc. (Queen's)	Res. Sci.
J. Tomica	B.Sc., M.Sc., Dipl. Expln. Tech., M.Sc., (V.S.C.H.T., Czechoslovakia), M.Sc. (Queen's), P.Eng.	Eng.
Y.S. Yu	B.Sc., M.Eng. (McGill)	Res. Sci.
D.F. Walsh	B.Sc. (Memorial)	Phys. Sci.
R.J.R. Welwood	B.Sc. (Queen's)	Phys. Sci.
A.S. Wong	B.Sc. (National Taiwan University), M.Sc. (Ottawa)	Phys. Sci.

Elliot Lake Laboratory

G. Zahary	B.Sc., M.Eng. (McGill), P.Eng.	Res. Sci.
G. Allen	M.A.Sc., M.Eng. (South Dakota)	Eng.
K.K. Cheng	B.Sc., M.Eng. (Tainan Chen-Kung, Taiwan)	Eng.
V. deKorompay	Dipl. Min. Eng. (Hungary)	Phys. Sci.
M. Gangal	B.Sc. (Agra, India), M.Sc. (Rookee, India & McGill), Ph.D. (Calgary)	Res. 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.
B. Kirk	B.Sc. (Waterloo)	Phys. Sci.
G. Knight	B.Sc. (Birbeck, London)	Res. Sci.
P.C. Miles	B.Sc. (Windsor)	Eng.
D. Moffett	B.A. (Dublin), Ph.D. (Ottawa)	Res. Sci.
D.R. Murray	B.A.Sc. (McDonald College)	Phys. Sci.
R.G.L. McCready	B.Sc., M.Sc. (Alberta), Ph.D. (Calgary)	Phys. Sci.
M. Savich	Dipl. Min. Eng. (Ljobljan, Yugoslavia), B.Eng., M.Eng. (McGill)	Res. Sci.
R.O. Tervo	B.A.Sc. (Toronto), Ph.D. (Bradford), P.Eng.	Res. Sci.
R.A. Washington	B.Sc., M.Sc., Ph.D. (McGill)	Res. Sci.
G. Just	B.E., Ph.D. (Queensland)	Post doc. Fellow

Canadian Explosives Research Laboratory

J.A. Darling	B.A. (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)	Chem.
C.A. Vary	B.Sc. (Ottawa)	Tech. Off.

Western Office, Calgary

K. Barron	B.Sc., M.Sc., Ph.D. (London)	Res. Sci.
W. Baxter	B.Sc., (Calgary)	Phys. Sci.
H.U. Bielenstein	B.Sc., M.Sc. (Alberta), Ph.D. (Queen's)	Res. Sci.
R.N. Chakravorty	B.Che., (Jadavpur, India), Ph.D. (Nottingham)	Res. Sci.
M.Y. Fisekci	Dipl. Eng., M.Eng., Ph.D. (Sheffield)	Res. Sci.
F. Grant	B.Sc. (Alberta), P.Eng.	Res. Sci.
J.B. Livesey	B.Sc., Ph.D. (Cardiff)	Res. Sci.
D. Mikalson	B.Sc., M.Eng. (Alberta)	Eng.
V. Srajer	M.A.Sc. (Univ. of Applied Science, Czechoslovakia)	Eng.

Canadian Explosive Atmospheres Laboratory

J.A. Bossert	B.Sc. (Queen's)	Res. Sci.
G. Lobay	B.Sc. (Manitoba)	Eng.
P. Mogan	B.A.Sc. (Toronto), P.Eng.	Res. Sci.
N. Sarin	Dipl. (Mech. & Auto Eng., England), B.A.Sc. (Waterloo)	Eng.
S. Silver	B.Sc. (Manitoba)	Res. Sci.
D.B. Stewart	B.Sc., M.Sc. (Queen's)	Res. Sci.

MINERAL SCIENCES LABORATORIES

R.L. Cunningham	B.Sc., M.Sc., Ph.D. (McGill)	Chief
J.C. Ingles	B.A. (Western Ontario)	Assistant Chief

Chemical Laboratory

R.G. Sabourin	B.Sc., (Ottawa)	Manager
C.H. McMaster	B.Sc., M.Sc. (Queen's)	Assistant Manager
G. H. Faye	B.A. (Saskatchewan)	Assistant Manager

Metals and Alloys

J.F. Fydell	B.A.Sc. (Toronto)	Chem.
E.H. MacEachern	B.Sc. (Mt. Allison)	Chem.
A.L. Letendre	B.Sc. (Sherbrooke)	Chem.

Ores and Fire Assay

J.C. Hole	B.A. (Toronto)	Chem.
R.R. Craig	B.Sc. (Glasgow)	Chem.

Solution Chemistry

R.J. Guest	B.Sc. (Acadia)	Res. Sci.
G.A. Hunt	B.Sc. (Carleton)	Chem.
D.J. Barkley	B.Sc. (Carleton)	Chem.
J.E. Atkinson	B.A. (Queen's)	Chem.
A.D. King	B.Sc. (British Columbia)	Chem.

Spectrochemistry

G.L. Mason	A.Metallurgy (Sheffield)	Chem.
J.L. Dalton	B.S., M.Eng. (Carleton)	Chem.
C.W. Smith	M.Sc., Ph.D. (Queen's)	Chem.
T.R. Churchill	B.Sc. (Western Ontario)	Phys. Sci.

Special Analyses

A. Hitchen	B.Sc. (McMaster)	Chem.
B. Nebesar	M.Sc. (McGill)	Res. Sci.
V.H. Rolko	B.Sc. (Manitoba)	Chem.

Special Projects

D.J. Charette	B.Sc. (Ottawa)	Chem.
E.M. Donaldson	B.Sc. (Manitoba)	Res. Sci.
E. Mark	B.A. (Toronto)	Chem.
H.F. Steger	B.Sc., Ph.D. (McMaster)	Res. Sci.

Ore Processing Laboratory

M.C. Campbell	B.Sc. (St. Francis Xavier), B.E. (N.S.T.C.), D.I.C., M.Sc. (London)	Manager

Hydrometallurgy

G.M. Ritcey	B.Sc. (Dalhousie)	Res. Sci.
B.H. Lucas	B.Sc. (Queen's), P.Eng.	Res. Sci.
H.W. Parsons	B.Sc. (Alberta)	Res. Sci.
V.M. McNamara	B.Sc., B.Eng., M.A.Sc., (Toronto), P.Eng.	Res. Sci.
A.J. Gilmore	B.Sc. (Manitoba)	Res. Sci.
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.
N. St. Martin	B.A.Sc., M.A.Sc. (Ottawa)	Phys. Sci.
A. Jongejan	Geol.Can.Drs. (Ph.D.) (Amsterdam)	Res. Sci.

Metallic Minerals

R.W. Bruce	B.Sc. (Queen's), P.Eng.	Res. Sci.
A.I. Stemerowicz	B.Sc. (Queen's), P.Eng.	Res. Sci.
D. Raicevic	B.Sc. (Belgrade)	Res. Sci.
G.I. Mathieu	B.A., B.Sc. (Laval)	Res. Sci.
R.H. Yoon	M.Eng. (McGill)	Res. Sci.

Engineering and Economic Evaluation

W.J.S. Craigen	B.Sc. (Queen's)	Phys. Sci.
V.F. Harrison	B.Sc. (Queen's)	Res. Sci.
F.J. Kelly	B.Ch.Eng. (N.S.T.C.)	Res. Sci.

Non-Metallic Processing

R.A. Wyman	B.Sc. (Manitoba)	Res. Sci.
I.B. Klymowsky	M.Eng. (McGill), P.Eng.	Res. Sci.
W.H. Cameron	B.Sc. (Queen's)	Phys. Sci.
G.A. Kent	B.Sc., M.Sc. (McGill)	Chem.

Industrial Liaison

E.G. Joe	B.Sc. (Queen's)	Phys. Sci.

Physical Sciences Laboratory

D.C. Harris	B.Sc., M.A., Ph.D. (Toronto)	Manager
Crystal Structure		
J.T. Szmanski	B.Sc., Ph.D. (London)	Res. Sci.
J.F. Rowland	B.Sc., M.Sc. (Queen's)	Res. Sci.
Solid State		
M.G. Townsend	B.Sc., Ph.D. (Southampton)	Res. Sci.
J.L. Horwood	B.A. (Toronto)	Res. Sci.
Corrosion		
G.R. Hoey	B.Sc., M.Sc., Ph.D. (Toronto)	Res. Sci.
R.J. Brigham	B.Sc., M.Sc., Ph.D. (McMaster)	Res. Sci.
A.W. Lui	B.Sc., M.A.Sc. (Windsor)	Res. Sci.
J.C. Saiddington	Chem.Eng., M.A.Sc. (Toronto)	Phys. Sci.
Mineralogy		
L.J. Cabri	B.Sc., M.Sc., Ph.D. (McGill)	Res. Sci.
W. Petruk	B.Eng., M.Sc., Ph.D. (McGill)	Res. Sci.
S. Kaiman	B.Sc., M.A. (Toronto)	Phys. Sci.
M.R. Hughson	B.Sc. (Western Ontario)	Phys. Sci.
J.L. Jambor	B.A., M.Sc. (British Columbia), Ph.D. (Carleton)	Res. Sci.
T.T. Chen	B.Sc. (National Taiwan University), M.Sc. (Carleton), Ph.D. (Cornell)	Res. Sci.
Metallurgical Chemistry		
J.E. Dutrizac	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Res. Sci.
D.J. MacKinnon	B.Sc., M.A., Ph.D. (Ottawa)	Res. Sci.
E. Rolia	B.A. (British Columbia)	Chem.
D.J. Francis	B.Sc., Ph.D. (Alberta)	Res. Sci.
R.J.C. MacDonald	B.Sc. (St. Francis Xavier)	Phys. Sci.
V.S. Sastri	B.Sc., M.A., Ph.D. (New York)	Chem.
Physical Chemistry		
A.H. Webster	B.A., M.A., Ph.D. (British Columbia)	Res. Sci.
S.A. Mikhail	B.Sc., M.Sc., Ph.D. (Cairo), Dr. Eng. (Technical University of Norway)	Post doc. Fellow
S.M. Ahmed	B.Sc., M.Sc., Ph.D. (Saskatchewan)	Res. Sci.
R. Sutarno	B.E., M.E., Ph.D., (N.S.T.C.)	Res. Sci.
R.F. Pilgrim	B.Sc. (Queen's)	Res. Sci.
L.G. Ripley	B.Sc., M.A. (Queen's)	Res. Sci.
D.M. Farrell	B.Sc. (British Columbia)	Chem.

Industrial Minerals Laboratory

G.W. Riley	B.Sc. (Camborne School of Mines), P.Eng.	Manager
Construction Materials		
V. M. Malhotra	B.Sc., B.E. (W. Australia)	Res. Sci.
H.S. Wilson	B.E. (Saskatchewan)	Res. Sci.
E.E. Berry	C.Chem., M.R.I.C. Ph.D. (Surrey)	Res. Sci.
G.G. Carette	B.Sc. (Laval)	Eng.

Non-Metallic and Waste Minerals

R.K. Collings	Eng. Dipl., B.E. (N.S.T.C.), P.Eng.	Res. Sci.
A.A. Winer	B.A.Sc. (Toronto) P.Eng.	Res. Sci.
S.S. Wang	B.Sc. (Hong Kong Baptist), M.Sc. (California), Ph.D. (Toronto)	Phys. Sci.
C.A. Hamer	Dip. Eng. (Dalhousie), B.E. (N.S.T.C.), M.Sc. (Queen's)	Res. Sci.

Ore Mineralogy

R.M. Buchanan	B.A., M.A. (Toronto)	Phys. Sci.
J.A. Soles	B.A.Sc., M.A.Sc., Ph.D. (McGill), P.Eng.	Res. Sci.
R.S. Dean	B.Sc., M.Sc., Ph.D. (McGill), P.Eng.	Res. Sci.

Ceramics

K.E. Bell	B.E. (Saskatchewan), P.Eng.	Res. Sci.
T.A. Wheat	Ph.D. (Leeds)	Res. Sci.
D.H.H. Quon	B.Sc. (National Sun Yat Sen U.), M.Sc. (Ohio), Ph.D. (Michigan)	Res. Sci.
D.J. Green	B.Sc. (Liverpool), M.Sc., Ph.D. (McMaster)	Res. Sci.
V.V. Mirkovich	Dipl.Ing. (Zagrev), Ph.D. (Toronto)	Res. Sci.
T.B. Weston	B.A. (Toronto)	Res. Sci.

PHYSICAL METALLURGY RESEARCH LABORATORIES

H.V. Kinsey	B.Sc. (Queen's), P.Eng.	Chief (Seconded to Director General's Office)
R.K. Buhr	B.Eng. (McGill)	Acting Chief

Corrosion

G.J. Biefer	B.Sc., Ph.D. (McGill)	Res. Sci.
J.B. Gilmour	B.Sc. (Queen's), Ph.D. (McMaster), P.Eng.	Res. Sci.
R.D. McDonald	B.Sc. (Queen's)	Res. Sci.
I.C.G. Ogle	B.Sc., Ph.D. (British Columbia)	Res. Sci.

Engineering Physics

A.J. Williams	B.Sc., M.Sc., Ph.D. (Birmingham), P.Eng.	Res. Sci.
D.M. Fegredo	B.Sc., M.Sc., Dipl. I.I.Sc. Ph.D. (Sheffield), A.I.M.	Res. Sci.
L.P. Trudeau	B.A.Sc., M.A. (Toronto)	Res. Sci.
O. Vosikovsky	B.A.Sc., Ph.D. (Prague)	Res. Sci.

Ferrous Metals

J.D. Boyd	B.A.Sc. (Toronto), Ph.D. (Cambridge)	Res. Sci.
D.R. Bell	B.Eng. (McGill)	Res. Sci.
M.J. Godden	B.Met., Ph.D. (Sheffield)	Res. Sci.
R.F. Knight	B.Sc., M.Sc. (Queen's)	Res. Sci.
M.J. Lavigne	B.A., B.A.Sc., Ph.D. (Laval)	Res. Sci.
D.E. Parsons	B.A.Sc. (Toronto)	Res. Sci.
W.R. Tyson	B.A.Sc. (Toronto), Ph.D. (Cambridge)	Res. Sci.

Foundry

K.G. Davis	B.Sc., M.A.Sc., Ph.D. (British Columbia)	Res. Sci.
C.J. Adams	B.Sc. (Sir George Williams), M.Sc. (Met.) (McGill)	Res. Sci.
E.I. Szabo	M.Sc., Ph.D. (Nottingham)	Res. Sci.
R.D. Warda	B.A.Sc. (British Columbia), Ph.D. (Cambridge)	Res. Sci.

Mechanical Testing

P.J. Todkill	B.A.Sc. (Toronto)	Eng.
J. Harbec	B.Eng. (McGill), P.Eng.	Eng.

Metal Processing

M.J. Stewart	B.A.Sc., Ph.D. (British Columbia)	Res. Sci.
A.F. Crawley	B.Sc., Ph.D. (Glasgow)	Res. Sci.
J.T. Jubb	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Res. Sci.
H.M. Skelly	B.Sc., Ph.D. (Glasgow)	Res. Sci.

Metal Physics

W.N. Roberts	M.A., Ph.D. (Leeds)	Res. Sci.
E.E. Laufer	B.Sc., M.Sc. (Dalhousie), 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.
J. Ng-Yelim	B.Sc. (Ottawa)	Phys. 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.

Non-Destructive Testing

V.L. Caron	B.A.Sc. (Laval), M.Eng. (Paris), P.Eng.	Res. Sci.

Non-Ferrous Metals

J.O. Edwards	B.Sc., M.Sc. (Manchester), P.Eng.	Res. Sci.
D.C. Briggs	B.Eng., M.Eng. (McGill), Ph.D. (Queen's)	Res. Sci.
A. Couture	B.A., B.A.Sc. (Laval), P.Eng.	Res. Sci.
J.-L. Dion	B.A.Sc. (Montreal)	Eng.
B. Lagowski	B.Sc., M.Sc. (Polish Univ., London)	Res. Sci.
W.A. Pollard	B.Sc., A.R.S.M. (London), P.Eng.	Res. Sci.
G.E. Ruddle	B.A.Sc., M.Sc. (Waterloo), D.Sc. (Virginia), P.Eng.	Res. Sci.
J.J. Sebisty	B.A.Sc. (Toronto), P.Eng.	Res. Sci.
R. Thomson	B.Sc., A.R.C.S.T., Ph.D. (Glasgow)	Res. Sci.
L.V. Whiting	B.Sc., M.Sc., Ph.D. (McGill)	Res. Sci.

Welding

K. Winterton	B.Sc., Ph.D. (Birmingham), P.Eng.	Res. Sci.
W.P. Campbell	B.Sc. (Queen's), P.Eng.	Res. Sci.
J. Gordine	B.Sc., Ph.D. (Leeds)	Res. Sci.
Z. Paley	B.Sc., M.Sc. (Haifa), Ph.D. (McGill)	Res. Sci.

EARTH PHYSICS BRANCH

NAME	DEGREES	CLASS TITLE
OFFICE OF THE DIRECTOR-GENERAL		
K. Whitham	M.A. (Cantab.), Ph.D. (Toronto) F.R.S.C.	Dir. Gen.
E.B. Manchee	B.A.Sc., M.A. (Toronto)	Prog. Off.
Administration		
J.L. Kelly	B. Comm. (Ottawa)	Chief Admin Off.
J.J. Parks		Finan. Off.
Library		
W.M. Tsang	B.A. (Taipei), B.L.S. (McGill)	Chief Lib.
C. Levesque	B.A. (Carleton)	Asst. Lib.
Machine Shop		
G.E. Sanders		Tech. Off.
Drafting and Design		
J.W. Geuer		Chief Draft.
Photographic Services		
E.J. Gelinas		Tech. Off.
Personnel Services		
R.D. Gray	Dipl. Bus. Admin. (E.O.I.T.)	Pers. Adv.
DIVISION OF SEISMOLOGY AND GEOTHERMAL STUDIES		
M.J. Berry	B.Sc., M.A., Ph.D. (Toronto)	Res. Man.
Special Projects		
D.H. Weichert	B.A.Sc., M.Sc., Ph.D. (British Columbia)	Res. Sci.
Seismicity, Seismic Hazards and Applications		
F.M. Anglin	B.Sc. (Ottawa), M.Sc. (Western Ontario)	Res. Sci.
P.W. Basham	B.A.Sc., M.Sc., (British Columbia)	Res. Sci.
R.J. Halliday	B.Sc., (Toronto)	Phys. Sci.
H.S. Hasegawa	B.Sc., M.Sc. (Alberta), Ph.D. (British Columbia)	Res. Sci.
R.B. Horner	B.Sc. (Manitoba)	Phys. Sci.
G. Leblanc	B.A. (Montreal), L.Ph. (Immaculate Conception), M.A. Massachusetts, M.Sc. (Boston), Ph.D. (Penn. State)	Res. Sci.
W.E. Shannon	B.Sc. (British Columbia)	Phys. Sci.
A.E. Stevens	B.Sc. (McMaster) M.Sc., Ph.D. (Western Ontario)	Res. Sci.
R.J. Wetmiller	B.Sc. (Manitoba), M.Sc. (British Columbia)	Res. 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. (British Columbia)	Phys. Sci.
J.A. Lyons	B.Sc. (Toronto), M.Sc. (Western Ontario)	Phys. Sci.
J.A. Mair	B.Sc. (Alberta), M.A., Ph.D. (Toronto)	Res. Sci.
A.J. Wickens	B.A. (Saskatchewan), M.Sc. (Ottawa)	Res. Sci.
C. Wright	B.Sc. (Durham), Ph.D. (Australian National University)	Res. Sci.

Seismological Instrumentation Laboratory

R.T. Grogan	B.A.Sc., B. Eng. (Carleton)	Tech. Off.
R.B. Hayman	B.Sc. (Bristol), P. Eng.	Phys. Sci.
F. Kollar	B.Sc. (Budapest), Ph.D. (British Columbia)	Res. Sci.
F. Lombardo		Tech. Off.
D.J. Monsees		Tech. Off.
J.T. Thomas		Tech. Off.

Geothermal Studies

M. Burgess	B.Sc. (Ottawa)	Phys. Sci.
J.D. Collier	S.B., (M.I.T.), M.A. (U.C.L.A.)	Phys. Sci.
A.M. Jessop	B.Sc., Ph.D. (Nottingham)	Res. Sci.
A.S. Judge	B.Sc. (London), Ph.D. (Western Ontario)	Res. Sci.
T.J. Lewis	B.A.Sc., M.Sc. (British Columbia), Ph.D. (Western Ontario)	Res. Sci.
A.E. Taylor	B.Sc. (McMaster), M.Sc. (Ottawa)	Phys. Sci.
M.A. Woodley	B.Sc. (Carleton)	Phys. Sci.

Postdoctorate Fellows

C.M. Keith	M.A. (Cantab.), Ph.D. (Edinburgh)
P.P. Raj	B.E. (Madras), M.E. (Roorkee), Ph.D. (Bangalore)

SUBDIVISION, VICTORIA GEOPHYSICAL OBSERVATORY

W.G. Milne	B.A. (Toronto), M.A. (California) Ph.D. (Western Ontario)	Chief Sci.

Administrative Services

V.M. Styles	Admin. Off.

Observatories, Instrumentation, and Technical Services Group

M.N. Bone	B.A.Sc. (Toronto)	Phys. Sci.
H. Bennetts		Tech. Off.

Seismo-Tectonics

R.D. Hyndman	B.A.Sc., M.A.Sc. (British Columbia) Ph.D. (Australian National Univ.)	Res. Sci.
G.A. McMechan	B.A.Sc., (British Columbia), M.Sc., (Toronto)	Res. Sci.

Engineering Seismology and Seismicity

G.C. Rogers	B.Sc. (British Columbia), M.Sc., (Hawaii)	Phys. Sci.

Geophysical Surveys and Structural Interpretation

D.R. Auld	B.A.Sc. (British Columbia)	Phys. Sci.
L.K. Law	B.A.Sc. (Toronto), M.Sc., (Western Ontario) Ph.D. (Cantab.)	Res. Sci.
R.P. Riddihough	B.Sc. (Kings College), D.I.C., M.Sc. (Imperial College) Ph.D. (London)	Res. Sci.
L.E. Stephens	B.Sc., M.Sc. (Queen's)	Phys. Sci.

Postdoctorate Fellows

K. Lee	B.S. (Seoul), Ph.D. (Pittsburg)	

DIVISION OF GEOMAGNETISM

P.H. Serson	B.A., M.A., Ph.D. (Toronto)	Res. Man.

Special Projects

A. Nandi	B.Sc. (Calcutta), B.E.E. (Jadavpur), M.Sc. (Queen's)	Comp. Sci.

Geomagnetic Observatories

G.A. Brown		Tech. Off.
A.B. Cook	B.A. (Queen's)	Phys. Sci.
J. Hruska	Dip. Phys., Ph.D., R.N. Dr. (Charles, Czech.)	Phys. Sci.
G. Jansen van Beek	B.Sc. (Alberta)	Phys. Sci.
O.J. Jensen	B.A. (McGill)	Tech. Off.
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.

Rapid Variations

P.A. Camfield	B.Sc. (Queen's), S.M. (M.I.T.), 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.
R.D. Kurtz	B.Sc., M.Sc. (Alberta), Ph.D. (Toronto)	Res. Sci.
E.R. Niblett	B.A., M.A. (Toronto), Ph.D. (Cantab.)	Res. Sci.
F.C. Plet	B.Sc. (Carleton)	Tech. Off.
J.K. Walker	B.E., M.Sc. (Saskatchewan) Ph.D. (Alberta)	Res. Sci.

Instrumentation

F. Andersen	B.A. (British Columbia)	Res. Sci.
G.L. Carr		Tech. Off.
W. Hannaford	B.Sc., M.Sc. (Ottawa)	Res. Sci.
D.F. Trigg	B.A.Sc. (British Columbia)	Res. Sci.

Paleomagnetism

E. Irving	B.A., M.Sc., D.Sc. (Cantab.), F.R.S.C.	Res. Sci.
P. Lapoint	B.Sc., M.Sc. (Ottawa)	Phys. Sci.
J.K. Park	B.Sc. (Calgary)	Phys. Sci.
J.L. Roy	B.A. (Laval), B.Sc. (Montreal)	Res. Sci.

Postdoctorate Fellows

P.H. Schmidt	B.Sc. (New England), Ph.D. (Australian National Univ.)	
W.A. Morris	B.Sc. (Leeds), Ph.D. (Open University)	
H.L. Lam	B.Sc. (Lakehead), Ph.D. (Alberta)	

GRAVITY AND GEODYNAMICS DIVISION

J.G. Tanner	B.Sc., M.Sc. (Western Ontario), Ph.D., (Durham)	Res. Man.

Surveys and Interpretation

Surveys

J.B. Boyd		Tech. Off.
R.V. Cooper	B.Sc. (St. Mary's)	Tech. Off.
D.W. Halliday		Tech. Off.
D.B. Hearty	B.A. (Carleton)	Tech. Off.

Interpretation

R.A. Gibb	B.A. (Carleton), B.Sc. (Aberdeen), M.Sc., Ph.D. (Birmingham)	Res. Sci.
A.K. Goodacre	B.A., M.A. (British Columbia), Ph.D. (Durham)	Res. Sci.
D. Nagy	B.Sc. (Sopron), M.A.Sc., Ph.D. (Toronto)	Res. Sci.
L.W. Sobczak	B.A.Sc. (Toronto)	Res. Sci.
J.F. Sweeney	B.A., M.A., (Ph.D. State U of N.Y.)	Res. Sci.
M.D. Thomas	B.Sc., Ph.D. (Wales-Swansea)	Res. Sci.

Geodynamics

D.R. Bower	B.Sc., M.A. (Carleton), Ph.D. (Durham)	Res. Sci.
H. Dragert	B.Sc., (Toronto), M.Sc., Ph.D. (British Columbia)	Res. Sci.
L.G. Dussault		Tech. Off.
J.J. Labrecque	B.A. (Jean-de-Brêbeuf), B.Sc., M.Sc. (Montreal)	Tech. Off.
A. Lambert	B.Sc., M.A. (British Columbia), Ph.D. (Dalhousie)	Res. Sci.
J. Liard	B.Sc. (Montreal), M.Sc. (McGill)	Phys. Sci.
J.A. Orosz		Tech. Off.
M.K. Paul	B.Sc., M.Sc. (Calcutta), Ph.D. (Jadavpur)	Res. Sci.
J. Popelar	M.Sc., R.N. Dr. (Charles, Czech.)	Res. Sci.
S.B. Sim		Tech. Off.
J.R. Weber	B.Sc., M.Sc. (Zurich), Ph.D. (Alberta)	Res. Sci.
M.O. Wheeler	B.A. (British Columbia)	Phys. Sci.

Standards and Information

R.J. Buck	B.Sc. (Queen's)	Phys. Sci.
R.K. McConnell	B.Sc. (Carleton & Western Ontario)	Phys. Sci.
P.J. Winter		Tech. Off.

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. Off.

Instrumentation

R. Beach		Tech. Off.
J.F. Halpenny	B.Sc. (Carleton)	Tech. Off.
J.A. O'Brien		Tech. Off.
H.D. Valliant	B.Sc. (Carleton) M.Sc. (Western Ontario)	Res. Sci.

Postdoctorate Fellows

P.Y. Shen	B.Sc. (Taiwan), M.Sc. (British Columbia), Ph.D. (Western Ontario)

SURVEYS AND MAPPING BRANCH

NAME	DEGREES	CLASS TITLE
OFFICE OF THE DIRECTOR-GENERAL		
R.E. Moore	B.E. (N.S.T.C.), B.Sc. (Delft), P. Eng. (Ontario)	Director-General
R.A. Stewart	B.Sc. (New Brunswick), M.Sc., Ph.D. (Ohio State), P.Eng. (Ontario)	Scientific Adviser
W.L. MacLellan	Nova Scotia Land Surveyor	Consultant
A.C. McEwen	LL.B. (London), LL.M. (East Africa), Dominion Land Surveyor, Ontario Land Surveyor, Newfoundland Land Surveyor	A/Assistant Director (Plans)
H.T. Posten		Pers. Adviser
J.D. Dextraze	B.A. (Ottawa)	Fr. Tech. Spec.
E.H. Valin	B.A. (Ottawa)	Fr. Tech. Spec.
Foreign Aid		
J.I. Thompson	B.A.Sc. (Toronto), P.Eng. (Ontario)	Surv. Eng.
L.E. Pelton	B.Sc. (New Brunswick), Dominion Land Surveyor	Surv. Eng.
Branch Administration		
J.A. McArthur		Chief Admin. Off.
J.M. McGuire		Fin. Off.
Management Information and Production Systems		
L.J. Chouinard	B.A. (Laval), B.A.Sc. (Laval)	Surv. Eng.
Systems Control		
S.B. Lerner		Admin. Off.
Information Services		
J.F. Mazerall	B.Sc. (New Brunswick)	Surv. Eng.
J.D. Tremblay		Info. Off.
B.A. McAulay	B.A. (New Brunswick)	Info. Off.
Branch Secretariat		
E.W. Kerr	Ontario Land Surveyor, Dominion Land Surveyor	Surv. Eng.
Research and Training		
J.M. Murakami	B.Sc. (Saskatchewan), P.Eng. (Ontario)	Surv. Eng.
T. Wray	B.Sc. (Belfast), M.A. (Toronto) F.R.G.S.	Mathematician
R.J. Fitzgerald	B.Eng. (McGill)	Engineer
D. Dewar	B.Sc. (Mt. Allison)	Computer Sci.
M. Coupal	B.Sc. (Laval)	Surv. Eng.
N. Parent	B.Sc. (Laval)	Surv. Eng.
M. Doucette	B.Sc. (New Brunswick)	Surv. Eng.
O. Lepage	B.Sc. (Laval)	Surv. Eng.

Library

V.E. Hoare	B.A. (Carleton), M.L.S. (McGill)	Librarian

GEODETIC SURVEY DIVISION

L.J. O'Brien	B.Eng. (McGill), M.Sc. (Ohio State)	Dominion Geodesist

Technical Coordination

L.P. Robertson	B.Sc. (Iowa)	Surv. Eng.
P.C. Atkinson	B.Sc. (New Brunswick)	Surv. Eng.
C.E. Hoganson	B.E. (N.S.T.C.)	Surv. Eng.

Administration

J.E. Raymond		Admin. Off.

Instrument Maintenance

N.A.B. Bramwell		Eng. Supp.

Electronic Maintenance

F.H. Hawkins		Electronics Tech.

Survey Group

J.V. Thompson (Retired December '76)	B.A.Sc. (British Columbia)	Surv. Eng.
G. Babbage	B.Sc. (Capetown), Dominion, Ontario, and Nova Scotia Land Surveyor, P.Eng. (Ontario)	Surv. Eng.

Primary Horizontal Control

A.D. Selley	B.Sc. (Manitoba), P.Eng. (Ontario), Dominion Land Surveyor	Surv. Eng.
G.A. Corcoran	B.Sc. (Ottawa), B.Eng. (McGill), Dominion Land Surveyor	Surv. Eng.
G.L. Fraser	B.Sc. (Queen's), Dominion Land Surveyor	Surv. Eng.
R.H. McDowell	B.Sc. (New Brunswick)	Surv. Eng.
M.T. Swanson	B.Sc. (Manitoba), Dominion Land Surveyor	Surv. Eng.
C.G. Vigneault	B.A.Sc. (Laval), Quebec Land Surveyor	Surv. Eng.
B.G. Mousseau	B.Sc. (Ottawa)	Surv. Eng.

Primary Vertical Control

F.W. Mosienko	B.Sc. (Saskatchewan)	Surv. Eng.
F.W. Young	B.Eng. (N.S.T.C.), B.Sc. (Mt. Allison), P.Eng. (Nova Scotia)	Surv. Eng.
P. Boudreault	B.A. (Laval), B.Sc. (Laval), P.Eng. (Quebec)	Surv. Eng.
Y. Gilbert	B.Sc. (Laval), P.Eng. (Quebec)	Surv. Eng.
R.S. Smith	B.Sc. (Mt. Allison), B.E. (N.S.T.C.)	Surv. Eng.
W.L. Gale	B.Eng. (Carleton), B.Ed. (Queen's)	Surv. Eng.
R.I. Emmett	Nova Scotia Land Surveyor	Eng. Supp.
W.C.D. Sundholm	B.Sc. (Saskatchewan)	Eng. Supp.
G.J. Neigel	B.Sc. (Saskatchewan)	Eng. Supp.
N.H. Frost	B.Sc. (Manitoba)	Surv. Eng.

Supplementary Control

C.R. Colwell	B.Sc. (New Brunswick)	Surv. Eng.
J.V. Brown	Nova Scotia Land Surveyor	Surv. Eng.
R. Chewpa	B.Sc. (Toronto), Dominion Land Surveyor	Surv. Eng.
D.L. MacQuarrie	Nova Scotia Land Surveyor	Surv. Eng.
V.J. Doucette	B.Sc. (N.S.T.C.)	Surv. Eng.
B.R. Justason	B.Sc. (New Brunswick), New Brunswick Land Surveyor	Surv. Eng.
L.J. Frenette	B.Sc. (New Brunswick)	Surv. Eng.
P.E. Langlais	B.A., B.Sc. (Laval)	Surv. Eng.
A.R. Eaton	B.Sc. (McGill)	Surv. Eng.
C.R. Penton	B.Sc. (New Brunswick)	Surv. Eng.

Technological Research

S.A. Yaskowick	B.A.Sc. (Saskatchewan), Eng. Phys.	Surv. Eng.
G.A. Wilkinson	B.A.Sc. (British Columbia), Eng. Phys.	Surv. Eng.
S. Vamosi	B.Sc. (Sopran, Hungary), M.Sc. (Ohio State)	Surv. Eng.

Geodesy Group

C.D. McLellan	B.A., M.A. (Queen's)	Surv. Eng.

Physical Geodesy

G. Lachapelle	B.Sc. (Laval), M.Sc. (Oxford), L.Ph. (Helsinki), Dr. Sc. (Graz, Austria)	Surv. Eng.
J. Kouba	D.Ing. (Czech. Tech. U.), M.Sc. (New Brunswick)	Surv. Eng.
J.A.R. Blais	B.Sc. (Montreal), M.A. (Toronto)	Mathematician

Computations and Adjustments

J.P. Henderson	B.A.Sc. (Toronto), M.Sc. (New Brunswick)	Surv. Eng.
D.S. Beattie	B.Sc. (Mt. Allison), B.E. (N.S.T.C.)	Surv. Eng.
L.W. Churcher	B.Sc. (Queen's)	Surv. Eng.
M.C. Pinch	B.Sc. (New Brunswick)	Surv. Eng.
J.D. Boal	B.A.Sc. (Toronto), P.Eng. (Ontario)	Surv. Eng.
D.V. St. Helene	B.Sc. (Dalhousie), B.E. (N.S.T.C.)	Surv. Eng.
R.J. Carriere	B.Sc. (New Brunswick)	Surv. Eng.

Data Services

G.M. Armstrong	B.Sc. (New Brunswick)	Surv. Eng.
R.L. Forgues	B.Sur., B.A.Sc. (Laval)	Surv. Eng.
K.C. MacKenzie	B.Sc. (New Brunswick)	Surv. Eng.
R.B. Roberts	B.A. (Trinity College, Dublin)	Eng. Supp.
R.A. Forbes		Eng. Supp.

TOPOGRAPHICAL SURVEY DIRECTORATE

J.M. Zarzycki	M.Sc.Eng. (Warsaw), Ph.D. (Swiss Fed. Inst. of Technology, Zurich), P.Eng. (Ontario, Quebec, Alberta)	Director
J.H. O'Donnell	B.A.Sc. (Laval), Quebec Land Surveyor, Ontario Land Surveyor	Assistant Director
J.R.R. Gauthier	Dipl.Ing. (France), B.Sc. (New Brunswick), Ing. (Quebec), P.Eng. (Ontario)	Assistant Director
E.D. Lawson		Executive Assistant

Administration

W.J. Bottomley		Admin. Off.

Research and Development Section

M.M. Allam	B.Sc. (Alexandria, U.A.R.), Ph.D. (Geodesy, Air Photography and Cartography Institute, Moscow)	Surv. Eng.
E.A. Fleming	B.A. (British Columbia)	Surv. Eng.
B.A. Low	B.Sc. (Victoria)	Surv. Eng.
J.D. Mears	B.A. (Western Ontario)	Computer Sci.
G.K. Schliebener	B.Eng. (Ottawa), P.Eng. (Ontario)	Surv. Eng.
C.K. Wong	B.Sc. (Taiwan), M.Sc. (New Brunswick)	Surv. Eng.
S. O'Neill	B.Sc. (New Brunswick), P.Eng. (Ontario)	Surv. Eng.

Mapping Program Section

L.M. Sebert	B.A.Sc. (Toronto), Dominion Land Surveyor P.Eng. (Ontario)	Surv. Eng.
R. Gareau	B.Sc. (New Brunswick)	Surv. Eng.
M. Frigon	B.A.Sc. (Laval), Quebec Land Surveyor	Surv. Eng.
R.K. Rose	B.Sc. (New Brunswick)	Surv. Eng.
K.G. Hodgins		Draft. & Illus.
C.K. Chaly	B.Sc. (Kerala State, India), M.Sc. (New Brunswick), P.Eng. (Ontario)	Surv. Eng.

Topographic Mapping Division

D.G. Anderson		Eng. Supp.
D.A. MacKay	B.Sc. (Dalhousie & N.S.T.C.)	Surv. Eng.
J.R. Holt	B.Sc. (Stephen F. Austin)	Surv. Eng.

Mapping Section No. 1

J.D. MacDonald		Draft. & Illus.
M.E. Sabourin		Draft. & Illus.
W.J. Winges		Draft. & Illus.
E.G. Jessiman		Draft. & Illus.

Mapping Section No. 2

A.E. Kamp		Draft. & Illus.
F.R. Snook		Draft. & Illus.
S.M. Ullyett		Draft. & Illus.
C.S. Cook		Draft. & Illus.
J.R. Lortie		Draft. & Illus.
R.M. Simser		Draft. & Illus.

Aerial Photography Division

W.G. Landles		Admin. Off.

Interdepartmental Committee on Air Surveys

J.A. Morton		Admin. Off.

National Air Photo Library

P. Andrews		Prog. Man.
P. Furlong	B.A. (Toronto)	Prog. Man.
S. Chaplin	B.A. (Mt. Allison)	Tech. Supp.
W. Isken	B.A. (Carleton)	Tech. Supp.

National Air Photo Library Reproduction Centre

G.M. Nitschky		Admin. Off.
W.J. Dilworth		Photographer
J. Hyams		Photographer
R. Boulianne		Tech. Insp.

Canada Map Office

G.A. Clemmer		Admin. Off.

DIRECTORATE OF MAP PRODUCTION

T.H. Kihl, succeeded on January 1 by R. Groot	M.Sc. Geodesy (Delft), D.T.S.	Director
R. Groot	M.Sc. (Delft), D.T.S.	A/Assistant Director

Administration

L.P. St. Pierre		Admin. Off.

Coordinator, Map Production

D.H. Ketch	B.Sc. (New Brunswick)	Gen. Tech.

Automated Cartography

J.L. McDougall	B.Eng. (Civil)	Phys. Sci.
M.E.H. Young	B.Sc. (Queen's), M.A.Sc. (Toronto), P.Eng. (Ontario)	Surv. Eng.
T.C. Bartello		Electronics Tech.
E. Paveck	B.Math., M.Math. (Waterloo)	Computer Sci.
S. Law	B.Math., M.Math. (Waterloo)	Computer Sci.
R. Rackow	B.Sc. (Saskatchewan), M.Math. (Waterloo)	Computer Sci.
A.M. Zingaro	B.Sc. (McMaster)	Computer Sci.
M.T. Dolle	B.Sc. (York)	Computer Sci.

Aeronautical Charts Division

R.M. Defoe	B.Sc. (Royal Military College), P.Eng. (Ontario)	Surv. Eng.
R.A. Delaney		Draft. & Illus.
T.M. Cobb		Draft. & Illus.
R.E. Reinburg		Draft. & Illus.
P. Katznelson	B.A. (Carleton)	Gen. Tech.
N. Grant	B.A., M.A. (Carleton)	Phys. Sci.

Cartography Division

G. Montagano		Eng. Supp.
L. Peskett		Draft. & Illus.
G. Millette		Gen. Tech.
G. Shoup		Draft. & Illus.
G. Laidlaw		Draft. & Illus.
G. Peer		Draft. & Illus.
R. Aunaste	B.A. (Tarta, Estonia)	Draft. & Illus.
J. Curran		Eng. Supp.
W.J. Clark		Draft. & Illus.
D. Joiner		Draft. & Illus.
L.P. Trudel		Draft. & Illus.
B.B. Robertson		Draft. & Illus.
J.B. Hogan	B.A. (Carleton)	Draft. & Illus.
B. Cromie	B.A. (Queen's)	Phys. Sci.

Map Reproduction Division

T. Frith		Admin. Off.
A. Hammond		Printing Sup.
J. Hurtubise		Printing Sup.
A.A. Baldock	B.A. (Carleton)	Printing Sup.

Geography Division

G. Falconer	B.A., M.A. (Cantab.)	Phys. Sci.
B. Cornwall	B.A., M.S. (British Columbia)	Phys. Sci.
J.M.O. Morawiecki	B.A., M.A. (Ottawa)	Phys. Sci.
B. Berghout	B.A. (Carleton)	Phys. Sci.
B. Brickman	B.A., M.A. (Carleton)	Phys. Sci.
C. Chapdelaine	B.A. (Montreal)	Phys. Sci.
D.M. Fairbairn	B.A. (Queen's)	Phys. Sci.
C. Gosson	B.A. (Ottawa)	Phys. Sci.
P. Harker	B.A. (McMaster), M.A. (Waterloo)	Phys. Sci.
R. Jay	B.A., M.A. (Queen's)	Phys. Sci.
I. Jost	B.A. (Warsaw), M.A. (Ottawa)	Phys. Sci.
K. Lightfoot	B.A. (Carleton)	Draft. & Illus.
D. MacKay	B.A., M.A. (Carleton)	Phys. Sci.
I. Marshall	B.Sc. (Saskatchewan), P.Ag. (Ontario)	Phys. Sci.
M. McLaughlan	B.A. (Queen's)	Tech. Supp.
C.P. Ravel	B.A. (Sherbrooke)	Phys. Sci.
J.J.S. Thompson	B.A. (Carleton)	Phys. Sci.
V. Wilson	B.Sc. (Hull, England), M.A. (Simon Fraser)	Phys. Sci.
S. Palko	B.Eng. (Prague), M.Sc. (Saskatchewan)	Phys. Sci.
S. Kelly	B.A. (Brock)	Phys. Sci.

Geography Division (Cont'd.)

H.E. Mindak		Draft. & Illus.
P. Baldock		Draft. & Illus.
C.L. Bohm		Draft. & Illus.
J.C. Allen		Draft. & Illus.
L. Leafloor		Tech. Supp.

Toponymy Division

J.A. Rayburn	B.A. (Western Ontario), M.A. (Kentucky)	Phys. Sci.
W. Yeo	B.A. (Calgary), M.A. (Queen's)	Phys. Sci.
R. Disipio		Sci. Asst.
M.R. Munro	B.A. (Carleton)	Phys. Sci.
R. Leduc	B.A. (Montreal)	Sci. Asst.
K. O'Brien	B.A. (Carleton)	Tech. Supp.
H. Kerfoot	B.Sc. (London)	Sci. Asst.
M. LaHam	B.A. (Ottawa)	Sci. Asst.
B. MacIntosh	B.A. (Carleton)	Sci. Asst.

INTERNATIONAL BOUNDARY COMMISSION

A.C. McEwen	LL.B. (London), LL.M. (East Africa), Dominion Land Surveyor, Ontario Land Surveyor, Newfoundland Land Surveyor	Commissioner

Engineers

W.M. Smith	B.Sc. (New Brunswick), Dominion Land Surveyor	Surv. Eng.
N. Paquette	B.Sc.App. (Arpentage)(Laval), Quebec Land Surveyor	Surv. Eng.
C.J. Gustafson	B.Eng. (Carleton)	Surv. Eng.
J. Ferguson-Roberts	B.Sc. (Toronto)	Surv. Eng.

LEGAL SURVEYS DIVISION

D.R. Slessor	B.Sc. (Manitoba), Ontario Land Surveyor Dominion Land Surveyor, P.Eng. (Ontario)	Surveyor General
W.V. Blackie	B.Sc. (Cape Town), Nova Scotia Land Surveyor, Dominion Land Surveyor, Ontario Land Surveyor	Assistant Surveyor General
R.O. Semper	Nova Scotia Land Surveyor, Dominion Land Surveyor, Prince Edward Island Land Surveyor, New Brunswick Land Surveyor	Div. Planning Off.

Administration

J.B. Comerford		Admin. Off.

Field Surveys

L.L. Anderson	B.A.Sc. (Toronto), Alberta Land Surveyor, P.Eng. (Ontario), Dominion Land Surveyor	Land Surv.
R.G. McBurney	B.A.Sc. (Waterloo), P.Eng. (Ontario) Dominion Land Surveyor	Land Surv.
W.D. Stretton	Ontario Land Surveyor, Dominion Land Surveyor	Land Surv.
T.A. Maki	B.Eng. (McGill)	Land Surv.
J.H. Lewis		L.S. Supp.
D.W. Dryden	B.T. Geodetic Sciences (Ryerson)	L.S. Supp.
S.A. Repstock	Dominion Land Surveyor	Land Surv.
G.D. Aucoin	Dominion Land Surveyor	L.S. Supp.
S. Hutchinson	Dominion Land Surveyor	Land Surv.
R.E. Lafrenière	Dominion Land Surveyor	Land Surv.
J. Brennan	B.Sc. (New Brunswick)	Land Surv.
I.M.D. Fox	B.Eng. (McGill), Dominion Land Surveyor, British Columbia Land Surveyor	Land Surv.
M.H. Collins	British Columbia Land Surveyor, Dominion Land Surveyor	Land Surv.
D.K. Nielsen	British Columbia Land Surveyor	Land Surv.
W.R. Barraclough	Dominion Land Surveyor	L.S. Supp.
G.S. Olsson	Alberta Land Surveyor, Dominion Land Surveyor	Land Surv.
D.A. Bouck	Dominion Land Surveyor, Alberta Land Surveyor	Land Surv.
D.D. Pearce	B.Sc. (Carleton), Dominion Land Surveyor	Land Surv.
G.J. Zeldenrust	Saskatchewan Land Surveyor	Land Surv.
A. McTaggart	Dominion Land Surveyor, Manitoba Land Surveyor	Land Surv.
P.E. Stevens	Manitoba Land Surveyor	Land Surv.
D.H. Browne	Ontario Land Surveyor, Dominion Land Surveyor, Nova Scotia Land Surveyor	Land Surv.
J. Hill	Ontario Land Surveyor	Land Surv.
D.G. McMaster	Ontario Land Surveyor	Land Surv.
A.M. MacLeod	Dominion Land Surveyor	Land Surv.
G.J. Campbell	B.T. Geodetic Sciences (Ryerson), Dominion Land Surveyor	L.S. Supp.

J. Sasseville	Quebec Land Surveyor	Land Surv.
Y. Sanfaçon	Quebec Land Surveyor	Land Surv.
D.A. Tetreault	B.A. (Montreal), Quebec Land Surveyor	Land Surv.
W.D. McLellan	New Brunswick Land Surveyor	Land Surv.
J. Covert	Dominion Land Surveyor, Prince Edward Island Land Surveyor, Nova Scotia Land Surveyor	Land Surv.
H.S. McLaren	New Brunswick Land Surveyor	Land Surv.

Instruction and Support

R.G. Snowling	B.A.Sc. (British Columbia), Dominion Land Surveyor, P.Eng. (Ontario)	Land Surv.
S.W. Young	B.Sc. (Alberta)	L.S. Supp.
F. Vanderkuip	B.Sc. (Minerva Academy, Greningen, Holland)	Draft. & Illus.
P.I.R. Sauvé	Ontario Land Surveyor, Dominion Land Surveyor	Land Surv.
D.J. Macdonell	Ontario Land Surveyor	Land Surv.
E.F.L. Cole	Ontario Land Surveyor	Land Surv.
K.G. Hamilton	Certified Survey Technologist	L.S. Supp.

Plan Examination

R.T.B. McCurdy	Dominion Land Surveyor, Ontario Land Surveyor, Nova Scotia Land Surveyor	Land Surv.
M. Wuhr	Nova Scotia Land Surveyor, Dominion Land Surveyor, Alberta Land Surveyor, New Brunswick Land Surveyor, Prince Edward Island Land Surveyor	Land Surv.
W.R. Griese	Dominion Land Surveyor, Saskatchewan Land Surveyor, Alberta Land Surveyor	Land Surv.
W.W. Clark	B.Sc. (Carleton)	L.S. Supp.
A.E. Dickson	Dominion Land Surveyor	Land Surv.
V.J. Vinette	B.A. (Ottawa)	L.S. Supp.
R.G. Wallis	Nova Scotia Land Surveyor	L.S. Supp.
M. Patterson	Philippines Land Surveyor	L.S. Supp.
S. Mortimer		L.S. Supp.
G.S.P. Isaacs	Nova Scotia Land Surveyor	L.S. Supp.
D. McLacklen	B.A. (Ottawa)	Tech. Supp.

Research and Development

H.E. Jones	B.Sc. (Queen's), P.Eng. (Ontario), Dominion Land Surveyor	Land Surv.
C. Bonnell	B.Sc. (New Brunswick), P.Eng. (Ontario), Nova Scotia Land Surveyor, Dominion Land Surveyor	Land Surv.
J.C. Mitchell	B.A.Sc. (Ottawa), P.Eng. (Ontario), Dominion Land Surveyor	Land Surv.
G.E. LeSueur	B.A. (Toronto), M.Rel. (Toronto), Dominion Land Surveyor, Alberta Land Surveyor	Land Surv.
C.A. Silliphant	B.Sc. (New Brunswick), P.Eng. (Ontario)	Land Surv.
E. Kappler	Dominion Land Surveyor	Land Surv.

CAP Program

G. Raymond	B.Sc. (Laval), L.L.L., Quebec Land Surveyor, Dominion Land Surveyor	Land Surv.

CANADA CENTRE FOR REMOTE SENSING

NAME	DEGREES	CLASS TITLE
OFFICE OF THE DIRECTOR-GENERAL		
L.W. Morley	Ph.D. (Toronto), D.Sc. (York), F.R.S.C., P. Eng.	Director-General
E.A. Godby	B.Sc., M.Sc. (Alberta), P. Eng.	Associate Director-General
Program Planning and Evaluation Unit		
J.C. Henein	B.Sc. Eng. (Cairo), M.Sc. (Carleton), P. Eng.	Chief
A.K. McQuillan	B.Sc., M.Sc. (Western Ontario), Ph.D. (Toronto)	Program Eval.
A.M. Kelly	B.Sc. (St. Francis Xavier), M.Sc. (M.I.T.)	Program Plann.
V.P. Britton		Plann. Liais.
Administration Division		
R.C. Bone	B.A. (Winnipeg)	Chief
B.C. McGurrin	B.A. (Loyola), B.L.S. (Ottawa)	Head, Sci. Inf. Retrieval
G. Leckie	B.A. (Windsor), M.L.S. (Western Ontario)	Assistant Head, Sci. Inf. Retrieval
A. Grebenc	B.Sc. (Carleton)	Head, Fin.
J. Whitehead		Head, Admin.
Personnel		
F.B. Macdonnell	B.A. (Queen's), F.R.C.O.	Pers. Admin.
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		Op. Off.
J.F. Fleming	B.Sc. (Carleton)	Q.C.
C. Petzinger	B.A.Sc. (British Columbia)	Sr. Mission Manager
R. McKibbon		Op. Tech.
Airborne Systems Section		
J.E. Smyth	B.Sc. (Alberta), P.Eng.	Head
J. Granot	B.Sc., M.Sc. (Israel), P.Eng.	Electr. Eng.
A.J.M. Baillie	B.Eng., M.Eng. (British Columbia)	Electr. Eng.
J.R. Gibson	B.Sc. Eng. Sc., M.Sc. (Saskatchewan)	Electr. Eng.
W. Ladan	Dip. (Netherlands)	Design Shop Sup.
K. Holthusen	Dip. (Germany)	A/C Sheet Metal
J. Waddell		Sr. Electr. Tech.
J. Rene de Cotret	Dip. (Hull)	Electr. Tech.
J.E. Allen	Dip. (Ryerson)	Electr. Tech.
M. Lalonde	Dip. (Algonquin)	Jr. Electr. Tech.
D. Percy	Dip. (Algonquin)	Jr. Electr. Tech.

Program Development Section

L. Bronstein	B.Eng. (McGill), M.Sc. (M.I.T.), P. Eng.	Head

Microwave Studies

R.K. Raney	A.B. (Harvard), M.S. (Purdue), Ph.D. (Michigan)	Res. Sci.

Sensor Development Section

J.N. de Villiers	B.Sc. (Edinburgh), Ph.D. (Canada)	Head
A.L. Gray	B.Sc. (Belfast), M.Sc., Ph.D. (Calgary), P. Eng.	Res. Sci.
R.A. O'Neil	B.Sc. (Calgary), Ph.D. (McMaster)	Res. Sci.
H.H. Zwick	B.A., M.A., Ph.D. (Saskatchewan)	Res. Sci.
C. Livingstone	B.Sc., M.Sc. (British Columbia), Ph.D. (Western Ontario)	Sensor Tech.
R. Marois	Dip. (Algonquin)	Sensor Tech.

DATA PROCESSING DIVISION

E. Shaw	B.Sc., Ph.D. (Birmingham)	Chief

Instrumentation Division

D.N. Davis	B.Sc., (Alberta), M.Sc.Eng. (London), D.I.C. (Imperial), P.Eng.	Head
T.J. Butlin	B.Sc. (Dundee), P. Eng.	Sr. Electr. Eng.
R. Chow	B.Sc. (New Brunswick), M.Sc. (Carleton), P. Eng.	Sr. Electr. Eng.
T.O. Froelich	Ing. (West Berlin)	Sr. Electr. Tech.
S. Methot	Dip. (Algonquin)	
K. Hannam	Dip. (Mohawk)	Electr. Tech.
J.S. Garand	Dip. (Hull)	Electr. Tech.
R. Shergold	O.N.C. (England)	Drafts.

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. Syst. Eng.
H. Edel	B.A.Sc. (Ottawa), P.Eng.	Syst. Sci.
S.S. Vishnubhatla	B.Sc. (India), M.Sc. (Carleton), Ph.D. (Ottawa)	Syst. Sci.
G.W. Plunkett	B.Eng. (Carleton), P.Eng.	Syst. Sci.
J. Princz	B.Sc. (British Columbia)	Syst. Sci.

Data Control and Distribution Section

A.B. Collins	B.Sc. (Michigan)	Head
M. Battikha	B.Eng. (McGill), M.Eng. (Concordia), P.Eng.	Station Manager, Shoe Cove Satellite Station
R.L. Irwin		Station Manager, Prince Albert Satellite Station
D.C. Latour	B.Sc. (Carleton)	Image Analyst
G. Duplessis		Q.C. Tech.
L. Sabadoz	B.Sc. (Manitoba)	Q.C. Tech.
R. Graves	Dip. (Algonquin)	Q.C. Tech.

Operations Section

M.A. Jager	O.N.C. (England)	Head
R.E. Moore		Shift Sup.
D. Presley		Shift Sup.

APPLICATIONS DIVISION

W.M. Strome	B.Sc. (Alberta), M.A.Sc. (British Columbia), 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), Ph.D. (Waterloo)	App. Sci.
T.T. Alfoldi	B.A.Sc., M.A. (Toronto), P.Eng.	App. Sci.
W.D. Bruce	B.A. (Brock), M.Sc., Ph.D. (McMaster)	App. Sci.
J. Cihlar	B.Eng., (Prague), M.A. (Guelph), Ph.D. (Kansas)	App. Sci.
C. Goodfellow	B.Sc. (Waterloo)	App. Sci.

Methodology Section

D.G. Goodenough	B.Sc. (British Columbia), M.Sc., Ph.D. (Toronto)	Head
S. Shlien	B.Sc. (McGill), D.Sc. (M.I.T.)	Res. Sci.
F. Ahern	A.B. (Cornell), Ph.D. (Maryland)	Res. Sci.
R. Lowry	B.Sc. (Saskatchewan), Ph.D. (Imperial)	Res. Sci.
R. Brown	B.Sc., M.Sc., Ph.D. (Manitoba)	Res. Sci.

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. (Edinburgh), Ph.D. (British Columbia)	Res. Sci.
R.M. Koerner	B.A. (Sheffield), M.A. (Sheffield), Ph.D. (London)	Res. Sci.
F.P. Hunt		Field Op. Mgr
D.L. Cameron		Admin. Off.

EXPLOSIVES BRANCH

NAME	DEGREES	CLASS TITLE
B.P. McHugh	B.Sc.	Director
T.R. Robertson	B.Sc.	Deputy Director
J.T. desRivieres	B.Sc.	Explosives Inspection Specialist
L.J. Saulnier	M.Sc.	Regional Inspector Atlantic Region
A.A. Leclerc	B.A.	Regional Inspector Quebec Region
W.O. Taylor	B.Sc.	Regional Inspector Central Region
D.I. Campbell	B.Sc.	Regional Inspector Pacific Region
D.J. McCulloch	B.Sc.	Assistant Regional Inspector Pacific Region
L.B. Buchanan	M.Sc.	Regional Inspector Ontario Region
P.A. Houldsworth	B.Sc.	Assistant Regional Inspector Ontario Region
J.R. Bissonnette		Technologist
D.M. McLeish		Administrative Officer

CANADA CENTRE FOR GEOSCIENCE DATA

NAME	DEGREES	CLASS TITLE
C.F. Burk, Jr.	B.Sc. (Western Ontario) Ph.D. (Northwestern)	Phys. Sci.
K.L. Gunn	B.Sc., M.Sc. (Toronto)	Phys. Sci.
G.A. Chappell		Syst. Anal.

INVENTIONS AND PATENTS TO 1974

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.H. 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. Woodroffe	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 Electro-magnetic 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
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 Can. Patent
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
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. Friedrich	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
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
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 Spectrophotometer	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. 442,902 filed 19-2-74
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	Q. Bristow	To be exploited on a Know-How basis
Oxygen Probe with Self-contained Source of Oxygen	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
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

PATENTS GRANTED 1975-76

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