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CANADA GEOLOGICAL SURVEY – COMMISSION GÉOLOGIQUE 1842

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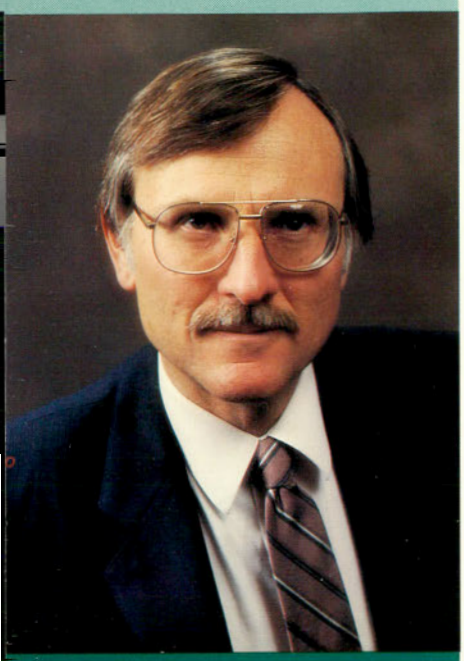


Message from the Assistant Deputy Minister

FOR THE GEOLOGICAL SURVEY OF CANADA

It gives me great pleasure, as the new Assistant Deputy Minister, to introduce the second annual review of the Geological Survey of Canada Sector (GSC). I am delighted to be assuming responsibility for a world-class organization which is so highly regarded both here in Canada and abroad.

Over the past year, the GSC management team has directed much careful thought and effort to reshaping the Survey's organizational framework and internal accountability systems to accommodate the increased visibility and responsibility that the GSC assumed within the Department of Energy, Mines and Resources, when, in April 1987, it was made a separate Sector. Concurrently, the Survey's scientific program and research goals have come under close scrutiny to ensure that the GSC continues to be fully responsive to the needs of its clients. In this regard, I would like to take this opportunity to express, on behalf of the entire Survey, gratitude to my predecessor, Dr. Raymond Price, who has left the management ranks to return to his first love — research. His commitment, tireless efforts and even-handed leadership were instrumental in guiding the GSC successfully through this period of change and restructure. We all wish him every success for the future.

For the immediate future a close working partnership with industry will be one of our high priority goals. Increasingly, a key role of governmental scientific institutes is to respond to the needs of Canadian industry, to support their growth and to foster much-needed economic development. The GSC has traditionally enjoyed strong ties and excellent cooperation with industry, and we hope to build on this — particularly with respect to major joint research ventures, technology transfer, and liaison with industry advisory groups. We will also be seeking ways in which we can make the GSC more flexible and adaptive to the new challenges arising from changes in the national economy and governmental priorities and in the growing societal concern about enviromental issues.

The cornerstone of our role on the national scene will continue to be the provision of geoscientific information and advice for the formulation of policy, for economic development, for environmental protection, for public safety and security and for sovereignty. The need to strengthen and build on our existing geoscience knowledge base will remain a prime concern. Towards this end, the GSC will continue to maintain a dynamic balance between geoscientific mapping and observation, applied and basic research, and sevice to our clients.

In the pages that follow are highlighted some of the GSC's recent accomplishments, many of which contribute to the development of new concepts in the earth sciences. All of them contribute to the maintenance of an authoritative and unbiased Canadian geoscience knowledge base available for use by government, industry, academia and the public at large.

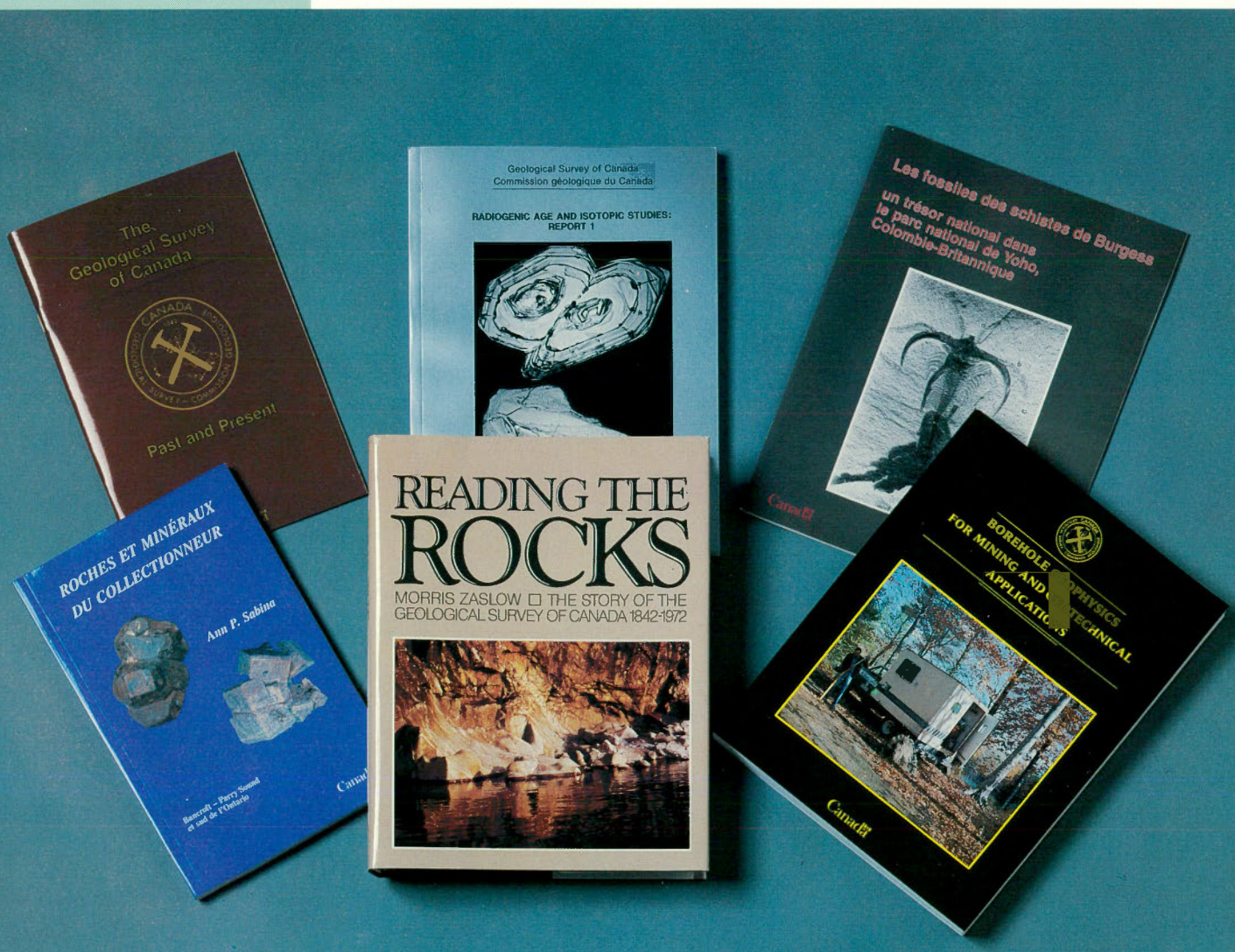
I am proud to be leading the Geological Survey of Canada, an institution whose long tradition of productivity and excellence constitutes such a fundamental contribution to Canada's economic health and prosperity.

Elkanah A. (Ken) Babcock

Introduction

Following a restructuring in April 1987 of the Minerals and Earth Sciences Program of the Department of Energy, Mines and Resources (EMR), the GSC was established as a separate Sector within the Department. This reorganization gave the GSC a higher profile and stronger voice within the EMR organization.

The GSC's objectives and its commitment to its clients nevertheless remain unchanged: *to provide for Canadians the best possible geoscientific knowledge, technology and expertise about Canada and its offshore areas, its mineral and energy resources and the natural conditions that affect land and seabed use.*



Organization

To strengthen and focus productivity and coordination as well as to increase the sharing of common services and logistical support, the new Geological Survey of Canada Sector has grouped together activities that address the same themes or policy issues: **Energy**, **Minerals**, **Environment**, **Information**.

The new organizational framework brings together the former GSC divisions under four Branches:

Information

The *Program, Planning and Services Branch* and *Office of the Chief Scientist* plans, coordinates and evaluates the GSC's scientific programs. It coordinates cooperative work with the provinces and the territories under the Mineral Development Agreements; manages special, sector-wide activities such as the Frontier Geoscience Program and international relations; oversees the departmental Research Agreements Program; and provides central administrative services. Through its Geoscience Information Division, this Branch prepares and delivers the Survey's publications, maps and reports and maintains its central library.

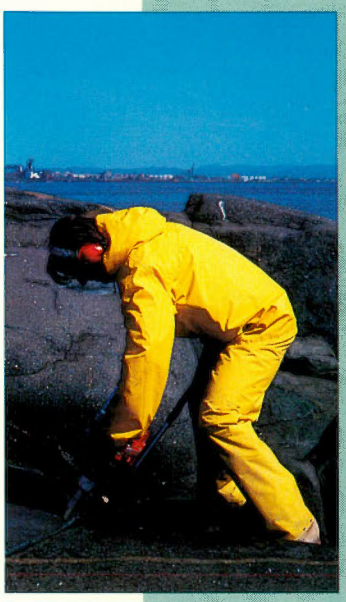
Energy

The *Sedimentary and Marine Geoscience Branch* provides geoscientific information about the sedimentary basins of western and Arctic Canada, the Cordillera, the offshore regions of the East and West Coasts and of the Arctic. The Branch is responsible for oil, gas and coal resource assessments and for marine and frontier geoscience programs. It comprises three divisions: the Atlantic Geoscience Centre (Dartmouth, Nova Scotia), the Cordilleran and Pacific Geoscience Division (with offices at Vancouver and at Sidney, British Columbia) and the Institute of Sedimentary and Petroleum Geology (Calgary, Alberta).

Logistics support was provided to 232 research parties working in the Canadian Arctic in the 1987 field season, making it one of the largest field operations in the history of PCSP.

Minerals

The *Continental Geoscience and Mineral Resources Branch* provides a national geoscience knowledge base on Canada's mineral resources, on the rocks of the Canadian Shield and on the "deep" geology and geophysics of the Canadian landmass. Its two Ottawa-based divisions are the Mineral Resources Division and the Lithosphere and Canadian Shield Division.

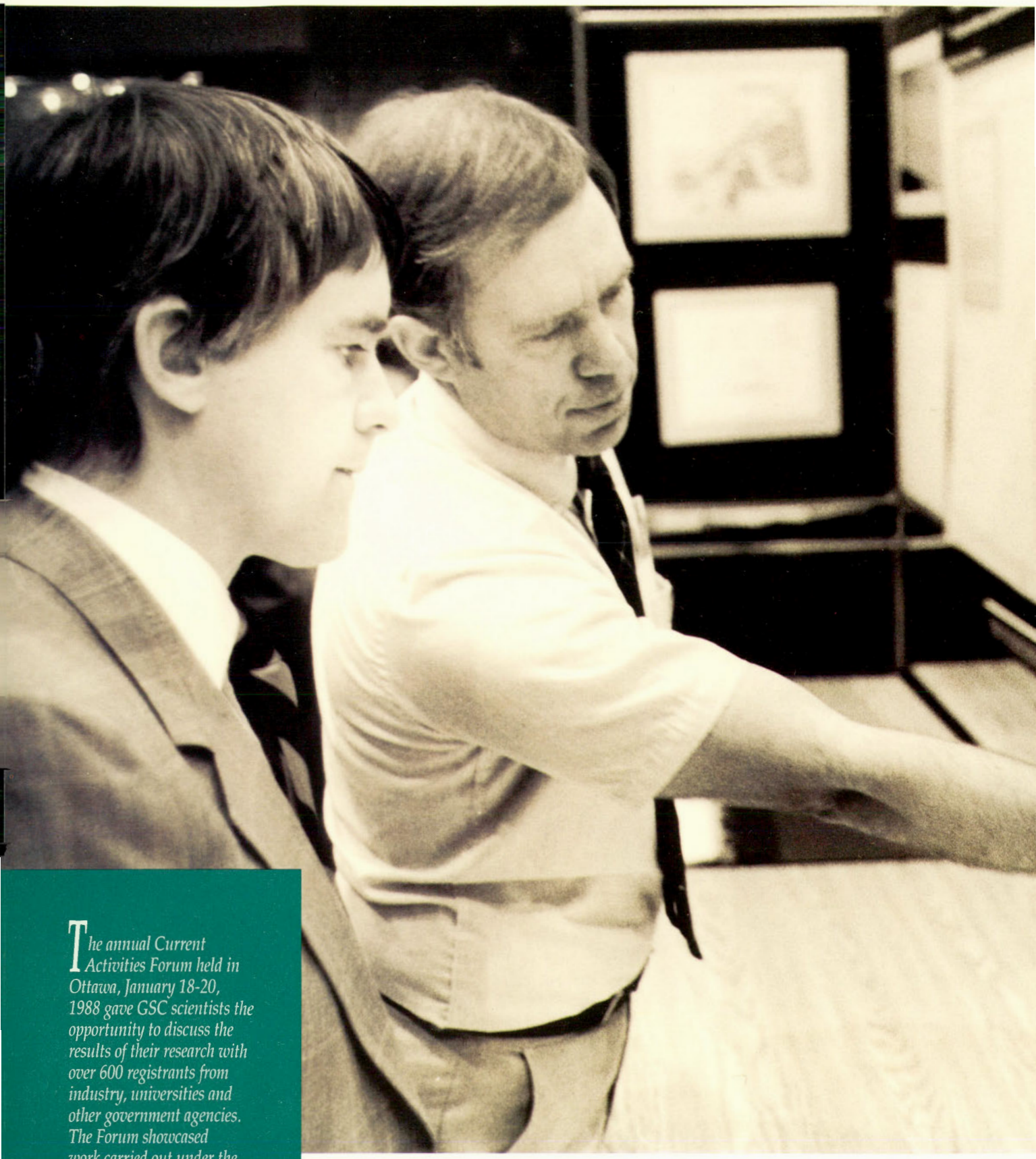


Environment

The *Geophysics and Terrain Sciences Branch* provides information and expertise on Canada's physical environment through the operation of national geophysical networks and surveys, through the study of unconsolidated deposits, and through engineering and other associated studies related to terrain use and hazards. Headquarters and research facilities for its two divisions, the Terrain Sciences Division and the Geophysics Division, are located in Ottawa; observation facilities for the national seismological, geomagnetic and geodynamic networks are found throughout Canada.

Arctic Sovereignty

Joining the new Sector is the *Polar Continental Shelf Project (PCSP)* which provides logistics support and advice to scientific research groups working in the Arctic. It also keeps the scientific community and Arctic residents informed of research projects underway in the Arctic. PCSP headquarters are located in Ottawa, with base camps at Tuktoyaktuk and Resolute, N.W.T, and at the floating Ice Island Research Station in the Arctic Ocean.



The annual Current Activities Forum held in Ottawa, January 18-20, 1988 gave GSC scientists the opportunity to discuss the results of their research with over 600 registrants from industry, universities and other government agencies. The Forum showcased work carried out under the Frontier Geoscience Program, Lithoprobe, Mineral Development Agreements and the Energy Research and Development Program.

Information

Office of the Chief Scientist and Programs, Planning and Services Branch

Information

One of the most important activities of the Branch is ensuring that the results of GSC's scientific program are made available, as maps, reports or data files, as quickly and cost-effectively as possible. Information is disseminated to a wider non-specialist public as well through a range of technical and public information activities. The Branch also operates the National Geoscience Library.

Whatever the audience, the Branch is responsible for ensuring tnat GSC's traditional levels of scientific and literary excellence, accuracy and authority are maintained. In 1987-88, about 5800 pages of new scientific text, as well as some 1000 pages of general text (e.g. popular booklets, Open File reports) were published by the GSC. Many scientific reports were also published directly in outside journals.

The GSC is coordinating production of the Canadian contribution to the Decade of North American Geology (DNAG) project, and during the year the Branch focussed considerable effort on planning and putting in place adequate staff and facilities to handle the nine DNAG volumes that will comprise the *Geology of Canada* series. Two volumes, *Quaternary Geology* and *East Coast Canada*, are slated for publication during 1988-89.

Coordination

The Branch is responsible for the overall quality and integrity of GSC's scientific programs, for the information and management systems by which they are planned and evaluated, and for the common administrative services that support them. It also coordinates special national programs that are delivered by more than one of GSC's Branches, and GSC's involvement in external collaborative, multi-agency research initiatives. Examples of these special programs are the federal geoscience elements of the Mineral Development Agreements with the provinces and territories, the Frontier Geoscience

Major publications of 1987-88:

Current Research: **This six-volume, 1275 page annual report presents the latest scientific results from many of the GSC's ongoing projects.**

Metallic Minerals on the Deep Seabed: **Technology now makes it possible to explore deep seabed mineral occurrences. This report reviews the main types of these occurrences and their depositional environments. A world map displays major tectonic features, distribution of manganese modules, various types of metalliferous sediments and areas of present and past hydrothermal activity on the seafloor.**

Quaternary Geosciences in Canada: **In 1983 the Canadian Geoscience Council set up a review committee to determine the effectiveness with which Canadian scientists and institutions are responding to developments in Quaternary science. Their report includes 25 conclusions and 13 recommendations.**

Debris Flow Hazard in the Canadian Rocky Mountains: **Valleys in the Rocky Mountains are frequently subjected to debris flows, rock and snow avalanches and flash floods. This report presents a method for identifying past activity as an aid to designing protective works and preparing land use restrictions.**

(Continued on next page)

Airborne Resistivity Mapping: Airborne electromagnetic systems were developed in Canada in the 1950s as an aid to mineral exploration. By the 1970s, these techniques were being applied all around the world. The reports that make up this volume present an up-to-date review of this valuable prospecting tool.

***Terrestrial Impact Structures Map:* There is growing interest in theories that link major events in the history of the Earth (e.g. extinction of the dinosaurs) to the impact of such extraterrestrial bodies as meteors. This map shows craters that have associated meteoric material or shock metamorphic features.**

***Paleogeography Map of North America 18 000 to 5000 Years Ago:* Most of Canada was once covered by the Laurentide Ice Sheet, the world's largest known glacier. This map traces the uncovering of Canada from the last maximum ice coverage, 18 000 years ago, to 5000 years**

(Continued on next page)

Lithoprobe, one of the largest multi-disciplinary earth sciences studies ever undertaken in Canada, is aimed at learning more about the earth at depth and the interior processes that create mineral deposits.

Program and Lithoprobe. Highlights of these programs are discussed in the pages that follow.

The Branch also monitors and coordinates the Sector's involvement in various federal programs such as the Northern Oil and Gas Action Plan (NOGAP), Northern Land Use Planning, all aspects of GSC work funded through the Energy Research Program and all international activities. These programs are planned, directed and evaluated through regional or task coordinators who work closely with the Steering Committees, comprised of industry and government personnel.

The Branch directs the departmental Research Agreements Program. This program provides funds to scientists and researchers at Canadian universities and institutes for work in support of departmental priorities. In 1987-88, $1.39 million was awarded to 171 projects at 40 research centres across Canada.

International Activities

Most geoscience phenomena are global in scale, requiring international cooperation for their understanding. Data from one part of the globe may have important implications thousands of kilometres away. For example, data from studies of hydrothermal vents on the floor of the Pacific Ocean are shedding light on the processes that formed mineral resources in the Canadian Shield.

Clearly, a crucial factor in the development of a national geoscience knowledge base is that GSC scientists stay abreast of new conceptual and technological developments from around the world. For these reasons, GSC has formal reciprocal research agreements with many countries including China, the United Kingdom, U.S.A. and the U.S.S.R. Collaborative work is also an excellent way to keep research costs at a reasonable level, and the GSC is

participating in several international initiatives, such as the Ocean Drilling Program, whose costs would be prohibitive for a single country.

Canadian expertise in the geosciences is highly regarded, and each year our scientists receive requests for technical advice and assistance from all over the world. Canadian industry normally derives considerable benefit from these contacts as opportunities for sales of equipment and services arise. In 1987-88 there were a number of significant developments resulting from GSC's international programs. These include:

Ocean Drilling Program (ODP): Canada, represented by the GSC, is a member of the international ODP, a multidisciplinary scientific research initiative to gather information on the geology of the deep oceans and continental margins. New strategic objectives for the 1990's were set as the ODP moved away from its preliminary phase of global exploration to one focussed on specific fundamental geoscience problems, many of direct interest to Canada: for example, technological development in bare-rock drilling and downhole logging techniques, earthquake monitoring from boreholes in the seafloor and investigations relating to seafloor metallic deposits. During the year, GSC scientists participated in research cruises in the Indian Ocean and the Eastern Antarctica and were involved in the planning of future site drilling programs.

Canada/U.S.S.R. Arctic Science Agreement: Originally signed in 1984, and renewed for an additional two years in early 1987, this bilateral agreement comprises cooperative work under four broad themes: Geoscience and Arctic Petroleum, Northern and Arctic Environment, Northern Construction, and Ethnography. Sharing of information and exchange visits under the geoscience component of this agreement continued to be highly successful. Most notably Canadian scientists have had the rare opportunity to conduct field work in areas of the U.S.S.R. difficult to access . The resulting correlation charts, rock sample analyses and joint publications have led to an improved knowledge about Arctic geology.

ago when only a small remnant of the ice sheet remained on eastern Baffin Island.

Cyprus Crustal Study Project: Initial Report, Holes CY-2 and 2a: **Ophiolites are rocks that have long been recognized as portions of the ancient ocean floor emplaced onto continental margins during mountain building. The Troodos Ophioliate on Cyprus is one of the best examples in the world and is being studied by an international group of scientists to develop a better understanding of the oceanic crust. This is the first of several reports on this project to be published by the GSC.**

An Ancient Western North American Margin: An Alpine Rift Model for the East-Central Canadian Cordillera: **This report applies the general theory of plate tectonics to unravelling the geological history of this complex region. From Precambrian to Tertiary time, east-central British Columbia underwent extension, subduction and finally, during the Jurassic to the early Tertiary, collision of cratonal masses.**

The Ocean Drilling Program's JOIDES Resolution *is the world's most sophisticated drill ship. GSC scientists were on board this year as the* Resolution *conducted "ground-breaking" experiments in Indian Ocean and Eastern Antarctica.*

Staff from the Environmental Marine Geology Section of the Atlantic Geoscience Centre examining a core sample from Hudson Bay.

Energy

Sedimentary and Marine Geoscience Branch

This Branch provides geoscience information about the sedimentary rock-covered regions which comprise over half of the Canadian landmass (nearly 6 million square kilometres) and its offshore areas. Within this vast area is found all of Canada's hydrocarbon energy resources — oil, natural gas and coal, as well as important sediment-hosted minerals such as lead, zinc, uranium and potash.

The Branch focusses special attention on Canada's sedimentary basins, both off and onshore. Because these basins are where Canada's coal, oil and gas resources are found, the information that this Branch compiles has important implications for a wide range of energy-related policy issues. It provides critical information, expertise and advice ranging from estimating and identifying Canada's energy supply to analyzing its longer-term resource potential.

Most of GSC's marine geology activities are concentrated in this Branch and thus it plays a similar role in providing geoscience information and policy-related advice on Canada's oceans and their management. This includes such topics as near-shore and deep sea mining, ocean pollution and the demarcation of Canada's offshore boundaries.

The Branch consists of three divisions: the Atlantic Geoscience Centre in Dartmouth, Nova Scotia; the Institute of Sedimentary and Petroleum Geology in Calgary, Alberta; and the Cordilleran and Pacific Geoscience Division with facilities in Vancouver and at the Pacific Geoscience Centre in Sidney, British Columbia.

Some highlights of the past year include:

Atlantic Geoscience Centre: In a continuation of Frontier Geoscience research aimed at defining the deep structure, origin and history of sedimentary basins of eastern Canada, 800 km of deep seismic reflection were shot across the Grand Banks margin, Jeanne d'Arc and Orphan Basins. Seismic refraction studies using ocean bottom seismometers were used to complement the

Frontier Geoscience Program:
The Frontier Geoscience Program (FGP) was established in 1984, as a 10-year program to help Canada to achieve its goal of long-term energy self-sufficiency. The program's objective was to develop an understanding of the origin and history of sedimentary basins in the frontier regions and to establish a geoscience data base from which the oil and gas potential of the East and West Coast offshore regions, the Arctic Islands and the western Arctic could be determined.

An external independent evaluation of the FGP, completed in 1988, which was based on feedback from its users — energy companies, government agencies, universities — concluded that the program is producing important new information about the geology and reserve potential of Canada's frontier areas. GSC management is using the report to adjust the program's objectives in light of industry and government priorities and to plan the data output phase. The program continues to benefit from joint ventures and information-sharing with industry.

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Some milestones of the scientific program include: the *Labrador Sea Basin Atlas*, now nearing publication; the release of maps related to thermal maturity studies in the Arctic Islands and Western Arctic; completion of regional gravity coverage of the Yukon from the coast southward to 64°N; and the preliminary interpretation of an integrated geological/geophysical seismic survey of the Queen Charlotte Basin.

During the year scientists at the Pacific Geoscience Centre, Sidney, B.C., conducted many scientific studies off Canada's West Coast aboard the Vector.

reflection data and define the seismic velocities at depth. Aeromagnetic surveys over the whole basin and eastern margin of the Grand Banks were completed. The results of these studies are being integrated with conventional seismic and well data to define the regional structure, stratigraphy and geochemistry of the basins. The concept of an atlas devoted to the synthesis of all geoscience data for a specific basin region is being used to present the results. In 1987, the *Labrador Sea Basin Atlas* neared publication, and compilation for the Grand Banks and Scotian Shelf Atlases advanced rapidly.

The GSC also initiated its own borehole program on the Grand Banks to provide ground truthing of shallow stratigraphic units previously defined only on the basis of seismic data and to investigate the physical properties and stress history of surficial sediments forming the foundation of any offshore development.

In the North, processing of Hudson Bay seismic data acquired in 1986 was completed. In addition to providing new control for bedrock mapping of the Bay, the data obtained has provided new information on the glacial history of this important part of Canada and indicated the rapid retreat of ice following the last glacial period. Studies of the Quaternary geology of Hudson Bay and those conducted from the Ice Island research station off Axel Heiberg Island will provide information on previous marine temperatures of significance to Global Change investigations.

Research conducted under Energy R&D and NOGAP programs established a regional classification of sediments, active coastal erosion and subsurface permafrost problems in the Beaufort Sea-Mackenzie Delta area. Collaboration with Gulf Canada has produced new models of permafrost development that are critical for estimating seabed compaction with offshore hydrocarbon exploitation. Ice and iceberg scour distribution and frequency of recurrence studies continued in the Beaufort and Grand Banks regions and will form the basis for future ice scour risk analysis.

Cordilleran and Pacific Margin Division: Under the Frontier Geoscience Program, a major new project to assess the hydrocarbon potential of the Queen Charlotte Basin was begun. Eleven research cruises were undertaken which continued studies on the Juan de Fuca Ridge and in the Queen Charlotte Sound. Aeromagnetic data of the Queen Charlotte Islands and continental margin were published in 77 geophysical maps. Heat flow measurements from

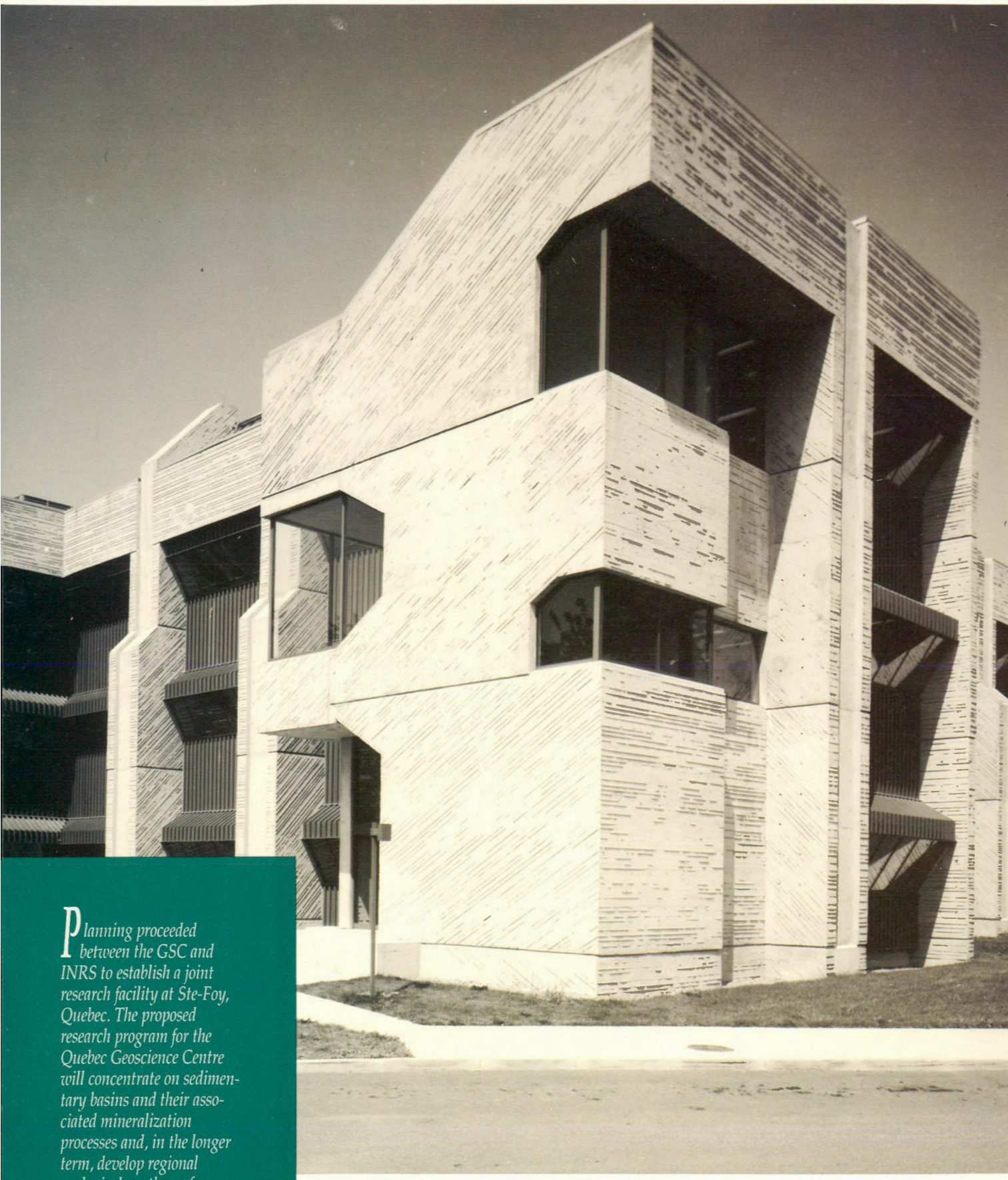
the Queen Charlotte Sound and Hecate Strait combined with bottom water temperatures help define the present thermal state of the Queen Charlotte Basin. These data are being compared with Phanerozoic thermal maturation values to produce models of the thermal history of the Basin.

On land, systematic regional mapping of the Yukon's lead-zinc rich Selwyn Basin was completed, as was the regional gravity coverage of the Cordilleran north of 64°N. In April 1987, the GSC completed its first deep drill hole (367 m) in the Fraser Delta as part of a continuing subsurface mapping program which will improve future earthquake hazard assessment by evaluating the ancient record of earthquake activity. Fifty-one seismograph stations continue to monitor earthquake activity in Western Canada, and analysis of data from the 1986 earthquake near Prince George, B.C., was completed; this will provide essential information on ground stability for the building codes used in urban development.

Institute of Sedimentary and Petroleum Geology: Two major energy studies neared publication during the year: *Conventional Oil Resources of Western Canada (Light and Medium)* and *Coal Resources of Canada.* Interest by industry and government groups in these volumes has been strong and numerous workshops put on by GSC about its methodology to evaluate petroleum resources have been very successful. Some 40 projects were active in the western Arctic and Arctic Islands under the Frontier Geoscience Program; highlights for 1987-88 included the production of a summary of the petroleum resource potential of the Arctic Ocean region, the completion of geological mapping of Prince Patrick and Eglinton islands at the 1:250 000 scale, and the start-up of detailed mapping in the Northern Yukon and field studies in the Beaufort-Mackenzie area.

A national program of coal geoscience continued to gain strength. GSC scientists, working closely with counterparts in provincial agencies, coal companies and universities, developed national standards for assessing and reporting coal resource potential, carried out focussed research studies and began to build comprehensive computer databases and syntheses of national coal geoscience information. The two main thrusts of the coal program — the diverse composition and properties of coals in Canada, as well as their distribution and nature — are directly applicable to coal exploration, evaluation, development, utilisation and management.

Three major cooperative projects to assess the resource potential of the Western Canada Sedimentary Basin were in progress: the Peace River Arch project (formalized in April 1987 by a Memorandum of Understanding with the Alberta Geological Survey), the Williston Basin project, and a new natural gas assessment project. The new gas-chromatography-mass spectrometry (gc-ms) facility carried out groundbreaking work on oil-oil and oil-source correlations in the Williston Basin project and in a number of frontier area projects. Jointly, these projects are refocussing attention in the detailed geological evolution and hydrocarbon resources of the Western Canada Sedimentary Basin.



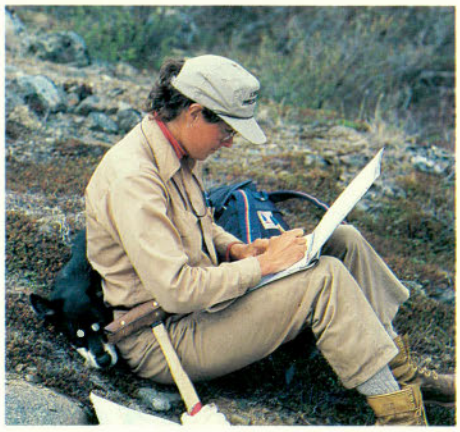
Planning proceeded between the GSC and INRS to establish a joint research facility at Ste-Foy, Quebec. The proposed research program for the Quebec Geoscience Centre will concentrate on sedimentary basins and their associated mineralization processes and, in the longer term, develop regional geological syntheses for eastern Canada.

Minerals

Continental Geoscience and Mineral Resources Branch

Canada's mineral wealth is a major concern of this Branch. Many of its activities are focussed on the development of exploration models for use by Canadian industry and on the maintenance of a national geoscience information base on Canada's non-fuel mineral resources. Federal and provincial governments and industry use this information to assess resource potential to develop mineral policies and to assist and support the exploration and exploitation of the mineral wealth of the country.

Geological studies are concentrated in the Maritimes and the Precambrian Shield, but mineral investigations are national in scope. The Shield, covering most of Quebec, Ontario, the Northwest Territories and parts of Manitoba and Saskatchewan, contains most of Canada's known deposits of base metals, iron ore, gold, silver and a host of other metals, all essential to the national economy and export trade. The Branch also studies the deep geology of Canada (i.e. the geology of the basement crustal rocks underlying the sedimentary cover) and carries out geophysical and geochemical surveys throughout Canada. The Branch coordinates GSC's chemical, isotopic and mineralogical analytical services.



The Branch's two Ottawa-based divisions are the Lithosphere and Canadian Shield Division and the Mineral Resources Division. A new division will be established in Quebec City in 1988-89 as part of the new Centre géoscientifique de Québec, a joint venture between the GSC and l'Institut national de la recherche scientifique (INRS)

Highlights for 1987-88 include:

Lithosphere and Canadian Shield Division: A synthesis of Precambrian geoscience data was prepared that documents the formation of an Early

Mineral Development Agreements:

Mineral Development Agreements (MDA) involve federal participation in cooperative research projects to strengthen and diversify the mineral economies of the provinces and territories. MDA output is published by the GSC as maps, publications and Open File reports or presented orally at geoscience meetings. It has been instrumental in stimulating exploration activity across the country, notably in British Columbia, Newfoundland and Nova Scotia. In July 1987 an MDA with the Northwest Territories was signed, and work continued under the eight other MDAs and a federal program that the GSC is coordinating in Quebec — the Gaspé and St. Lawrence Initiative. Another Canada/ Quebec project, the Asbestos Initiative in Quebec's Eastern Townships, was completed.

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On site field studies and direct observation are a key element of geological mapping.

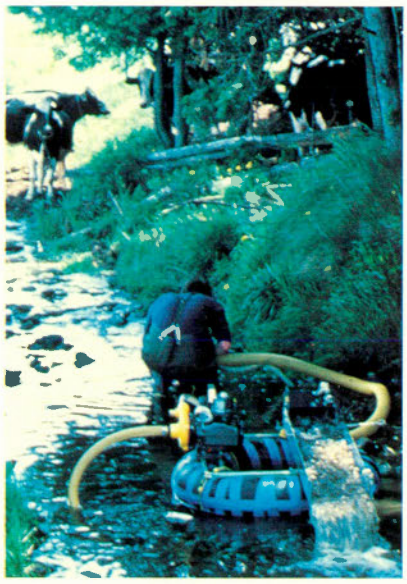
Lithoprobe:

The 5-year, $25 million Lithoprobe program is one of the largest multidisciplinary earth science studies ever undertaken in Canada. It will keep Canadian scientists at the forefront of worldwide studies aimed at learning more about the earth at depth and the interior forces that create mineral deposits.
The program is funded by the Natural Sciences and Engineering Research Council of Canada (NSERC) and EMR, and coordinated by a Secretariat at the University of British Columbia. The GSC played an active role in putting Lithoprobe into place and in providing staff, expertise and equipment. Scientific results continue to be impressive, providing spectacular images of the lower crust beneath Vancouver Island, the Southern Cordillera, the Kapuskasing Structural Zone, the Great Lakes and the Gulf of St. Lawrence. These results are shedding dramatic new light on old ideas, in some cases totally revising scientific understanding of these regions.

GSC's mineral exploration research of heavy minerals in Quebec's Eastern Townships added significantly to existing knowledge on the origin of alluvial gold in southern Quebec; indicated several previously unrecognized areas with gold bearing potential; and generated considerable mineral exploration interest in the region. Shown here heavy mineral samples are collected with a portable suction dredge.

Proterozoic craton consisting of numerous discrete terrains, each with its own geological and metallogenic history. In the Northwest Territories, continuing studies of major tectonic zones focussed on the southern extension of the Thelon Tectonic Zone and on a gold producing area in the central Slave Province; mapping on a scale of 1:250 000 was completed in the Chesterfield Inlet area and detailed structural mapping in central Baffin Island was started. Field work in the eastern half of the Cape Smith belt (northern Quebec) was completed and results include an innovative model of very complex structures that will be useful as a guide to future exploration programs in the mineralized part of the belt.

In the southern Shield, remapping of the north shore of Georgian Bay was continued as part of the interpretation of new seismic results from the joint Canada/USA Great Lakes International Multidisciplinary Program on Crustal Evolution (GLIMPCE); this project has produced some spectacular new results on the structure of the crust beneath the western Great Lakes which confirm the discontinuous nature of the classic "Grenville Front" in this region. A new annual publication, *Radiogenic Age and Isotopic Studies* presents, in consolidated format, analytical results generated by the Survey's world-class geochronology unit.



Two commercial successes resulted from technology transfer to industry: a receiver capable of multichannel data collection for audiomagnetotelluric, magnetotelluric and controlled EM measurements, and a portable seismic refraction instrument. In both cases, Canadian manufacturers are aggressively seeking new international markets for these instruments.

Mineral Resources Division: The development of geologcial models and geophysical and geochemical signatures of mineral deposits focussed on gold, platinum group elements, massive sulphides and rare metals. Highlights

include a new technique for determining the age of Precambrian gold deposits, the release on Open File of a major report on Platinum Group Element environments, and further advances in the understanding of seafloor hydrothermal sulphides. In resource assessment, the biennial report on uranium exploration indicated a 10% increase in resources over the last two years. An appraisal of mineral resources of parts of South Moresby Island (British Columbia) and adjacent offshore was completed on a priority basis for Parks Canada. The release of results of regional geochemical and airborne radiometric surveys contributed to a significant increase in staking activity, especially in British Columbia, Newfoundland and Nova Scotia.

GSC scientists continued to participate in the International Strategic Minerals Inventory (producing the ISMI report on tungsten as a Canadian contribution) and provided technical assistance to CIDA projects in Jamaica, Thailand and Zimbabwe, as well as to the International Atomic Energy Agency. The GSC's index to Canadian mineral deposits, CANMINDEX, was adapted to microcomputers making the data more accessible and reducing operating costs.

Geophysical equipment in the Skyvan aircraft was upgraded, and a detailed survey flown over Maniwaki, Quebec, as part of a study of radioactivity in soils and radon in houses; this research is being conducted jointly with the Department of Health and Welfare. In the area of exploration technology, new developments will find wide application in the private sector: in borehole geophysics, work continued on the refinement of the special gamma-gamma, heavy metal "assaying" log; in biogeochemistry, a new technique for rapid sampling of treetops using a helicopter was successfully tested; and in data integration, a number of new software programs for the application of spatial analysis techniques in mineral deposit probability distribution were being investigated.

Installing magnetotelluric recording equipment to study the electrical structure of the Earth.

Land slump in the Arctic caused by melting permafrost. GSC's assessment of permafrost-related hazards is used for safe land-use planning and for protection of the environment.

Environment

Geophysics and Terrain Sciences Branch

This Branch provides most of GSC's national geophysical and terrain science information, including work related to the understanding of environmental and climatic change and to earthquake and terrain hazards in Canada. The Branch operates national seismological, geomagnetic and geodynamic networks and observatories, conducts aeromagnetic and gravity surveys, and a wide variety of geological mapping and sampling projects across Canada.

The information obtained by the Branch is used to provide expertise and policy advice to a wide range of government, university and industry clients with a special emphasis on public safety and the environment, and includes applications to mineral exploration. As an example, power utilities, exploration companies and Emergency Preparedness Canada (EPC) are informed regularly about geomagnetic field activity that could disrupt their operations if corrective measures are not taken. The media and EPC are also informed promptly about all earthquakes felt in Canada and their probable effects on the public.

The Branch's terrain sciences activities provide systematic knowledge of the earth's surficial materials and terrain conditions. The study of the origin, distribution and engineering properties of such materials is critical to safe and economical land-use planning, to the protection of the environment, and as an aid to mineral prospecting. The Branch also carries out the bulk of Canadian research on permafrost and its associated hazards. Knowledge of surficial geology provides a baseline against which to evaluate contemporary global change and understand past global change.

The Branch comprises two divisions: the Geophysics Division and the Terrain Sciences Division, both based in Ottawa but with facilities and projects throughout Canada.

Nuclear Fuel Waste Management Program:

A series of reports published in October 1987 marked the completion of the GSC's formal involvement with Atomic Energy of Canada Limited (AECL) in this cooperative program of geoscience research aimed at developing the concept of subsurface

(Continued on next page)

A Courtenay, B.C., elementary school was damaged by an earthquake in central Vancouver Island in 1946.

disposal of high-level nuclear fuel waste. The GSC is continuing, however, to work with AECL on another project involving earthquake monitoring in Northern Ontario which will aid the design of a possible subsurface disposal facility.

David Nickerson, M.P. for the Western Arctic joined GSC staff to inspect progress on the new operations centre of the Yellowknife seismic array. The Yellowknife facility monitors underground nuclear explosions as Canada's contribution to a comprehensive test ban treaty.

Highlights for 1987-88 include:

Geophysics Division: In seismology, almost 1500 earthquakes, 35 of which were felt, were documented in or near Canada. Canada exchanged seismic data with other countries (notably Sweden, U.S.A., U.K. and U.S.S.R.) in support of its role in the global seismicity network that monitors earthquakes and underground nuclear explosions. Meanwhile, modernization of seismological facilities at Yellowknife continued on schedule. In geomagnetism, daily and three-weekly forecasts of geomagnetic activity over Canada were supplemented by the issuance of 10 "alerts" of major geomagnetic activity. Gravity coverage was completed of the entire polar continental shelf from the Mackenzie Delta to Ellesmere Island; data from other surveys off the East and West Coasts, and the Great Lakes were added to the National Gravity Data Base. In geodynamics, provision of real-time positioning and navigation for the Ice Island were continued. Results from twelve years of intensive monitoring of tilt, strain, well levels and gravity variations of the Charlevoix seismic region have been accepted for publication in 1988-89; no clear correlations were found between these parameters and earthquake occurrence. An aeromagnetic survey covering all of Lake Superior completed mapping of the Great Lakes. Magnetic anomaly maps at the 1:5 million scale were published for Canada (fifth edition and the first compiled entirely from digital data), and for North America (in collaboration with the U.S. Geological Survey).

Terrain Sciences Division: Glacial deposits studies in the High Arctic focussed on collecting dateable materials with the aim of gaining information about climatic change. Field tests, with support from the Department of Indian and Northern Affairs, carried out to monitor the interaction between the Norman Wells pipeline and its surrounding permafrost soils determined that the pipeline's right-of-way was stable with some minor problems resulting from erosion and drainage; permafrost stability studies will continue over the long term. Work continued in southern British Columbia to assess landslide hazard, and studies of the massive rockslide triggered by the major Nahanni (Northwest Territories), earthquake of 1985 were completed. Systematic terrain mapping in western Newfoundland revealed numerous areas of mountainside sagging by gravitational creep, a formerly unrecognized hazard in eastern Canada.

The relationship of surficial geology to maple die-back in the Thetford Mines area of Quebec was studied under contract by the University of Montreal; preliminary results showed mineral deficiencies and climatic fluctuations among the contributing factors.

Four national synthesis maps were published portraying the retreat of the Laurentide Ice Sheet and the paleogeography of northern North America from 18 000 to 5000 years ago. Two major publications are nearing completion: the multi-volume *Beaufort Sea Atlas*, of value for the planning of hydrocarbon exploration and assessment of environmental impact, and an atlas showing sea level changes throughout the coastal regions of Canada during post-glacial times. Sedimentological research on glacial deposits was applied to practical problems in mineral exploration in drift-covered terrain and to seismic hazard research. GSC scientists played an active role on the Organizing Committee and in the scientific program of the International Union for Quaternary Research's (INQUA) successful XIIth International Congress held in Ottawa, July 31–August 9, 1987, and are becoming increasingly involved in many aspects of the new international Global Change Program.

Portable seismographs are used by GSC to monitor the aftershocks of the magnitude 6.6 1985 Nahanni earthquake. Some 350 tremors of magnitude 3.0 or more have been recorded since the original event; the most significant this year being a magnitude 6.2 earthquake in March 1988.

Depressor fin and seismic source (air gun) are readied for deployment as part of a deep-tow refraction seismic survey to map subsea permafrost on the Beaufort Sea continental shelf.

Arctic Sovereignty

The Polar Continental Shelf Project (PCSP)

Through the provision of transportation, accommodations and communications, the Polar Continental Shelf Project coordinates scientific studies in the Canadian Arctic and provides vital support and advice to scientific research groups working in the Arctic Islands, the northern mainland, and on the Arctic Ocean. It works closely with other sections of Energy, Mines and Resources and cooperates with other government departments and agencies, and university groups in providing expertise, facilities and transport in support of their studies. An important function of PCSP is to keep both the scientific community and northern residents informed of ongoing Arctic scientific projects. PCSP's interagency, multidisciplinary character is designed to foster safe, effective and economical scientific research in the Canadian Arctic. The activities supported by PCSP are critically important to the exercise of Canada's sovereignty in its Arctic regions and an assertion of its ability to show leadership as a polar country.

PCSP maintains base camps at Tuktoyaktuk at the mouth of the Mackenzie River, at Resolute on Cornwallis Island, and at the Ice Island Research Station in the Arctic Ocean. Fieldwork, coordinated from these camps, is generally carried out between mid-February and late September. PCSP headquarters are in Ottawa.

Marine Science Atlas of the Beaufort Sea: Geology and Geophysics: *A significant portion of Canada's oil and natural gas potential is in our northern regions, making the Beaufort Sea an area of considerable interest and economic importance. The maps and diagrams of this report present the framework within which exploration is now taking place.*

Highlights

Logistics support was provided to 232 research parties working in the Canadian Arctic in the 1987 field season, making it one of the largest field operations in the history of PCSP.

At the Tuktoyaktuk base camp a new warehouse/laboratory building was completed and living quarters were upgraded for improved safety and efficiency. Designs for a new accommodation and storage building at the Resolute base camp were completed; construction is scheduled to begin during the summer of 1988.

Geological mapping projects were supported in the Richardson Mountains, (northern Yukon), on Prince Patrick Island, on Boothia Peninsula, and on northwest Devon Island. Reflection seismic profiling in the marine channels of the Sverdrup Islands was based on Lougheed Island.

Continuing studies of the "fossil forest" on Axel Heiberg Island, ranging from paleobotany to soil science, were recorded by a film crew for release as a documentary. The site was under consideration by National Museum staff for possible heritage status.

In the Beaufort Sea area, studies supported by PCSP included physical and chemical oceanography, shoreline studies, the biology of shorebirds, and the physics of sea ice around drilling platforms. In Lancaster Sound, marine wildlife studies were carried out to prepare for possible designation of this unique area as a marine national park. Assessment of northern Ellesmere Island was carried out in preparation for the establishment of a new national park.

The permanent research station on the Ice Island was occupied from early March to the end of August 1987; PCSP supported marine geological, geophysical and oceanographic investigations of the continental shelf north of Meighen Island. The "Island's" irregular path along the borders of the Arctic Ocean was continuously tracked using satellite navigation.

Canadian scientists continued to take advantage of the unique research opportunities available at PCSP's Ice Island Research Station adrift in the Arctic Ocean.

Range of PCSP-supported research parties in 1987 field season.

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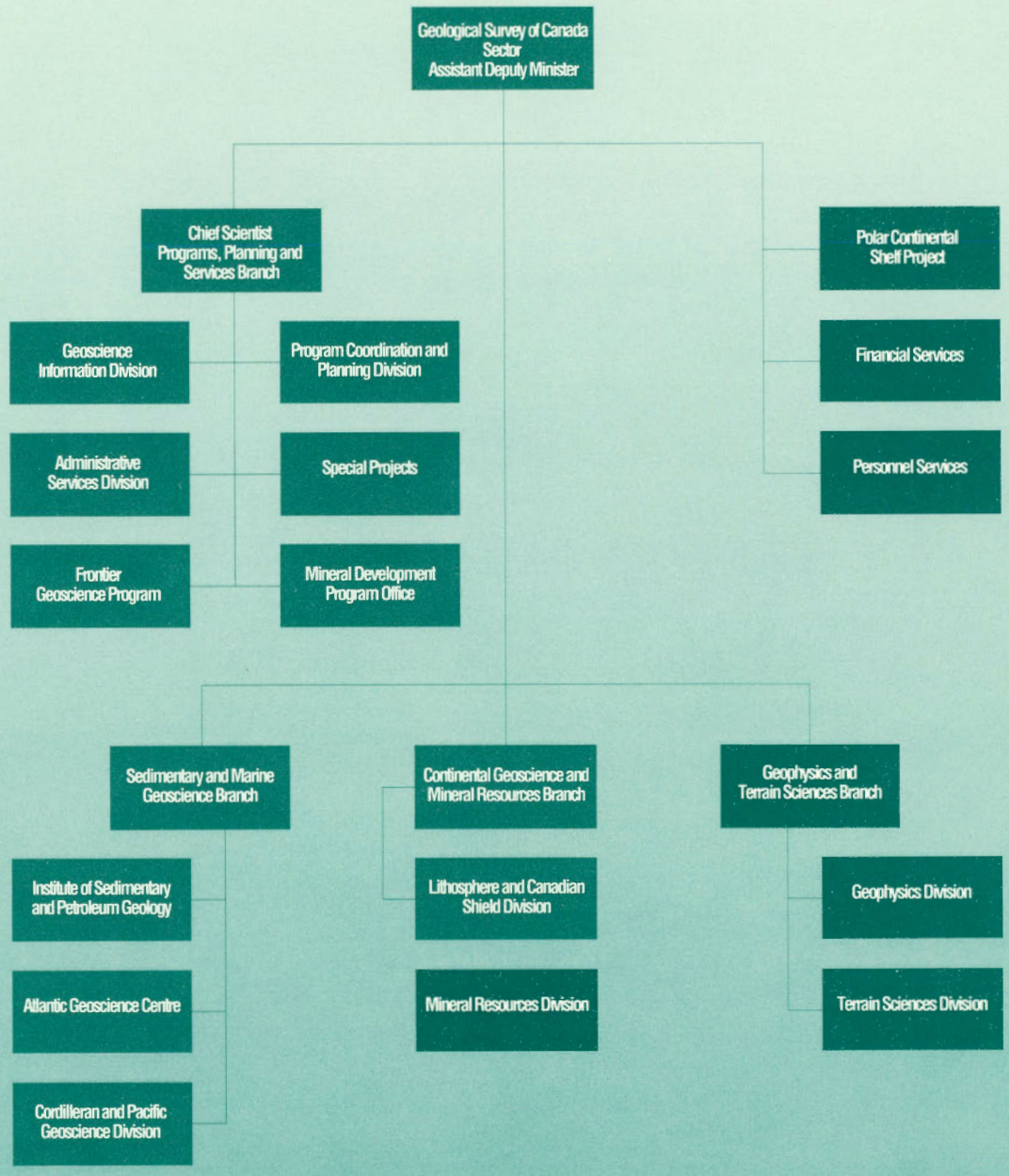
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Geophysics Division
Terrain Sciences Division

Sector Financial Statement

GEOLOGICAL SURVEY OF CANADA

1987-88 Expenditures (in thousands of dollars)

	Total	Personnel	Operating	Capital	Grants and Contributions	Person-Years
Sedimentary and Marine Geoscience						
Cordilleran and Pacific Geoscience	7,609	3,902	2,986	721	—	77
Sedimentary and Petroleum Geology	14,496	7,238	6,727	531	—	156
Atlantic Geoscience Centre	13,880	5,874	7,196	810	—	120
	35,985	**17,014**	**16,909**	**2,062**	—	**353**
Continental Geoscience and Mineral Resources						
Mineral Resources	15,180	8,106	6,474	600	—	166
Lithosphere and Canadian Shield	9,993	5,422	4,032	539	—	96
	25,173	**13,528**	**10,506**	**1,139**	—	**262**
Geophysics and Terrain Sciences						
Geophysics	17,143	5,824	8,152	3,167	—	121
Terrain Sciences	8,989	4,840	3,831	318	—	90
	26,132	**10,664**	**11,983**	**3,485**	—	**211**
Programs, Planning and Services						
Geoscience Information	5,004	3,446	1,443	115	—	101
Planning, Common Services and Special Projects	5,048	2,648	2,269	131	—	53
	10,052	**6,094**	**3,712**	**246**	—	**154**
Polar Continental Shelf Project	**6,342**	**946**	**4,500**	**896**	—	**20**
Program Management and Support (Sector Headquarters)	**4,922**	**570**	**145**	**11**	**4,196**	**11**
Total - Sector	**108,606**	**48,816**	**47,755**	**7,839**	**4,196**	**1,011**