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GEOLOGICAL SURVEY OF CANADA

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RESERVE/RÉSERVÉ

NOT TO BE TAKEN FROM THE ROOM
POUR LA CONSULTATION SUR PLACE

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

Canada

THE ENERGY OF OUR RESOURCES

THE POWER OF OUR IDEAS

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MESSAGE FROM THE ASSISTANT DEPUTY MINISTER OF THE GEOLOGICAL SURVEY OF CANADA

The Geological Survey of Canada is proud of its record of working with partners in industry and government, applying top-flight geoscience expertise to the challenges they face. One of our most pressing goals for the immediate future is to increase the number of collaborative projects that we undertake.

Towards that end, we have set in motion many new programs and initiatives. Two that started up this year are:

- the *Industrial Partners Program* which enables the application of our skills to a company's specific problems. Costs are shared, and both the corporate partner and the Survey contribute expertise. Based on the very strong response to the program in its first year of operation, we are increasing the GSC funds available from $500 000 to $1.5 million in the coming year.
- a new *Federal-Provincial Liaison Office* which further strengthens and streamlines our collaborative work with provincial and territorial geological surveys. This will ensure that our efforts are complementary and focused on pertinent challenges in every part of the country.

Companies in the mining and petroleum industries are confronting declining reserves, a need for more sophisticated techniques to find new reserves, and strong competition in global markets. The Survey is responding by developing and applying expertise and technological tools to help Canadian companies achieve a sharper competitive edge. An excellent example of this is our collaboration with Scintrex Ltd. to develop a new digital gravity meter. GSC scientists worked closely with the company, providing evaluation and calibration that will be critical to wide acceptance and sales in the exploration industry.

In another example, the Survey recently conducted research, in partnership with the international Ocean Drilling Program, at active volcanic ridges on the ocean floor off Canada's Pacific coast. Three kilometres beneath the surface of the ocean, we were able to watch and study massive sulphide deposits being formed. The knowledge gained is giving Canadian mining companies new approaches to understanding formations and finding new reserves.

We are also moving to support Canadian mineral, energy and environmental industries by conducting work outside of Canada, with the objective of creating new markets for Canadian-made products or services and stimulating employment opportunities for Canadians. An example is our work with Solinst Canada Ltd. to market a groundwater monitoring technology developed by a GSC scientist. Through this scientist's contacts we have been able to secure contracts for the equipment with the U.S. Department of Energy.

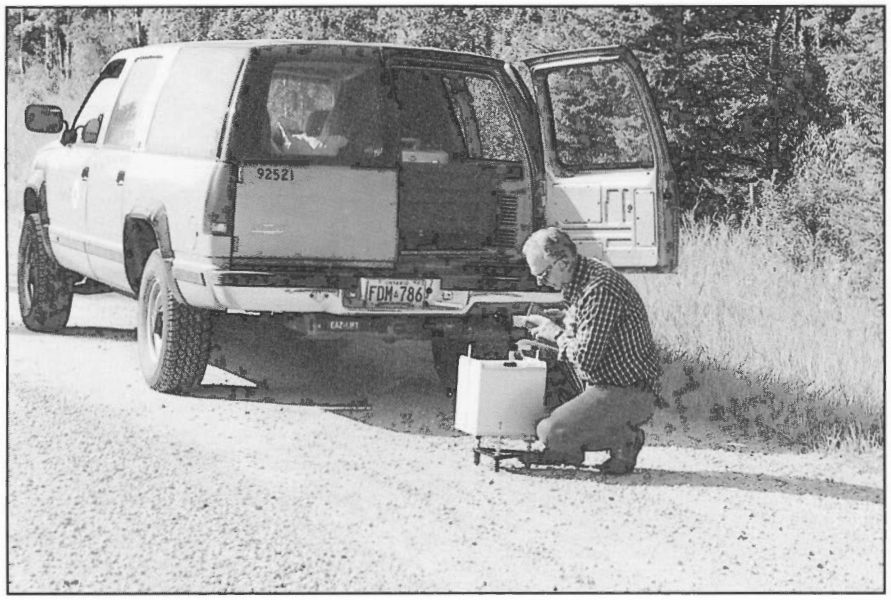
Industries as well as government agencies at all levels face new environmental imperatives that have radically changed the way they do business and respond to the priorities of all Canadians. Virtually every environmental question has a geoscience aspect, and we are contributing our expertise and extensive knowledge base to address specific environmental issues. Throughout this report you will find many examples of this, ranging from our work in

Quebec's Grande-Baleine area to acquire baseline geoscientific information as a basis for environmental assessments of any hydro-electric development, to research in British Columbia's heavily populated and environmentally sensitive Fraser Delta area that will help planners make more informed decisions about future development.

In this annual review, you will also come across the names of many of the organizations with which we have collaborated in the realm of mineral and energy exploration. The Survey brings something unique to these shared endeavours. As Canada's national focus of geoscience expertise, we can provide our partners with internationally recognized scientific knowledge, skill and tools that can help solve their specific problems and advance their quests.

We invite you to review the work we have underway, and would welcome your enquiries on collaboration in research projects with us.

Elkanah A. Babcock



D.B. Hearty, GSC

Scintrex CG-3 Automated Gravity Meter

Scintrex developed their CG-3 Automated Gravity Meter under the federal Program for Industry/Laboratory Projects (PILP) with technical support from the GSC and financial assistance from the National Research Council. During the development phase, the GSC was involved in the evaluation of the prototype version and made design recommendations that were incorporated into the production model. A calibration line for evaluating repeatability and scale stability was established between Orangeville and Orillia, Ontario. An extensive evaluation of one of the new gravity meters (X054), which is owned by GSC, has been conducted and a report describing the results of this analysis will be sent to Scintrex and made available as a GSC Open File.

CELEBRATION

Sir William Logan, founder of the Geological Survey of Canada

CELEBRATING 150 YEARS OF SERVICE

Petro-Canada and the Mining Association of Canada are among the many partners across the country helping to celebrate the Geological Survey's 150th anniversary throughout 1992. Because of this collaboration and sharing of resources, we have been able to get excellent public visibility for the geosciences. Some notable examples are:

➢ ***Maclean Hunter's magazines,*** **Maclean's** ***and*** **L'Actualité,** ***carried a special supplement about the Survey early in the year that brought wide coverage.***

➢ ***The Royal Canadian Geographical Society led a consortium including Energy, Mines and Resources Canada, Parks Canada and many industry sponsors such as Ashtech, that mounted an expedition in May 1992 to climb Canada's highest peak, Mount Logan (named for GSC's founder Sir William Logan).***

➢ ***Noranda, Institut national de la recherche scientifique (INRS) and Banque nationale were co-sponsors of an excellent public exhibit about the Survey at the Musée du Séminaire de Québec that will be open until spring 1993.***

INTRODUCTION

The Geological Survey's basic mandate to provide a geoscientific knowledge base for Canada has been in place for 150 years. Its implementation requires leadership, responsiveness and an insistence upon excellence. In looking ahead, the Survey recognizes that its staff are the key to its success and that a number of external factors must be considered. These include an increased emphasis on consultation and partnership with the provinces, industry and other clients and adaptation to rapidly changing technology.

Among the broad issues that will affect the Survey's future are the environment and sustainable development, changes in global markets and the need to strengthen the Survey's presence in all regions of Canada.

To better equip itself to deal with these challenges, the Survey has created a program structure which makes a clear link between activities and the needs that they serve. The program elements are: Geoscience Surveys, Minerals, Energy, Environmental Geoscience and Geoscience Information. Highlights of our research for 1991-92 are grouped accordingly.

E X P L O R A T I O N

PROBING THE EARTH'S DEPTHS: LITHOPROBE

As part of the Canadian LITHOPROBE program, the Geological Survey of Canada participated with the mineral industry, universities and provincial surveys in joint research programs to get a clearer picture of shallow crustal structures important for mineral exploration in the Canadian Shield. Over the past three years, high frequency vibroseis reflection surveys were conducted in the Matagami, Selbaie and Blake River mining camps in Quebec, the Buchans camp in Newfoundland, the Thompson camp in Manitoba and in Sudbury, Ontario.

Some Recent Highlights

Matagami (Noranda Exploration): The Matagami felsic volcanic complex is part of the Abitibi belt, the largest Archean greenstone terrane on earth, and is host to one of the most productive base metal camps in Canada. The Matagami volcanic complex is subdivided into a lower, felsic Watson Lake Group and an upper, mafic-felsic Wabassee Group. The contact between the two groups is marked by the Key Tuffite, a thin but extensive exhalite horizon that hosts most of the massive sulfide deposits. The LITHOPROBE study mapped the attitude of the contact along an east-west transect, using the seismic reflection method adapted to mineral exploration.

Sudbury (INCO Exploration and Technical Services Inc., Falconbridge Ltd., Ontario Geological Survey): The Sudbury Structure is situated at the contact between Early Proterozoic Huronian supracrustal rocks of the Southern Province and Archean basement rocks of the Superior Province. The Structure is the site of a possible impact event and associated igneous activity. It is also outlined by pronounced potential field anomalies and is well-known for its nickel-copper deposits. The main objectives of the LITHOPROBE study were to evaluate seismic exploration techniques in a complex setting and to determine the shape of the Sudbury Structure at depth. The high frequency vibroseis data demonstrates that lithological contacts can be mapped beneath the northern half of the Structure. These contacts define a relatively simple layered structure. The southern half of the Structure is dominated by south-dipping reflections. The seismic images have important implications for models of Sudbury magmatism and mineralization. For example, a consequence of the newly defined crustal model is that some ore-bearing mafic units on the margins of the Sudbury Igneous Complex may be repeated at depth.

Ground-Truthing: As part of the LITHOPROBE Abitibi-Grenville transect, GSC joined forces with Noranda Exploration, Les Mines Selbaie, and Falconbridge Ltd., to calibrate the new high frequency reflection seismic data. A program of rock property measurements has now been completed using six boreholes, up to 2000 m deep. Density logs and velocities determined from full waveform sonic logs provide a link between the in situ rock properties and the observed seismic reflection data. Results indicated that the effects of macroscopic fracturing are only important to a depth of 300 m and lithological variations within the crust are the primary cause of seismic reflections.

Partners:

- ▲ FALCONBRIDGE LTD.
- ▲ NORANDA EXPLORATION
- ▲ LES MINES SELBAIE
- ▲ INCO
- ▲ ONTARIO GEOLOGICAL SURVEY

E. Adam, GSC

Lithoprobe trucks, Matagami, Quebec.

GEOSCIENCE SURVEYS

Canadians need more and better geological, geophysical and geochemical maps and regional geological interpretations for two major reasons.

The first relates directly to Canada's economic competitiveness in global markets. Together the mineral and fuel industries account for about 10% of Canada's gross domestic product. The healthy competitive position in world markets traditionally enjoyed by Canada's mineral industries is now challenged by the lower production cost of mineral products from overseas sources. To retain its competitive edge in an increasingly globalized market system, the Canadian mineral industry will have to discover tomorrow's domestic mineral reserves using up-to-date geoscience maps and advanced geological concepts and technologies.

The industry needs to explore at depths below the current generation of discoveries (generally surface to 500-600 metres) in existing mineral camps and to find "world class" deposits in both frontier and developed mineral areas. A similar requirement exists for locating new energy resources in Canada's interior producing basins (e.g Western Canada Sedimentary Basin) as well as for continued exploration of Arctic and offshore basins.

The second major need relates to the increasing complexity of society's impacts on the physical environment. To mitigate such impacts and to plan sustainable development, it is essential to precisely document the baseline or "natural state" of Canada's landmass. The effect of the environment on society also generates the need for tools to evaluate earthquake risk and other natural hazards to construction and engineering. The understanding of such phenomena rests on an understanding of the geological framework and the geological processes that shape this framework over time. Geoscience surveys are the foundation of this understanding.

- Two National Mapping Program (NATMAP) projects began in 1991. The Shield Margin Project is studying the Cu-Zn-Ni-Au-rich Flin Flon-Snow Lake Belt and its sub-Paleozoic continuation in Manitoba and Saskatchewan. It pulls together the expertise of over 50 participants from GSC, the Manitoba and Saskatchewan Geological Surveys and six universities, and has actively involved the mineral exploration industry. The project has already generated important new products and perspectives on the Belt, and the design and implementation of the central project digital database is well underway. Preliminary "trans-border" compilation maps for portions of the Belt and its southerly continuation should by released by late 1992.

- The Slave Province NATMAP Project also moved ahead with the development of a joint GSC-Government of the Northwest Territories-Department of Indian and Northern Affairs proposal and reconnaissance field work in which all three agencies participated. A major, jointly funded field program was also established that will see its first fully operational year in 1992.

- Collaboration with British Columbia counterparts resulted in considerable progress in unravelling the geology of the Hazelton Group, a structurally complex Jurassic unit that extends the length of the Canadian Cordillera from the Washington State-British Columbia border to Alaska. It hosts a number of mineral deposits including those in the currently active Iskut and Toodoggone camps, as well as important porphyry copper deposits such as those in Highland Valley. It also contains the main hydrocarbon source rocks of the Interior Cordillera.

■ A study of glacial sediments on the Canadian Prairies started as part of the Canada-Manitoba Mineral Development Agreement. The work included full cooperation with Manitoba Energy and Mines, and with the Manitoba Water Resources Branch and the University of Waterloo for a hydrogeological component. A major drilling program was carried out in southeastern Manitoba where unconsolidated sediments and underlying bedrock were cored at 23 sites. Preliminary results of the presence of visible gold and sulphide minerals in Quaternary sediments are promising.

■ Two important projects neared completion in northern Quebec's Ungava Peninsula that will shed light on its virtually unknown geology. Of particular note was the discovery of a new greenstone belt that will be the target of future industry exploration. As well, new 1:50 000 scale maps produced from the work have already assisted industry in a complete re-evaluation of economic Cu-Ni-PGE mineralization of the area. From a scientific standpoint the work has permitted a reinterpretation of the processes of tectonic assembly and growth of the northeastern Canadian landmass.

■ In a major collaborative effort GSC, the Geodetic Survey of Canada, National Defence's Mapping and Charting Establishment and the U.S. Defense Mapping Agency (DMA) completed the regional gravity survey of part of southern Yukon. About 1850 gravity survey observations, at 10-12 km spacing covering twenty-five 1:250 000 map sheets, were collected in the first year of a three-year program in which the costs will be shared by GSC and DMA at a ratio of 1:3. The data will contribute to the National Gravity Mapping Program, to studies of resource potential and geological structure in Yukon, and to a better determination of the geoid for the surveying industry.

■ GSC participated in Arctic '91, a successful international expedition that carried out scientific programs from Swedish and German icebreakers (ODEN and POLARSTERN). Of particular note, it collected the longest seabed sediment samples ever from the Arctic Ocean as part of a paleoclimate global change project. The expedition also gathered high resolution seismic reflection profiles and multi-channel seismic data over a wide region of the eastern Arctic.

SALE OF SPANS TECHNOLOGY TO AQUATER SPA OF ITALY

Aquater SPA of Italy purchased Spatial Analysis Systems (SPANS) technology from TYDAC Technologies of Ottawa after studying GSC's experience with the system. SPANS technology, developed by TYDAC, integrates a variety of geoscience data including geomagnetic, geochemical and satellite information, to produce maps and computer-generated images that can be used as guidelines for exploration. The Survey's success with this integrated analysis system was a factor in Aquater's decision to purchase it. Aquater has also become the Italian agent for TYDAC.

K. Card, GSC

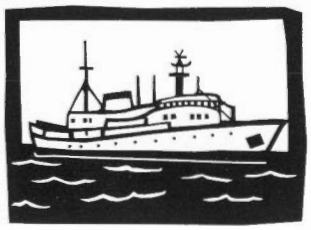
Shown here, a 2.7 billion year old unconformity in the Vizien greenstone belt, northern Quebec.

GSC MAPPING SPARKS EXPLORATION INITIATIVES BY INDUSTRY IN NORTHERN QUEBEC

Two major mining companies have launched a joint exploration venture in the central Ungava region of northern Quebec as a direct result of information provided by recent GSC mapping. This exploration program follows the discovery by GSC scientists of a previously unrecognized, economically prospective greenstone belt and the subsequent release of a digital open file map of the area.

The discovery of the Vizien greenstone belt underscores the inadequacy of the existing geological map of Canada. The current map, based largely on reconnaissance mapping more than 30 years old, shows a sea of pink rocks (granites and gneisses) for most of the northern Shield. As a result, these areas have been considered to have low mineral potential and have received little mineral exploration attention. In reality, many of these regions simply lack adequate levels of information to enable the exploration industry to assess their mineral potential or to consider exploration or mining activity. This led to the GSC's three-year geological project to map the central Ungava region to modern standards and therefore provide an updated scientific infrastructure for the area and establish the necessary background to support mineral exploration in the huge, unexplored region. From a scientific standpoint, the work has permitted a reinterpretation of the processes of tectonic assembly and growth of the northeastern Canadian landmass.

- A GSC scientist led an experiment in seafloor environmental geoscience at the site of the Titanic. Exposed on the seabed since 1912, the wreck represents a unique time gauge for measuring rates of sedimentary processes on the seafloor such as corrosion and contaminant migration rates in sediments, and sediment transport processes and rates. As well, the impact of the Titanic on the seafloor is a useful analogue for the iceberg pitting process on the continental shelf. An IMAX film of this expedition will be released in 1992.
- GSC in collaboration with the Department of Fisheries and Oceans and the Innu Nation undertook a unique experiment, the Arctic Delta Failure Experiment (ADFEX), for the purpose of better understanding the mechanism and the change in sediment properties that result from slumping and sliding. This will help in plans to mitigate against such natural hazards in the event of coastal development.



MINERALS

Mining is among Canada's most important industries. The value of non-hydrocarbon mineral production amounts to about $20 billion annually. Minerals and metals account for 5% of Gross Domestic Product and 19% of export earnings. Mining and mineral processing employ 150 000 workers and support 115 "one-industry towns". Canada leads the world in per capita mineral production and mineral exports, and is among the leading producers of a range of commodities including zinc, uranium, nickel, gold, platinum metals, titanium concentrates and potash. There is great potential for the discovery of new mineral resources in Canada and our exploration industry is arguably the world's most entrepreneurial and productive.

The prosperity of the minerals sector of the Canadian economy requires a broad array of knowledge, expertise and technology. The GSC has, from its inception, had a mandate to provide comprehensive geological knowledge concerning Canada's mineral resources and to assess resource potential. It has also played an active role in contributing concepts and methods for mineral exploration.

THE OCEAN DRILLING PROGRAM AND BASE METAL MASSIVE SULPHIDE DEPOSITS

Falconbridge, Noranda Mines, Cominco and Hudson's Bay Mining and Smelting may all benefit from the drilling of 95 m of massive sulphide (containing ore grade copper and zinc) during Leg 139 of the Ocean Drilling Program (ODP) in September, 1991. The site is about 340 km west of Vancouver Island, on the Canadian portion of the Juan de Fuca Ridge. Samples of core from this and 21 other holes in the region have yielded important information on pore water and vent fluid compositions, and on fractionation trends in igneous rocks, that will have direct bearing on improving the understanding of terrestrial deposits and exploration strategies.

This deposit is a modern analogue to giant deposits such as the Kidd Creek Mine near Timmins, Ontario, the Brunswick No. 12 Mine near Bathurst, New Brunswick, the Ruttan deposit near Leaf Rapids, Manitoba, and the Sullivan deposit near Kimberly, British Columbia.

As part of a comparision of these modern deposits with ancient deposits, the GSC began a collaborative study with Falconbridge Ltd. of their Kidd Creek Mine. Investigation of this very large (130 million tonne) volcanogenic massive sulphide deposit will be integrated with results of studies on samples obtained from the ODP drilling. Similar studies are underway, with industry support, at the Brunswick No. 12 Mine (with Noranda Mines), the Sullivan Mine (with Cominco), and the Ruttan Mine (with Hudson's Bay Mining and Smelting).

R. DiLabio, GSC

Samples of sand from eskers may contain kimberlite indicator minerals.

GSC RESEARCH USED IN DIAMOND EXPLORATION

Aber Resources, SouthernERA Resources and Kennecott Exploration are among the many exploration companies that have asked the GSC for information on ice flow history in the area of active diamond exploration in the Northwest Territories. The companies are using drift prospecting techniques for exploration because this area was glaciated, and they require data on ice flow directions in order to help trace kimberlite indicator minerals back to their sources. The Survey published open file maps of ice flow information for the heart of the diamond play in the Lac de Gras-Aylmer Lake area.

This knowledge is used by federal and provincial governments to formulate and promote policies concerning resource management, land use, regional development, trade, international development and sovereignty. It has been used by industry to more effectively plan and undertake mineral exploration, as well as by the scientific community at large and the general public.

- Many polymetallic sulphide occurrences were discovered during a joint project with the Ministère de l'Énergie et des Ressources du Québec (MERQ) aimed at better defining the Grenville Orogen in the Portneuf – Saint-Maurice area. Following publication of preliminary results highlighting the economic potential of the region, which was correlated with the metasediments hosting the Montauban deposit, several mining companies acquired mining rights for the whole of the newly discovered metasedimentary belt and initiated extensive exploration.

- Over the past decade geochronology has proven very powerful in advancing our understanding of the evolution of the Canadian landmass and its mineral resources. It is an important component of most bedrock mapping projects, particularly in the Precambrian Shield, which lacks the fossil record used for dating younger sequences. One of many successful projects in 1991 involved the use of paleomagnetic properties to rapidly and cheaply extrapolate the age of precisely dated dyke swarms throughout the Shield; this work graphically highlights terrain continuities and discontinuities in crustal evolution over half of the Earth's history.
- GSC conducts MERAs (Mineral and Energy Resources Assessments) for Indian and Northern Affairs Canada prior to the establishment of new national parks in the Northwest Territories and Yukon. Results are used as a basis for discussion with native communities. In 1991 assessments were completed for the proposed South Moresby National Marine Park and Bluenose Lake Park.

K. Lamirande, Geoterrex Ltd. Ottawa

Air photo taken during a production flight in the Geoterrex Cessna 404, Titan C-GGTA over Alberta at an altitude of 3445 m above sea level.

GSC-INDUSTRY AEROMAGNETIC CONSORTIUM

PanCanadian, Esso, Mobil, Shell, and Amoco participated with GSC in the second phase of a three-year, cost-sharing aeromagnetic survey program in southern Alberta and British Columbia. In 1991/92, data acquisition was completed over 73 202 line km in the area. The survey will contribute to current oil exploration in Alberta, and the data will ultimately become part of the GSC's publicly accessible National Aeromagnetic Data Base. The results also contribute to the GSC's Western Canada Basin Initiative program and to ongoing LITHOPROBE investigations in this part of Canada. The joint venture cost $658 000 with the companies contributing nearly 40 percent of the funding.

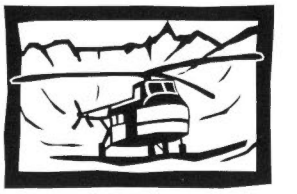
EMR

Coal mine at Sheerness Generating Station, Sheerness, Alberta.

ALBERTA POWER FUNDS COALFIELD MODELLING AND RESOURCE ASSESSMENT

Alberta Power Ltd. provided $40 000 to GSC to develop a computer model of the Sheerness and Battle River coalfields of central Alberta. The electrical utility company purchases coal for its thermal power generating stations from Luscar Ltd. and Manalta Coal Ltd., which operate strip mines in both coalfields. In order to increase the efficiency of these mining operations and hence minimize cost to the thermal power stations, Alberta Power approached GSC to develop a computer model incorporating more than 3000 boreholes from these coalfields. This project complemented the objectives of GSC's National Coal Inventory and the computer model, which includes a complete resource assessment and economic analysis, was completed in 1991-92. GSC provided the model in digital format to Monenco Ltd., which conducted a mine planning study (under contract from Alberta Power) using the MINTEC mine planning software.

As a result of this work and GSC's geological modelling technology, Alberta Power acquired a digital computer model with high integrity for a fraction of the cost of an equivalent model using less automated commercial systems. As well, the mine plan developed from this model showed that reorienting existing high walls to conform to regional depositional trends would reduce stripping costs, hence optimizing the deployment of high cost mining equipment.



ENERGY

The development of renewable and non-renewable energy resources is fundamental to sustaining Canada's needs for industrial growth and foreign trade. Canada possesses, in its onshore and offshore territories, literally dozens of sedimentary basins of varying size and potential for extraction of fossil energy resources. A comprehensive understanding of the origin and evolution of these sedimentary basins and of those terrains having geothermal energy potential is imperative to providing the necessary information on the qualitative and quantitative distribution of the nation's oil, gas and coal resources and the potential for development of geothermal energy.

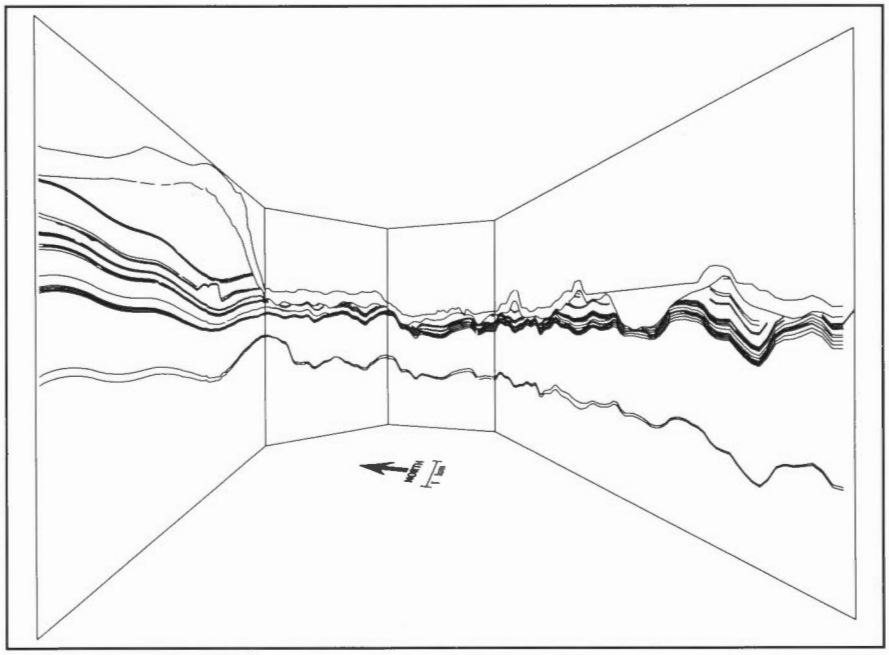
Responsible long term management of Canada's energy resources also requires an extensive knowledge of the geological factors affecting resource emplacement and distribution. So that the greatest national benefit can be realized, geoscience research must be directed specifically toward providing knowledge for the future management of these resources. This knowledge facilitates exploration and development by the

private sector, in addition to providing the basis for policies and decision-making in the public sector.

The relative geoscience effort directed by GSC toward the principal energy commodities is roughly proportional to their importance in Canada's fossil energy use, i.e. oil 50%; gas 30%; coal 20%.

- A compilation of all magnetic data in the Arctic Ocean and North Atlantic is underway. The resulting database will be the first to combine, in digital form, the results of major aeromagnetic surveys in the Arctic by industry and research agencies in Russia, the U.S. and Canada. Understanding the evolution of the Arctic is important since large hydrocarbon resources have been discovered around its margins.

- An East Coast multidisciplinary basin project gained momentum in 1991. This project synthesizes existing data and interpretations with up-to-date numerical basin simulation techniques for the Sable and Jean d'Arc sub-basins. Cost-shared with major exploration companies, the project is tracking detailed hydrocarbon-charge histories of sedimentary basins. Numerical modelling of basin charge history facilitates more accurate predictions of basin resource potential.



D. Hughes, GSC

Shown here, a three-dimensional cross-section illustrating the configuration of coal beds (Sheerness Coalfield) showing the elevation above sea level.

ENVIRONMENT

Environmental concerns of Canadians have increased dramatically in recent years to the extent that they are now as important to the public as national unity, the economy and taxes. Concern with local issues of waste disposal, toxic chemicals and polluted air and water has fused with the broader concerns of ozone depletion, acid rain and global warming. The availability of sound advice based on a comprehensive understanding of the geoscience aspects of environmental issues is therefore a priority for the Survey.

- GSC began preparation of a new series of 14 "collage maps" covering six regions in Canada. By integrating geological data with previously collected National Geochemical Reconnaissance data, these maps illustrate the degree to which variations in bedrock geology affect background levels of some environmentally sensitive elements.

- In the Atlantic Provinces, work continued on the identification of areas that have extremely high levels of fluoride in drinking water obtained from local wells.

- As a component of extensive outdoor radon surveys in Saskatchewan, British Columbia and Alberta, GSC is conducting experiments to determine the optimum positioning of sample detectors, particularly the height above ground, and the ideal type of detector for variable climatic conditions. These surveys should also delineate the seasonal variations in outdoor radon.

- A new multidisciplinary project began in Quebec's Grande-Baleine area, which will be affected should the Hydro-Quebec's megaproject go ahead. The goal of this pilot project is to better define the geoscientific information necessary for environmental assessments of such megaprojects. The surficial deposits of a representative sector of the Grande-Baleine area will be geologically and geochemically surveyed, thematic studies of the stability and terrain dynamics undertaken, as well as studies of the distribution and the dynamics of permafrost, of geochemical processes in surface environments, and of geodynamics in estuarine, coastal and marine areas.

- Global Change research continued in two IRMAs (Integrated Research and Monitoring Areas) – the Mackenzie Valley and High Arctic. A major inventory of landslides was completed for a 1800 km corridor in the Mackenzie IRMA. This will form the basis for future study of landslides and landslide triggers. A new GSC-developed drill for collecting "precision" ice cores was used successfully in the High Arctic IRMA. Research started in the new Palliser IRMA of the southwest Prairies; the focus is on determining drought frequency as recorded in lake and pond sediments.

- Significant progress was made to define a paleoclimatic record for northwestern Canada for the past 15 million years. This work is being conducted jointly with the U.S. Geological Survey and is based on a study of fossils collected from cores made through Neogene sediment of the Beaufort Sea, and surface samples from the Old Crow Basin in Yukon and adjacent Alaska.

- The national seismograph network is being completely modernized through the replacement of the older analogue standard and regional stations by broad band digital equipment. The new network will permit rapid, and largely automatic, location of earthquakes both in Canada and worldwide, and, through the provision of digital data from a network of up to 80 seismographs across Canada, allow the mechanisms of events in Canada to be much more accurately established.

- On a related note, the magnetic observatory network is undergoing an upgrade through the installation of the GSC-developed Canmos magnetometer system. The system will reduce operating costs while supplying the user with data that is of increased accuracy and more rapidly sampled. It also enables Canada to participate in Intermagnet, an international program to supply users with near real-time magnetic data via satellite links.

- GSC entered into three joint ventures with Canadian electrical utilities aimed at addressing their increasing concern about the effects of geomagnetically induced currents (GICs) on their power distribution system. The first, with Ontario Hydro, is designed to establish the correlation between magnetic activity and the GICs observed on the major transmission lines in south-western Ontario. The second, with Hydro-Quebec, aims to determine the spatial variation of magnetic disturbances during magnetic storms. The third, with the Canadian Electrical Association, will evaluate the hazard of various levels of geomagnetic activity across Canada to electrical utilities.

- Canada's Yellowknife seismic array facility was among the top three stations in terms of detecting global seismic events in a worldwide experiment in which 34 countries tested procedures for exchange of seismic data as part of the verification for a comprehensive nuclear test ban. The highly successful experiment, three years in the planning, was coordinated by GSC scientists on behalf of the Geneva Conference on Disarmament, Group of Scientific Experts.

G. Fader, GSC

Shown here, the diverse marine life of the Grand Banks seafloor.

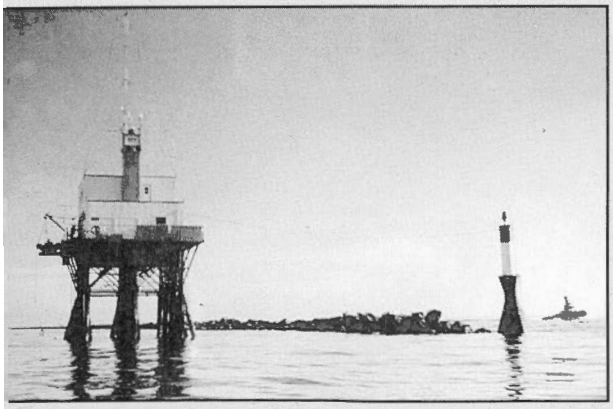
OFFSHORE SURVEYS DISCOVER CLAMS AND SEA CUCUMBERS

Mother Snow's Fine Foods Inc., a seafood products company in Armdale, Nova Scotia, has investigated and harvested a potential new commercial resource based on the results of offshore geological surveys conducted by the GSC. The surveys showed high density occurrences of clams on the Grand Banks of Newfoundland. The company has estimated the new resource could be worth several million dollars annually. Large herds of sea cucumbers (marine invertebrates with soft, cylindrical bodies 2 to 20 cm long) were also detected through regional offshore geological surveys. The discovery triggered an evaluation of the sea cucumber find as a potential new fishery by the Department of Fisheries and Oceans. Increasingly, GSC interaction with industry and its regulatory agencies involves fishing opportunities and fishery habitat issues.

ENVIRONMENT/PUBLIC SAFETY

Partners:

- University of Alberta
- University of British Columbia
- Carleton University
- Guelph University
- University of Victoria
- University of Calgary
- Simon Fraser University
- City of Richmond, British Columbia
- B.C. Hydro
- Public Works Canada
- Transport Canada
- Canadian Coast Guard
- Fisheries and Oceans Canada
- Environment Canada



J. Luternauer, GSC

Sand Heads Lighthouse, British Columbia.

FRASER RIVER DELTA, BRITISH COLUMBIA

The Fraser River delta is a densely populated floodplain underlain by sediments that could become unstable if subjected to a high energy shock such as that caused by an earthquake. The GSC is working with a number of agencies in the delta area to identify evidence of past earthquake-triggered liquefaction or failures, to generate information that can help assess earthquake vulnerability of the delta and to define evidence of, and processes contributing to, instability of the offshore part of the delta.

Shallow geophysics surveys were conducted, in cooperation with the municipalities of Richmond and Delta, to provide data for regional assessment of liquefaction potential and ground motion amplification during earthquake shaking. A reconnaissance of more than 30 percent of the area was completed and results indicate significant variation in liquefaction potential within the delta. The final map showing the potential for this hazard will be invaluable for land use planning, particularly to the municipalities and public utilities.

The results of this work seem to be corroborated by a GSC/private sector study which identified widespread evidence for prehistoric liquefaction on the Fraser delta. Large numbers of sand dykes and sills which cut the uppermost sediments of the delta were emplaced less that 2000 years ago, probably during a large earthquake.

Another study, by GSC and the universities of Guelph and British Columbia, discovered that submarine slopes at the mouth of the Fraser River are highly unstable. This could present a risk to structures such as the Sand Heads Lighthouse, which is within 80 m of a major failure scarp. The results of the study, which were published in 1992, prompted the Coast Guard to remove staff from the lighthouse and hire geotechnical experts to conduct a detailed evaluation of the conditions.

This instability also poses a risk to submarine power cables in the area. Four scientific offshore surveys were completed with B.C Hydro. These showed areas of past failures and will help the utility company plan where to place new cables and replacement cables.

Other work included downhole geophysical logging of ten boreholes and a joint project with researchers from Simon Fraser University to confirm the presence of gas in the shallow unconsolidated sediments. Future work will address the mechanisms, magnitude and frequency of the slope instability processes mapped and described in the past year. This will provide data for a landslide risk analysis.

GEOSCIENCE AND PUBLIC SAFETY

Although there has been an increase in concern over the impact of society on the environment, the Survey also has to maintain its activities related to the ways in which the natural environment threatens society and constrains human activities.

Some of these concerns have changed their focus. For example, the potential impact of earthquakes on nuclear power stations and repositories for their waste has brought new demands for information on long term site stability. Geomagnetic storms, previously of greatest concern because of their effect on mineral exploration surveys, now threaten modern communication, navigation and power transmission systems.

- GSC, the Scripps Institution of Oceanography and NASA's Jet Propulsion Laboratory joined forces in a pioneering experiment that made the first set of combined ocean-acoustic/GPS-geodetic measurements off Vancouver Island. The long-term scientific objectives are to track the present-day motion of the Juan de Fuca plate and to measure peak strain rates at the outer North American plate margin overlying the Cascadia subduction zone – both are key factors in estimates of seismic risk for southwest British Columbia.

- GSC promoted interdisciplinary collaboration with scientists from federal, provincial, municipal, academic and industrial agencies and public interest groups in a three-day workshop to discuss research projects and their results with a view to obtaining a better understanding of the submarine environment in Howe Sound, British Columbia. Issues addressed included distribution of fish population, forestry practices, pulp mill effluent, acid rock drainage, volcanological and landslide hazards, ocean water chemistry, and sediment distribution patterns. Follow-up briefings were held to apprise interested people in local communities of the relevance of the research.

- GSC was invited to contribute information on the level of Canada's volcanic hazard and on Canada's preparedness to deal with a volcanic emergency. Such knowledge is relevant to the potential dangers of airborne volcanic ash to aircraft safety. Recent eruptions have resulted in tens of millions of dollars in engine damage, and it is recognized that potential liability claims in the event of a passenger jet crash could be enormous. Adequate warning of volcanic eruptions remains a problem that requires the recognition and reporting of such events coupled with an effective international communications network.

Gilles Lemieux, GSC

GSC Map Library

CANADA'S NATIONAL GEOSCIENCE LIBRARY RENOVATED

The GSC Library at 601 Booth Street in Ottawa is Canada's premier earth sciences library. To better serve its clients and to reduce long-term operating costs, an extensive program of renovation was carried out this year to upgrade storage and retrieval systems. This was a major undertaking – the map library alone has over 260 000 maps, and all of them had to be relocated during the renovation.

INFORMATION

Geoscience information is the ultimate output of almost all GSC programs. While some of this information is resident in the experience and expertise of its staff, the greater part is made available through maps, publications, data files and reference material.

Advances in the speed, technology and availability of electronic communication and data storage have dramatically affected almost all aspects of contemporary life. The conduct of the Survey's research and the output of its results must keep pace with this information revolution.

- GSC's first CD-ROM product (Compact Disc – Read Only Memory) was released. The disc contains seven GSC databases of general interest to the Canadian geoscience community and includes images and full-text files in addition to structured data. This pilot project to evaluate the long-term relevance of CD-ROM technology for scientific information was initiated as part of the 150th anniversary celebrations to commemorate GSC's important role as a collector and disseminator of Canadian geoscience data.

■ Significant achievements in the development and implementation of digital map production procedures were made, with focus shifting from development to production. The GSC also published over 9000 pages of scientific information this year, 3000 of which belong to two volumes of the "Geology of Canada" series. Over 11 000 pages of open file reports were produced.

NEW PUBLICATIONS

➢ Two volumes of the "Geology of Canada" series were released in English and French: "Geology of the Innuitian Orogen and Arctic Platform of Canada and Greenland" and "Geology of the Cordilleran Orogen in Canada". Of note, the Cordilleran volume includes an important digitally-produced map "The Tectonic Assemblage of the Cordillera".

➢ The "Scotian Shelf Basin Atlas", the second volume of the East Coast Basin Atlas series, was completed in 1991. Prepared with digital cartographic technology, it provides comprehensive regional coastal seabed and basin geoscientific data.

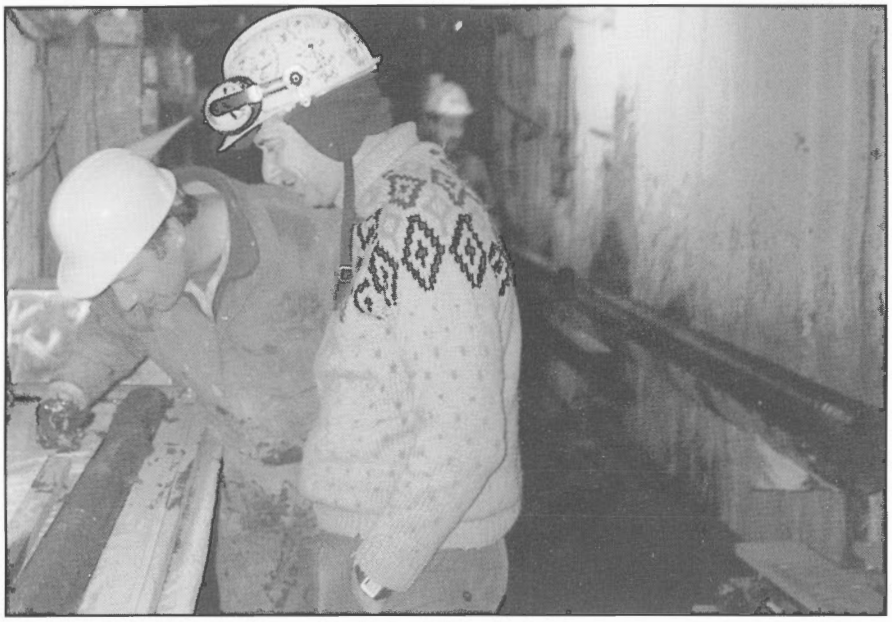
➢ "Radiogenic Age and Isotopic Studies: Report 5" presents new geochronological data.

➢ "The Cyprus Crustal Study Project" reports on deep drilling in Cyprus carried out by an international consortium of scientists.

➢ "Evolution and Hydrocarbon Potential of the Queen Charlotte Basin, British Columbia" gives results of a multidisciplinary basin analysis project.

➢ "Shear-sense Indicators: a Review" is the critical evaluation of the kinematic significance of natural geological deformation structures, with particular reference to the determination of shear-sense.

➢ Four volumes of the annual series "Current Research" were released.



GSC

Shown here, geologists examining core sample.

MACKENZIE DELTA GEOLOGY/PERMAFROST TRANSECT

Shell Canada Resources and Imperial Oil Resources worked with GSC scientists in a multidisciplinary study of the geological, geothermal and geotechnical conditions of perennially frozen sediments in the Mackenzie Delta area. This joint government-industry initiative, called the Mackenzie Delta Geology/Permafrost Transect, started in 1991. Continuously cored boreholes, the deepest of which reached 450 m, were drilled in the vicinity of three major hydrocarbon fields. As part of the sampling program, specimens of naturally occurring gas hydrates were recovered for the first time in Canada. Further study will aid in interpreting the geological and paleoclimatic history of this area and contribute to our knowledge of the detailed geotechnical properties of permafrost, an issue vital to the development and transport of oil and gas in the area.

ARCTIC LOGISTICS

The Polar Continental Shelf Project

The Polar Continental Shelf Project (PCSP) is a unique and internationally recognized federal agency that provides a comprehensive logistics support network for scientists working in the Canadian Arctic. It operates from bases in Resolute and Tuktoyaktuk in the Northwest Territories, and from the Canadian Ice Island Research Station in the Arctic Ocean. In keeping with its mandate to help maintain Canada's stewardship of its Arctic region, PCSP plays a key role on behalf of other federal agencies in increasing awareness of the Arctic among all Canadians.

- PCSP, which is linked administratively to GSC, supported 280 science programs in 1991 including 14 under the Arctic Awareness Program (this program was cancelled in late 1991 due to funding restrictions).
- Plans to decommission the Ice Island Research Station were completed as the island travelled southward out of the Arctic Ocean. The clean-up will leave the site as it was found.

- PCSP conducted more than $900 000 in business with northern companies and communities. It also continued efforts to raise science awareness in Arctic communities by an active program of school visits. A newsletter describing research supported by PCSP was distributed to all Arctic communities and user groups in Canada and abroad.

- PCSP entered joint ventures with other agencies operating in the Arctic with a view to enhanced cost effectiveness. These included an agreement with the Science Institute of the Northwest Territories governing areas of cooperation among its respective Arctic bases and research stations, and a joint three-year, fixed-wing aircraft contract with Atmospheric Environment Service (AES), which requires fixed-wing services into its High Arctic Weather Stations in the eastern Arctic.

Gilles Lemieux, GSC

Over 500 people attended GSC's Minerals Colloquium held January, 1992. Shown here (from left): GSC Assistant Deputy Minister Ken Babcock, Lang lecturers Howard Stockford and Jim Gill from Aur Resources, and in the spirit of the 150th anniversary, Sir William Logan, personified by Les Gallagher from EMR Communications.

RESEARCH GRANTS

The Research Agreements Program of Energy, Mines and Resources Canada, which GSC coordinates, provided grants totalling $2 million to support 213 projects in the natural sciences and in engineering that will be carried out at 42 Canadian universities and research centres. The Natural Sciences and Engineering Research Council (NSERC) contributes about one third of the funding for university-based projects.

ORGANIZATION CHART

Geological Survey of Canada Sector
Assistant Deputy Minister

- *Office of the Chief Scientist*
- *Polar Continental Shelf Project*
- *Geoscience Information and Communications Division*
- *Coordination and Planning Division*
- *Geophysics, Sedimentary and Marine Geoscience Branch*
  - *Atlantic Geoscience Centre*
  - *Geophysics Division*
  - *Institute of Sedimentary and Petroleum Geology*
  - *Pacific Geoscience Centre*
- *Minerals and Continental Geoscience Branch*
  - *Continental Geoscience Division*
  - *Cordilleran Division*
  - *Mineral Resources Division*
  - *Québec Geoscience Centre*
  - *Terrain Sciences Division*

GEOLOGICAL SURVEY OF CANADA

1991-92 Expenditures (in thousands of dollars)

	Total	*Personnel*	*Operating*	*Capital*	*Grants and Contributions*
Assistant Deputy Minister	3 794.0	234.2	129.8	0	3 430
Chief Scientist's Office	764.4	355.5	408.9	0	—
Polar Continental Shelf Project	6 929.4	1 280	5 380.1	269.3	—
Geoscience Information and Communications Division	8 577.2	4 756.8	2 552.8	1 267.6	—
Coordination and Planning Division	3 426.9	1 576.6	1 272.1	578.2	—
Geophysics, Sedimentary and Marine Geoscience Branch					
Director General	302	208	72	22	—
Institute of Sedementary and Petroleum Geology	15 386	8 484	6 013	889	—
Atlantic Geoscience Centre	13 582	6 992	5 516	1 074	—
Geophysics Division	12 648	6 377	4 979	1 292	
Pacific Geoscience Centre	5 529	2 814	1 726	989	—
Total	**47 447**	**24 875**	**18 306**	**4 266**	—
Minerals and Continental Geoscience Branch					
Director General	843	705	123	15	—
Québec Geoscience Centre	2 814	1 426	1 134	254	—
Cordilleran Division	3 959	2 500	1 203	256	—
Terrain Sciences Division	8 631	5 057	3 116	458	—
Continental Geoscience Division	10 290	5 920	3 253	1 117	—
Mineral Resources Division	15 766	9 652	4 784	1 330	—
Total	**42 303**	**25 260**	**13 613**	**3 430**	—
Sector Total	**113 241.9**	**58 338.1**	**41 662.7**	**9 811.1**	**3 430**

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