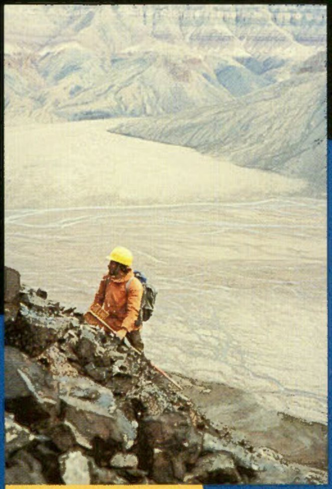
Geological Survey of Canada

1997 - 1998



CANADA 1842 GEOLOGICAL SURVEY - COMMISSION GÉOLOGIQUE

Natural Resources Canada
Ressources naturelles Canada
Canada

Innovative partnership project looks at Baffin Island

The geoscience knowledge base of the Northwest Territories received a boost from the launch of a project to compile, in digital, GIS-compatible format, all available geoscience information for northern Baffin Island and Melville Peninsula. Of particular interest will be a new mineral potential analysis – the geology of the region suggests that the area could contain diamond, base metal, and gold deposits.

All the data compiled by the project will be distributed on CD-ROM and via the Internet, ensuring that northern communities and the mineral exploration industry will have easy access to it. The CD-ROM will also contain information relevant to environmental studies, education, carving stone exploration, and effective land-use planning.

The Iqaluit-based Qikiqtaaluk Corporation, the GSC and the N.W.T. Department of Resources, Wildlife and Economic Development are sharing the costs for the project, with technical assistance from the N.W.T. Geology Division of Indian and Northern Affairs Canada. The project underscores the partners' commitment to cooperation and sustainable development, and is already being viewed as a model for collaborative program delivery for the North.

Photograph: Looking west across Elwin Inlet river valley, from a talus slope of gneiss blocks, Baffin Island. Credit: T. Iannelli

Map detail, from soon-to-be released GSC Open File 3633, shows bedrock geology of northwestern Borden Peninsula, Baffin Island.

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Table of contents

Message from the Minister

The Honourable Ralph Goodale, Minister of Natural Resources Canada.

Sound science, hard work and innovation are what make the Geological Survey of Canada a catalyst of economic growth. The GSC is one of the organizations that will lead Canada to the forefront of the knowledge-based economy.

The Geological Survey of Canada's tradition of scientific excellence has contributed to an impressive array of Canadian successes.

In the past few years, for example, GSC innovation has helped create more reliable methods of finding diamonds and contributed to the development of Canada's first diamond-bearing kimberlite in the Northwest Territories. New GSC three-dimensional seismic techniques have resulted in a tenfold increase in the effective depth of prospecting for minerals, reducing the need for as many expensive test drillholes. And GSC's exploration technology (EXTECH) project is helping to extend the life of mining communities by developing and applying new concepts and methods for base metal exploration. Airborne surveys conducted by EXTECH contributed to the discovery of the Camel Back massive sulphide deposit in New Brunswick's Bathurst mining camp.

These accomplishments carve for Canada a place in the new knowledge-based economy where creativity and innovation are the currency. They distinguish us as a country to which the world will look for solutions in the twenty-first century.

Advanced technological tools and readily accessible knowledge, through initiatives such as GSC's Internet-based Geoscience Knowledge Network, give Canadian companies the necessary edge in today's highly competitive world market. GSC's scientific expertise and innovation are also helping advance our understanding of the potential impacts of climate change in Canada and of measures needed to adapt to this change. What we are learning from this should contribute to our long-term goal of developing our natural resources so that we protect the health of our environment and preserve it for future generations.

Rural and remote communities will experience some of those benefits, thanks to two agreements that GSC signed this year as part of the Intergovernmental Geoscience Accord: a bilateral agreement with Newfoundland and a trilateral agreement with the Northwest Territories and the federal department of Indian Affairs and Northern Development. These agreements allow the provincial and federal governments to work together in addressing the changing geoscience research needs of these regions.

The ingenuity and dedication of the people who serve the GSC is known widely and admired. I look forward to seeing where GSC's innovations will take us in the new millennium.

Ralph Goodale

Minister's National Advisory Board on Earth Sciences (MNABES)

The GSC, as part of NRCan's Earth Sciences Sector, benefits tremendously from the advice and guidance of this "blue chip" advisory group which meets twice yearly and reports directly to the Minister of Natural Resources. MNABES provides client-focussed advice on the programs, priorities and strategic plans of both the GSC and its sister organization Geomatics Canada. It also reviews reports of technical advisory committees and advises on cooperative programs.

MNABES comprises 12 senior representatives of key client groups in industry, government and universities, including, for the board members who focus on the GSC: mineral exploration, petroleum exploration, geotechnical engineering and environmental geoscience, and insurance related to geological hazards. MNABES also has four ex-officio members from national geoscience associations and the Committee of Provincial Geologists.

Recent issues that MNABES has focussed on include GSC partnerships with industry, provinces and territories and universities; funding for geoscience at the federal and provincial government levels; GSC's management structure; climate change; the role of geoscience in the economic development of the North; and the GSC's Information Highway initiative, the Geoscience Knowledge Network.

Minister Goodale met with MNABES at their meeting in April 1998. From left, Gerald Pollock, Jacquelin Gauthier, Stephan MacPhee, Marc Denis Everell, Jan Boon, Robert Mummery, Diane Thompson, Robert Moses, Susan Nichols, Ralph Goodale, Robert McNutt, Edward Kennedy, Nancy Vanstone, Michel Brunet, Toby Gilsig.

Patricia Hunt, GSC

Geoscience Surveys

A comprehensive national geoscience knowledge framework for Canada forms the basis of sustainable development of Canada's mineral, energy, water and other resources, land-use decision making, and public health and safety planning linked to natural hazards. GSC's National Geoscience Mapping Program (NATMAP), a partnership with provincial and territorial agencies, is one of the key mechanisms for delivery of this work.

Start-up of western NATMAP project

The Central Foreland project is a five-year multidisciplinary study over a broad area of rich mineral and petroleum potential that includes the Rocky Mountain Front Ranges, Foothills and adjacent plains of northeastern B.C. and southern parts of the Yukon and the Northwest Territories. Bedrock and surficial geology maps produced by the project will give rise to economic activities that far exceed the mapping investment from the partners. Research partners come from GSC and Indian and Northern Affairs Canada; the B.C., Yukon, and N.W.T. governments; six universities; eight petroleum companies; and the Royal Tyrrell Museum of Paleontology. Preliminary work has already resulted in eight publications and maps. The project also includes a strong training component for students and industry geologists.

New maps released for southern Baffin Island

GSC released three new geological maps for the Iqaluit-Kimmirut area of southern Baffin Island in January 1998. These complete a set of nine stemming from GSC fieldwork, and provide bedrock geology and related information for an area of 28 000 square kilometres that includes Inuit-owned lands, a territorial park and the future capital of Nunavut. New aeromagnetic data will be released in the summer of 1998. Previous release of geological maps resulted in a "staking rush" in 1996 and significant investment by the mineral exploration industry. Follow-up exploration by industry in 1997, with total expenditures of over $6 million to date, resulted in the delineation of massive sulphide mineralization and suggested a potential new mineral district.

New partnership project in Saskatchewan

GSC established a partnership with the Saskatchewan Geological Survey (SGS) and the universities of Regina and Saskatchewan to provide a systematic geological-geochronological knowledge context for a belt of high gold and base metal potential. The project area, which forms a geological bridge between the La Ronge gold camp in Saskatchewan and the Lynn Lake base metal camp in Manitoba, was identified by the Saskatchewan minerals industry as a priority area for updated geological mapping. GSC's work targets the question of regional correlations with sequences in adjacent Manitoba, as well as thematic studies such as geochronology and geophysics. SGS is concentrating on detailed studies in the mineral-rich belt.

Nechako NATMAP leads to increased exploration

The Nechako project for the central Canadian Cordillera in British Columbia has completed three field seasons and forged strong links between the GSC and the B.C. Geological Survey, as well as with partners in universities and key mineral explorationists in the region. The objectives are to rapidly bring this poorly-known area into a modern framework, and to examine the role of Tertiary crustal extension and volcanism in controlling topography, rock and mineral distribution. The area contains the Babine Porphyry Copper belt, but because much of the area is covered in thick glacial deposits and young volcanics it has been under-explored. Advances in understanding the regional geological framework have resulted in increased exploration interest – there was a 23% increase in claim staking in one area following the release of a lake geochemistry survey.

Geological record ends archeological debate

An interesting offshoot of the Alberta Foothills project was the resolution of a longstanding debate in North American archeology about the existence of an ice-free corridor along the Foothills at the height of the last ice age, along which the first human inhabitants of the Americas were thought to have travelled south. GSC, working with three universities, tested the theory of the existence of this corridor by using a new technique (cosmogenic chlorine-36 exposure dating) to date the 600 km long Foothills Erratics Train, which marks where two major glaciers converged. The results showed that there could not have been an ice-free corridor until the end of the last ice age, some 13 000 years ago.

Churchill NATMAP: first results

The Western Churchill project completed a successful first year. The aim of this multidisciplinary initiative in the Northwest Territories is to provide a comprehensive geoscience knowledge base for an area with gold, diamonds, and base metal potential encompassing Rankin Inlet, Arviat and Baker Lake. The project pools the resources of GSC, the Government of the N.W.T. and Indian and Northern Affairs Canada. The first year resulted in major new models for the Precambrian tectonic history and mineral potential of the area. Regional mapping of ice flow indicators in Keewatin was begun. This will help trace mineral deposits back to their sources in bedrock by providing information on the history of glacial transport. The project has attracted strong industry support.

Ice flow dynamics provide clues for mineral exploration. Striae mapping determines ice flow direction.

I. McMartin, GSC

Wrap-up for three NATMAP projects

- *The Magdalen Basin project concluded with a synthesis of the data and the final drafting of digital maps of northern Nova Scotia and southeastern New Brunswick. The publication of a CD-ROM on the project will contribute to the knowledge infrastructure required for hydrocarbon and mineral resource assessment in the Maritimes. The CD-ROM contains about forty maps at various scales and a georeferenced database (ordering information on page 35).*
- *The Shield Margin project, initiated in March 1991 as one of two inaugural NATMAP projects, focussed on the Flin Flon Belt of northern Manitoba and Saskatchewan. The final synthesis maps, and geological, geophysical and geochemical information sets will be released in a final CD-ROM set next year. A summary of the research will be published in two special issues of the* Canadian Journal of Earth Sciences.
- *The Alberta Foothills project saw the completion of its bedrock and surficial geological mapping work, and most maps were released. Maps and cross-sections of the subsurface structure, at 1:50 000 and 1:250 000 scales, together with synthesis reports, will be made available in digital and paper format over the next few years.*

NATMAP

Follow-up to the Slave NATMAP

Surficial geology mapping was extended into the Hope Bay area of the Slave Geological Province, as follow-up to the successful Slave NATMAP project. Identifying the nature and distribution of surficial materials, including potential granular deposits, regional till sampling, and mapping of ice flow indicators, are essential elements in this integrated approach to assist land-use management and planning for infrastructure development, as well as guiding mineral exploration in the search for base metals, gold and diamonds. Monitoring of geotechnical installations relating to permafrost investigations along a proposed transportation corridor in the Coppermine area was continued. Project highlights include the continued refinement of regional background geochemical values and kimberlite indicators in till as a guideline for natural occurrence, improvements in regional exploration methods, and collaboration with exploration industry during mapping in the Hope Bay volcanic belt.

Partnership in the Superior Province

Partners from the GSC, Ontario and Manitoba geological surveys, Lithoprobe, universities and industry had an active year in the western Superior Geological Province. The project integrates the NATMAP bedrock geoscience initiative in western Ontario-northeastern Manitoba with the Western Superior Lithoprobe transect, as well as ongoing programs of the provincial surveys, the GSC and the Canadian Mining Industry Research Organization (CAMIRO). The goal is to provide a comprehensive framework for understanding the exposed and subsurface geology, Earth structure and mineral potential (base and precious metals, diamonds) across an under-explored part of this richly endowed region. The 1997 mapping program overturned conventional wisdom on stratigraphy, plutonism and tectonic history in several project areas in Ontario and Manitoba, with field results being tested by geochronological and geochemical studies. Another highlight was a $1.4 million GSC/Lithoprobe contract for seismic reflection surveys in northwestern Ontario. Initial results show complex crustal structure, and corroborate 1996 refraction results that showed thicker crust than expected. A teleseismic study co-funded by industry is testing popular models for the age and origin of the Superior Province.

Alberta Lithoprobe

Results from the Peace River Arch Industry Seismic Experiment (PRAISE) were released. These provided new insight into fault history associated with hydrocarbon emplacement, and tectonic evolution of the crust that hosts recent diamond discoveries in the Buffalo Head Hills of northern Alberta. Results of the U.S.-Lithoprobe DeepProbe experiment, the largest refraction experiment ever conducted (nearly 8% of the earth's circumference!) yielded an unparalleled view of the shallow mantle from northern Alberta to southern New Mexico. New interpretative results came out of the SALT (Southern Alberta Lithospheric Transect) seismic experiment, revealing the roots of an ancient mountain belt to be geometrically similar to the modern Pyrenees. Reactivation of these old structures during younger sedimentation and petroleum migration, particularly in southwestern Alberta, continues to be an area of ongoing research of considerable interest to the petroleum industry. The Alberta Basement Transects project entered its final stages of interpretation and synthesis.

Dating glacial sequences in the Yukon

The oldest, longest record of glacial and interglacial events in North America was discovered during regional surficial geology mapping along the Tintina Trench north of Dawson. This record extends from about 3 million to 200 000 years ago and was dated using paleomagnetism, pollen analysis, and paleosol (soil) studies. The earliest glacial event is very important because it was responsible for the northwest diversion of the Yukon River into Alaska. The stratigraphic sections also expose preglacial sequences that revealed an age for the formation of the Tintina Trench and its association with the ancestral south-flowing river and placer gold deposits. These studies should help identify areas where other placer gold deposits may be concealed under younger sediments.

A new trilateral agreement laid the groundwork for coordination of geoscience in the Northwest Territories. Stephen Kakfwi, Minister of Resources, Wildlife and Economic Development for N.W.T. described the partnership as "a cost-effective means for all parties to achieve their goals" and that it would "contribute to realizing the full potential of our resources in the North." The signing took place at the Prospectors and Developers Association annual meeting in Toronto, March 9, 1997.

From left, Joe Handley for the Government of N.W.T., Murray Duke for NRCan, Dave Nutter for DIAND.

C. Relf, DIAND

FOCUS ON

Canadian Diamonds

Canada is expected to join the world ranks of major diamond producers in 1998. GSC surficial and bedrock mapping has played a role in the discoveries that have been made, including the tremendous Lac de Gras kimberlites in the Northwest Territories that will be the first to be mined. Discoveries have also been made elsewhere in the N.W.T., and in Alberta, Saskatchewan, and Ontario. GSC scientists continue to contribute to this exciting development, through research related to kimberlites and by targetted bedrock, surficial, geophysical, and geochemical mapping.

NEW DIAMOND EXPLORATION MODEL FOR SASKATCHEWAN

A GSC team is working with the Fort à la Corne Joint Venture (a consortium of exploration companies) to document the diamond potential of 101 million-year-old kimberlite volcanic rocks in central Saskatchwan. They have determined that two, separate, highly explosive eruptions spread kimberlite ash and coarser material over broad areas of the tropical lands and seas that covered most of modern-day Saskatchewan at that time. This material contains uneconomic microdiamonds and, on the basis of preliminary analysis, what appear to be eroded fragments of macrodiamonds. This is a new exploration model for Canada. It differs from traditional models that concentrate on the kimberlite pipes, as in South Africa and at Lac de Gras. GSC's research is made public within one year of the results being provided to the industry partners.

DEVELOPMENTS IN DIAMOND EXPLORATION METHODS

GSC scientists completed preliminary studies at the recently discovered Peddie kimberlite near New Liskeard, Ontario. This kimberlite is being developed as GSC's first multidisciplinary test site for diamond exploration methods. The kimberlite has a very thin cover of glacial till (2 to 3 m), which allows easy excavation through the glacial sediments into the kimberlite. Large kimberlite samples were taken for indicator mineral studies, age determination of the intrusion, and petrology studies. The kimberlite contains a high volume of large olivine grains that give the pipe a distinctive mineralogical signature and this can be traced down-ice in the overlying till. The excavations also revealed an unweathered upper portion of the kimberlite displaying what may be the first reported striated kimberlite surface. Geophysical, biogeochemical and soil geochemical tests are planned for the site.

MICROFOSSILS HELP FIND DIAMONDS

In the research in the Fort-à-la-Corne area, microfossils (foraminifera) and radiometric age studies are leading the way in dating diamond-bearing deposits. Kimberlite deposits in this area were covered by ancient seas, with wave action reworking the deposits and raising the possibility of diamonds being concentrated in nearshore and shoreline sands. Crushed residues of marine sediment prepared to concentrate microfossils have proven to contain abundant diamond-indicator minerals such as garnet, diopside, and ilmenite. It is possible that certain "agglutinating" foraminifera may have attached diamonds to their microscopic shells.

First known exposure of glacially striated kimberlite.

B. McClenaghan, GSC

SPREADING THE WORD

During the past year, GSC staff gave many public lectures and media interviews on the economic impact, history, science, and technology of diamond exploration at several public and professional venues across Canada and at investment promotion seminars overseas in Australia and Hong Kong.

FOCUS ON

Metals in the Environment (MITE)

GSC's new MITE initiative responds to increasing government and industry requirements for geoscience knowledge necessary to develop national and international policies concerning metals and their release to the environment, and to formulate regulations for Canada. MITE is helping define Canada's leadership role in the sustainable use of metals.

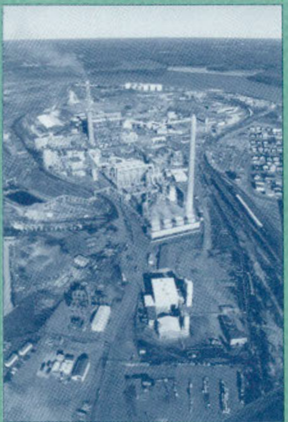
Metals in the environment are derived from natural, geological sources as well as from the activities of our modern society, from mining and manufacturing to urban living. It is important to understand trace metals in the environment as they play both positive and negative roles in biological processes: zinc and copper are bioessential, while lead and mercury can be toxic. MITE is designed to provide a geological basis for environmental studies, defining the range of natural "background" metal concentrations, the mineral form and reactivity of metals, and the processes controlling their movement in the surficial environment.

MITE goals are to:

- **determine the rate at which metals are released from natural sources to other environmental media (soils, lakes) which also receive input from human (anthropogenic) sources,**
- **develop criteria that differentiate between metals in the environment derived from natural or anthropogenic sources, and**
- **validate various "stratigraphic" historical records in light of natural processes and variability.**

MITE research is varied, including, in its first year, studies of:

- **the distribution of metal-rich particulates derived from smelter activity at Flin Flon, Manitoba, Trail, B.C. and Rouyn-Noranda, Quebec;**
- **the factors influencing the distribution of trace elements in soils, lake sediments and waters, peat and tree rings to differentiate between natural variations and additions due to smelter and other human activity around Rouyn-Noranda;**
- **the source of mercury in fish in Kaminak Lake, N.W.T., and of high mercury levels in wildlife in southwest Nova Scotia;**
- **the glacial dispersal of mercury-rich debris near Pinchi Creek, British Columbia;**
- **the effects of weathering during postglacial time on surficial deposits in different geological terrains; and**
- **laboratory techniques to meet specific MITE requirements.**



Initial results obtained near the Horne smelter in Rouyn, Quebec, confirmed the usefulness of a new tool which combines the study of tree rings (dendrochronology) with elemental and isotopic geochemistry to characterize and monitor environmental change.

Noranda Inc.

MITE is part of the federal government's effort to develop a framework for the application of science and technology to promote sustainable development in the natural resources sector. Within this, GSC scientists are collaborating in MITE-related activities with scientists from Environment Canada and Fisheries and Oceans, and developing linkages with university researchers.

Minerals

GSC's minerals research provides geoscience innovation and insight that helps the mineral exploration industry discover the reserves required to sustain Canada's position as one of the world's leading suppliers of minerals and metals. It ensures that the Canadian government has the geoscience information necessary to formulate mineral policies in areas of federal jurisdiction and to promote the technological capability of the Canadian exploration services industry.

Gold in Saskatchewan

Gold potential in Saskatchewan is the focus of collaboration for GSC scientists and their provincial, university and industry colleagues. In central Saskatchewan, outcrop exposures of previously unexplored sediments are being examined for their potential to host paleoplacer deposits derived from the Precambrian Shield to the north. About 115 million years ago, powerful south-flowing rivers, carrying sediments up to gravel size, drained the gold-bearing Shield area of what is now northern Saskatchewan, possibly concentrating gold and other precious metals in the river sediments. Preliminary analysis of the samples supports the concepts behind this new exploration model. Results of this research were made public last fall. The potentially prospective outcrop covers a large area south and east of Prince Albert. GSC is also working with the Saskatchewan Geological Survey to interpret paleoplacer gold prospects in southwestern Saskatchewan, that have been the target of recent industry staking and exploration.

Mineral finds in the North

GSC regional multisensor airborne surveys, carried out under the National Gamma-Ray Spectrometry Program (see NATGAM report, page 33), provide geochemical and geophysical information directly applicable to mineral exploration. In northern Canada, three of several mineral deposits discovered by these surveys resulted in exploration and development expenditures of tens of millions of dollars and have produced significant additions to Canada's mineral inventory. Southeast of Great Bear Lake, polymetallic mineralization at Lou Lake (Nico) and at Sue Dianne represent new Canadian deposit types and contain gold, cobalt, copper, bismuth and tungsten in over 150 million tonnes of ore, for a total resource of over US$7 billion. Along the east arm of Great Slave Lake, the Thor Lake deposit contains several rare and strategic metals, including a combined beryllium, tantalum and niobium resource exceeding US$5 billion. Mining feasibility studies are underway at all three deposits.

Mineral exploration in Newfoundland

Products of the first year of a collaborative project with the Newfoundland government were a new model for gold mineralization in eastern Newfoundland and a review of same-age deposits throughout the Avalon belt, which extends from Newfoundland to the Carolinas in the U.S. The Avalon Belt is characterized by two distinct episodes of porphyry and epithermal mineralization, controlled by well-defined geological features. It is also similar to the magmatic arcs of the Pacific Ring of Fire. Results are demonstrating that this underexplored area has significant mineral potential.

New Brunswick mining camps

Following on the success of EXTECH II at promoting exploration in the Bathurst mining camp, the New Brunswick Department of Mines and Energy is looking at a similar program for the Restigouche area. A pilot project in 1997 evaluated the effectiveness of three airborne geophysical techniques: electromagnetics, spectrometry and aeromagnetics. The GSC is providing the technical expertise to monitor data acquisition and compilation. Evaluation of results will be carried out in conjunction with industry partners. Based on the results, an extensive airborne exploration program is planned for 1999.

Knowledge transfer triggers exploration

Long-term research on mafic magmatic terranes in Canada, and maintenance of a national knowledge base on their potential to contain nickel, copper and platinum deposits has been transferred by GSC to industry through public talks, workshops, and reports. This has led to major exploration efforts. Over 50 000 hectares were staked in the Rottenstone Domain of Saskatchewan, following an extensive industry geophysical survey stimulated by GSC activities in the region. In the N.W.T., the release of GSC data resulted in the staking of the entire Muskox Complex and its subsurface northern extension. This was followed by two years of exploration, including geophysics programs exceeding $1 million. Such exploration programs are vehicles for collaborative, cost-shared follow-up research with the GSC. In the Muskox Project, this includes updating maps, resampling and detailed petrochemical analyzes of archived drill core from a major GSC program of the 1960s. GSC work in the Rottenstone Domain, is expanding the potential for new collaborative research with the provinces and industry.

New meteorite acquisition

The GSC more than doubled the size of the National Meteorite Collection of Canada with the acquisition of the Terry E. Schmidt Meteorite Collection – and it did not cost taxpayers a cent. The Schmidt Collection, constituting more than 900 specimens, was offered for sale in 1993 following the death of Mr. Schmidt. GSC traded for the collection, giving up a piece of the Abee, Alberta, meteorite without harming the integrity of the specimen. The acquisition makes Canada's meteorite collection, which dates back to 1855, one of the largest (1700 specimens) and most impressive in the world. The collection could now play a key role in Canada's contribution to space research in the next century. Canadian space rocks will also support the study of the origin of meteorites and the potential for resource development of other planets.

The transfer of a piece of the Abee, Alberta, meteorite from the Canadian national collection to the American meteorite dealer, Russ Kempton, was the final step in three years of negotiation to acquire the Schmidt Collection. From left: Russ Kempton, Richard Herd, curator of the Canadian collection.

Tools for modern mineral exploration

The GSC is engaged in several initiatives with industry and academia to develop three-dimensional GIS tools for applications in mining and mineral exploration. Powerful new data management and visualization software are now available, and these have great potential for increasing our understanding of Canada's mineral wealth and improving exploration efficiency. To accelerate the adoption of this new technology, GSC is pursuing opportunities for transfer of its expertise through partnership projects with industry, and by conducting courses and workshops. Some examples:

- ***GSC and Lithoprobe have developed and promoted the use of seismic reflection techniques for mineral exploration in crystalline terrains. Industry interest has grown steadily, culminating recently with the first mining-related 3D seismic survey in Canada, jointly funded by GSC and industry, and several subsequent industry-funded surveys.***
- ***A Downhole Seismic Imaging consortium (Inco, Falconbridge, Noranda and several Canadian and European universities) was established in June 1997. Strategic objectives are to develop a new deep exploration technique to locate base metal orebodies using borehole seismic receivers and to transfer this technology to the mining and geophysical services industry. Research has demonstrated the potential of this technique to provide cost-effective direct detection of ore and stratigraphic mapping for mineral exploration to depths of two to three kilometres. The five-year project is funded by industry and GSC, with universities participating through individually funded joint research projects.***

A GSC, industry and university team carried out field work near Sudbury as part of the Downhole Seismic Imaging initiative.

G. Wint, Noranda

New prospecting strategies for Quebec

Research, combining glacial dynamics and the composition of Quaternary sediments, continued with the Quebec Department of Natural Resources on the Ashuanipi project in north-central Quebec. A regional model integrating data from Ashuanipi with Quebec-Labrador data revealed several major reorientations of the direction of ice flow during the last glaciation. Knowledge of the complex glacial history of the region will help mineral explorationists optimize their prospecting strategies.

Is there life on Mars?

GSC scientists are studying Martian meteorites using the unique cathodoluminescence imaging capabilities of GSC's microprobe laboratory. GSC's recently installed, Canadian-designed system permits the study of textures that cannot be observed by other imaging systems. In collaboration with the U.S. National Aeronautical and Space Administration (NASA), they examined the Martian meteorite that captured the public's imagination because it displayed textures thought to indicate life on Mars. The glass associated with carbonate material in the meteorite was found to exhibit an unusual internal structure which is under evaluation. Cathodoluminescence techniques will play an important role in any future examination of samples from the Red Planet, either meteorites or material returned to Earth by a robotic lander.

Energy

Geoscientific knowledge about the energy resources contained in Canada's sedimentary basins supports the environmentally responsible development of these resources. GSC research on regional hydrocarbon geoscience is carried out with provincial and territorial agencies and with industry. Integrated thematic studies focus on the processes by which hydrocarbon deposits are formed and the geological characteristics of known resources.

Hydrocarbon potential of eastern Canada

In cooperation with Shell Canada, GSC carried out research to clarify the evolution and the reservoir potential of certain parts of eastern Canada, including Anticosti Island, which is part of a major exploration effort by Shell. Work also continued in the Humber Zone of the Appalachians of Quebec to define the structural style of the northern margin of the Gaspé Peninsula. This revealed a classic foreland basin structure and resulted in the development of a consistent model for the evolution of the variations observed from southwestern Newfoundland to the Quebec City region. An integrated tectono-stratigraphic model showing source rock levels and potential hydrocarbon reservoirs was developed.

Partnership looks at Devonian petroleum systems

A team of about ten Canadian and international oil companies is working on the final year of a wide-ranging study of the regional architecture of Devonian petroleum systems in the Western Canada Sedimentary Basin. The goal of this three-year, GSC-led project is to provide a regional database and conceptual framework for strategic exploration planning in one of the most petroleum-prolific stratigraphic successions in western Canada. Results of the work are shared at an early stage with all participants and subsequently with the industry and geoscience community.

Petroleum exploration in Saskatchewan

Imminent changes in petroleum lands administration are expected to lead to new exploration of deeper sedimentary strata in Saskatchewan. GSC projects are working to support innovative exploration and development success.

- *At the request of Shell Canada, GSC undertook a study of oil quality variations in newly-discovered plays in older Paleozoic strata of southeastern Saskatchewan. The research showed that variations in oil quality were the result of the reservoir having been filled by two different charges of oil. The work established protocols for understanding of processes affecting the economic value of these oils in an active exploration play. Following Shell's release of these results, other companies have sought GSC's expertise.*
- *A scientific breakthrough was made in the use of organic geochemistry for judging migration distances in pooled crude oils. In one application of this new migration "odometer" method, Winnipegosis crude oils from southeastern Saskatchewan, previously thought to be sourced locally, were demonstrated to have migrated from very long range. The odometer data placed important new constraints on computer-based models for petroleum generation, migration and entrapment, and they are greatly assisting industry in devising or modifying their exploration strategies.*
- *Research near Jedburgh produced convincing evidence of post-Devonian magmatic intrusions, an insight of significance to petroleum exploration efforts in the area. Overall, the study serves to further characterize the hydrocarbon potential of wide regions and deeper strata in Saskatchewan.*

G. Mossop, GSC

Research sheds light on dolostones

Dolostones provide porous and permeable hosts for many commercial oil and gas reservoirs in the Western Canada Sedimentary Basin, but the origin of many massive dolostones has long been an enigma. Most previous models for regional-scale dolomitization of Alberta's Devonian limestones infer dolomite replacement at low temperatures, in either near-surface or shallow to intermediate subsurface environments. New GSC work, linking geochemical characteristics with fluorescence and enhanced (diffused plane-polarized light) petrography, has given rise to a very different conclusion: dolomitization from hot brines at depths of at least a few hundred metres. This new "thermoflux" model should be a boon to petroleum explorationists.

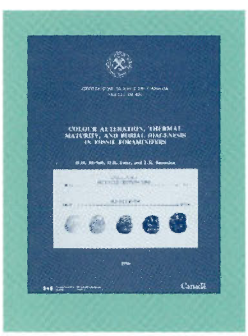
Oil and gas pipeline safety

Electric currents induced in oil and gas pipelines during geomagnetic disturbances disrupt the corrosion prevention systems. Excessive corrosion can result in leakages with potential for serious environmental damage. Now an improved understanding of geomagnetic effects on pipelines is being obtained through the work of an international consortium, led by the GSC and involving industrial and academic partners in Canada and Scandinavia. The research involves recording the first high-resolution profiles of the pipeline voltages produced by geomagnetic disturbances. GSC modelling techniques are providing a framework for understanding the observations, and promise the possibility of developing a capability for simulating geomagnetic effects on pipelines. This simulations will help in the design of corrosion prevention systems that can counteract the effects of geomagnetic disturbances.

GSC pioneers techniques to support petroleum exploration

GSC developed a new approach to the analysis of microscopic amounts of crude oils trapped as fluid inclusions in rock samples. The fluorescence micro-spectroscopy technique allows scientists to determine properties of trace amounts of oil both within reservoir rocks and along migration pathways. The technique may be applied to the detection of reservoirs that have had multiple filling episodes, and also to determine the quality of original oils that have been subsequently displaced by gas, altered or lost. Development of new techniques is a prime function of GSC's unique organic geochemistry laboratories at Calgary.

Another innovative technique developed by GSC assesses the thermal history of sedimentary basins and their consequent petroleum resource potential. The *Foraminifera Coloration Index* is a measure of the colour variations that microfossils exhibit as a consequence of exposure to heat. This technique is the focus of research to examine the effects of ancient high pressure regimes on the thermal alteration of organic material in the Western Canada Sedimentary Basin. ARCO Exploration has applied it with success in the Qiong Dong Nan Basin of the South China Sea. Petrotrin, Trinidad's national oil company, is seeking GSC collaboration to use the technique in the Trinidad Basin.



Faulting and hydrocarbon potential

Understanding the factors that influence the distribution of hydrocarbons within sedimentary basins is the key to assessing undiscovered petroleum and the associated geological risks in developing these resources. One of the most poorly understood, but likely to be one of the most important factors, is faulting. GSC and industry are collaborating on studies in the oil- and gas-rich Sable and Jeanne d'Arc basins off Canada's East Coast to assess the role of faults as barriers or conduits to hydrocarbon migration. The studies have implications at both the regional scale (defining migration pathways that are important for volumetric assessments) and at the more detailed, individual pool or field scale (assessing influence of faulting on reservoir producibility).

Paleontology of the Beaufort-Mackenzie Basin

In support of renewed petroleum exploration interest in the Mackenzie Delta/Beaufort Sea area, GSC is providing the basic geoscience knowledge base that industry needs to evaluate the region. Building on the 1996 publication of the *Geological Atlas of the Beaufort-Mackenzie Area*, the GSC has produced two major publications on the paleontology of the Beaufort-Mackenzie Basin: one on foraminifera (microfossils), the other on palynomorphs (plant microfossils). Petroleum exploration relies heavily on detailed correlation of source and reservoir units, and paleontology remains the major tool for providing such correlations.

- New foraminifera from the Upper Cretaceous and Cenozoic of the Beaufort-Mackenzie Basin of Arctic Canada
  By D.H. McNeil
  Special Publication 35, Cushman Foundation for Foraminiferal Research, $40.00 (US)
- Paleocene-Pliocene deltaic to inner shelf palynostratigraphic zonation, depositional environments and paleoclimates in the Imperial ADGO F-28 well, Beaufort-Mackenzie Basin
  By G. Norris
  GSC Bulletin 523. $17.90 in Canada, $23.27 outside Canada

Gas Hydrates

Gas hydrates incorporate natural gas into a solid ice-like structure under conditions of low temperature and high pressure. They occur in association with deep permafrost and in offshore sediments overlain by deep water. Although little studied in nature, they represent a significant potential energy source, a hazard to conventional exploration drilling, and a possible source of greenhouse gases during global warming.

In 1997, Canadian and Japanese scientists joined forces in a multi-million dollar research partnership involving the GSC on both the west coast and in the Canadian Arctic. In the Arctic, the Japan National Oil Corporation (JNOC) and the Japan Petroleum Exploration Company (JAPEX) are working with GSC scientists to develop and test new exploration technologies for gas hydrates and to acquire geoscience and engineering information about the natural distribution and properties of gas hydrates in an Arctic setting. Funding was provided by the Japanese partners, with the GSC leading the scientific program in the Mackenzie Delta, N.W.T.

In February 1998, a team, which also included the U.S. Geological Survey and a variety of Canadian and Japanese companies, drilled the first ever gas hydrate research well in the Arctic. During the 39-day program, the test well was drilled to a depth of 1150 m, providing a unique opportunity to document the geology and geophysical properties of deep permafrost and gas hydrates. For example, core samples collected from between 896 m and 952 m represent the first Arctic gas hydrates samples ever recovered below permafrost.

Innovative, on-site laboratory testing characterized gas hydrate concentrations and the physical properties of the enclosing sediments. Japanese participation included testing of new drilling and geophysical technologies for gas hydrate applications. Four coring systems were evaluated, including a state-of-the-art pressure and temperature controlled core barrel designed to recover samples in-situ. Additional research concentrated on casing design, cementing technologies, and geophysical characterization of the geological setting of the hydrate deposits and overlying permafrost.

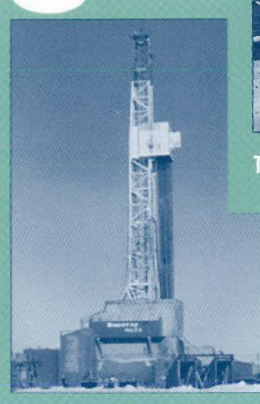
Over the next year, the GSC will coordinate, with JNOC and other collaborators, an extensive post-field research program prior to an ambitious gas hydrate research well to be drilled by JNOC in offshore Japan in 1999.

GSC expertise in marine gas hydrates is recognized world wide and has resulted in international collaboration with Korea, India and the U.S., as well as Japan. Last year, in collaboration with the U.S. Navy Research Laboratory, the University of Victoria and Dalhousie University, GSC completed a mapping survey of extensive deposits of hydrate on the continental slope of Vancouver Island. This extended the work carried out over several years by the GSC and JAPEX, making the gas hydrate field off Vancouver Island one of the best understood in the world.

The GSC/University of Victoria team also completed a second report on marine gas hydrates off Japan in a project funded by JAPEX. Collaborative studies with Korea are at the preliminary discussion stage. Arrangements for studies of marine gas hydrate off India with the India Oil and Gas Corporation are underway.

The Mackenzie Delta fieldwork.

T. Mroz, U.S. Dept. of Energy



Marine Geoscience

GSC's marine programs address the scientific problems and needs for geoscience information for Canada's coastal and offshore territories. The resulting marine geoscience knowledge supports government strategies at all jurisdictional levels, helps resolve land-use questions, and is used by oil and gas, telecommunication, engineering and survey firms for a broad spectrum of exploration and development applications.

Atlantic Canada's changing coastlines

GSC studies Atlantic Canada's changing coasts, where rising sea levels contribute to widespread shoreline erosion and landward coastal retreat. Seabed mapping has revealed many submerged features (lakes, rivers, drowned shorelines), and recent studies of sea-level rise have been based in part on radiocarbon dating of marsh accretion in the Bay of Fundy. These and other analyzes of historical tide and wave records, combined with digital overlays of air photographs taken over the last 50 years, provide clear evidence of episodic sea-level rise and coastal change. Severe storm impacts are being documented along the Nova Scotia coast; this contributes to improved hazard assessment and mapping. A case study of coastal sand budgets and shore dynamics on the North Shore of Prince Edward Island is helping to improve prediction of climate change impacts and coastal erosion, as well as to develop solutions for beach and sand dune conservation, estuarine management, and navigation safety.

Slope stability on the Fraser Delta

GSC completed mapping of the mouth of the Fraser River as part of a study of recent slope failures. The rate of industrial, urban and agricultural development of the Fraser's huge delta has made Vancouver one of the fastest growing regions of Canada. Given the delta's human and economic importance, it is essential to understand the forces that trigger its periodic seafloor instability. The conditions controlling the delta also apply to other deltas and coastal regions in Canada, making it an excellent field laboratory for developing analytical techniques to improve understanding of seafloor instability. The added risk of seismic shaking in the Greater Vancouver region, the increased risk of soil liquefaction and the consequences of ground deformation underscore the need for continued collaborative studies to identify the magnitude, frequency, distribution and origins of seafloor instability, and their potential impact on engineering structures.

Doing business with the GSC

GSC makes its expertise available to the Canadian geoscience community on a collaborative and cost-recovery basis. In the case of collaborative projects, GSC works closely with industry partners, sharing costs and expertise on projects of mutual interest. Collaboration can take various forms, for example, technology transfer or cooperative research. All information generated by GSC's collaborative programs is made available to the public in a timely fashion.

One of GSC's major goals is to help Canadian resource and environmental companies succeed internationally in today's highly competitive global market. To this end, GSC can make its unique expertise and facilities available on a cost-recovery basis, where such work does not represent competition with the private sector.

For more information on business opportunities with GSC, contact:

Business Development
Earth Sciences Sector
Natural Resources Canada
615 Booth Street
Ottawa, Ontario K1A 0E9
Telephone: (613) 992-8916
Fax: (613) 995-8737
E-mail: dreade@.nrcan.ca

Seabed stability and design standards

Repetitive seafloor mapping is providing information on modern seabed processes that is crucial for design standards for subsea facilities and environmental monitoring. Data for the Grand Banks is showing low frequencies of seabed scouring by keel-dragging icebergs and that seabed sediments are not being transported significantly over a ten-year timeframe. On Sable Island Bank, repetitive mapping from multi-beam surveys has been integrated with data from cores and bottom-mounted current meters and cameras to determine the stability of the seabed under storm conditions. This information was used to design and install the pipeline bringing gas ashore for the Sable Offshore Energy Project.

Offshore glaciers control sediments and resources

GSC completed a study of the history of glacial ice advance and retreat in the Bay of Fundy and Gulf of Maine as part of a new project to reconstruct former ice margins and the sea level history of the region. The offshore survey showed that the glacial history is very complex and identified features such as the Fundian Moraine, a 200 km long, 20 m high ridge of till along the north flank of Browns Bank. This ridge is a natural reef attracting many species of fish and it is an important fishing area. The moraine also modifies the ocean currents on Browns Bank, playing a major role in concentrating lucrative scallop resources and marine aggregates.

Crustal blocks in the Gulf of St. Lawrence – a key framework

The Gulf of St. Lawrence covers a significant and complex portion of the Canadian Appalachians. GSC recently completed a multi-year effort to delimit the nature and distribution of crustal blocks in the region, an essential starting point for regional basin syntheses. The basic definition of crustal block distribution provides a key framework for ongoing studies of basin formation, sediment fill and hydrocarbon potential.

Advanced technology facilitates marine studies

The technological advances that allow increased navigational and positioning accuracy at sea have influenced the use of multibeam bathymetry data as a staple marine geoscience tool. Such data, particularly when merged with other geological or geophysical techniques, allow for insight into previously unaddressable geoscientific problems. A recent example is the success with which high resolution bathymetry and magnetics were able to read the complex geological structure of Western Newfoundland as it stretches into the Gulf of St. Lawrence. The result was a more complete overall onshore-offshore tectonic "picture" of the region, with implications for the ongoing industry assessment of the area's petroleum potential.

"Off the shelf"

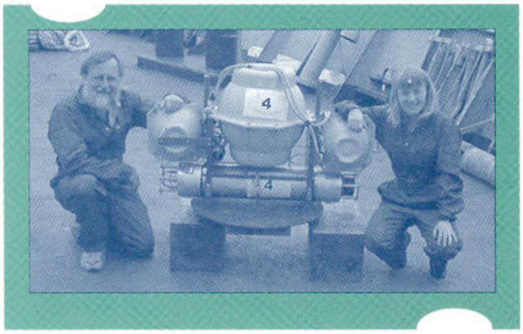
A large chunk of Canada, equivalent to the area of the Prairie provinces, lies in water beyond the continental shelf of Canada's east, west and Arctic coasts. The GSC carries out mapping and scientific investigations in these areas in support of many key economic and public policy issues.

On the economic side, there are potentially mineable seabed deposits of copper and other metals within Canadian territory off the West Coast. These have already been the focus of international studies. There is also a global movement towards hydrocarbon exploration in deeper water areas of the continental margin, led by activity in the Gulf of Mexico. The GSC provides information on regional geology, seabed indicators of hydrocarbons, and hazards to development in Canadian marine areas. Gas hydrates occur in deep water on the continental margin. They are both a potential energy resource and a source of shallow gas that destabilizes the seabed, creating a hazard to hydrocarbon development and seabed cables.

The offshore areas adjacent to Canada also preserve a record in seabed sediment of changing climatic conditions and the movement of ocean currents. Past conditions of climatic warmth are analogs of what we can expect with global warming, an issue of great public concern. Recent GSC investigations include studies of abrupt climate change in the Labrador Sea. Design and protection of engineered structures benefit from GSC's assessments of sediment instability and shallow gas in hydrocarbon exploration areas off Atlantic Canada and areas where fibre optic cables run.

Ocean bottom seismometers go digital

For marine-based studies of the crustal structure and basin framework of Canada's continental margins, one of the most basic geophysical tools has been the Ocean Bottom Seismometer (OBS). In the 1970s and 1980s, the GSC built and deployed an analog OBS as part of its initial investigations of the basic framework of Canada's eastern margins. GSC recently upgraded its aging analog OBS to allow for digital data acquisition. This was carried out through an agreement with Dalhousie University. The move to digital is especially timely as there is a worldwide movement back to regional, framework investigations of continental margins. Canada is now well-positioned to contribute to these studies both scientifically and logistically, as such instrumentation is not commonly available. The pool of 14 fully digital seismometers, together with a refurbished airgun array (seismic source), represents a significant revenue-generating opportunity.



Climate Change

Climate change is the most challenging global environmental issue of our time. Understanding the science behind it is a critical part of developing actions to adapt to a changing climate and to mitigate the changes. The geological record of the past provides a reference point against which we can assess the nature and significance of contemporary changes. It allows us to separate the effects of natural and human-induced change and tells us much about the current state of the Canadian landmass. The work of the Geological Survey of Canada is providing the basic understanding of the natural environment within which these changes are taking place and an insight into the processes at work.

CLIMATE CHANGE STUDY FOR THE PRAIRIES

A major GSC study of climate change and associated impacts on the southern Prairie provinces is nearing completion. Since 1991, scientists have been investigating geological records of past environmental change in the Palliser Triangle, the heart of the Prairie grain belt. Their studies highlighted the vulnerability of this strategic region's water and soil resources. Past droughts have been far more severe than those in the historic period, causing regional water tables to drop many metres, leaving most lakes dry and triggering sand dune activity. A multimedia CD-ROM, to be released in late 1998, will present study results, along with general information about climate change and the Palliser Triangle. It will be aimed at students, educators and the public.

NEW CLIMATE CHANGE SERIES

Alterations in precipitation and temperature from climate change will affect lake and sea levels, river systems, soil erosion, permafrost distribution, and natural carbon storage sites including peatlands. Understanding these changes will be the basis for formulating adaptation strategies. To help build this understanding, GSC launched a new publication series that synthesizes information on the impacts of climate change on active geological processes in Canada. These reports highlight areas of Canada where geological hazards could be worsened or ameliorated by climate change. The first to be released is *Sensitivity of eolian processes to climate change in Canada* **(to order, see page 34). The report deals with the impacts of climate change on wind erosion in Canada, with an emphasis on Canada's sensitive Prairie regions. In press are reports on coastal sensitivity and alpine processes. In development are reports on fluvial processes, permafrost sensitivity and organic terrain sensitivity.**

ARCTIC OCEAN REVEALS CLIMATE CHANGE CLUES

The goal of the landmark SHEBA project (Surface Heat Budget of the Arctic Ocean) is to better understand the planet's climate by studying how clouds, air, snow, ice and water exchange energy in the Arctic region. As part of SHEBA's start-up in September 1997, the Canadian icebreaker, *Louis St. Laurent*, **escorted SHEBA's research vessel to the high Arctic. GSC scientists used the cruise to obtain sediment cores from both ends of the Northwest Passage. In cooperation with Fisheries and Oceans scientists, the cores are being studied to determine recent and past changes in marine plant and animal populations and how these relate to climate change or pollution. They were also analyzed for changes that indicate past differences in sea and glacier ice cover and changes in freshwater runoff, sediment provenance, and depositional style. Radiocarbon dates from shells in the cores, for estimates of sedimentation rates and changes over time in biological productivity, will be available by April 1999.**

LIMITING CO_2 EMISSIONS

Industry and government are looking at innovative ways to limit CO_2 emissions to the atmosphere. Coal-fired utility companies, interested in demonstrating that CO_2 can be effectively sequestered underground, are keen to experiment with pumping unwanted CO_2 into coal seams, where it can be trapped. Petroleum companies are looking at enhancing methane production from their fields through the use of waste CO_2 from utilities. CO_2 flooding is a relatively common gasfield practice in conventional reservoirs (sandstone or limestone), but is unproven in coal-hosted gas deposits. GSC is collaborating with industry and the Alberta government to test the sequestration idea on coals in the Fenn-Big Valley area of southern Alberta.

PERMAFROST AND CLIMATE CHANGE

GSC carried out a detailed assessment of the Mackenzie Valley in the Northwest Territories to find out how permafrost will respond to climate warming. This area is the transportation corridor to proven energy and mineral reserves in the Arctic and will have a key role in economic development in the north. The study demonstrated how the southern Mackenzie Valley, about 30% of which is underlain by permafrost, will virtually disappear as a result of a 2°C increase in mean annual air temperature. The final report, which is in publication, will include information on the distribution of ground ice, potential for thaw subsidence and slope destabilization, and the relationship between ground temperatures and a warming climate. This will be useful to local community planners, land-use authorities and aboriginal land and water boards.

Although research on the magnitude of climate change is still subject to some uncertainty, the fact that our climate is changing is real and its negative effects are with us already. We must start now to minimize those effects and learn how best to adapt to them.

CLIMATE CHANGE ONLINE

GEOS, Natural Resources Canada's Internet publication about the Earth, devoted a special issue to climate change research: www.nrcan.gc.ca/geos/

The Natural Resources Canada climate change website is at: www.climatechange.nrcan.gc.ca

Fact sheets and additional information can be found at the GSC website at:
http://sts.gsc.nrcan.gc.ca/page1/clim

INNOVATIONS IN GLACIOLOGY TECHNOLOGY

Studies of cores from Arctic ice caps contribute baseline information to GSC's climate change and environmental research programs. Core analysis reveals histories of change in ice accumulation, temperature, atmospheric acid and salt loading, pollen, trace gases (eg. CO_2 and methane), heavy metals (eg. lead and mercury), and micro-organisms. A new lightweight ice coring drill "SIMON", capable of retrieving ice cores from depths to 150 m, was developed by the GSC and funded by the Japan-Canada Science and Technology initiative. SIMON was successfully tested on the Devon Ice Cap and produced 101 m of continuous core for analysis by GSC and Japanese partners. Icefield Instruments Inc., a Canadian company, used the GSC drill as a model to produce a commercial version that is sold internationally. GSC's partnership with the company also led to the successful development of a new hand-held solid conductivity meter for measuring ice core acidity.

The Palliser Triangle in the southern Prairies is an agriculturally important area that is vulnerable to climate change.

D. Sawchyn, Univ. of Regina

Environment

Knowledge provided by the GSC of Canada's geological hazards (earthquakes, volcanoes, magnetic storms, landslides), potentially hazardous geological conditions (permafrost, naturally occurring metal compounds) and environmental issues (climate change, pollution) provides the basis for sound planning that touches directly on the safety and health of Canadians.

The Saguenay Flood

GSC continued to study after-effects of the Saguenay Flood with a focus on the over 1000 landslides caused by the torrential rains. The goal, under the Federal Action Plan, is to provide the geoscientific information needed for safe land management. Two initiatives were carried out with Quebec agencies: one to develop tools that will help manage areas of landslide risk and redefine the geoscientific parameters used in risk assessment; the other to reconstruct the history of similar past events to document the recurrence of floods and landslides. In support of the Quebec Department of Transport, GSC also undertook geomorphological surveys in Ville-de-la-Baie. These identified unstable slopes and resulted in ten geomorphological maps of the most vulnerable areas, as well as a 1:20 000 scale map of surface formations for the entire region.

Volcano watch

Several agencies, including GSC, are working to ensure Canadians are well prepared to handle the damaging effects of volcanic eruptions. A key initiative is training for weather forecasters so they can provide timely warnings to the aviation industry of volcanic ash plumes which can damage airplanes flying through them. GSC is also part of the Canadian Interagency Volcanic Event Notification Plan, which pulls together key agencies to coordinate response to a volcanic eruption. As part of this effort, the GSC took part in a two-day exercise in January 1998 that simulated a volcanic eruption of Mount Baker. The exercise was designed to test the response of municipal, provincial and federal emergency preparedness groups in the Fraser Valley.

Oka radon study

GSC provided advice to Quebec's Direction de la Santé publique (DSP) about the distribution of areas with high radon gas potential around the former St. Lawrence niobium mine near Oka, Quebec. As follow-up to a 1995 DSP survey that identified radon levels above Health Canada guidelines in a residential area near Oka, GSC, under its National Gamma-Ray Spectrometry Program, contracted an airborne gamma ray survey (AGRS) which revealed a strong association between those high radon values and elevated uranium concentrations in the bedrock. The correlation of airborne and ground data is impressive and has already been used by DSP to guide future land use development in the area. The study demonstrated that AGRS surveys offer a predictive tool for areas of elevated radon concentrations. DSP and GSC will conduct a similar survey over an area to the west of Oka in 1998.

Waste disposal in permafrost

Dealing with wastes from Arctic mining and hydrocarbon development requires new techniques that take into account the permafrost environment. Investigations, with federal and territorial authorities and Queen's University, at the abandoned nickel mine in Rankin Inlet are showing that encapsulation of sulphide-rich mine tailings in permafrost may be an effective way of inhibiting further oxidation and acid drainage from these materials. Abandoned sumps used for disposal of oil and gas drilling fluids in the Mackenzie Delta are being used in a joint study with Carleton University to test the effectiveness of permafrost to contain dissolved contaminants. This work will be used to improve the retention of wastes in any situation where onsite disposal is feasible.

Groundwater study in the Greater Toronto Area

GSC's groundwater study in the Oak Ridges Moraine, in its fourth year, has established new methods for evaluating this strategic resource, which are also applicable to other areas. Hallmarks of this research have been an emphasis on innovative field and digital mapping techniques, initiating and maintaining broad partnerships, and the timely communication of results to stakeholders. The work has resulted in a successful strategy for identifying new groundwater resources based on an efficient sequence of geophysical surveys interpreted in terms of the geological model. This has set the stage for groundwater development strategies that are being evaluated by municipalities and the private sector. Workshops highlighting the new technologies and research results attracted more than 200 participants in the past year.

Outreach is an important component of GSC's groundwater programs.

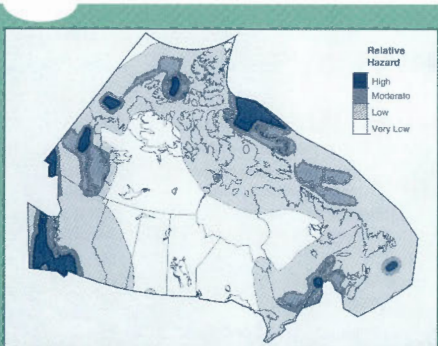
D. Sharpe, GSC

Earthquakes

Canada's most earthquake-prone areas are its West Coast and the St. Lawerence River Valley, both of which are major population centres, contain strategic industries and are key transportation points for Canadian exports. A major earthquake in either area would have an immediate devastating effect on the local communities, as well as a long-term impact on the national economy. Through studies of the location and mechanisms of earthquakes and by synthesizing that information for the *National Building Code* and for local emergency planners, the GSC ensures that Canadians are as well prepared as possible for any earthquake.

NEW MAPS WILL REDUCE SHOCK OF BIG QUAKES

Strong earthquakes in urban areas could cause much personal injury and billions of dollars of property damage. Building codes and modern construction techniques, however, can reduce these costs and risks significantly. Earthquake hazard zoning maps are an important factor in this equation, and GSC has just released trial versions of the Year 2000 maps for Canada. These maps become official when the next edition of the *National Building Code* comes into effect in the year 2001, but trial versions are issued in advance for evaluation and testing in the engineering and construction industries. Research and refinements of the maps continue.



***National Building Code* Year 2000 trial seismic hazard map.**

"FRIENDLY" EARTHQUAKES

During the past year both eastern and western Canada have been shaken by "friendly" earthquakes – earthquakes strong enough to be felt widely but not to cause damage. These earthquakes served two very useful purposes. They heightened public awareness of the potential for earthquakes in both areas, and provided people with a vivid reminder to make their own emergency preparations. Through study of these moderate earthquakes, GSC researchers have also gleaned much information about the local causes of earthquakes, and how the ground and buildings respond to moderate earthquakes.

FRASER DELTA QUAKE: LESSONS FOR THE SEISMOLOGISTS

The strongly felt magnitude 4.6 earthquake that shook the greater Vancouver area on June 24, 1997, is providing new insight into the seismic hazard of the region. The earthquake occurred 37 km west of the city and was well recorded on a network of special seismographs designed to track strong ground motions. For the first time, records were obtained from both bedrock and soil-based stations in the Vancouver area. These enabled seismologists to obtain the best estimates to date of the response of different sites to seismic shaking. This information is of particular relevance to understanding the variation of shaking on the deep soils of the Fraser River delta.

EASTERN CANADA: QUAKES AND THE INTERNET

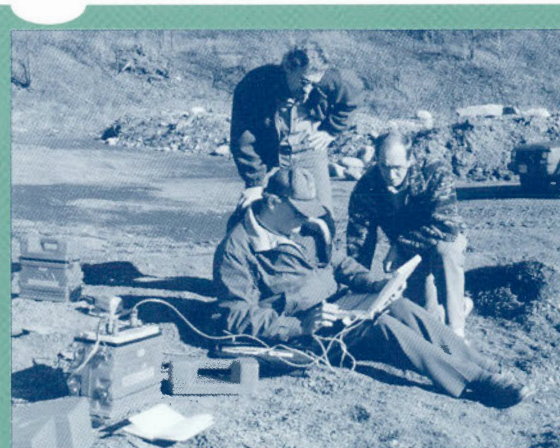
The Quebec City region was shaken by a magnitude 5.2 earthquake, November 5, 1997. Centred near Cap-Rouge, the earthquake was the largest to have occurred under an eastern Canadian city since the 1944 Cornwall, Ontario, earthquake and it was the largest in the Quebec City region since 1864. The quake caused some minor damage, and public and media interest lasted for a full week as aftershocks were felt locally. Within 20 minutes of the earthquake, the public were using Web-based forms, designed by GSC's seismology group, to report what they had felt. Over the next four weeks, 1100 online responses were received from more than 200 communities in Ontario, Quebec, New Brunswick and the northern New England states. The information was used to prepare preliminary maps of the intensities, and these have been posted on the Web site www.seismo.nrcan.gc.ca, **together with sample "felt" reports and photos of the GSC's aftershock field survey.**

NEOSEISMICITY AND GRENVILLE INHERITANCE

The Cap-Rouge earthquake also refocused attention on the role of ancient geological structures, such as the St. Lawrence paleo-rift, in the seismicity of eastern Canada. The Cap-Rouge event provided one of the best recordings available of a seismic sequence in this region, enabling the GSC to document the main physical parameters as well as the regional geological context for the event. In addition, a study of the regional fault pattern associated with the Saguenay graben, conducted in collaboration with the University of Quebec at Chicoutimi, clarified the geological context of the magnitude 6 earthquake which shook Chicoutimi in 1988. These studies have increased our understanding of eastern Canada's seismicity.

TRACKING EARTHQUAKE "FOOTPRINTS" ON THE SEAFLOOR

Researchers from the GSC, U.S. Geological Survey and six West Coast universities completed an ambitious survey in Puget Sound, and the Georgia and Juan de Fuca Straits looking for the "footprint" or fault traces related to recent earthquakes. The SHIPS (Seismic Hazard Investigation of Puget Sound) study used two ships and 240 ocean and land seismometers, as well as sensitive listening devices towed behind the ships to record sound waves generated by bursts of compressed air. The sound waves bounce off deep sediment layers and allow scientists to create images of the geological architecture many kilometres beneath the seafloor. Earlier studies found the surface expression of many faults which have disturbed sediments deposited during and since the last glaciation, 10 000 years ago. These faults would have been obscured by vegetation or erosion on land but show up clearly on the seafloor. Researchers are hoping to unravel the complicated fault patterns of the region, thus adding to our basic understanding of regional earthquake processes.



Monitoring aftershocks of the Cap-Rouge earthquake.

M. Lamontagne, GSC

Pipeline safety and terrain hazards

GSC took on a pipeline safety research program, formerly managed by the National Energy Board. Its goal is to develop new design standards for pipelines, both on land and offshore, to meet failure conditions caused by natural hazards. The program is improving methods for predicting the impact of upheaval buckling, ice scour, moving slopes, thawing and freezing soils on a pipeline, its coatings and well bores. The results provide a basis for establishing regulations and they help industry make decisions regarding safe and cost-effective pipeline design and maintenance strategies. The program encompasses several collaborative projects, with a broad base of industry, government and academic partners. Most projects are strongly supported by Canadian and international industry, leveraging Panel of Energy Research and Development (PERD) funds by a factor of ten.

Groundwater study in Quebec

The Laurentian Piedmont, which extends from the Ottawa Valley to Charlevoix, is one of the major hydrogeological features of southern Quebec. GSC mapping demonstrated a close relationship between its aquifers and the major sand deltas of the Champlain Sea. In the Portneuf region, fourteen separate aquifers were mapped in the drainage basins of the Sainte-Anne, Jacques-Cartier and Portneuf rivers. Guidelines for regional hydrogeological mapping in granular surface aquifers are under development. These will provide provincial and municipal planners with a database structure, the map formats and computer tools necessary to acquire, analyze and depict the geoscientific data essential to rational assessment and management of groundwater resources.

Geology shapes climate

Uplift of the St.Elias Mountains and the Alaska Range, the youngest and highest mountains in North America, has profoundly affected climate and vegetation on their north sides. This is the conclusion reached by GSC and U.S. researchers who have just compiled a record of high latitude pollen and spore data spanning the last 18 million years. Uplift of these ranges over the last 10 million years has induced a drier, more continental climate in interior Yukon and Alaska, causing a transition from diverse tree-dominated forests to boreal forest and tundra environments. This research contributes to geological mapping and basin analysis in the region, and to understanding gas hydrate formation.

Pipeline was laid above ground following slope failure which ruptured the original buried line, northern British Columbia.

D.E. Lawrence, GSC

International Connections

The Geological Survey of Canada's long tradition of scientific excellence, coupled with its leadership and advocacy of geoscience on the world stage, has earned it a sterling reputation with the global geoscience community. As a result of GSC's international connections, tremendous benefits have accrued to Canada. Partnerships with other countries to carry out geoscientific research of mutual benefit have led to advances in understanding the global environment and opened doors for Canadian industry.

Multinational Andean Program (MAP)

Canadian expertise in modern mapping tools, mineral deposit geology, fieldwork, and geophysics has been put to good use in this Canadian International Development Agency (CIDA)-funded, GSC-led project, the goal of which is to map the shared borders of Argentina, Bolivia, Chile and Peru. The project will provide a knowledge base for mineral exploration in this remote part of the Andes. Highlights of the past year included:

- a GSC-led field tour of Peruvian open-pit copper mines; this strengthened links between the participating government agencies and mining companies active in the area.
- the completion of two new 1:250 000 map sheets for a remote, mineral-rich area of the high Andes.
- training for the participating countries in *Fieldlog*, a GSC-developed program, which allows for the seamless transfer of geological field data to digital map sheets.

Canadian industry also became involved in the program. Ten Canadian mining companies and CIDA funded an aeromagnetic and radiometric survey flown by a Canadian company over a potentially mineral-rich area of northeastern Argentina.

GSC contract in Argentina

In partnership with Watts Griffis McOuat Ltd., GSC took part in a technical upgrading of the Argentinian geological survey (Servicio Geologico Minero Argentino) in the areas of airborne magnetics and radiometrics, regional geochemistry and metallogeny. This was part of a broader project, the Proyecto Asistencia Servicio Minero Argentino (PASMA). Training is a core element of the GSC work and it ranges over many disciplines: from all aspects of carrying out geophysical and regional geochemical surveys to the geology of various deposits types. GSC held a one-week mineral deposit modelling short course in Ottawa for seven Argentine geologists, with an associated three-week field trip.

Resolving ecological problems in the Amazon

In 1997, with the support of CIDA, GSC geochemists and their Brazilian counterparts began a joint research project to monitor the spread of mercury and other metals originating from hundreds of small artisanal gold mines in the Amazon. A conservative estimate is that 50 tons of mercury are released annually into the environment in Brazil. Metallic mercury can transform into toxic compounds in the natural environment, and these can find their way into the food chain with possible grave repercussions on the health of the population.

The 1997 project focussed mainly on the river systems. Preliminary results show higher than normal levels over large areas, with toxic levels detected at a few sites near the mining operations. The results were sufficiently alarming that a decision was taken to expand the study in 1998. With added support from CIDA, the team will conduct a monitoring survey of the drinking water supply and also try to establish the extent of the contamination derived from atmospheric release.

Canadian seismic study links with Iran

A devastating magnitude 7.1 earthquake in Iran in May 1997 was recorded on a Canadian seismograph network as part of the GSC/ Lithoprobe Western Superior Teleseismic Project, which uses distant earthquakes to study the structure of the Earth's lithosphere. In the month following the earthquake, a GSC scientist staged an aftershock study in Iran in collaboration with Tehran University, the University of Toronto and Nanometrics Canada, a manufacturer of highly advanced seismographs. Analysis of the many aftershocks recorded on the digital instruments will help us understand the tectonic environment that caused this and other earthquakes in this part of Iran. The study also offered an opportunity to introduce Canadian technology to Iran, and led to their interest in acquiring 50 Canadian seismographs.

GSC contributes to International Europrobe Project

GSC participated in an international Europrobe seismic project designed to study the Trans-European Suture Zone in Poland. Europrobe is modelled after Canada's successful Lithoprobe program, which studies deep crustal and lithospheric structure using multidisciplinary techniques. GSC data recovery during the Polish project was 99.9% successful, supporting our reputation as a world leader in crustal seismic refraction studies.

Y. Maurice, GSC

Canada/U.S. coal resource assessment

Innovative computer-based technologies for coalfield modelling and resource management, developed by GSC, have been successful in characterizing coalfields in Atlantic Canada and the Prairies. The U.S. wants to use these technologies for its new national coal assessment program. Based on shared interests and mutual benefits of cooperation, the U.S. Geological Survey and the GSC have developed a workplan aimed at developing computer-based national assessments of coal resource supplies, economics, quality and availability. Other possible synergies include integrated studies of coalfields along the U.S./Canada boundary and development of international coal quality databases.

Mercury emissions: an international issue

As part on the Metals in the Environment initiative (see page 9), GSC scientists are working with international colleagues to identify sources of mercury and research how it is mobilized in the environment. A thorough understanding of these questions is essential to effective mercury amelioration in Canada and around the world. GSC took part in the first International Workshop on Mercury Flux Intercomparison organised by the University of Nevada and sponsored by the Electric Power Research Institute. The workshop compared measurement technologies used by scientists from the U.S., Germany, Sweden and Canada over a naturally mercury-enriched site in the Nevada desert. The site was chosen to allow scientists to measure the amount of mercury vapour (natural flux) released to the air from natural sources. Future work is planned, with GSC scientists involved in the selection of field sites in California and Nevada.

GSC transfers knowledge and expertise to Guinea

GSC supervised a major geoscience initiative in Guinea funded by the World Bank. The project, which pulls together geophysics, geology and GIS, is intended to assist in improving the geoscience infrastructure of the country, particularly for exploration purposes. Training is a significant component of the contract, and the past year saw four Guineans at GSC to learn about coordinating geophysical and geological surveys and using remote sensing software.

World Minerals Project

The World Minerals Geoscience Database Project, sponsored in part by industry, will construct and maintain digital databases of global geology and mineral deposits. These will be suitable for geographic information systems (GIS), summary reporting and cartography. The project builds on GSC's mineral deposits expertise and will aid Canadian companies involved in world-wide exploration for gold, copper, nickel and zinc deposits. Cooperation with other national and international scientific agencies will include sharing and linking of data sets and synchronisation of digital data standards. Products will also be tailored for the general public, for display and delivery over the Internet. The first products should be available to the public by the year 2000. Products from the related World Map Project (the precursor to the World Minerals Project) may be available in early 1999.

Seafloor studies in the world's oceans

International research on the genesis of massive sulphide and related gold deposits continues to be pioneered by GSC. In collaboration with Canadian universities, GSC is carrying out multinational projects in the Atlantic, Pacific and Indian Oceans. Mineralized rifts and volcanic edifices, discovered through GSC leadership, are yielding important new information that aids exploration for copper, zinc an gold deposits in Canadian mining camps (Bathurst, Noranda and Yukon-Tanana). Seafloor studies also provide basic knowledge on the Earth's crust, and quantitative information on global fluxes of greenhouse gases and metals for environmental studies. Innovative Canadian deep-sea technology makes a fundamental contribution to this international team effort.

Information

GSC's extensive scientific output is delivered to clients in a variety of ways, ranging from traditional publications and staff talks to the latest in digital GIS-based maps and interactive access on the Internet.

Windfall for Logan Legacy Fund

The Logan Legacy Fund, run by the Canadian Geological Foundation to raise monies to preserve GSC's rare earth science archival materials, was the recipient of $27,600 from the Ottawa'97 Organizing Committee. Ottawa'97, the annual meeting of the Geological and Mineralogical Associations of Canada, was sponsored by GSC and took place May 1997. Donations from the 1997 public campaign raised over $7,300. Significant conservation work was completed during the year. Six volumes from the Sir William Logan Collection received complex conservation treatment. A new reconditioning program treated six items from the Logan collection and 51 volumes from the Early Exploration Collection. Five volumes of *Palaeontographica* were rebound. A deacidification program was completed by the National Library of Canada, as was an appraisal of the historical value of the Logan collection.

Gold Rush centennial map

As a joint project to mark the centennial of the Gold Rush, the Yukon Geology Program and the GSC completed a compilation map of Yukon geology at 1:500 000 in draft form. This wall-sized map will, for the first time ever, pull together a complete picture of the geology of the Yukon as a single image. The map, which will be available in paper and digital formats, should prove to be a best seller with explorationists working in the Yukon.

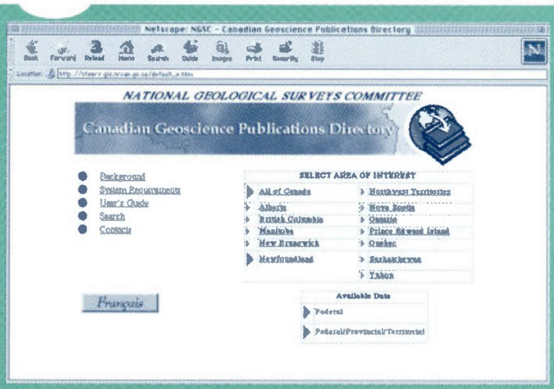
New magnetic map of North America

The GSC, and the U.S. Geological Survey and their Mexican counterpart, the Consejo de Recursos Minerales, developed plans for a new magnetic map of North America to be released early in the next century. The project will require close collaboration to ensure improved data coverage and quality. Planning has focussed on respective aeromagnetic programs, and data acquisition, processing and compilation. The Consejo started an ambitious program that will acquire regional aeromagnetic coverage for all of Mexico over the next five to eight years. This will be of great value for mineral resource reconnaissance.

Geoscience Knowledge Network

Dramatic changes in digital information and communications technology are transforming the way geological surveys manage and disseminate their geoscience information and knowledge. In response, GSC, in collaboration with its provincial and territorial counterparts, is developing a Geoscience Knowledge Network initiative. The goal is to provide instantaneous access to digital geoscience information and knowledge on the Internet.

The Geoscience Knowledge Network will provide Internet access to interoperable, multidimensional digital geoscience information in a client-focussed manner through a network of linked sources within GSC. It is hoped that this will lead to a broader pan-Canadian geoscience knowledge network initiative, which would involve provincial and territorial geoscience surveys, universities and other public and private sector partners and stakeholders. The National Geological Surveys Committee has taken an important first step towards this through the development of the Canadian Geoscience Publications Directory.



The Canadian Geoscience Publications Directory provides "one stop" user-friendly access to a geographically-displayed catalogue of government survey geoscience publications and maps. This trail-blazing initiative was coordinated by the National Geological Surveys Committee. Visit it at: http://ntserv.gis.nrcan.gc.ca/

The Geoscience Knowledge Network will use the framework and tools developed by other government initiatives such as the Canadian Geospatial Data Infrastructure (http://cgdi.gc.ca). **The cornerstones of the initiative are:**

- **Client-focussed access and broader usage by both traditional and non-traditional geoscience information users.**
- **Customized delivery of information to meet the needs of diverse user groups.**
- **Partnerships to foster an alliance of geo-science information sources, collective decision-making, and the use of national and international standards.**
- **Networked interfaces between sources to ensure interoperability while preserving the unique character of each source.**

Geology for the public

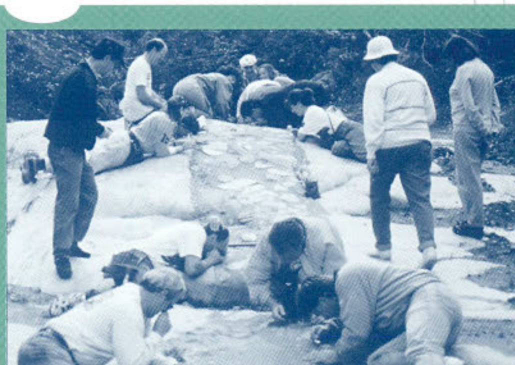
GSC staff are helping revolutionize how we relay geological information to the public. Some public awareness initiatives of the past year were:

- *Quebec City online:* ***Located at the junction of three geological provinces, the Quebec City region is a unique setting for an introduction to geology. With funding from the Quebec government, GSC developed a website*** **Si la Terre m'était contée...La Région de Québec sous la loupe des géologues** ***that presents this information for the public in a lively, non-technical manner. Visit it at:*** *http://www.inrs.uquebec.ca/cgq/geotour/index.html*

- *Geology on a poster:* ***"Geoscape Vancouver" a colourful poster summarized the key earth science issues relevant to Vancouver residents. After extensive consultation with educators, geotechnical companies, land-use planners, environmental consultants and members of the general public, GSC staff have now produced a non-traditional geological map of Vancouver "Geomap Vancouver". Other geoscience groups across Canada and the U.S. are initiating similar projects for their communities.***

- *Digital geology:* ***A new interactive digital "library" of information pulls together all existing geoscience information for southwestern British Columbia. Designed for educators, the CD-ROM contains an easy-to-use, searchable database with photographs, maps, figures and text. Ask about gold mining for a particular area, and you can create a customized file complete with modern mineral assessment reports and a map of existing mines.***

Posters and CD-ROM are available from GSC bookstores (see page 44)



As part of Ottawa'97, primary and secondary school teachers from across Canada took part in the first field trip sponsored by the Canadian Geoscience Education Network. The field trip, led by GSC staff, visited spectacular outcrops in the Papineau-Labelle Wildlife Reserve. Teaching of earth sciences concepts came alive during the "on the rocks" discussions.

P. Tremblay, INRS

Major synthesis of the Silurian of Canada

The synthesis of all available data on an entire geological system for the entire country is a rarely realized achievement. GSC has brought together the efforts of 38 scientists from industry, universities, museums and provincial geological surveys, and compiled a huge quantity of GSC data into the comprehensive *Correlation Chart and biostratigraphy of the Silurian rocks of Canada*. This is a major contribution to global stratigraphy. This benchmark volume captures all work to date on this subject, making it readily accessible to the scientific community. The volume was published by the International Union of Geological Sciences and is available through the GSC Bookstore in Calgary (see page 44).

Connecting with the North

GSC continued to build connections with northerners. Through the Mineral and Energy Resources Assessment (MERA) program, GSC staff took part in community meetings and consultations on the resource potential of proposed park areas and on the importance of resource assessment for land-use planning. Scientists met with communities near their field areas to explain their research and its applications. GSC research was presented at key northern events including the Nunavut Mining Symposium, the Yellowknife and Whitehorse geoscience meetings and the Pivvik'97 Conference. Other links include GSC participation in consultations on Sustainable Development North of 60º and on the Working Group of the Federal Government's Northern S & T Strategy.

Where geology and art meet

GSC scientists took part in a workshop at Carleton University with the Inuit Art Foundation and seven Inuit artists. The objective was to introduce the carvers to basic geological concepts and sources of expertise available to them. Discussions focussed on what carvers look for in good carving stone and how geologists can best provide information to the communities about identifying new carving stone sites. Quarrying problems, assessment of carving stone potential in park sites, and control over carving-stone sites were also raised as issues.

National Gamma-Ray Spectrometry Program (NATGAM)

The GSC's new National Gamma-Ray Spectrometry Program promotes a partnership approach to collecting and sharing high quality gamma-ray spectrometric data throughout Canada and the effective application of this information to diverse geoscientific activities, ranging from mineral exploration to environmental applications.

For over 60 years, the GSC has been a world leader in developing equipment and methods for accurately measuring natural radioactivity. This tradition of innovation ranges from the evolution of airborne and portable field spectrometers in the 1960s, to creating international calibration standards in the 1990s.

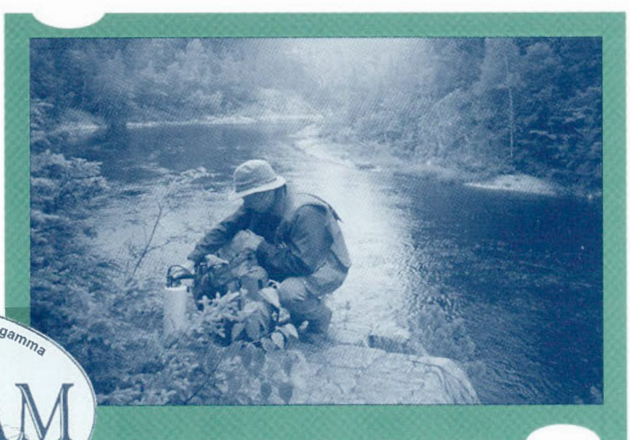
Systematic airborne radioactivity mapping of Canada began in 1969. In the late 1970s, additional coverage was funded by the federal-provincial Uranium Reconnaissance Program, laying the groundwork for a partnership approach that has become the hallmark of today's NATGAM. In recent years, increasing recognition of important mapping and exploration applications of gamma-ray spectrometry prompted a series of federal-provincial surveys throughout Canada.

Recent government partnership initiatives such as GSC's EXTECH and NATMAP programs, as well as multi-disciplinary projects with the governments of the Yukon, British Columbia and New Brunswick, have combined gamma-ray spectrometry with other geophysical methods to provide rewarding new views of established and frontier regions. NATGAM's well-established partnership approach recognizes that responsibility for meeting Canada's geoscientific knowledge requirements is shared with provincial, university and industry partners.

The GSC's internationally recognized leadership in gamma-ray spectrometric surveying is based on practical applications that have resulted in many Canadian exploration success stories. These demonstrate the unique ability of gamma-ray spectrometry to meet the requirements of traditional geoscientific activities such as surficial and bedrock geological mapping and mineral exploration, as well as the growing need for environmental knowledge. Examples are found in this report: exploration success in northern Canada (page 10) and environmental applications at Oka, Quebec (page 23).

NATGAM offers benefits to all participants and stakeholders. Industry partners provide funding in exchange for reduced survey costs, quality control, exclusivity, contract supervision, data interpretation and follow-up assistance. Governments contribute funding and expertise with the goal of collecting publicly accessible data, to national standards, at reduced cost. Various stakeholders (non-participating exploration industry, bedrock and surficial geological mappers, prospectors, environmentalists, land-use planners) ultimately gain timely access to high quality geophysical/geochemical data.

For more information see the contact numbers on page 44 or visit the NATGAM web site:
http://gamma.gsc.nrcan.gc.ca/



A Sampler of GSC Products

The Geological Survey of Canada publishes its research in many scientific journals and commercial publications. It also has an in-house scientific publishing capability and sells both print and digital products through its bookstores across Canada (see directory, page 44). A selection of priced products published by the GSC in 1997-98 follows.

SENSITIVITY OF EOLIAN PROCESSES TO CLIMATE CHANGE IN CANADA

By S.A. Wolfe and W.G. Nickling

This report documents the erosional and depositional processes caused by wind, mainly sand dune activity and wind erosion of farmland. It highlights possible impacts of climate change on these processes. The report concludes that the most affected areas will be the southern prairie regions of Saskatchewan and Alberta, and that other provinces, including Manitoba and Ontario, are likely to be affected.

GSC Bulletin 421. $14.30 in Canada, $18.55 outside Canada.

LAKE WINNIPEG PROJECT: CRUISE REPORT AND SCIENTIFIC RESULTS

Edited by B. J. Todd, C. F. M. Lewis, L. H. Thorleifson, and E. Nielsen

Lake Winnipeg is a major feature in Manitoba's geology, and it plays a vital role in hydroelectric generation, fisheries and recreation. In 1994, the GSC, Manitoba Hydro, Manitoba Geological Services Branch, the Freshwater Institute and several universities carried out a survey of the lake. Phanerozoic rocks terminating at a buried escarpment, thick clay, and extensive ice scour were highlights of the findings.

GSC Open File 3113. $145.80 in Canada, $189.55 outside Canada.

GOLD METALLOGENY OF THE CAPE RAY FAULT ZONE, SW NEWFOUNDLAND, CANADA

By B. Dubé and K. Lauzière

This bulletin synthesizes five years of work on gold metallogeny in the Cape Ray Fault Zone, a major crustal fault zone, which is the second most important gold-bearing structure in the Canadian Appalachians. The geological setting and structural evolution of the Cape Ray deposit are described in detail, along with its metallogenic characteristics and the various occurrences discovered along the fault.

GSC Bulletin 508. $27.90 in Canada, $36.25 outside Canada.

NATURAL GAS RESOURCE ASSESSMENTS

Appraisals of oil and gas resources in the major sedimentary basins of Canada are undertaken on an ongoing basis by Natural Resources Canada. These provide objective estimates of Canada's oil and gas resources, generate data for forecasting future supply, and serve as a basis for efficient resource management and planning. The following new reports are part of a series on the natural gas resources of western Canada.

- **CARBONIFEROUS AND PERMIAN GAS RESOURCES OF THE WESTERN CANADA SEDIMENTARY BASIN, INTERIOR PLAINS**

  By J. Barclay, G. Holmstrom, P.J. Lee, R.I. Campbell and G.E. Reinson

  GSC Bulletin 515. $22.20 in Canada, $28.85 outside Canada.

- **MANNVILLE GAS RESOURCES OF THE WESTERN CANADA SEDIMENTARY BASIN**

  By W.J. Warters, D.J. Cant, H.P. Tzeng, and P.J. Lee

  GSC Bulletin 517. $22.65 in Canada, $29.40 outside Canada.

- **UPPERMOST CRETACEOUS, POST-COLORADO GROUP GAS RESOURCES OF THE WESTERN CANADA SEDIMENTARY BASIN, INTERIOR PLAINS**

  By A.P. Hamblin and P.J. Lee

  GSC Bulletin 518. $21.25 in Canada, $27.60 outside Canada.

GEOLOGY AND METALLOGENY OF THE KLUANE MAFIC-ULTRAMAFIC BELT, YUKON TERRITORY, CANADA: EASTERN WRANGELLIA – A NEW Ni-Cu-PGE METALLOGENIC TERRANE

By L.J. Hulbert

This bulletin provides the information needed for a better understanding of a newly recognized area of potential economic significance. It covers intrusions, sulphide deposits and mineralized occurrences, and the surrounding local geology and tectonomagmatic framework.

GSC Bulletin 506. $34.50 in Canada, $44.85 outside Canada.

OAK RIDGES MORAINE STUDIES

The Oak Ridges Moraine is a water-bearing complex which nourishes 30 watersheds and sustains a vibrant cold-water fishery, ecologically sensitive wetlands and kettle lakes. The area also has several over-capacity landfills. A digital regional map and groundwater workshop proceedings provide industry and planners with coordinated map coverage for the wise use of earth and water resources in the Greater Toronto Area.

- **SURFICIAL GEOLOGY OF THE GREATER TORONTO AND OAK RIDGES MORAINE AREA, SOUTHERN ONTARIO**

  By D.R. Sharpe, P.J. Barnett, T.A. Brennand, D. Finley, G. Gorrell, H.A.J. Russell, and P. Stacey

  GSC Open File 3062. $15 in Canada, $19.50 outside Canada

- **WATER RESOURCE INVESTIGATIONS, OAK RIDGES MORAINE, ONTARIO: GEOLOGY AND HYDROGEOLOGY**

  Edited by H.A.J. Russell, D.R. Sharpe, M.J. Hinton, and F. Johnson

  GSC Open File 3540. $54.60 in Canada, $70.98 outside Canada

MAGDALEN BASIN NATMAP – ONSHORE GEOLOGICAL DATABASE

By G. Lynch, P.S. Giles, C. Deblonde, S.M. Barr, S.W.J. Piper, C. St. Peter, R.J. Hetu, S.C. Johnson, G. Pe-Piper, R. St-Jean, J.B. Murphy, F.W. Chandler, R.C. Boehener.

This CD-ROM contains all the data collected during the five years of the NATMAP project in the Maritimes Basin (three maps at 1:250 000, 12 at 1:50 000, 20 at 1:20 000 and one map at 1:100 000) and a terrain database. A user-friendly visualization tool takes the user on an interactive guided tour and permits easy access to the data and the maps.

CD-ROM, Open File 3564, $75.00 in Canada, $97.50 outside Canada.

MACROSCOPIC IDENTIFICATION KEY OF 36 SPHAGNUM SPECIES IN EASTERN CANADA

By D.-F. Bastien and M. Garneau

This illustrated field guide for the macroscopic identification of 36 Sphagnum species (genus of mosses encountered in peatlands of eastern Canada) provides two identification keys to help the user identify most of the species described in this guide. Descriptions provide information about the distinctive characteristics, distribution and habitat of each species. Colour illustrations aid identification.

GSC Miscellaneous Report 61. $24.00 in Canada, $31.20 outside Canada.

PRE-CARBONIFEROUS GEOLOGY OF THE NORTHERN PART OF THE ARCTIC ISLANDS

By H. Trettin

Some of Canada's most complex geology in one of its most remote and difficult terrains, is described in this landmark synthesis of information on the geology of the Arctic Islands. It includes eight maps of northern Ellesmere Island and Axel Heiberg Island at the 1:250 000 scale.

GSC Bulletin 425. $51.30 in Canada, $66.70 outside Canada

Major map compilations

GEOLOGICAL MAPS AND CORRELATION CHART OF NORTHERN ELLESMERE AND AXEL HEIBERG ISLANDS, DISTRICT OF FRANKLIN, NORTHWEST TERRITORIES

Compiled by H.P. Trettin and U. Mayr

Eight maps with descriptive notes and correlation chart.

GSC Maps 1881A-1888A. $74.00 in Canada, $96.20 outside Canada.

GEOLOGICAL MAPS, DESCRIPTIVE NOTES AND LEGEND, PARTS OF NORTHERN QUEBEC AND NORTHWEST TERRITORIES

Compiled by M.R. St-Onge and S.B. Lucas

Six maps and notes, with a bilingual legend sheet.

GSC Maps 1911A-1916A. $74.00 in Canada, $96.20 outside Canada.

AIRBORNE GEOPHYSICAL SURVEY DATA, BATHURST, NEW BRUNSWICK

Seventy-two maps including aeromagnetic, helicopter-borne frequency domain electromagnetic, magnetic, radiometric geophysical surveys.

GSC Open File 3347. $15.00 per map sheet in Canada, $19.50 outside Canada

MAGNETIC AND GRAVITY MAPS WITH INTERPRETED PRECAMBRIAN BASEMENT, SASKATCHEWAN

Compiled by W. Miles, P.E. Stone and M.D. Thomas

Five colour sheets at 1:1 500 000 scale.

GSC Open File 3488. $75.00 in Canada, $97.50 outside Canada

GEOLOGY OF SPATSIZI PLATEAU WILDERNESS PROVINCIAL PARK

By C.A. Evenchick and H.J. Parsons

This colourful, popularized brochure describes the geology of the park and the geological processes that formed it. Ideal for the general public and for schools. A must for those visiting the park.

GSC Miscellaneous Report 60. $3.00 in Canada, $3.90 outside Canada.

Ordering information

Unless otherwise indicated, publications and CD products may be ordered from the GSC bookstore in Ottawa or from our regional offices in Sainte-Foy, Calgary and Vancouver (see page 44 for addresses). Prepayment by cheque or money order made out to the Receiver General of Canada is required. VISA and Mastercard are accepted. All prices listed are in Canadian dollars, and are subject to change without notice. Applicable taxes and shipping and handling costs are extra.

Services

Aeromagnetic and gravity data

GSC's Geophysical Data Centre provides customized data for exploration and geoscience research by industry, government and academia. National aeromagnetic, gravity and digital elevation data are available as colour plots, line contours and digital data at a variety of scales, in most formats and on various media or via FTP. Products range from more economically-priced generic coverage to customized, project-specific data sets. Quotes are available on request.

Geophysical Data Centre
Geological Survey of Canada
615 Booth Street, Rm. 235
Ottawa, Ontario K1A 0E9
Telephone: (613) 995-5326
Fax: (613) 952-8987
E-mail: infogdc@agg.nrcan.gc.ca
Web site: http://gdcinfo.agg.nrcan.gc.ca/cat/

Airborne gamma ray/magnetic/ VLF-EM data

The GSC collects and publishes combined gamma-ray spectrometric, aeromagnetic and VLF-EM data as maps and digital data accompanied by SurView, a viewing and printing application. It also maintains calibration facilities for airborne and field portable gamma-ray spectrometers, supervises airborne survey contracts, and gives training and workshops. A new National Gamma-Ray Spectrometry Program (NATGAM) was established to promote these activities through partnership (see page 33).

Airborne Geophysics Section
Geological Survey of Canada
601 Booth Street, Rm. 594
Ottawa, Ontario K1A 0E8
Telephone: (613) 992-1235
Fax: (613) 996-3726
E-mail: natgam@gsc.nrcan.gc.ca
Web site: http://gamma.gsc.nrcan.gc.ca/

Geomagnetic data

The GSC has a substantial archive of analog and digital geomagnetic data, collected over many years. Digital data from the Canadian Magnetic Observatory Network, which spans the length and breadth of the country, are telemetered to the Geomagnetic Laboratory near Ottawa. The GSC geomagnetism world wide web site provides a greatly expanded service to clients, including access to magnetic storm forecasts and information on magnetic declination, the North Magnetic Pole and other geomagnetism activities.

Geomagnetic Laboratory
Geological Survey of Canada
7 Observatory Crescent
Ottawa, Ontario K1A 0Y3
Telephone: (613) 837-4561
Fax: (613) 824-9803
E-mail: rcoles@geolab.nrcan.gc.ca
Web site: www.geolab.nrcan.gc.ca/geomag/

Crustal-scale expertise

SEISMIC REFRACTION

GSC has 234 recorders and field service units (computers) that employ GSC-developed *Lithoseis* software, along with field expertise in designing and conducting refraction experiments, and substantial experience and expertise in data processing and interpretation.

ELECTROMAGNETICS

GSC has two high-frequency magnetotelluric systems (Phoenix V5) and 16 long-period magnetotelluric recording units (LIMS), as well as display and processing software and data acquisition, processing, modelling and interpretation expertise.

Crustal Geophysics
Geological Survey of Canada
615 Booth Street, 2nd Floor
Ottawa, Ontario K1A 0E9
Telephone: (613) 992-0758
Fax: (613) 992-8836

These are available for cost-recovery and collaborative activities.

Paleontology services

GSC paleontologists and laboratory facilities are available nationally and internationally for a variety of cost-recovery and collaborative activities. These include fossil identifications and interpretations, laboratory preparations, referrals of paleontological samples and tasks to specialists, contributions to regional stratigraphic studies, short courses and training (in-house and external), needs analysis, and advice on setting up laboratories and other facilities. Increasing focus is on microfossils (primarily conodonts and foraminifera) and palynomorphs.

T.P. Poulton
Geological Survey of Canada
3303 - 33 Street N.W.
Calgary, Alberta T2L 2A7
Telephone: (403) 292-7096
Fax: (403) 292-6014
E-mail: poulton@gsc.nrcan.gc.ca

Core and sample repository

This facility houses cores, drill cuttings and associated documents for all wells drilled on Canada Lands north of 60° and in the offshore regions of the west and east coasts. Cuttings from oil and gas wells in the Prairie provinces and British Columbia also are available. There are 14 examination booths and seven core tables available for use by clients. Repository staff retrieve material for examination and sampling as requested. The sampling of cores and unwashed cuttings is permitted under strict guidelines, and any resulting thin sections, slides or analytical data must be returned at the end of the loan period.

A.J. Scott
Geological Survey of Canada
3303-33 St. N.W.
Calgary, Alberta T2L 2A7
Telephone: (403) 292-7057
Fax: (403) 292-5377
E-mail: ascott@gsc.nrcan.gc.ca

Marine equipment rental

The GSC has unique marine equipment which is available for use by external partners under certain arrangements. International requests for scientific collaboration often involve use of this specialized equipment. The GSC can make the equipment available, under agreement, to industry to enable them to tender on a contract or to be a sub-contractor on a GSC-initiated project.

For example, the GSC made its ocean bottom seismometers available to a Canadian company, Geoforce, to enable it to bid on a contract with the British Antarctic Survey to conduct surveys in the South Atlantic.

To explore possibilities, contact:

R. Pickrill
Telephone: (902) 426-3587
Fax: (902) 426-4104

R. Currie
Telephone: (250) 363-6419
Fax: (250) 363-6565

Earth Sciences Information Centre

ESIC has Canada's largest collection of books, journals and maps on the earth sciences with worldwide coverage. It offers clients on-line access to the library holdings (two million items), the federal geoscience database GEOSCAN, and a scientific and technical inquiries service. ESIC collections also include photos, GSC Open Files, CD-ROMs, videos, technical reports and audio tapes.

ESIC's products and services, including the Library Catalogue and the GEOSCAN database, can be accessed through the World Wide Web. Some fees for document delivery and reference services apply to external clients. For a brochure or more information, contact the Information Desk at (613) 996-3919 or visit the ESIC home page at: www.nrcan.gc.ca/ess/esic/esic_e.html

GSC Laboratories

ANALYTICAL CHEMISTRY LABORATORIES

These laboratories specialize in the total analysis of geological and environmental samples for most elements of the periodic table. They are equipped with state-of-the-art equipment including laser ablation and electrothermal vaporization ICP mass spectrometry. Extremely small samples can be analyzed for trace elements and for isotope ratios of certain elements such as boron, lithium, lead and osmium. Chelation ion chromatography coupled with plasma spectrochemical techniques allows for the analysis of pore fluids and brines, as well as ultra-trace analysis of geological materials. The laboratories collaborate with industry and universities on method and instrument development projects, and offer training in instrumental technology and applications to geochemical analysis.

D.C. Grégoire
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8
Telephone: (613) 995-4213
Fax: (613) 943-1286
E-mail: gregoire@nrcan.gc.ca

ANALYTICAL METHOD DEVELOPMENT LABORATORY

This laboratory focusses on speciation of elements in sediments, soils and waters; cost-effective methods to analyze surface waters to ppb, ppt and ppq levels by ICP-MS and ICP-AES; and methods by which to differentiate geogenic and anthropogenic sources of metals. This state-of-the-art laboratory includes a Class-100 Cleanroom. New methods are designed and tested mainly through collaborative projects in environmental and exploration geochemistry with scientists in GSC, elsewhere in Canada and abroad in other government, university and industry institutions. The methodology is developed and transferred to Canadian commercial geochemical and environmental laboratories through collaborative learning, training and international publications.

G.E.M. Hall
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8
Telephone: (613) 992-6425
Fax: (613) 996-3726
E-mail: hall@gsc.nrcan.gc.ca

DELTA-LAB

The GSC-Quebec isotopic geochemistry laboratory analyzes stable isotopes of hydrogen, carbon, nitrogen, oxygen and sulphur using PRISM-VG, Isotech, SIRA-12, GC-COMBUSTION-Prism, auto-water for oxygen, and elemental analyzer and extraction lines for water, carbonates, sulphides, sulphates and organic matter. With this equipment, the laboratory can cover the entire range of stable isotopic tracers applied to hydrogeological, environmental, metallogenic, diagenetic and sedimentological studies by analyzing the isotopes of water, reagent hosts and dissolved components.

M.M. Savard
Québec Geoscience Centre/GSC-Québec
2535, boul. Laurier, C.P. 7500
Sainte-Foy (Québec) G1V 4C7
Telephone: (418) 654-2634
Fax: (418) 654-2615
E-mail: msavard@nrcan.gc.ca

DENDROCHRONOLOGY AND DENDROGEOCHEMISTRY LABORATORY

This facilty analyzes tree growth as a bioindicator of natural or anthropogenic environmental disturbances. Growth parameters are measured using a high-precision Unislide Velmex micrometer (0.001 mm) connected to a QC-1000 Metronics Inc. data acquisition system used for transferring and processing data. Applications related to climate change, environmental geodynamics, environmental geochemistry and dendrogeochemistry (radial distribution of trace elements and stable isotopes) can be developed in order to document the nature and temporal evolution of inorganic contaminants in the environment and other phenomena.

C. Bégin
Québec Geoscience Centre/GSC-Québec
2535, boul Laurier, C.P. 7500
Sainte-Foy (Québec) G1V 4C7
Telephone: (418) 654-2648
Fax: (418) 654-2615
E-mail: cbegin@nrcan.gc.ca

GAMMA-RAY SPECTROMETRY LABORATORY

This laboratory analyzes geological and environmental samples to measure absolute radioelement concentrations of potassium (%), equivalent uranium (ppm), and equivalent thorium (ppm). The spectrometer utilises two, lead-shielded, 14 cm by 14 cm sodium iodide detectors. A GSC-designed software package processes data acquired by the detectors and records gamma-ray spectra from successive samples. Calibration of the spectrometer is accomplished using potassium (RGK-1), equivalent uranium (RGU-1), and equivalent thorium (RGTh-1) standards recognised by the International Atomic Energy Agency. Laboratory services are available on a cost-recovery basis.

P.B. Holman
Geological Survey of Canada
601 Booth St.
Ottawa, Ontario K1A 0E8
Telephone: (613) 992-1237
Fax: (613) 996-3726
E-mail: pholman@nrcan.gc.ca

GEOCHRONOLOGY LABORATORY

GSC's Geochronology Laboratory specializes in rock and mineral age dating and isotopic microanalysis using U-Th-Pb, Sm-Nd, Rb-Sr, and Ar-Ar isotopic systems. The laboratory has long been involved in the development of age-dating techniques to resolve important questions in geological mapping and the timing of tectonic and mineralizing events. Different chronometers are closely integrated to provide optimal approaches for answering an ever-expanding range of geoscience questions. Advice from laboratory staff and use of its state-of-the-art facilities are available to clients in Canada and abroad.

Laboratory facilities include the Sensitive High Resolution Ion Microprobe (SHRIMP), which allows unprecedented insights into the genesis and history of single mineral grains and rocks. The latest analytical development is the coupling of an infrared laser to a gas-spectrometer, which permits dating of small samples at enhanced resolution and has also extended the measurable age range of Ar-Ar technique down to 5000 years.

O. van Breemen
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8
Telephone: (613) 995-0810
Fax: (613) 995-7322
E-mail: ovanbreemen@gsc.nrcan.gc.ca

GEOCRYOLOGY RESEARCH LABORATORY

GSC and Carleton University have established an important new Geocryology Laboratory at the university to facilitate joint research and to ensure adequate training for scientists and students in the field of permafrost research. GSC contributions to the facility include: high precision thermal calibration equipment, a needle probe thermal conductivity measurement system, a cold room, and miscellaneous equipment suitable for experimental work and field studies. This comprehensive research-oriented laboratory can support fundamental and applied research.

M. Burgess
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8
Telephone: (613) 996-9317
Fax: (613) 992-2468
E-mail: burgess@gsc.nrcan.gc.ca

GEOMAGNETIC LABORATORY

This laboratory develops, tests and calibrates geophysical instruments for several GSC activities: geomagnetism, marine geophysics, crustal geophysics and seismology. For external clients, it calibrates magnetometers, magnetic compasses, and magnetotelluric systems. Operational and scientific groups collect and use geomagnetic data from across Canada for a variety of purposes, including the production of magnetic charts for navigation by compass and magnetic storm warnings. Scientific and engineering collaborations with industrial and academic partners are welcomed. Research specialities include the effects of magnetic storms and other related phenomena on modern technological systems such as electric power transmission and pipelines.

R.L. Coles
Geological Survey of Canada
7 Observatory Crescent
Ottawa, Ontario K1A 0Y3
Telephone: (613) 837-4561
Fax: (613) 824-9803
E-mail: coles@geolab.nrcan.gc.ca

LIGHT STABLE ISOTOPE (LSI) LABORATORY

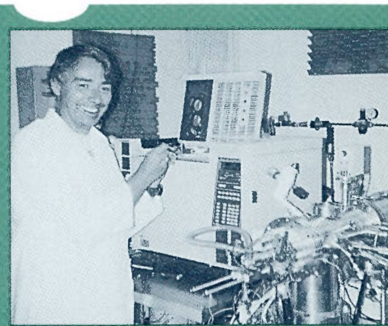
This laboratory specializes in the application of oxygen, hydrogen, sulphur and carbon isotope geochemistry to the study of hydrologic, petrologic, and ore-forming processes. A complete range of inorganic and organic Earth materials are analyzed as macro and micro samples, using state-of-the-art and, in some cases, world-leading techniques, including laser-based fluorination of microscopic samples. It is involved in many activities, including a government-industry project to document paleohydrothermal systems and alteration associated with volcanic-associated massive sulphide deposits, the GSC-led Sullivan Project, and a recalibration of the internationally accepted scale for sulphur isotope geochemistry. Collaborating scientists from government, industry and university work closely with laboratory personnel. Where appropriate, collaborators may carry out analytical procedures themselves, or rely on support from laboratory staff, on a cost-sharing basis.

B.E. Taylor
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8
Telephone: (613) 995-4673/992-4046
Fax: (613) 996-9820
E-mail: btaylor@nrcan.gc.ca

MICROANALYSIS FACILITY

This laboratory's principal function is the imaging and chemical analysis of geological materials such as microfossils and of sediment/mineral grains. The facility houses an Environmental Scanning Electron Microscope (ESEM) with attached energy dispersive spectrometer, an X-ray diffractometer, and an optical image analysis system. It is capable of examining unconsolidated marine sediment samples in a natural (wet) state for more accurate characterization of geotechnical properties such as porosity. A recent upgrade to the ESEM allows for the quantitative analysis of sulphides and silicate minerals. The facility collaborates with outside users in a variety of ongoing projects in geological, environmental, and biological studies, and is open to new research initiatives.

F.C. Thomas
Geological Survey of Canada
P.O. Box 1006,
Dartmouth, Nova Scotia B2Y 4A2
Telephone: (902) 426-4635
Fax: (902) 426-4465
E-mail: thomasf@agc.bio.ns.ca



GSC's Gas Chromatograph-Mass Spectrometer was used in the study of Saskatchewan oils.

B.Rutley, GSC

MICROPALEONTOLOGY LABORATORY

This laboratory specializes in microfossil (conodonts and radiolarians) processing and extraction. Facilities include a scanning electron microscope and energy dispersive spectrometer. The laboratory collaborates with governments, industry and universities. Where appropriate, collaborators may work individually or supported by laboratory staff on a cost-sharing basis.

S. Irwin
Geological Survey of Canada
101 - 605 Robson Street,
Vancouver, B.C. V6B 5J3
Telephone: (604) 666-7719
Fax: (604) 666-1124
E-mail: sirwin@gsc.nrcan.gc.ca

MINERALOGICAL LABORATORIES

GSC's Mineralogical Laboratories are equipped to conduct physical, optical, chemical and crystallographic analysis of minerals utilizing electron-microprobe, scanning-electron microscope, and x-ray diffraction techniques. In addition to their own research, the highly qualified professional staff provide mineral analysis to the other programs of the GSC and also provide expertise and training to the scientific community.

G.M. LeCheminant
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8
Telephone: (613) 995-4686
Fax: (613) 943-1286
E-mail: lechemin@nrcan.gc.ca

ORGANIC GEOCHEMISTRY LABORATORY

This laboratory is equipped to perform organic geochemical analyzes of oils, coals and sediments and some types of environmental analyzes. Data from these analyzes can be used for assessing the organic carbon content, petroleum generation potential, maturity and paleoenvironment of deposition of sediments, oil-oil and oil-source correlations, maturity and degree of biodegradation, direction and relative distance of migration of hydrocarbons, the simulation (using pyrolysis techniques) and kinetics of oil and gas generation from sediments and coals, and the type and origin of hydrocarbon contamination in sediments. The laboratory provides organic geochemical analyses on a cost per sample basis.

M.G. Fowler
Geological Survey of Canada
3303-33rd St. N.W.
Calgary, Alberta T2L 2A7
Telephone: (403) 292-7038
Fax: (403) 292-7159
E-mail: fowler@gsc.nrcan.gc.ca

ORGANIC PETROLOGY LABORATORY

This laboratory is equipped with a range of microscopes, including standard petrological microscopes for determining thermal maturity (including vitrinite reflectance and fluorescence) and organic facies, for interpreting the origin of pyrobitumens, for measuring homogenization temperatures, and for investigating hydrocarbon fluid inclusions. An image analysis system for automated optical microscopy (e.g., particle size and shape analysis), a confocal scanning microscope for 3-D imaging (e.g., micropaleontological applications) and a scanning electron microscope are also available.

L.D. Stasiuk
Geological Survey of Canada
3303-33rd St. N.W.
Calgary, Alberta T2L 2A7
Telephone: (403) 292-7199
Fax: (403) 292-7159
E-mail: vstasiuk@gsc.nrcan.gc.ca

PALEOMAGNETIC LABORATORY

This well equipped laboratory specializes in Quaternary magnetostratigraphic correlations, tracking large scale ancient fluid-flow events, Cordilleran tectonic displacements and structural rotation problems. Most of the work done in the lab is collaborative with partners from universities and government covering the costs of sample preparation (performed on site) and measurement.

R.Enkin
Geological Survey of Canada
9860 West Saanich Road
Sidney B.C. V8L 4B2
Telephone: (250) 363-6431
Fax: (250) 363-6565
E-mail: enkin@pgc.nrcan.gc.ca

PALEONTOLOGY LABORATORIES

These laboratories are available for the preparation of samples for microfossils (principally foraminifera and conodonts), palynomorphs and other organic residues. Together with the sophisticated microscopic equipment available in the Organic Petrological Laboratory and specialists, these facilities offer a comprehensive range of services unequaled in Canada.

T.P. Poulton
Geological Survey of Canada
3303 - 33 Street N.W.
Calgary, Alberta T2L 2A7
Telephone: (403) 292-7096
Fax: (403) 292-6014
E-mail: poulton@gsc.nrcan.gc.ca

PALYNOLOGY LABORATORY

This laboratory specializes in the analysis of rock and sediment samples for palynological and other research. Principal techniques include the breakdown of rocks and sediments using hydrochloric and hydrofluoric acid to produce organic residues, and the use of heavy liquid and sieving techniques to concentrate palynomorphs (fossil spores, pollen, dinoflagellates, etc.) within the residues. Material from different geological ages requires different treatments, and this laboratory has the expertise and equipment to work with material from the entire range of geological ages. It is the only facility of its kind in the Maritimes.

R. A. Fensome
Geological Survey of Canada
P.O. Box 1006
Dartmouth, Nova Scotia B2Y 4A2
Telephone: (902) 426-2732
Fax: (902) 426-4465
E-mail: fensome@agc.bio.ns.ca

RADIOCARBON (^{14}C) DATING LABORATORY

The ^{14}C laboratory provides dating control for many of GSC's surficial mapping and environmental projects. As well, the lab sets national standards and maintains a Canadian ^{14}C database that may be consulted by Canadian or other researchers visiting the Ottawa laboratory facility. The laboratory will consider providing dating control for university researchers on a case by case basis at a cost per sample.

R. McNeely
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8
Telephone: (613) 995-4241
Fax: (613) 992-0190
E-mail: mcneely@gsc.nrcan.gc.ca

SEDIMENTOLOGY LABORATORY

This laboratory provides analysis of unconsolidated sediments. A number of tests are available to GSC scientists, including Atterberg limits, grain size (sieving, particle size analyzer, or settlement column) and carbon content. The laboratory allows the GSC to explore non-standard processing techniques and to customize analysis for given GSC projects. The laboratory will consider providing specialized (i.e. non-commercially available) sedimentological analysis to university or other stakeholders on a cost per sample basis.

P. Lindsay
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8
Telephone: (613) 992-6609
Fax: (613) 992-0190
E-mail: plindsay@nrcan.gc.ca

UNCONSOLIDATED MARINE SEDIMENT LABORATORY

This provides access to several user-friendly facilities to measure the physical and visual properties of unconsolidated marine sediments. A state-of-the-art multisensor track utilizes a Cesium 137 source to digitally measure sound velocity, shear strength and water content as well as other physical properties of whole round cores (not split) along their entire length. Additional physical measurements can be taken with an Image x-radiograph system, which can orient the whole core and record the information. Once cores have been split, a camera can easily capture the core face colours before oxidation commences, against photographic standards for future archival reference. External researchers are welcomed.

K. Robertson
Geological Survey of Canada
P.O. Box 1006
Dartmouth, Nova Scotia B2Y 4A2
Telephone: (902) 426-6127
Fax: (902) 426-4465
E-mail: kroberts@agc.bio.ns.ca

GSC laboratory in top ten

GSC's Radiocarbon Dating Laboratory was ranked in the top 10% in a quality assurance/quality control program involving 75 laboratories worldwide. It is one of the top facilities in the world providing age determinations on wood, peat, shells, and other fossil organic material. This dating infrastructure is providing the critical chronological framework for geological events and environmental changes that have occurred in Canada over the last 50 000 years.

Finances

EARTH SCIENCES SECTOR

1997-1998 Expenditures ($000's)

GEOLOGICAL SURVEY OF CANADA

MINERALS AND REGIONAL GEOSCIENCE BRANCH	SALARY	OPERATING	CAPITAL	TOTAL	REVENUE,* COST SHARING
Director General	194	34	2	230	0
Continental Geoscience	5,630	3,594	489	9,713	875
GSC Pacific (Ottawa)	2,065	1,015	569	3,649	147
GSC Pacific (Sidney)	2,952	1,050	411	4,413	708
GSC Pacific (Vancouver)	1,894	834	139	2,867	1,692
Mineral Resources	7,057	1,608	372	9,037	1,610
Total	19,792	8,135	1,982	29,909	5,033
SEDIMENTARY AND MARINE GEOSCIENCE BRANCH					
Director General	176	43	5	224	0
GSC Atlantic	5,143	2,781	724	8,648	1,706
GSC Calgary	6,975	3,336	587	10,898	974
GSC Québec	1,333	1,162	294	2,789	131
Terrain Sciences	5,109	2,144	273	7,526	420
Total	18,736	9,466	1,883	30,085	3,231
TOTAL GSC	38,528	17,601	3,865	59,994	8,264
GEOMATICS CANADA	31,874	24,407	3,532	59,813	35,303
POLAR CONTINENTAL SHELF PROJECT	796	3,287	86	4,169	1,620
CORPORATE SERVICES**					
*Executive Services****	1,513	676	55	2,244	95
Policy, Planning, Information and Services	8,813	4,585	1,072	14,470	221
Grants and Contributions				1,370	
Total Corporate Services	10,326	5,261	1,127	18,084	316
TOTAL SECTOR	81,524	50,556	8,610	142,060	45,503

* *Includes additional funds from intellectual property, vote netted revenue, revolving fund, specified purpose accounts, and transfers from other government departments.*

** *Provides support to the Geological Survey of Canada, Geomatics Canada and the Polar Continental Shelf Project.*

*** *Includes Business Development Office.*

Organization

- **Natural Resources Canada**
  - *Minister*
  - *Deputy Minister*
- **Earth Sciences Sector**
  - *Assistant Deputy Minister*
  - *Chief Geoscientist*
  - **Polar Continental Shelf Project**
  - **Geomatics Canada**
  - **Geological Survey of Canada**
    - **Sedimentary and Marine Geoscience Branch**
      - *GSC Atlantic*
      - *GSC Calgary*
      - *GSC Québec*
      - *Terrain Sciences Division*
    - **Minerals and Regional Geoscience Branch**
      - *Continental Geoscience Division*
      - *GSC Pacific*
      - *Mineral Resources Division*
  - **Policy, Planning, Information and Services**
    - *Geoscience Information Division*
    - *Management Services and Administration*
    - *Policy, Planning and Coordination*
    - *Federal/Provincial/Territorial Liaison Office*
  - **Business Development**

How to reach us

Nova Scotia/Atlantic Canada

Geological Survey of Canada
Challenger Drive, P.O. Box 1006
Dartmouth, N.S. B2Y 4A2

Telephone: (902) 426-3225
Fax: (902) 426-1466
e-mail: agc@agc.bio.ns.ca

Quebec

Geological Survey of Canada
Québec Geoscience Centre
2535, boul. Laurier
P.O. Box 7500
Sainte-Foy (Quebec) G1V 4C7

Telephone: (418) 654-2604
Fax: (418) 654-2615
E-mail: aachab@nrcan.gc.ca

Bookstore
Telephone: (418) 654-2677

Ontario

Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A OE8

Telephone: (613) 996-3919
Fax: (613) 943-8741
E-mail: esic@nrcan.gc.ca

Bookstore
Telephone: (613) 995-4342
Toll-free long distance (Canada and U.S.)
1-888-252-4301
Fax: (613) 943-0646
E-mail: gsc_bookstore@gsc.nrcan.gc.ca

Alberta/Prairies

Geological Survey of Canada
3303-33rd Street N.W.
Calgary, Alberta T2L 2A7

Telephone: (403) 292-7000
Fax: (403) 292-5377

Bookstore
Telephone: (403) 292-7030
Fax: (403) 299-3542
E-mail: gsc_calgary@gsc.nrcan.gc.ca

British Columbia

Geological Survey of Canada
Suite 1600-605 Robson Street
Vancouver, B.C. V6B 5J3

Telephone: (604) 666-0529
Fax: (604) 666-1124
E-mail: gscvan@gsc.nrcan.gc.ca

Bookstore
Telephone: (604) 666-0271
Fax: (604) 666-1337

9860 West Saanich Road
Sidney, B.C. V8L 4B2

Telephone: (604) 363-6500
Fax: (604) 363-6565

Visit the GSC's Web Site: www.nrcan.gc.ca/gsc/