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GEOLOGICAL SURVEY of CANADA



Geoscience for Canada

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GEOLOGICAL SURVEY OF CANADA

The Geological Survey of Canada (GSC), established in 1842, is Canada's national geoscience agency, with 550 employees working across Canada (addresses on back cover).

The GSC provides Canada with a comprehensive geoscience knowledge base contributing to economic growth, sustainable development, health and safety, and environmental protection.

The GSC works in collaboration with other government departments in Canada at all levels, with Canadian industry and universities, and with other countries and international organizations.

WWW.NRCAN.GC.CA/GSC

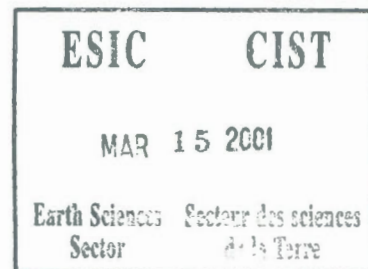
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TABLE of CONTENTS

2	A message from the Minister of Natural Resources
4	Introduction: Building a GSC for tomorrow's world
	Geoscience at work across Canada
5	Geoscience surveys
10	Minerals
14	Energy
17	Natural hazards
21	Climate change
26	Marine geoscience
31	Information
	Special reports and case studies
8	NATMAP, Canada's National Geoscience Mapping Program
12	PGMs: Metals for the new millennium
13	Extech III
20	Catastrophic landslides
24	Hydrogeology
28	International connections
30	Marine mapping and offshore mining
33	National Geochemical Reconnaissance Program
34	Products, services and opportunities
7	Doing business with the GSC
27	Marine equipment rental
34	Earth Sciences Information Centre
34	Data collections for Canada's offshore
34	Aeromagnetic and gravity data
35	Crustal-scale expertise
35	Core and sample repository
35	Set your compass with CGRF2000
35	How to order GSC products
36	Laboratories
40	Finances
<i>Inside back cover</i>	Organization
<i>Back cover</i>	How to reach us



A MESSAGE

FROM THE
MINISTER



*The Honourable
Ralph Goodale,
Minister of Natural
Resources Canada*

For more than a century and a half, the Geological Survey of Canada (GSC) has been immensely important to our country. From the Survey's earliest years in the 1840s when Sir William Logan and his colleagues began to study this country's landmass, Canada's history has been inextricably linked to geological discovery. The work of the GSC, a part of Natural Resources Canada (NRCan), has been essential to the development of the country, to our understanding of our immense resources, and to building a prosperous nation.

In today's knowledge-based economy, information is one of our most vital resources. Our success relies not just on our in-depth knowledge of Canada's landmass and resources, but what we do with what we know. We must be innovative in developing knowledge and ensuring it is easily accessible by people, businesses and organizations.

The Targeted Geoscience Initiative (TGI) is an excellent example of how the GSC is working toward that goal. This \$15-million, three-year program will produce new geological maps and data about under-explored areas with a high potential for mineral deposits, and make this information accessible through the Internet. The data collected under TGI will also help communities assess the environmental and social impact of proposed mining projects. The result will be new mining sector activity that is environmentally sound and economically beneficial for Canadians in rural, remote and northern communities.

As TGI shows, the Internet is an increasingly valuable tool for the GSC, its partners and its clients. It potentially allows Canadians and people around the world access to the GSC's huge collection of geoscience data. The GSC is quickly adapting to the Internet age and helping ensure that accurate, up-to-date scientific data gets into the hands of those who need it, when they need it, no matter where they are.

The GSC also plays a key role in supporting NRCan's commitment to sustainable development. By adding to our understanding of Canada's geology, the GSC's work underpins our ability to develop resources, increase productivity and create new employment while ensuring a healthy environment for the generations to come.

And geoscience is important to our understanding of one of the Government of Canada's top priorities — climate change. The GSC is developing tools and innovative methods to study past climate changes, assessing the impacts of climate change on permafrost in the North, and participating in programs to monitor changes in shorelines, sea levels and sea ice.

This past year has been filled with GSC accomplishments that have had a direct impact on Canada's economic strength, technological ingenuity and innovation, and its ability to make wise decisions about resource development. And, as this annual report demonstrates, I am confident that the GSC will continue to work at the cutting-edge of geoscience and contribute to the well-being of Canadians in this new millennium.

I applaud the GSC's staff for their dedication to this unique scientific organization and its goals. Their expertise ensures that the Geological Survey of Canada, along with its partners in the private sector and academia, will lead the way to the future. ●



The opening of the Canada-Nunavut Geoscience office by Nancy Karetak-Lindell, Ralph Goodale and Peter Kilabuk.

NEWS FROM NUNAVUT

Minister Goodale, Peter Kilabuk, Minister of Sustainable Development for Nunavut, and Nancy Karetak-Lindell, Member of Parliament for Nunavut (on behalf of the Minister of Indian Affairs and Northern Development) signed the *Memorandum of Agreement on Government Geoscience Program Coordination in Nunavut*, September 29, 1999. The agreement ensures that Nunavut's geoscience needs, the national responsibilities of the GSC, and the client needs of the three signatories are met. Similar agreements for geoscience coordination exist with most provinces and territories.

Minister Goodale also opened the new Canada-Nunavut Geoscience Office in Iqaluit. A collaborative initiative involving NRCan (GSC), the Government of Nunavut and DIAND, the office provides accessible geoscience information and expertise in Nunavut to support sustainable development, education and training, public awareness, and capacity building. GSC scientist, David Scott, was appointed Chief Geologist of the office.

BUILDING A GSC FOR TOMORROW'S WORLD

Geoscience is a cornerstone of Canada's intellectual infrastructure. It provides the basic knowledge needed for sound decision-making in support of mineral, oil and gas exploration, environmental assessment and land-use planning. Geoscience underpins efforts to help Canadians develop strategies to mitigate the effects of hazards such as earthquakes and adapt to the impacts of climate change.

The GSC has been providing fundamental geoscience information about Canada for almost 160 years, and its track record of successes is part of Canada's proud history. Today, like all Canadian science agencies, the GSC is adapting itself to times of fast-paced and dramatic change. An increasingly "plugged in" world requires that the GSC meet the challenges of handling all aspects of its scientific work through the Internet and other digital media.

The Internet has the potential to place GSC's vast geoscience holdings at the fingertips of virtually all Canadians and individuals around the world. This broader range of clients will put greater demands on GSC expertise and knowledge for a wide range of issues involving everything from basic data to new products, syntheses and knowledge integration. The link between sound science and policy choices at all levels of government will become more urgent, and will have to be communicated quickly in ways that are easily heard and understood.

Over the past year, the GSC, as part of NRCan's Earth Sciences Sector (ESS), has focused much thought, time and effort on the development of a new five-year ESS strategic plan. This is a

fundamental step in positioning all parts of ESS to meet the future challenges and needs of Canadians.

The strategy is based on a vision of ESS as "an international leader in the provision of earth science knowledge and advice". A key to achieving this vision will be partnerships and strategic alliances with other government departments, the provinces and territories, the academic community and industry. The pursuit of excellence in management underpins the strategic plan, with the ultimate goal of using taxpayers' money more effectively. There will be an even greater focus on client awareness, federal-provincial-territorial liaison, performance measurement, business planning, and project management.

The strategic plan clearly aligns ESS goals and objectives with those of Natural Resources Canada. These goals aim to provide earth science information that helps decision-making and strategic planning linked to natural hazards, climate change, land use, and sustainable development of our natural resources. Together, they provide a clear framework that will make it easier to communicate the impact of federal endeavours in the earth sciences.

PROVIDING GEOSCIENCE FOR CANADIANS

The GSC's strategic goals are to provide geoscientific knowledge that is clearly linked to Canada's social and economic needs.

- geoscience that supports sound economic, environmental and social decision-making.
- geoscience that furthers economic goals.
- geoscience that minimizes impacts of natural resource development, other land uses and climate change.
- geoscience that enhances the safety and economic security of Canadians.



Geoscience Surveys

Geoscience for sound economic, environmental and social decisions



A comprehensive national geoscience knowledge base encompassing Canada's vast landmass and offshore territories provides the framework for mineral and petroleum exploration, groundwater resource management, land-use decision-making and many other applications. The knowledge base also contributes to understanding and preparing for natural hazards, particularly earthquakes, and climate change. The GSC carries out much of this work in consultation and collaboration with partners in the provinces, territories, universities and industry.

ALBERTA LITHOPROBE: A WORLD-CLASS SYNTHESIS

The national research program, Lithoprobe, provides a major opportunity to map the subsurface crust and lithosphere of the Canadian landmass. One of its flagship projects, the Alberta Basement Transect, is now complete. It was designed to examine the evolution of the crystalline basement beneath one of Canada's major petroleum-producing areas, the Alberta Basin. The project saw industry buy-in and timely release of results. Some \$2.2 million were raised from more than 25 industry partners to cover much of the cost of geophysical data acquisition. Products include magnetic anomaly coverage of the entire Western Canada Sedimentary Basin and more than 2,000 line kilometres of high-quality seismic reflection profiles. The profiles, which extend from north-eastern British Columbia to southwestern Alberta, cross many key hydrocarbon production trends and afford the first insights into the seismic character of the basin. Special volumes of the *Bulletin of Canadian Petroleum Geology* and of the *Canadian Journal of Earth Sciences*, giving project results, were published in the past year. ●

MACKENZIE VALLEY AEROMAGNETIC SURVEY

The GSC, supported by the Canadian exploration community, acquires high-resolution regional aeromagnetic data over many regions in Canada for its geoscience programs and in support of provincial/territorial needs. Participants in the surveys benefit from cost-shared, high-quality data and from the expertise of the GSC's aeromagnetic group, which has helped establish industry standards in aeromagnetic data acquisition. A multi-year survey is in progress over the Mackenzie Valley, NWT, the site of one of western Canada's greatest hydrocarbon reservoirs. Aeromagnetism is an essential geoscience tool for such remote, inaccessible regions. In this particular frontier area, a 25-year exploration moratorium has left significant gaps in data available publicly. ●



GSC staff travel to all corners of Canada to unravel the geological history contained in its rocks (shown here, Chesterfield Inlet, Nunavut). This information underpins mineral, oil and gas exploration and helps us understand and mitigate against natural hazards and the impacts of climate change.

LITHOPROBE SNORCLE

Another important Lithoprobe project, SNORCLE, in its final field season, completed acquisition of 1,800 km of seismic reflection data. This is the best deep seismic cross-section ever collected, starting in the oldest known rocks on Earth near Yellowknife and finishing with the youngest continental rocks along the continental shelf of British Columbia. The research, which focuses on understanding the growth of the North American continent, has direct application to gold, diamond and petroleum exploration. For example, electromagnetic work identified an anomaly which correlates with a geological feature associated with the Lac de Gras diamond mine. Exploration companies who have supported the project include De Beers (Monopros), BHP, Kennecott Exploration, Diavik Diamonds and Royal Oak Mines Inc. ●

NORTHWESTERN REINDEER ZONE PROJECT

The GSC and its partners, the Saskatchewan and Manitoba geological surveys, completed this project, which successfully developed the tectonostratigraphic framework of the Reindeer Zone on the Manitoba-Saskatchewan border. Results published from the 1999 field season established links with economically important, similar geological units outside the project area in Manitoba and central Saskatchewan. The project has provided guidance to universities, industry and provincial surveys for future directions in thematic research, mineral exploration and bedrock mapping in northern Saskatchewan and Manitoba. It has also stimulated exploration for crystalline graphite, gold, nickel and platinum group elements by industry. ●

DIGITAL GEOLOGY MAP OF YUKON RELEASED

The first comprehensive bedrock geology map of the entire Yukon was completed by the GSC and its partners, the Yukon Government and DIAND. Of particular interest to explorationists and educators, the CD-ROM contains data and software that allows users to create high quality geological maps of Yukon tailored to their specific needs. For example, information can be pulled together by specific area or type to create a geological map that shows all the rocks in Yukon that may contain gold or tungsten. Data can also be combined with cultural and other data to create maps that help decision-making linked to resource assessment, exploration and land-use. *Yukon Digital Geology* by S. Gordey and A. Makepeace, Open file D5826, \$60.00, CD-ROM, available from the GSC Sales Office in Vancouver (see back cover). ●

GEOIDE MOOSE MOUNTAIN PROJECT

The GSC is a key partner in this new three-year project funded by GEOIDE, the national Network of Centres of Excellence in geomatics. This project will develop methodologies for integrating geological, photogrammetric, remote-sensing and geophysical 3D digital data, for application to resource assessment in foreland thrust and fold belts. The project will also assess the fundamental relationships between these multiple datasets, with a view to supporting geological interpretations in key areas of the foreland of the Canadian Cordillera. To achieve these objectives, activities related to mapping and exploration are being conducted with industry, university and government partners using a combination of new and conventional tools, methodologies and datasets. ●

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
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E-mail: dread@nrcan.gc.ca

NATMAP: CANADA'S NATIONAL GEOSCIENCE MAPPING PROGRAM

NATMAP is designed to increase the level and quality of geoscientific mapping of Canada. NATMAP projects pull together teams of provincial, territorial, university, industry and GSC researchers. They have been an outstanding success in terms of scientific results, innovation, impact on Canadian industry, and the training and development of Canadian scientists.

http://ntserv.gis.nrcan.gc.ca/natmap/natmap_e.html

NATMAP milestones for the year were:

CENTRAL FORELAND PROJECT

In the project's second year, participation expanded to include nine universities, and four provincial and territorial agencies. Focusing on the Foothills of northeastern B.C. and the southern territories, the project has made important progress in bedrock mapping and associated thematic studies. Results are being released in a timely fashion as maps, papers and presentations at conferences and workshops. Surficial geology mapping completed its first field season in 1999. The subsurface component has already produced significant results, paving the way for developing syntheses using three-dimensional GIS. Collaboration and support from the petroleum industry was broadened with the signing of new agreements with Shell, Conoco and CanOxy (Wascana). www.nrcan.gc.ca/gsc/calgary/central_e.htm

NECHAKO PROJECT

The Nechako Plateau in central B.C., an area rich in mineral resources, has previously been under-explored because its bedrock geology is mostly obscured by glacial sediments. The Nechako project was developed to fill this gap. In its final year, the NATMAP team from the GSC, B.C. Geological Survey, B.C. Forest Service, universities and industry, focused on releasing results. These were presented at the Cordilleran Roundup in Vancouver and published as nine maps, a public education poster for the Fort Fraser area, and as a special volume of the *Canadian Journal of Earth Sciences*. Complete project maps and data will be released as a CD-ROM synthesis next year. Results are providing mineral explorationists,

environmentalists, and land-use planners with a comprehensive geoscience map base for their work. The research provided breakthroughs in understanding molybdenum, copper, mercury and gold mineralization environments, as well as regional and local chemistry of the area needed for sustainable development. www.em.gov.bc.ca/natmap/

ANCIENT PACIFIC MARGIN PROJECT

This new collaborative project of the B.C. Geological Survey, the Yukon Geology Program, several universities, GSC and industry is studying key portions of what was the western edge of North America 400 million years ago. It is a mineral-rich belt of rocks, which now lies some 500 km in from the coast and stretches from Washington State to Alaska. The NATMAP team is field testing a new working model to explain the early tectonic evolution of the Cordillera. Project partners carried out a productive first field season near the B.C./Yukon border and released three bedrock maps under the NATMAP banner.

WESTERN SUPERIOR PROJECT

The Western Superior NATMAP project has contributed to an improved understanding of the regional stratigraphy and history of magmatism, deformation and mineralization of the Red Lake area of northern Ontario. This has defined new targets for massive sulphide mineralization, prompted mining companies and prospectors to reconsider exploration strategies for precious metals (gold and platinum), and helped foster new mineral industry partnerships to ensure the health and longevity of Canada's third largest gold mining camp.

NATMAP AND LITHOPROBE JOIN FORCES

Work in western Superior, also pulled together researchers from the GSC, Ontario and Manitoba geological surveys, universities and industry. The project integrates the NATMAP bedrock geoscience initiative in western Ontario-northeastern Manitoba with the Western Superior Lithoprobe transect and with ongoing work by the provincial surveys, the GSC and the Canadian Mining Industry Research Organization. The goal is to provide a comprehensive framework for the exposed and subsurface geology, earth structure and mineral potential (base and precious metals, diamonds) across an under-explored part of the richly endowed Superior Geological Province. The project is developing new concepts to explain the formation of oceanic volcanic rocks, which have high mineral potential, and older continental blocks with diamond potential.

APPALACHIAN FORELAND AND ST. LAWRENCE PLATFORM PROJECT

Collaborative research with universities and the geological surveys of Quebec, New Brunswick and Newfoundland was started for this project that will provide new models to support hydrocarbon and mineral exploration on the ancient continental margin of North America. Initial fieldwork was carried out in the Montréal and Québec City areas, Gaspé, northern New Brunswick and western Newfoundland. GSC NATMAP support was essential in assembling an unprecedented critical mass of researchers. The project will eventually grow into the Geo-Atlas of the St. Lawrence, a virtual library on the geology and resource potential of Laurentian Margin of Eastern Canada. Rapid dissemination of data is assured through the project's website. www.inrs.quebec.ca/cgq/bridges

NATMAP GOES FOR GOLD IN NUNAVUT

Initiated in 1997, the Western Churchill NATMAP project is receiving strong support and recognition from industry and local communities. Its goal is to build a comprehensive geoscience knowledge base for an area in Nunavut, encompassing Rankin Inlet, Arviat and Baker Lake, that has rich gold, base metal and carving stone potential.

The work has resulted in a major rethink of the regional tectonic framework with important implications for mineral exploration strategies. Project results have also led to an improved understanding of areas that provide suitable targets for exploration. As one example, in 1999 new staking of 30,000 hectares of land for gold exploration near the Meadowbank gold deposit resulted from the NATMAP work.

The project has attracted strong industry support, in particular through innovative field workshops in isolated

tundra conditions. The NATMAP team includes scientists from the GSC, Government of the Northwest Territories and DIAND, as well as several universities.

Industry gold exploration, GSC's Western Churchill NATMAP activities, and prospecting courses are raising local awareness about mineral exploration and mining issues, and involving Inuit prospectors and elders in some very interesting initiatives. For example, the Baker Lake Inuit Heritage Centre is compiling Inuktitut place names for use on GSC maps.

As part of a prospecting course for Baker lake residents, GSC geologists Eva Zaleski and Sally Pehrsson (end, left and right) with Inuit prospectors Effie Arnaluaq and Martha Tickie (centre, left and right) look at galena samples on Martha's claim near Whitehills Lake.



Minerals

Geoscience furthering Canada's economic goals

Mineral exploration and mining are cornerstones of the Canadian economy, and essential to the international trade balance, job creation and community development. 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 also 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.



TECHNOLOGY TRANSFER LEADS TO NORANDA DISCOVERY

At the Prospectors and Developers Association conference in Toronto, March 2000, Noranda announced the discovery of a large new massive sulphide deposit in New Brunswick's Bathurst Camp using 3D seismic reflection techniques. This is the first time that this technique has been used by the mining industry. The ore-body, which is over 500 m across and from 8 to 50 m thick, was found at a depth of about 1.6 km, far beyond the detection limits of conventional field techniques. Although drilling showed that it is mainly pyrite and thus sub-economic, the discovery proved that seismic reflection techniques similar to those used by the petroleum industry can be used for mineral exploration. The discovery marks the culmination of a multi-year collaborative effort between the GSC and Noranda. ●

NEW MINERAL DISCOVERIES IN NUNAVUT

Year two of a GSC mapping project on northeastern Ellesmere Island, in collaboration with the German Geological Survey (BGR), saw the discovery of new mineral occurrences. The team of German and Canadian scientists, logistically supported by the Polar Continental Shelf Project (PCSP), unravelled the complex stratigraphy, sedimentology and structural history of the area, one of the Earth's least explored regions. Significant sphalerite and galena occurrences, as well as geochemical indications of lead, zinc, cadmium and other metals, were discovered and made public as a GSC Open File.

The mineral exploration industry is following up these discoveries. ●

NUNAVUT MINERAL AND ENERGY RESOURCE ASSESSMENT

GSC, supported by PCSP, DIAND and Parks Canada, released a report on the geology and non-renewable resource potential of Bathurst Island. It establishes high to very high potential for minerals and hydrocarbons in eastern Bathurst Island near the Polaris Mine, which is scheduled for closure. The report is a key document in decision-making about a proposed national park on northern Bathurst Island. A summary of the report in English, French and Inuktitut was used in public consultations. GSC participated with other agencies and stakeholders in a community meeting in Resolute, at which the report's economic and strategic implications were reviewed. The park is on hold while governments consider the balance needed between environmental protection and economic development in Nunavut. *Mineral and Energy Resource Assessment of Bathurst Island Area*, GSC Open File 3714. ●

GOLD DEPOSITS RESEARCH

The GSC published *Geological classification of Canadian gold deposits*, which should become a standard reference for everyone interested in gold deposits. Containing the results of recent GSC gold deposit work in Canada and abroad, this publication is a valuable tool for resource assessment studies and exploration planning. Looking to the future, the GSC will work with the Ontario Geological Survey and industry to better understand the fundamental geological parameters and processes responsible for the formation of the extremely rich gold deposits in Ontario's Red Lake district. Work conducted jointly with the Quebec ministry of natural resources and industry will focus on a gold and base-metal district in the Abitibi greenstone belt. Both projects will help design new exploration tools for gold and base metals. ●

EXPLORATION TECHNOLOGY

The Downhole Seismic Imaging Consortium with Falconbridge, Noranda and several universities has successfully demonstrated the capability of the instrumentation for cost-effective mapping of ore zones and structures at depths of two to three kilometers—commensurate with depths of practical sustainable mining—and to promote deep exploration in existing mining camps. In December 1999, the consortium conducted a survey in the Sudbury area to test instrumentation enhancements and to evaluate new data processing and interpretation software. Results are now being processed with the goal of producing images of a massive sulphide orebody. The GSC's commitment to the project underscores its support and interaction with Canadian industry to develop innovative techniques to enhance mineral exploration. ●
www.cg.nrcan.gc.ca/dsisoft



The Downhole Seismic Imaging survey in the Sudbury basin in November, 1998.

DISCOVERY OF MERCURY IN SEAFLOOR MINERAL DEPOSITS

Many hot springs on land are enriched in trace metals, and have produced economically important deposits of gold, silver and mercury. Recently, a multi-national team of researchers from the GSC, New Zealand and Germany discovered the first mercury-producing hot springs under the sea, at hydrothermal vents on the seafloor at depths of 200 m off the coast of New Zealand. The vents are colourful, though inhospitable places, where temperatures reach 200°C, and thick crusts of arsenic and sulphur are deposited. Despite this harsh environment, mats of sulphur-metabolizing organisms thrive. Seafloor volcanic activity accounts for some 70% of the world's active volcanoes and the discovery of significant quantities of mercury associated with seafloor hydrothermal systems provides important new data on the source, distribution and quantity of mercury being introduced into the environment from natural sources. ●

PGMS—METALS FOR THE NEW MILLENNIUM

As ultra low-emission vehicles begin to appear on our highways and the demand for more environmentally friendly power sources increases, Canada is well-positioned to supply the metals necessary for the energy technologies of the future. Low-emission vehicles rely on platinum group metals (PGMs), which include platinum, palladium and rhodium. These are used in catalytic converters to reduce emissions of oxides of nitrogen and other gases, which become major components of smog and contribute to greenhouse gases in the atmosphere.

Russia and South Africa currently supply more than 90% of the world's PGMs, however, their production is decreasing. Canada has the potential to become a world leader in PGM production. Sudbury is the world's fourth largest producer of PGMs and recent discoveries there as well as at the Raglan mine in northern Québec, promise even greater PGM reserves.

GSC scientists have been actively investigating potential new PGM environments including the Musk Ox Intrusion in Nunavut, the Kluane District of B.C. and Yukon, the Circum-Superior Belt in Manitoba and Quebec, and the Rottenstone Domain in Saskatchewan.

DIAMOND EXPLORATION IN SASKATCHEWAN

A GSC team developed a new diamond exploration model relevant to conditions in central Saskatchewan. Some 100 million years ago, two explosive eruptions spread kimberlite ash and coarser material widely over then-tropical Saskatchewan. This material, which was reworked by ancient rivers and marine currents, contains micro- and macro-diamonds and is widely dispersed. The new exploration model differs from traditional models that focus on kimberlite pipes such as are found in South Africa and at Lac de Gras, NWT. Industry shared exploration material and operating costs of this research, which is now in the public domain. The GSC also developed new borehole geophysical technology that is aiding exploration. Natural gamma-ray measurements, carried out as part of a borehole geophysical classification of the diamond-bearing strata, detected variations that clearly differentiate kimberlite strata, as well as those with diamond potential. GSC's transfer to industry of these tools and concepts stimulated new exploration in central Saskatchewan. ●

ENHANCED DIAMOND EXPLORATION STRATEGY

A major advance in GSC's kimberlite (diamonds) exploration research resulted from an agreement with several mineral exploration companies (Kennecott Exploration Inc., Aber Resources Inc., and partners) under which they provided to the GSC till geochemistry data, remotely-sensed imagery and field support for various properties in the Lac de Gras area, NWT. The GSC team used the data and support to improve understanding of the use of till geochemistry in regional and property scale kimberlite exploration, and to refine exploration criteria for kimberlite potential mapping. Preliminary results have been made public through presentations in Yellowknife and Vancouver. ●

CASE STUDY

EXTECH III: THE YELLOWKNIFE GOLD CAMP

GSC's EXTECH (EXploration Science and TECHnology) program, initiated in 1989, develops new approaches to mineral exploration in Canada and stimulates exploration in established mining camps. The goal of EXTECH III is to develop an integrated exploration model for gold deposits and to redress the declining gold ore reserves in the Yellowknife Gold Camp. EXTECH III partners include the Government of the NWT, DIAND, seven universities and industry, including Con, Giant Mine (Miramar Mining Inc.) and Yellowknife-based prospectors and exploration companies.

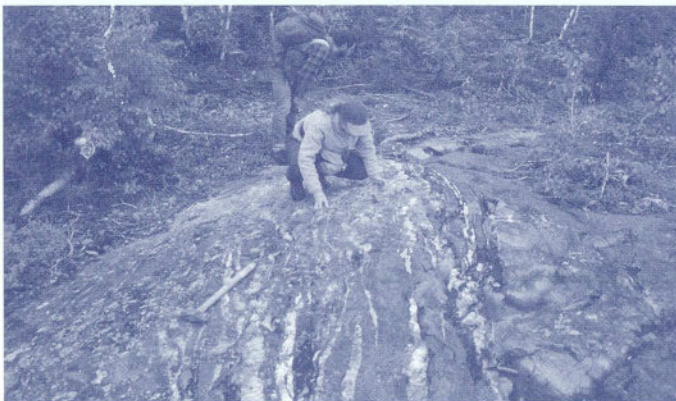
In its first year, EXTECH III undertook research that will lead to better understanding of the local mine geology and regional setting for a variety of styles of gold mineralization. The Yellowknife area has excellent outcrop exposure, and new studies range in scope from camp-wide projects to detailed studies focusing on the two main operating mines.

In addition to generating new knowledge, significant effort is being made to integrate existing information from the two operating mining properties, Con and Giant, into the study. The enhanced geoscience knowledge base resulting from this blend of new and existing research is being compiled in a digital format (2-D GIS) that will help develop improved models to aid effective exploration in the Yellowknife area, as well as providing an effective archive of the data generated in EXTECH III. A 3-D model of the deposits is also being developed. This will aid in the structural interpretation of the deposits and may help identify areas that are favourable for discovering new ore.

EXTECH III has already generated several successes. Information sharing between the two major mines has stimulated research questions related to the structure and geochemistry of these deposits. Borehole logging has revealed subtle differences that could not be detected by conventional visual, drill-core logging. Regional till sampling revealed anomalous gold grain counts and suspected kimberlite indicator minerals in an area to the east of the main gold trend (*Anomalous kimberlite indicator mineral and gold grain abundances, Drybones Bay and Yellowknife area, NWT, GSC Open File D3861*).

EXTECH III's broad spectrum of studies of the gold deposits in the Yellowknife belt will aid in developing new exploration tools for gold deposits in other parts of Canada. EXTECH III is also providing training of a new generation of gold deposit and exploration geologists.

For more information:
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EXTECH III partners (Karen Gochnauer and Scott Cairns, NWT Geology Division, DIAND) examine a complex vein system, south of the Discovery Mine, one of Canada's premier gold mines from 1949-1969.

Energy

Geoscience furthering Canada's economic goals

The energy industries represent another cornerstone of the Canadian economy. 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.



OIL AND GAS EXPLORATION IN THE NORTH

Spectacular gas discoveries in the Liard area in NWT, rising continental gas demand, rapid depletion of major gas reservoirs in western Canada, high market prices, major plans for pipeline expansion, and favourable interest from aboriginal communities, have renewed industry interest in the Canada's North. Current exploration activities, which extend to the entire Mackenzie Corridor, the Mackenzie Delta and the Beaufort Sea, are being helped by the GSC's knowledge of the region, built up over the past 25 years. Recent sales of GSC publications such as the *Geological Atlas of the Beaufort-Mackenzie area* (GSC Miscellaneous Report 59), have jumped dramatically. The GSC is now working on a companion atlas for the northern Canadian Mainland Sedimentary Basin. Chapters dealing with themes of particular interest, such as hydrocarbon occurrences, will be published initially as GSC Open Files, and will be available through an Atlas website and on CD-ROM. ●

NATIONAL GAS HYDRATES ESTIMATE

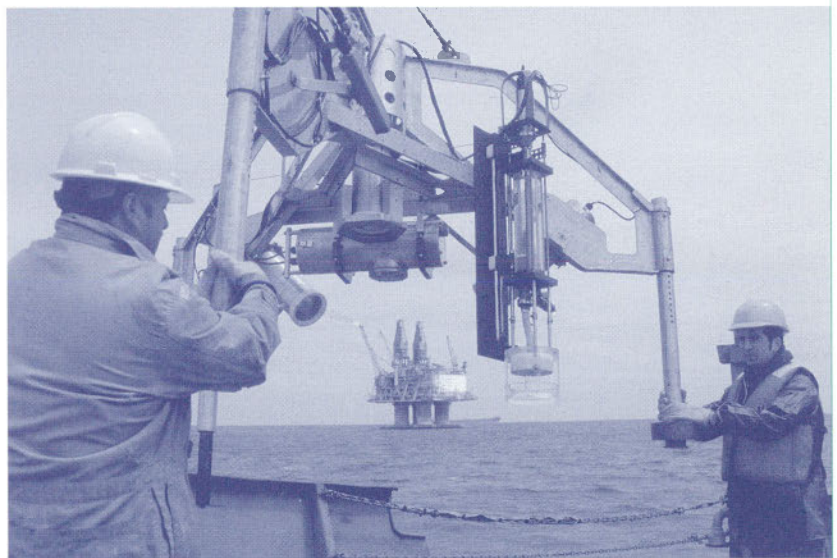
In collaboration with an Edmonton company, Northern Geothermal, GSC released the first national estimate of natural gas resources in gas hydrates (GSC Open File 3780). The assessment included natural gas-bearing hydrates in the Canadian Arctic and on the Atlantic and Pacific marine margins. It found a potentially large natural gas resource of between 4.4×10^{15} and 8.1×10^{14} cubic metres—over double the national estimate for conventional natural gas (2.68×10^{15} cubic metres). The work also showed that the thickness of individual hydrate accumulations is usually less than 100 metres, a factor that will have an impact on future resource development plans. The potential of this resource is large, and indications are that the most favourable locations for producing gas hydrates are in the Mackenzie Delta and Beaufort Sea. ●

POTENTIAL NEW METHANE GAS RESOURCES

GSC's regional analyses of two major coal zones beneath the Alberta Plains identified potentially recoverable methane gas resources of more than 25 trillion cubic feet. Methane production from similar coal seams in the Powder River Basin, Wyoming, is now well advanced, and the GSC reports have generated wide interest both in Canada and abroad. The studies were based primarily on databases of coal geology information developed through GSC's National Coal Inventory, supplemented by additional drill data in the deeper parts of the basin. The areas of highest potential are fairly restricted geographically, and will be subjected to more detailed 3-D analysis through partnerships with industry using unique technologies developed by the GSC. ●

DEVELOPMENTS ON THE EAST COAST

The GSC is responding to a fast growing demand for marine geoscience research related to hydrocarbon exploration and development off Canada's East Coast. One result of the research is a better understanding of seabed constraints to the installation of offshore production facilities. In 1999, for the Grand Bank and the deep waters of Flemish Pass, the GSC conducted a preliminary assessment of sediment thicknesses and properties, and the presence of hazards such as sediment failures, shallow gas and shallow faulting. On Sable Island Bank, a collaborative program with industry is documenting sediment scour below gas production facilities at the peak of severe winter storms. In the new lease blocks of the Scotian Slope, collaborative research is providing information about trigger mechanisms for slope sediment failures that are of major concern to the siting and operation of drilling platforms. ●



Exploration and development of energy resources off Canada's East Coast are being helped by the GSC's expertise and vast data collections.

DEVONIAN PROJECT CONCLUDES

The GSC delivered the final report of the Devonian Petroleum Systems of the Western Canada Sedimentary Basin project to participating companies in November 1999. Project participation was drawn from 16 companies, which contributed funding of \$460,000 and considerable indirect support. The two-volume report includes a huge amount of new data and interpretation on samples from parts of the four western provinces, Yukon and NWT. The report represents a considerable advance in our understanding of the factors controlling oil and gas resources in one of the two major hydrocarbon producing stratigraphic intervals in western Canada. A number of presentations have been made, and published articles are planned for 2001. ●

YUKON PETROLEUM POTENTIAL

In support of the Yukon Government's ongoing oil and gas resource management program, the GSC completed three hydrocarbon assessments in northern Yukon: for the Kandik and Bonnet Plume basins and for the proposed Arctic Circle land management area along the Dempster Highway. GSC's PETRIMES statistical program was the mainstay of the studies, with input from various geological and geophysical data sources, giving rise to probabilistic conceptual exploration play analysis. Quantitative estimates of oil and gas resource potential and the sizes of undiscovered fields were provided. Results will be published in Government of Yukon technical reports. They will also be available for integration into the GSC's Canada-wide hydrocarbon assessment program and for a proposed project investigating petroleum opportunities along the Mackenzie Corridor. ●

STORING CO₂ IN COAL SEAMS

An international consortium, led by the Alberta Research Council, is investigating the potential of coal seams to store CO₂ and at the same time produce coal-hosted methane gas. The GSC, with funding from the consortium, studied the regional distribution of CO₂ storage capacity within two major coal zones underlying the Alberta Plains. The research was based largely on databases in GSC's National Coal Inventory, supplemented by additional drilling data. GSC mapped the thickness, depth, maturity and distribution of CO₂ storage capacity within these reservoirs and identified sites for further analysis. The total defined CO₂ storage capacity exceeds 38,000 megatonnes, with the best areas providing storage capacities of greater than one megatonne per square kilometre. ●

GEOCHEMICAL STUDIES STRIKE OIL

The GSC, in collaboration with Chinese and Canadian oil companies, has successfully developed new ways to use molecular markers to differentiate oils derived from different levels of Paleozoic strata. A global approach has been taken, with samples collected from key basins in Canada, China, Russia, Australia and the United States. Initial results were released in the international journal *Organic Geochemistry*. The use of age-specific geochemical markers has led to a major revision of petroleum exploration directions in China's Tarim Basin. The GSC is applying similar approaches to petroleum systems in Canada's Williston Basin, with a concerted effort to search for oils derived from Cambrian source rocks, a new exploration frontier in an old petroleum province. ●

Natural Hazards

Geoscience for the safety of Canadians

Earthquakes, landslides, magnetic storms caused by solar activity, and volcanoes are all potentially damaging geological hazards in Canada. Permafrost and naturally occurring metals in the environment are geological conditions that can pose hazards. The scientific information that the GSC provides about these hazards is the basis for sound land-use and emergency preparedness planning that touches directly on the safety and health of Canadians.



UNDERSTANDING EARTHQUAKES

Collaborative work has led to a snapshot of crustal movement of the Juan de Fuca Plate over the last few years—information essential to understanding earthquake hazard for the West Coast. GPS measurements carried out by the SCRIPPS Institution of Oceanography at three locations offshore Vancouver Island were complemented by the GSC running two high-data-rate GPS receivers at Ucluelet and Sidney for the survey period. The Geodetic Survey, part of Geomatics Canada, carried out a resurvey across central Vancouver Island to the mainland and another across northern Vancouver Island to the mainland. Additional information came from the continuously-operating Western Canada Deformation Array GPS stations which provide a common reference from survey to survey. ●

WEB ACCESS TO GSC'S NATURAL HAZARD INFORMATION

GSC's seismic and geomagnetic data can be accessed through its website. Online data request forms can be filled out by clients and the requested information is sent by email. These services have been online since 1994. In the past year, over 146,000 requests for seismic wave form data, geomagnetic forecasts and data, and site-specific declination calculations were filled. The Internet and the Web have enabled the GSC to deliver a huge volume of data. ●

National Earthquake Hazards Program: www.seismo.nrcan.gc.ca

National Geomagnetism Program: www.geolab.nrcan.gc.ca/geomag/

CANADA AND JAPAN SHARE EARTHQUAKE INFORMATION

Strong links between the GSC and the Geological Survey of Japan are being forged through two major initiatives. Both are focused on efforts to compare and contrast the geology and physics of the Nankai (Japan) and Cascadia (western North America) subduction zones. The first initiative will study earthquakes and crustal deformation on land; the second will take measurements, for several decades, in drill holes in the ocean crust of the subduction zone. Japan has about 100 times the number of Canadian seismic and crustal deformation monitoring stations and, given the similar tectonic settings, Canadian researchers will learn much that can be applied to mitigate earthquake damage on Canada's West Coast. ●

ASSESSING FLOOD HAZARD FOR THE RED RIVER

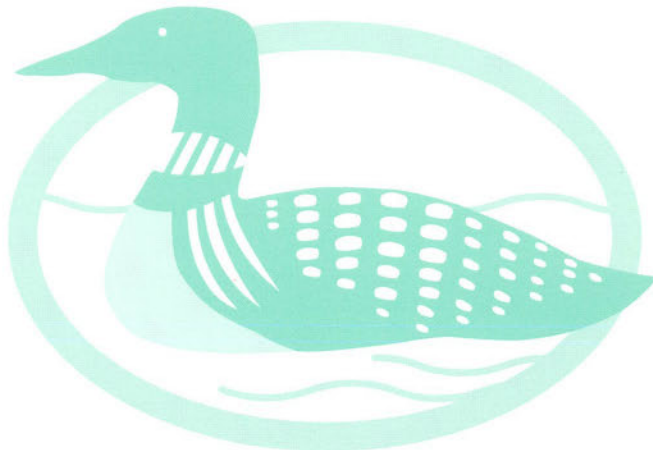
The 1997 Red River flood was a major natural disaster. Although damages were minimized in Winnipeg because of the Red River floodway and dikes, there is serious concern about what damage a larger flood would cause. In response, the GSC and the Manitoba Geological Survey initiated research that will reconstruct the past flood record for the Red River and assess the importance of geological processes that affect the flood hazard. This information will improve understanding of the frequency of extreme floods events, and will contribute to decision-making on enhancing flood protection measures in the Red River Valley. ●
<http://sts.gsc.nrcan.gc.ca/hydro/redriver/>

METALS IN THE ENVIRONMENT: NEW BRUNSWICK

Work under the GSC's Metals in the Environment (MITE) initiative is evaluating metal releases from the Belledune lead smelter in New Brunswick. One objective is to calculate the overall metal budget of the Bay of Chaleur, which makes up half the surface area within 25 km of the smelter. Results show that input of metals to the sediments of the bay has increased since the opening of the smelter, but that metal concentrations are reduced to natural background levels 5 to 10 km away from it. This is especially true for lead, which is present in the bay's surface sediments at three to four times the natural background values. ●

TOXIC SUBSTANCES RESEARCH INITIATIVE (TSRI): NOVA SCOTIA

A three-year, TSRI-funded and GSC-led project in Kejimikujik National Park, N.S., started up in 1999 to determine the sources and processes leading to high levels of mercury in loons. The project, which developed from a GSC-MITE activity, includes over 15 researchers from several government departments, universities and provincial departments. The role of GSC scientists is to identify geological sources and processes that are contributing mercury to the local environment, and to integrate these findings into a model of the overall biogeochemical cycle for mercury in the park. This includes determining the amounts of mercury, both total and in bioavailable (methyl mercury) forms, in soils, rocks, vegetation, lake sediments and waters. ●



METALS IN THE ENVIRONMENT: ROUYN-NORANDA

A major focus of the MITE initiative continues to be in the Rouyn-Noranda region, Quebec. Both regional and detailed scale studies of trace metal distributions in humus soils, peat, lake sediments and snows to determine the impact of the Noranda base metal smelter have been completed. In addition, detailed chronological investigations of atmospheric emissions from the smelter as recorded in trees have been undertaken. A highlight of this work was the discovery that combined carbon and hydrogen stable isotope and metal time series permit distinguishing periods of metal accumulation from anthropogenic (smelter) and natural geological sources. These different studies allow the definition of the metals footprint of the smelter on the regional environment, and permit deposition models to be developed. The models, which indicate a “footprint” of 35–45 km in the various sample media, will help constrain estimates of the amounts of metals deposited regionally, and, in collaboration with the smelter operator, indicate the amounts subject to long-range transport. ●

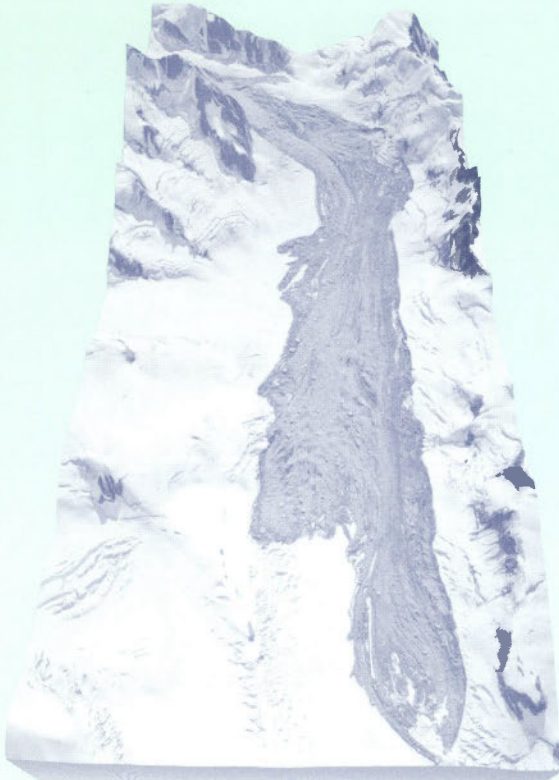
MONITORING STACK EMISSIONS FROM COAL-FIRED POWER PLANTS

Building on research at coal mines that supply electricity generation plants, GSC analyzed power-plant ashes and stack-flue gases to track emissions downwind. Partners in the work include major utility companies, government environment agencies and CANMET. Monitoring stations, which use moss to collect dust particles, have been installed around three power plants in Alberta (Battle River, Milner and Sheerness). Analysis of the trapped dust particles can be used to determine net deposition rates from stack emissions. The program, in cooperation with the International Energy Agency (IEA), should be completed in two years. ●

SPACE WEATHER PREDICTIONS

The GSC, Canadian Space Agency and several universities are working together in the Canadian Space Weather Program. Under this new initiative, funded in part by the Canada Space Plan, the GSC's geomagnetic forecast service is being expanded. It will serve as the Canadian Space Weather Forecast Centre, providing routine operational forecast services for Canada. The GSC's Geomagnetic Hazards Program is taking the lead in attracting industrial partners to this Canada-wide endeavour, and in conducting collaborative research with these partners. Magnetic storms, the most well-known features of space weather, can disrupt or even create a complete breakdown in a number of strategic modern technologies, such as electric power systems and satellites. Advance warning or forecasts, combined with a good understanding of the effects of magnetic disturbances on these technologies, allow for mitigation. www.geolab.nrcan.gc.ca

CASE STUDY: CATASTROPHIC LANDSLIDES



Perspective view to the southeast of the 1997 Mount Munday rock avalanche on Ice Valley Glacier, Waddington Range, southern Coast Mountains, B.C., 280 km northwest of Vancouver. This digital image was prepared from aerial photographs flown on August 20, 1997. Elevation of the top of the source area is 3,000 metres above sea level and the lower tip of the debris is at 2,100 metres. The length of the avalanche path is 4.7 km and its volume is 3.2 million cubic metres. The Mount Munday rock avalanche is one of nine known to have occurred on or adjacent to glaciers in the Coast Mountains since 1945.

The development of innovative analytical methods for understanding catastrophic landslides is a major component of GSC's ongoing partnership-based landslide research in the Cordillera.

GSC scientists, with colleagues from the University of British Columbia and Simon Fraser, are analyzing catastrophic rock avalanches in B.C.'s mountains. While these events generally occur in remote areas, they can have a huge impact on the forest industry, the salmon fishery, roads, railroads and pipelines. In October 1999, for example, debris from a rock avalanche in the Coast Mountains ruptured two natural gas pipelines that supply the Kitimat-Terrace-Prince Rupert area. Key industrial plants were shut down, resulting in temporary layoffs, and 17,000 homes were left without heat and power.

Climate change is a major cause of the landslides. Warming is making the glaciers retreat, and this can destabilize adjacent rock slopes, leading to catastrophic slope failure. Other triggers for the avalanches have been heavy rainstorms or rapid snow melt.

The GSC produces digital maps of the avalanches based on aerial photography. High precision data on rock avalanche volume, run-out distance and path characteristics can then be obtained from digital elevation models. This information is input into state-of-the-art dynamic analytical models developed at the University of British Columbia. Better understanding of these events is essential to the development of effective mitigation strategies to reduce landslide risk.

<http://sts.gsc.nrcan.gc.ca/page1/geoh/slide.htm>

Climate Change

Geoscience minimizing the impact of development and climate change

Geoscience knowledge has become increasingly important for the fundamental understanding of climate change. The GSC contributes to the Government of Canada's priorities by studying past climate changes, examining the potential for geological storage of carbon dioxide, contributing relevant data on current climate trends, and researching the impacts of climate change and possible adaptive response. Mitigation and adaptation are complementary approaches to addressing the challenge of climate change.



PALLISER TRIANGLE PROJECT COMPLETED

The Palliser Triangle project was GSC's response to climate model projections for the southern Prairies that indicate likely future increases in temperature, aridity, and the frequency of drought. Pulling together government and university scientists, the project's goal was to assess potential impacts of climate change on the land and water resources of the Prairies, based largely on lessons learned from the recent geological past. The project is now completed, and results show that water availability, particularly in relation to groundwater fluctuations, is the single most important factor controlling regional environmental change. The research also showed that some droughts in the recent geological past were far more severe than those of the 20th century, suggesting that management strategies based only on the historic record of climate variability are probably inadequate for addressing climate change. Project results were published this year by the GSC. ● <http://sts.gsc.nrcan.gc.ca/page1/clim/palliser/>

PRAIRIE ADAPTATION RESEARCH COOPERATIVE

The GSC was a leader in developing the Prairie Adaptation Research Cooperative (PARC), announced by Minister Ralph Goodale on March 24, 2000. PARC partners include federal and provincial agencies, universities and industry. All are committed to improving the ability of Prairies' residents to adapt to the climate change impacts and opportunities. PARC is a network of researchers, with its hub located at the University of Regina. It will facilitate interdisciplinary research of regional issues and serve as the Prairie node of a national Climate Impacts and Adaptation Network. Initial funding came from the Government of Canada's Climate Change Action Fund (CCAF). ● www.parc.ca

IMPACTS ON THE BEAUFORT SEA COAST

A GSC climate change program is improving our understanding of the rates and processes of coastal change. The Beaufort Sea coast, one of Canada's most rapidly changing shorelines, is a key study area. Even though its open water season is a mere 100 days annually, erosion rates can exceed 20 metres in that period. Coastal infrastructure at Tuktoyaktuk is under continual threat from erosion and flooding, and future development is constrained by uncertainty about the effects of climate change on this unstable coast. As the impacts of climate change are the result of changes in storm patterns, sea level, waves, currents and sea ice, GSC researchers have developed close links with Environment Canada and Fisheries and Oceans Canada to develop a comprehensive picture of coastal behaviour over the past 40 years. A new website, sponsored by the CCAF, highlights environmental aspects in the Beaufort region, such as permafrost and coastal erosion, that may be particularly sensitive to climate change. ●
<http://sts.gsc.nrcan.gc.ca/beaufort/>

PERMAFROST AND GLACIER MONITORING NETWORKS

Climate warming is expected to be the greatest in the high latitudes, with major effects on permafrost, glaciers and ice caps. The GSC is the lead federal agency conducting permafrost and glacier research in order to assess the impacts of climate change. As such, the GSC convened a national workshop to define the requirements of Canadian permafrost and glacier monitoring networks. Sponsored by the CCAF, the workshop was part of collaborative efforts with Environment Canada to develop a national cryosphere monitoring plan. Permafrost and glaciers are two of the main components of the cryosphere, which also encompasses sea ice, snow and lake ice. The outcome of the workshop is contributing to a national strategy document for Canada's participation in the World Meteorological Organization's Global Climate Observing System. ●
<http://sts.gsc.nrcan.gc.ca/permafrost/>

PERMAFROST DEGRADATION IN THE NORTH

Permafrost degradation due to climate warming will affect the stability of northern communities' infrastructure (roads, buildings, etc.), which relies upon the strength of the underlying frozen ground. The GSC, with support from the CCAF, initiated a pilot project in the Mackenzie Valley to assess impacts of permafrost degradation in Norman Wells, NWT. Databases of surficial materials, permafrost conditions, ground temperature, foundation systems in permafrost, and problems associated with existing buildings were compiled. The next step is to examine the impact of various climate warming scenarios on local permafrost conditions and the resulting effects on building foundations, with a view to defining adaptation options. The databases have been given to the community and the NWT government, as they are useful for land-use purposes as well as climate change studies. An exhibit on the project and the GSC's broader permafrost research activities is on display at the Norman Wells Historical Centre. ●



Joint GSC/Environment Canada automated climate and permafrost monitoring site, Kee Scarp, Mackenzie Valley, NWT

PARTNERSHIPS LOOK AT PERMAFROST

The GSC is developing the capacity to model various aspects of the ground thermal regime in permafrost regions. This entails a ground temperature model that can detect the presence or absence of permafrost. The successful application of the model to regional-scale permafrost mapping depends on the availability of reliable information about regional climatic conditions and local terrain characteristics. The GSC has a major effort underway to consolidate and integrate available information about surficial geology, surface vegetation, and topography into a GIS-based digital database. It has solicited partnerships with the NWT Forest Management Division to contribute classified satellite imagery for the entire Mackenzie Valley in support of this work, and the NWT Transportation Department to evaluate the model outputs with respect to route selection applications in public works. ●

CLIMATE RECORDS FROM THE SEA

GSC is part of a Canadian consortium in the International Marine Global Change Study (IMAGES). This year's project looked at climate records on the Scotian Margin and in the Labrador Sea. Sediment cores, collected from the North Atlantic and the Saguenay Fjord, will be used to measure the ages of the sediments and calculate the past physical and biological properties of the ocean surface and bottom water. These records are used in computer models that forecast long-term climate change in Canada and allow us to estimate changes from continued global warming, for example: more outbreaks of red tide, which triggers shellfish poisoning; increased storminess; and lower marine productivity. They also reveal events likely to accompany the start of any future Ice Age, such as the speed with which climate cooling will change living conditions in coastal areas and will impact offshore mining, shipping and fishing. ●

CLIMATE SYSTEM EVOLUTION AND DYNAMICS

The GSC continued to develop tools for high resolution climate reconstruction based on dendrogeochemical and isotopic analysis. They will be used to reconstruct temperature history and water availability during recent centuries in boreal and sub-arctic areas. This information is of importance for future developments in areas of great hydro-electric potential. The techniques can be used, as well, to assess ecosystem response to natural disturbances, such as forest fires, that are the result of climatic conditions. The GSC, in collaboration with Laval University, also continued to monitor current climatic conditions in sub-arctic regions using a network of weather stations in northern Quebec. ●

CLIMATE CHANGE MADE EASY

Temperature Rising: Climate change in southwestern British Columbia, a new educational poster, shows the scientific evidence for human influence on climate change, the impacts expected for southwestern B.C., and what individuals can do to reduce greenhouse gas emissions. This colourful poster was developed by NRCan, Environment Canada, Simon Fraser University and a range of other agencies. Temperature Rising and its resource kit were distributed free to educators in southwestern B.C. Temperature Rising, GSC Miscellaneous Report 67, is available from GSC Bookstores (see back cover for addresses), \$5.00. GSC is developing similar posters for regions across Canada. www.climatechangecanada.org

Sensitivities to Climate Change in Canada is another new GSC release. This easy-to-read atlas presents ten maps that illustrate changes that could occur with a doubling of atmospheric CO2, and highlight the sensitivity of our landscape and ecosystems to climate change. Topics include soil erosion, permafrost thaw, and shoreline sensitivity to sea-level rise. An online version is available at: <http://sts.gsc.nrcan.gc.ca/adaptation/sensitivities/>.

Both products were funded by the Government of Canada's Climate Change Action Fund.

HYDROGEOLOGY: GEOSCIENCE SUPPORTING WATER MANAGEMENT

Groundwater, a renewable and sustainable resource, is vital to the Canadian economy and our ecosystems. Groundwater supplies water to 30% of Canadians, and that number is growing. There are, however, major gaps in our understanding of this resource. While it is known that Canada's surface waters represents 20% of the world's useable freshwater, the amount of available groundwater is unknown. More needs to be known, too, about the number, size, characteristics and dynamics of Canada's main aquifers.

To wisely manage and protect our overall water resources, we have to know how much groundwater we have, how it is stored, and how it moves in the ecosystem. The GSC, with its expertise in regional mapping and geology, is well positioned to help develop this knowledge. The GSC is building a strong national hydrogeology program, with excellent connections at the local and provincial level across the country, and with groups such as the International Joint Commission and the U.S. Geological Survey.

Highlights of GSC's hydrogeology work in 1999-2000 are:

OAK RIDGES MORAINÉ STUDY, ONTARIO

The Oak Ridges Moraine hosts a major groundwater resource for the Greater Toronto area with its population of five million. The moraine is the source of the headwaters for over 30 rivers and home to wildlife and rare species of plants. Over the past five years, the GSC carried out a major groundwater study in the moraine with provincial, regional and local government partners. The work has established new standards for studies of the moraine and had far-reaching impact in terms of local planning. Some examples include:

- **Land-use planning:** The Ontario Ministry of Municipal Affairs commissioned the GSC to review development protocols for the Richmond Hill area. The GSC team used the results from the GSC regional study to define the context for the needed local hydrogeology studies. The GSC regional work has had a dramatic impact on land-use planning in the moraine, with GSC maps, data protocols and field techniques being adopted for regional and local groundwater assessment.
- **Water resource planning:** Regional governments in the Greater Toronto Area (Peel, Durham and York) enlisted GSC support to help improve strategic planning of surface and groundwater resources across the moraine. The GSC carried this out as a series of public presentations to highlight the new groundwater studies on the moraine and to strengthen the scientific basis for water resource planning. GSC was also invited to attend a workshop convened by the Ontario Government that will have a major impact on the province's ability to address future groundwater and surface water issues across Ontario. <http://sts.gsc.nrcan.gc.ca/orm/index.asp>

MAPPING THE ST. LAWRENCE LOWLANDS' AQUIFERS

A partnership involving regional stakeholders, the GSC, Environment Canada, Canada Economic Development, and the Quebec environment and transport ministries is carrying out a regional project to map the fractured rock aquifers of southwestern Quebec. This is a \$3,000,000 project over a four-year period, which focuses on the protection and quantitative aspects of groundwater resources. The methodology, which includes delineation of fractured aquifers, will be described in a report produced in collaboration with the Quebec Ministry of the Environment. It will offer stakeholders in Quebec an effective approach to better know and manage their groundwater resources.

NEW TECHNOLOGIES FOR AQUIFER MAPPING

Agriculture and Agri-food Canada and the GSC developed technologies to assess the vulnerability of near-surface aquifers to land-use activities such as livestock feedlots. These allow water-well data, which are variable in quality and consistency, to be integrated in standardized databases. Using GIS, aquifer vulnerability, as well as other maps and data were integrated with soil characteristics and surficial geology to make a powerful spatial analysis tool for surface land-use planning. The technologies are now being applied to water-well data in Manitoba.

For more information about the GSC's national hydrogeology program, contact Alfonso Rivera at (418) 654-2688; E-mail arivera@nrcan.gc.ca.

TOOLS FOR WATER RESOURCE MANAGEMENT

GSC's recent hydrogeology activities have generated geoscientific databases that provide valuable tools for effective groundwater resource management. The GSS developed HYDROLINK, a website prototype through which hydrogeology data will be easily accessible to provincial and municipal partners. In addition, software packages and computer tools, including GIMS (Geoenvironmental Information Management System), are in

production. These will give decision-makers effective tools for managing geoscientific information.



Marine geoscience

Geoscience for sound economic, environmental and social decisions

GSC's marine program addresses the scientific problems and needs for geoscience information about 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.



EAST COAST OFFSHORE MARGIN

The Natural Sciences and Engineering Research Council (NSERC) announced a major funding award for a multi-agency program to investigate Canada's East Coast offshore margins. Led by Dalhousie University, other partners include the GSC, Memorial University, the University of Calgary, and British, Danish and U.S. research groups. The award forms the cornerstone of the fledgling initiative, MARIPROBE, which will develop an understanding of the origin and evolution of Canada's extensive and resource-rich continental margins. The GSC will apply its crustal seismology and geodynamic modelling expertise to the research. As part of the award, the GSC will receive more than \$130,000 to upgrade its Ocean Bottom Seismometers. These instruments will become a shared resource for the GSC, Dalhousie and NSERC, and they will ensure continuation of Canada's international leadership for this type of investigation. ●

SEAFLOOR MAPS FOR THE SCALLOP FISHERY

The GSC ran a successful workshop in Lunenburg to introduce captains in the Nova Scotia scallop dragger fleet to new technology and to help them interpret GSC seafloor imagery. In a unique partnership between the GSC, the Canadian Hydrographic Service and the Offshore Scallop Producers of Nova Scotia, seafloor mapping technology has been applied to the production of digital maps of surface sediments and fisheries habitat on the highly productive scallop grounds of Browns, Georges and German Banks. Five separate "layers" of information are exported to electronic navigation systems for use by the offshore fishing fleet. Access to this new technology is expected to reduce environmental impacts and increase economic benefits for the scallop industry. ●

GEOLOGY, NATIONAL PARKS AND ARCHAEOLOGY

The GSC and Parks Canada are combining marine geological mapping with underwater archeology to interpret the long-term human history and geological evolution of Canada's marine parks. These studies provide baseline information for park interpretive centres and the underpinning of maps for future marine protected areas. Some recent highlights include:

- At Gwaii Haanas Marine Park Reserve in the Queen Charlotte Islands, the discovery of a drowned river system, tree roots and a stone tool on the seafloor indicates that sea-level rapidly rose 10,300 years ago. The research demonstrates that much of the continental shelf was exposed prior to this time and supported early humans, abundant vegetation and shellfish.
- Studies in Fathom Five National Marine park in Georgian Bay demonstrated lake levels and rivers were 125 m below present between 9,400 and 7,200 years ago. Drowned tree trunks and a possible fire tool made of stone were recovered from the shores of the drowned drainage system.
- At Cape Breton's Fortress Louisbourg, mapping revealed sunken ships and numerous other human constructions on the harbour floor. Sediment cores revealed that Louisbourg harbour was a freshwater lake 5,300 years ago, and that sea-levels have risen considerably since the last Ice Age. This trend, which threatens the fortress may be expected to continue. ●

OCEAN DRILLING PROGRAM AND INDUSTRY COLLABORATE

The GSC took part in important international meetings to explore collaborative projects involving the Ocean Drilling Program (ODP) and the petroleum industry. Eight proposals to drill on the continental margins were put forward by industry. Projects on the Grand Banks and in the Scotian Basin would take advantage of new blow-out prevention (BOP) capabilities being added to the ODP after its renewal in 2003. Both would add tremendously to the geoscience community's understanding of the history and architecture of the thick, oil-bearing sedimentary deposits along Canada's East Coast. ●

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 the 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.

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INTERNATIONAL CONNECTIONS

Canada is a recognized leader in the geosciences, and this expertise is much in demand. GSC's international connections bring significant benefits to both Canada and the partner countries. Work with other countries to carry out geoscientific research of mutual benefit has led to advances in understanding the global environment and opened doors for Canadian industry. It also exposes Canada's geoscientists to geological phenomena that may have important implications for Canada in mineral and petroleum exploration and development, natural hazard assessment, and environmental studies.

CONTRACT WITH IRELAND

A Canadian consortium, which includes the GSC, was awarded a three-year contract to act as the external scientific consultant for a project by the Geological Survey of Ireland to map the offshore region of Ireland (about 850,000 sq. km). Many aspects of the project, which has a total value of \$50 million over the next seven years, will be done under contract. The Canadian consortium will design the mapping survey, provide equipment specifications, and recommend training requirements. There will be opportunities for Canadian industry to get involved in subsequent phases of the project. The awarding of this consulting contract underscores Canada's excellent capability in offshore mapping.

CANADA/URUGUAY GEOSCIENCE AGREEMENT

NRCan Minister Ralph Goodale and Juan Storace, the Uruguayan Minister of Defence, signed a five-year agreement, December 6, 1999, under which the two countries will collaborate and exchange marine geoscience knowledge and information. Under the agreement Canada and Uruguay will cooperate on analyzing the marine geoscientific information needed to establish the outer limit of Uruguay's marine jurisdiction. Other aspects cover

geoscience information for purposes such as navigation safety and environmental studies. It is anticipated that this agreement will help Canadian geoscience businesses to provide products and services that can support sustainable economic growth in Uruguay's marine sector.

CANADA'S EARS TO THE GROUND

The GSC will be providing information to three of the four systems monitoring compliance with the Comprehensive Nuclear Test Ban Treaty. Seismographs, part of the Canadian National Seismological Network, detect underground tests. The Infrasound Array near Pinawa, Manitoba is able to detect atmospheric tests and the hydro-acoustic stations planned for the Queen Charlotte Islands will be able to detect nuclear explosions underwater. The Infrasound Array was officially opened in August 1999 and was the first of 60 planned international sites that will send infrasound data to the International Data Centre in Vienna. For more information, visit: www.seismo.nrcan.gc.ca

CHINESE PREMIER ZHU VISITS GSC

Zhu Rongji visited the GSC and Fisheries and Oceans (DFO) at the Institute of Ocean Sciences near Sidney, B.C., April 19, 1999. Mr. Zhu and his entourage were escorted through the facility by DFO Minister David Anderson. The Chinese government requested the visit because of Premier Zhu's interest in earthquakes and in climate change. Premier Zhu showed keen interest in research related to a potential West Coast megathrust earthquake, and in the collaboration between the GSC and Canadian emergency agencies, engineering organizations, public utilities, the Insurance Bureau of Canada and National Research Council (National Building Code) to mitigate the damage and consequences from such an event.

CROSS-BORDER GAS STUDY

As part of the National Oil and Gas Assessment program, the U.S. Geological Survey is reassessing shallow biogenic gas accumulations in the northern Great Plains. Part of the project was designed to elucidate the controls on the sites of gas accumulation in southeastern Alberta and southwestern Saskatchewan, with the expectation that models derived from these areas could be extrapolated to Montana. Microfossils were considered essential in this process, and GSC foraminiferal experts are collaborating in the project.



DROUGHT RELIEF FOR BRAZIL

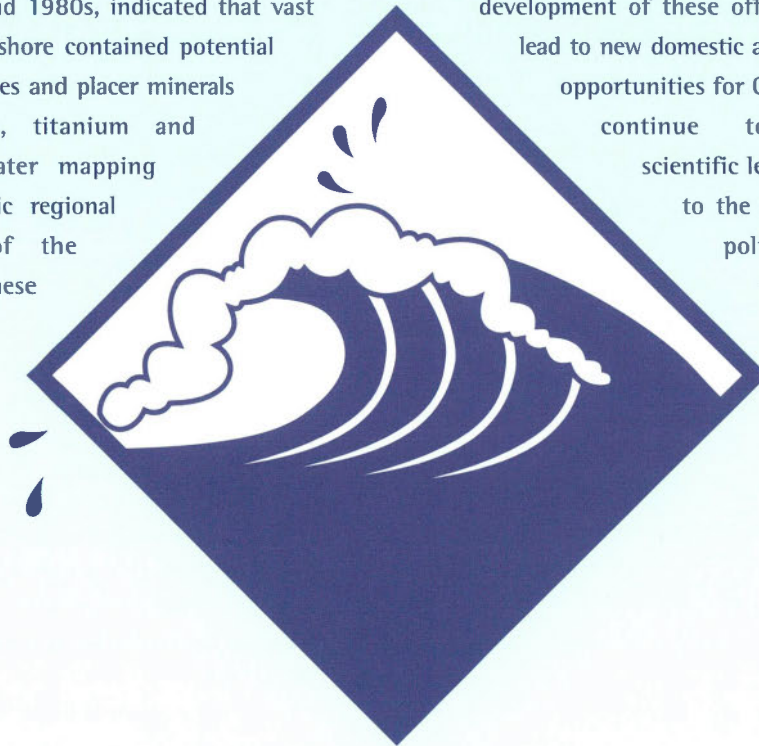
The GSC and the Geological Survey of Brazil (CPRM), with funding from the Canadian International Development Agency (CIDA), are launching a program that will apply state-of-the-art geoscience to the fight against drought in northeastern Brazil. The program will seek to transfer Canadian technologies to several Brazilian organizations to enhance their capacity in groundwater resource exploration, development and management. A large number of Canadian companies and public organizations have expressed interest in participating in the project, offering a wide variety of tools ranging from remote sensing and airborne geophysics to groundwater modeling and artificial aquifer recharge. The program includes a strong component to ensure that its activities respond to the needs of the population. <http://brazil.agg.gsc.nrcan.gc.ca/>

Some 25 million people living in an area of about 1 million square kilometres are affected by periodic droughts. These ruin the region's agriculture production, causing mass exodus of the population towards urban centres that cannot cope with the influx. Those who stay are afflicted by diseases and high mortality rates, especially infant mortality, due to undernourishment and the consumption of poor quality water. The new GSC-CPRM-CIDA project will provide better means to the population to cope with the disaster by developing the region's groundwater resources.

CASE STUDY: MARINE MAPPING SPARKS INTEREST IN OFFSHORE MINING

At their 1998 annual conference, Canada's Mines Ministers asked that an effective management regime be developed for Canada's offshore non-fuel minerals. Maximizing economic benefits from these valuable resources and diversifying the economic base of coastal communities were the overarching goals, while guiding principles required that government, industry and community interests be balanced with each having a voice in the process. This initiative is now well underway.

It was the GSC's regional mapping program that stimulated this interest in offshore minerals. The first phase of GSC's seabed mapping, conducted in the 1970s and 1980s, indicated that vast areas of the offshore contained potential marine aggregates and placer minerals such as gold, titanium and silica sand. Later mapping involved specific regional assessments of the potential for these materials.



Regional seabed mapping projects have identified new potential resources and defined the geological framework in which they are found. The future development of these offshore resources can lead to new domestic and foreign economic opportunities for Canada. The GSC will continue to provide the scientific leadership and advice to the development of the policy and legislative aspects of the new marine minerals initiative.

Information

Geoscience for sound economic environmental and social decisions

Delivery of GSC's extensive and diverse scientific output is tailored to clients' needs for information in a variety of formats, ranging from traditional publications to the latest in digital maps. The GSC is increasingly using the Internet as its prime means of communicating with traditional clients and a broader public. GSC staff are trail-blazing new ways of communicating complex scientific information at a level accessible and relevant for non-technical users, educators and students.

WWW.GEOSERV.ORG

Building on the GSC's successes in delivering scientific information on the Internet, GeoServ was developed to provide access to the wide variety of GSC's digital map data. GeoServ enables GSC scientists to incorporate dynamic and informative maps into web pages, giving experienced and novice users the means to fully explore the wealth of information in the GSC knowledge base. Some examples include "Urban Geology of Ottawa", which features engineering and water-well maps and data, and "Mapping Ancient History", which allows the user to explore the spread of ancient cultures and animals across the North American continent following after the Laurentide and Cordilleran ice sheets retreated. ●

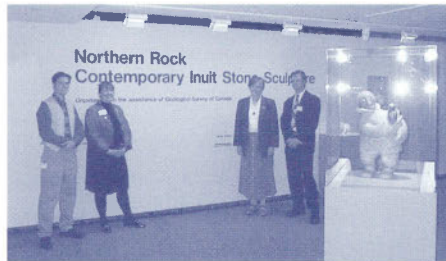
RESSOURCES GSC

The ResSources GSC program completed its second year of operation. Its goal is to build the GSC's component of the Canadian Geoscience Knowledge Network (CGKN) in partnership with GeoConnections. Through the program, GSC scientists and computer specialists are developing tools and procedures for managing and web-enabling GSC knowledge. Year two resulted in the addition of ten new project websites to the ResSources GSC homepage www.rgsc.nrcan.gc.ca/. The projects all demonstrate delivery of specific project and discipline information through the Internet. Working with provincial and territorial partners, ResSources GSC also played a major role in coordinating and promoting the National Geological Surveys Committee CGKN initiative: ● <http://cgkn.net>



“NORTHERN ROCK”: WHERE GEOLOGY AND ART MEET

The McMichael Canadian Art Collection in Kleinberg, Ontario, ran an innovative exhibit of Inuit sculpture, from May to October 1999. “Northern Rock: Contemporary Inuit Stone Sculpture” was designed to answer the question “what is that stone?”, which is commonly asked by visitors when Inuit stone sculpture is displayed. The GSC worked closely with the gallery to develop materials and text for the show, with a focus on describing the geology of the carving stone material on display, providing a glossary of geological terms relevant to the carving stone industry, and illustrating the role of geologists in the search for new sources of carving stone. Public response to the show was enthusiastic, and it received excellent reviews.



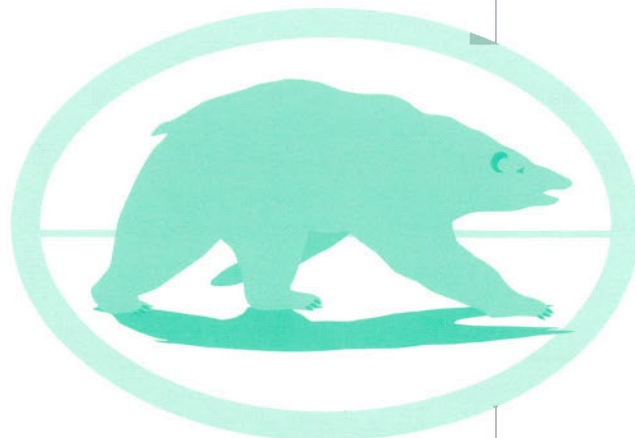
GSC contributors to “Northern Rock” exhibit, from left: Martin Stewart, Lyn Anglin and Rob Rainbird with curator Susan Gustavison (second from right).

GSC MAPS ARE ISO-CERTIFIED

The Ottawa-based cartographic group that produces most of GSC’s maps received ISO certification. The group is responsible for the digital production of multicolour geological maps for on-demand, and offset printing, and for the production of related publication graphics for GSC’s scientific output. The group provides a digital imaging services to the GSC and technical photographic services to the Earth Sciences Sector. The ISO certification represents a major achievement in process improvement, product improvement and accountability, and is an important step towards stronger client service and employee focus. ●

FIREBALL EXCITEMENT IN THE YUKON

The January 18, 2000, fireball that illuminated the pre-dawn sky of the southern Yukon led to intense interest by scientists, media and the public. GSC staff in Whitehorse, Ottawa, Vancouver and Sidney gave numerous media interviews and fielded many questions from the public. Charlie Roots in the Yukon Geoscience Office, liaised between eyewitnesses and experts in Canada and the U.S. He was instrumental in the recovery of samples of the meteorite (a rare, carbonaceous chondrite) and in defining its trajectory. The meteorite, subsequently named Tagish Lake, was detected by GSC seismographs in Hainey and Whitehorse, providing researchers with a precise impact time, approximate trajectory, and the location of the air burst. ●



CASE STUDY: NATIONAL GEOCHEMICAL RECONNAISSANCE PROGRAM

Canada's National Geochemical Reconnaissance (NGR) program provides a national lake and stream sediment and water survey database. It currently has site-specific information for 84,000 streams and 110,000 lakes across the country. About 20% of Canada's has been surveyed.

The GSC, under its NGR program, sets internationally recognised standards for regional geochemical surveys across Canada. Since 1973, sample collection, preparation procedures and analytical methods have been established and monitored to ensure consistent and reliable results regardless of the area, the year of collection, or the analytical laboratory.

The use of NGR data has led to the discovery of many mineral occurrences and several significant deposits. Of note, Viceroy Resources' Brewery Creek Mine, east of Dawson City, Yukon, has produced over 110,000 ounces of gold in three years of operation. Cominco's Kudz Ze Kayah project in Yukon has indicated resources of 11,300,000 tonnes containing zinc, lead, gold, silver and copper. Strange Lake, on the Quebec-Labrador border, has significant tonnages of potentially economic Zr-Y-Nb-Be-REE.

The GSC originally designed the NGR program to assist mineral exploration in Canada, but increasingly data are being applied to environmental purposes. Regional and national compilation maps have proven useful in demonstrating the range of natural background variation of many elements, and new techniques have been developed to determine natural baseline concentrations of elements in contaminated areas.

The range of activities carried out under the NGR program is considerable, and includes many participants. Surveys are funded by federal, provincial and territorial agencies, as well as by industry. Collection and analytical services are contracted out. Clients include the mining and mineral exploration industry, individual prospectors, environmentalists and biologists, land-use planners, and bedrock and surficial mappers.

Over the years, the NGR program has taken advantage of advances in analytical techniques and computer hardware and software. With ongoing and future projects in British Columbia, Yukon, Alberta, Ontario and New Brunswick, the NGR program continues to fulfil its mandate of establishing and maintaining a nationally consistent geochemical database. <http://ngr.gsc.nrcan.gc.ca>

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Martin McCurdy: mmcurdy@nrcan.gc.ca

Stephen Day: sday@nrcan.gc.ca

GSC geologist Stephan Day carrying out stream sampling in New Brunswick.



Products and Services



EARTH SCIENCES INFORMATION CENTRE (ESIC)

ESIC holds Canada's largest collection of books, journals, maps, atlases and photographs in the earth sciences, with world-wide coverage. The collection includes an increasing number of online electronic publications.

Many of ESIC's products and services are available through the Internet where clients have access to the Library Catalogue, the federal geoscience database GEOSCAN, reference services and document delivery.

The Library Catalogue has information on the status and location of the more than 2,000,000 holdings of ESIC and the GSC regional libraries. GEOSCAN, a searchable database of GSC publications, has over 40,000 bibliographic records concerning the Canadian landmass and offshore regions.

Enquiries can be sent via the ESIC website, e-mailed to ESIC@NRCan.gc.ca, and faxed to (613) 943-8742, or contact the Information Desk at (613) 996-3919. Document delivery requests should be sent to ESIC.ILL@NRCan.gc.ca. Some fees for document delivery and reference services may apply.

Visit ESIC online at www.nrcan.gc.ca/ess/esic.

Coordinates for GSC's regional libraries are:

Calgary Tel.: (403) 292-7165
E-mail: calgary.ref@gsc.nrcan.gc.ca
Québec Tel.: (418) 654-2677
E-mail: dupuis@gsc.nrcan.gc.ca
Vancouver Tel.: (604) 666-3812
E-mail: libvan@gsc.nrcan.gc.ca

DATA COLLECTIONS FOR CANADA'S OFFSHORE

The GSC's office at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia, is the principal repository for huge data collections for Canada's East Coast and Arctic offshore regions. The collections include marine acoustic, magnetic and gravity survey data; sediment grab and core samples; and rock and paleontological specimens collected as part of government/industry collaboration.

Contact: Iris Hardy
Telephone: (902) 426-6127
E-mail: ihardy@nrcan.gc.ca

AEROMAGNETIC AND GRAVITY DATA

Aeromagnetic, gravity and digital elevation data for Canada are available as colour plots or digital data. These national data sets can be scaled to any size, provided in most formats and supplied on a variety of media types including delivery via FTP. Products range from economically priced, generic coverage to customized, project-specific data sets. Quotes are available on request or visit our web site for product and pricing details.

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Geological Survey of Canada
615 Booth Street, Rm. 235
Ottawa, Ontario K1A 0E9

Telephone: (613) 995-5326
E-mail: infogdc@agg.nrcan.gc.ca
Web site:
<http://gdcinfo.agg.nrcan.gc.ca/toc.html>



CRUSTAL-SCALE EXPERTISE

The GSC provides instrumentation and expertise for crustal scale seismological and electromagnetic studies. In recent years this has involved international projects led by academia, industry or governments abroad, on a cost-recovery basis. Focus is on two areas:

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 and 16 long-period magnetotelluric recording units (LIMS), as well as display and processing software and data acquisition, processing, modelling and interpretation expertise.

Seismology & Electromagnetism
Geological Survey of Canada
615 Booth Street, 2nd Floor
Ottawa, Ontario K1A 0E9

Telephone: (613) 992-0758

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.

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SET YOUR COMPASS WITH CGRF2000

The Year 2000 upgrade of the Canadian Geomagnetic Reference Field (CGRF2000) was released on March 27, 2000. The CGRF is a mathematical representation of the magnetic field over Canada and adjacent areas. It is used to determine magnetic declination and values of other magnetic field components. CGRF2000 includes data from the recently launched Danish satellite Ørsted. The CGRF is used by clients in such diverse activities as mapping, forestry, resource exploration, and surveying. Magnetic declination values, derived from CGRF2000, are available through the website www.geolab.nrcan.gc.ca

Copies of the upgrade are available for \$100.00. Payment at the time of ordering may be made by VISA, MasterCard or by cheque payable to the Receiver General for Canada. Contact:

Larry Newitt
National Geomagnetism Program
Geological Survey of Canada
7 Observatory Crescent
Ottawa Ontario K1A 0Y3

Telephone: (613) 837-7915
E-mail: lnewitt@nrcan.gc.ca

HOW TO ORDER GSC PRODUCTS

The GSC publishes its research in many scientific journals and commercial publications. It also has a publishing capability, and all GSC products, both print and digital, are sold through the GSC Bookstore.

Publications and CD products may be ordered from the GSC Bookstore in Ottawa or from our sales outlets in Sainte-Foy, Calgary and Vancouver (see back cover for contact numbers).

GSC's new cyber-Bookstore at www.nrcan.gc.ca/gsc/bookstore provides online ordering as well as GSC's new product listing. The GSC Information Circular, at the same website, announces the release of new reports, maps and open files.

For orders, prepayment is required by cheque or money order made out to the Receiver General of Canada. VISA and Mastercard are accepted. Applicable taxes and shipping and handling costs are extra.

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 analysed 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.

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ANALYTICAL METHOD DEVELOPMENT LABORATORY

This laboratory focusses on speciation of elements in sediments, soils and waters; cost-effective methods to analyse 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.

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DELTA-LAB

The GSC-Quebec isotopic geochemistry laboratory analyses stable isotopes of hydrogen, carbon, nitrogen, oxygen and sulphur using PRISM-III, SIRA-12, GC-COMBUSTION-Prism-III (GC-IRMS), continuous elemental analyser with Prism-III (EA-CF-IRMS), auto-water for oxygen, and elemental analyser 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 analysing the isotopes of water, reagent hosts and dissolved components.

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Québec Geoscience Centre
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E-mail: msavard@nrcan.gc.ca

DENDROCHRONOLOGY AND DENDROGEOCHEMISTRY LABORATORY

These facilities help scientists to analyse tree growth and use trees as bio-indicators of natural and anthropogenic environmental disruptions. Tree growth parameters are analysed by means of a high-precision (0.001 mm) Unislide Velmex micrometer, connected to a Metronics Inc. QC-1000 data-acquisition system, which is used to transfer and digitally process data. Dendrochronology can be combined with geochemical analysis of growth rings to document the nature of environmental conditions as well as their spatial and temporal evolution. Applications related to climate change, environmental geodynamics and environmental geochemistry may be developed.

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GAMMA-RAY SPECTROMETRY LABORATORY

This laboratory analyses 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.

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GEOCHRONOLOGY LABORATORY

This laboratory specializes in rock and mineral age dating and isotopic microanalysis using U-Pb, Sm-Nd, Rb-Sr, and Ar-Ar isotopic systems. It has long been involved in developing 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 facilities are available to clients in Canada and abroad.

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GEOCRYOLOGY RESEARCH LABORATORY

GSC and Carleton University have established the 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.

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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.

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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 analysed 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 paleo-hydrothermal 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.

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MICROANALYSIS LABORATORY

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.

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MICROPALAEONTOLOGY 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
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FROM MILES TO MICRONS

Determination of stable isotope abundance in earth and biological materials provides key information to many areas of earth science. The Micro Isotopic Laser Extraction System was developed in the Light Stable Isotope Lab at the GSC to facilitate in situ sulphur isotope analysis of minerals on the sub-millimeter scale (ca. 125 μm). Using an IR laser, a system for producing pure fluorine, and a state-of-the-art mass spectrometer, isotopic zoning within minerals, and isotopic differences between adjacent grains, are measured with MILES at exceptional precision and accuracy. Mineral grains can also be analyzed, and oxygen and carbon isotope analysis will soon also be carried out. Such data are used to, among others, trace and explore hydrothermally altered and mineralized systems, study the origins of mineralizing fluids, and measure temperatures of geological processes.

MINERALOGICAL LABORATORIES

These 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.

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ORGANIC GEOCHEMISTRY LABORATORY

This laboratory is equipped to perform organic geochemical analyses of oils, coals and sediments and some types of environmental analyses. Data from these analyses 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.

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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.

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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.

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PALEONTOLOGY SERVICES

GSC paleontologists and laboratory facilities are available nationally and for many 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. Available expertise is increasingly being concentrated on microfossils (primarily conodonts and foraminifera) and palynomorphs.

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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.

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RADIOCARBON (¹⁴C) DATING LABORATORY

The ¹⁴C 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 ¹⁴C database that may be consulted by Canadian or other researchers. Part of the database is online at <http://sts.gsc.nrcan.gc.ca/radiocarbon/>. The laboratory will consider providing dating control for university researchers on a case-by-case basis at a cost per sample.

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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 analyser, 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.

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UNCONSOLIDATED MARINE SEDIMENT LABORATORY

This laboratory 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.

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Finances

EARTH SCIENCES SECTOR 1999-2000 EXPENDITURES (\$'000'S)

GEOLOGICAL SURVEY OF CANADA

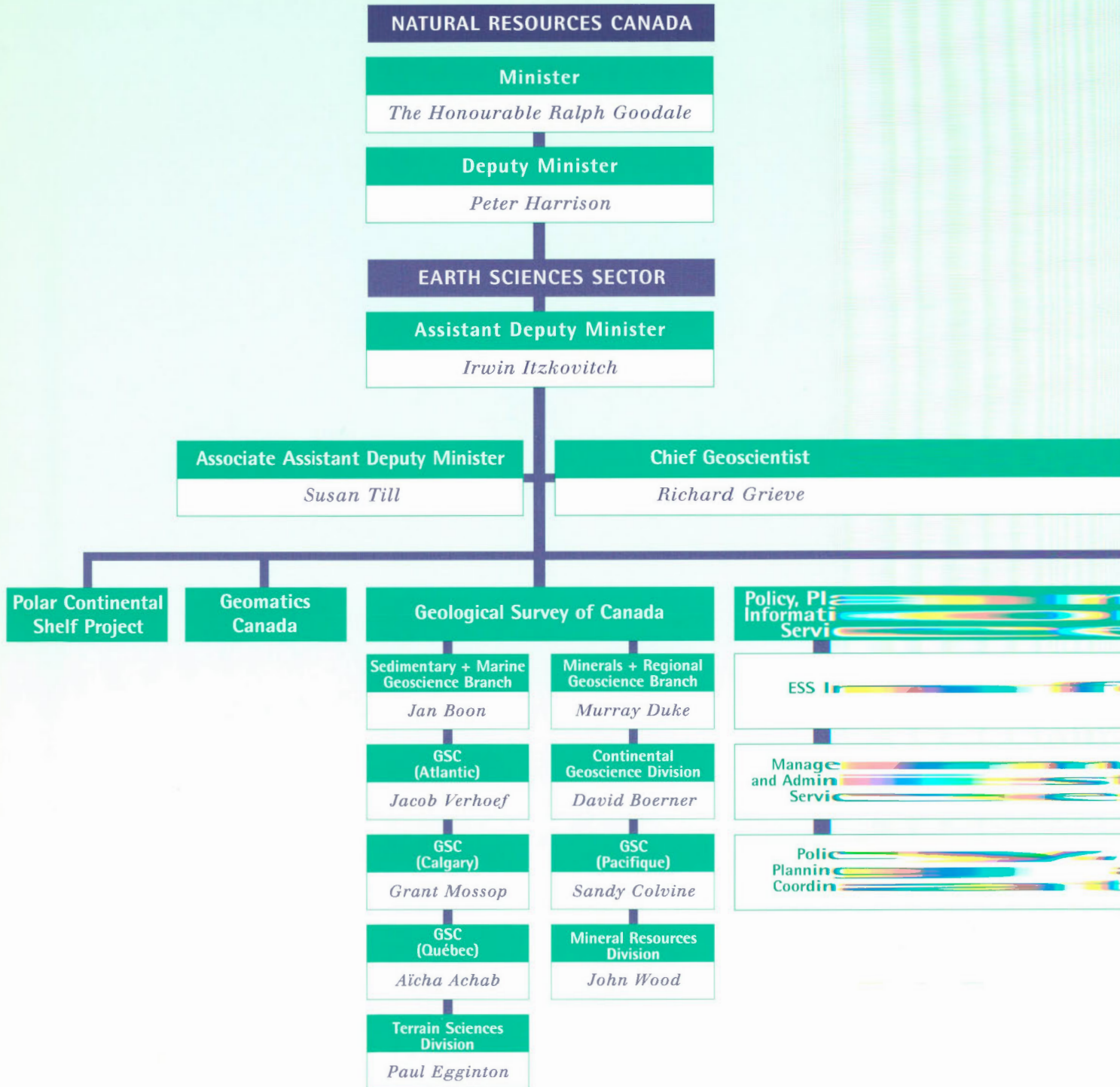
MINERALS AND REGIONAL GEOSCIENCE BRANCH	SALARY	OPERATING	TOTAL	REVENUE,* COST SHARING
Director General	213	68	281	0
Continental Geoscience	5,431	3,509	8,940	1,828
GSC Pacific	6,248	4,304	10,552	1,840
Mineral Resources	5,722	2,058	7,760	794
Nunavut	172	725	897	525
Total	17,786	10,644	28,430	4,986
SEDIMENTARY AND MARINE GEOSCIENCE BRANCH				
Director General	191	99	290	0
GSC Atlantic	5,446	2,525	7,971	615
GSC Calgary	5,784	4,356	10,140	864
GSC Québec	1,649	1,837	3,486	556
Terrain Sciences	4,676	3,640	8,316	734
Total	17,746	12,457	30,203	2,769
TOTAL GSC	35,532	23,101	58,633	7,756
GEOMATICS CANADA	29,377	29,465	58,842	28,261
POLAR CONTINENTAL SHELF PROJECT				
	744	3,681	4,425	1,811
CORPORATE SERVICES**				
Executive Services***	1,803	1,514	3,317	1
Policy, Planning, Information and Services	8,995	5,736	14,731	323
Grants and Contributions			1,697	
Total Corporate Services	10,798	7,250	20,724	324
TOTAL SECTOR	76,451	63,497	142,624	38,152

* 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



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