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Natural Resources
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Geoscience Making a Difference

Geological Survey of Canada



1994-1995

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Cover: The use of geological materials by the human race has been the key to economic growth and societal advancement. An interesting example: rocks arranged in patterns, such as this grouping of inuksuit on the southwest coast of Baffin Island, often contain symbolic, cultural and economic significance. Niungvaliruluit, the one shaped like a window, frames a major site several miles distant and has pointed countless generations of hunters in the right direction.

Photo: Norman Hallendy

The Geological Survey of Canada (GSC) is Canada's premier agency for geoscientific information and research, with world-class expertise focusing on geoscience surveys, sustainable development of Canada's resources, and technology innovation.

GSC supplies the fundamental national geoscience knowledge base required to support effective mineral and hydrocarbon exploration and development across Canada, to provide the geological basis necessary to understand and address health, safety and environmental issues, and to advocate the interests of Canadian geoscience at the international level.

GSC has an extensive capability in onshore and offshore geoscience surveys and in interpreting and managing geoscience information. This expertise is applied to assessments of energy and mineral resources, natural hazards, environmental and policy issues, and the development of exploration technology. GSC exists to support the Canadian economy by working with industry and other government organizations in Canada and throughout the world.

TABLE OF CONTENTS



2	A Message from the Minister: Geoscience making a difference
	<i>Geoscience at work across Canada: Some examples from 1994-95</i>
4	Geoscience Surveys
8	Minerals
14	Energy
18	Environment
22	Information
	<i>Special Reports</i>
3	Focus on: Program Review and the GSC
5	NATMAP: Canada's National Geoscience Mapping Program
6	Partnership Leads to Export Success for Phoenix Geophysics
9	Diamond Exploration Research Reports
10	Lessons from the Seafloor Guide Mineral Exploration on Land
12	Focus on: Marine Geoscience
15	Industrial Partners Program Gets Top Marks
21	Extraterrestrial Events
24	Focus on: International Connections
	<i>Services and Products</i>
3	Aerial Videos of Canada's Coasts
16	Geoscience Laboratories
17	Geophysical Data and Services
24	Cyberspace Connections
26	A Sampler of GSC Publications
30	Geological Maps of the World
28	Arctic Logistics: The Polar Continental Shelf Project
31	Directory: How to get in touch with us
32	Finances

GEOSCIENCE MAKING A DIFFERENCE



*The Honourable Anne McLellan,
Minister of Natural Resources Canada*

Canada's wealth of natural resources has defined the development of our nation and given us one of the highest standards of living in the world — indeed, the World Bank recently ranked Canada as the world's second wealthiest country based, in part, on its natural resources. As stewards and beneficiaries of these resources, we have a great responsibility to use them in an economically effective and environmentally responsible manner.

This is a complex task, requiring sound policies and positive action from governments at all levels, from industry and, indeed, from all Canadians. Because many of Canada's natural resources are the result of its geological make-up, an understanding of geology is a fundamental starting point for any effective policy direction or action.

Helping us understand our geology is what the Geological Survey of Canada does. It has a proud, 153-year-long tradition in building a world-renowned, comprehensive knowledge base about the Canadian landmass and its offshore. There are few areas where this geoscience infrastructure does not touch the lives of Canadians and the fortunes of our country. Examples include:

- wealth generation from the discovery of new mineral and energy resources,
- national policies and standards for the energy and minerals industries based on research and resource assessments,
- sustainable development and environmental protection initiatives built on sound scientific information about the landmass, and
- public safety issues related to natural hazards such as landslides and earthquakes.

In today's economic environment, we face the added challenge of balancing the need for the best, most up-to-date information about our geology against the long-term federal commitment to fiscal restraint. A rigorous rethinking of government services is underway, and the work of the Geological Survey of Canada has been part of this process. What has emerged is a validation of the need for a national geoscience infrastructure delivered in collaboration with the provinces and territories. Cost-sharing with clients and stakeholders will become more and more important.

We are facing a new era in Canadian geoscience, one that will provide both a challenge and new opportunities. I am confident that by working together we will end up with a revitalized Canadian geoscience capability that builds on the strengths of all partners.

A handwritten signature in black ink that reads "Anne McLellan". The signature is written in a cursive, flowing style.

Focus on: Program Review and the GSC

In 1994 the federal government, as part of its commitment to long-term fiscal restraint, undertook a rigorous examination of government services. Throughout Program Review, all departments were asked to evaluate their programs against six criteria: public interest, role of government, federalism, partnership, efficiency and affordability. The results of this review were included in the federal budget tabled on February 27, 1995 by The Honourable Paul Martin, Minister of Finance, in which major reductions to government spending over the next three years were announced.

From 1995-96 to 1997-98, Natural Resources Canada's budget will fall from \$1.012 billion to \$435 million. As part of this, the Geological Survey of Canada will experience a 32% reduction in overall resources over this period. Reductions of this magnitude mean significant staff reductions and will alter the way the Survey does business.

The new GSC approach will include:

- clearer definition of federal and provincial responsibilities for geoscientific studies — in general terms, the Survey will carry out activities that support broad national needs and support the resource industries in partnership with the provinces;

- strong client or stakeholder focus with increased cost-sharing;
- a more effective structure for managing S&T and a rigorous set of accountability instruments to measure relevance, performance and impact.

What will not change?

The Survey will continue:

- to emphasize collaborative, multidisciplinary studies;
- to maintain its commitment to national programs connected to energy and minerals deposits research, resource assessments, marine geoscience, bedrock and surficial mapping, the development of new exploration technology, and research linked to natural hazards, climate change and groundwater;
- to represent the interests of the Canadian consulting industry and science abroad; and
- to improve speed and access to our information through increased use of CD-ROM technology, on-demand printing and remote terminal links for sales and information.

Aerial Videos of Canada's Coasts

The GSC has for a number of years produced aerial coastal videos to provide reconnaissance information for remote areas. These were filmed with the cooperation of the Coast Guard in the south and the Polar Continental Shelf Project in the north. Intended primarily for oil spill contingency planning and coastal mapping purposes, they are available to the public. Applications of the footage are diverse: universities use them as teaching aids, the Nova Scotia Film Board to promote film locations, landowners to identify property erosion, provincial government agencies to monitor new construction and as baseline data for coastal zone management.



Robert Taylor

Cape Smokey, Nova Scotia.

With the recent acquisition of several industry collections, video footage is now available for all of Nova Scotia, New Brunswick, Prince Edward Island, most of Newfoundland, and much of the Arctic coastline. For more information about these video products, please contact Robert Taylor or Dave Frobels at (902) 426-7736 / Fax: (902) 426-4104.

** A listing of GSC's educational videos is in the inside back cover pocket of this publication.*

GEOSCIENCE SURVEYS

Like the bedrock that underlies Canada, geoscience surveys provide the foundation on which rests our knowledge of the country's geology and resource potential. This knowledge has a significant impact on the country's economy, the well-being of its citizens and the responsible development of its resources.

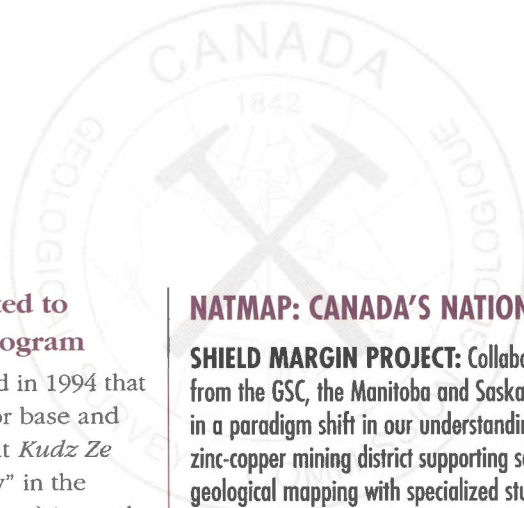
The information accumulated from GSC's bedrock, surficial, geophysical and geochemical surveys over the last 153 years forms a national geoscience knowledge base that can be used by resource industries, government departments and agencies, universities and the public.

The rapid release of maps resulting from current geoscience surveys helps mineral and energy exploration companies identify areas for potential resource development and attracts interest, and investment, to parts of Canada that might otherwise be left unexplored. For example, bedrock mapping in Quebec's central Ungava region in the early 1990s revealed previously unknown belts of greenstones — a rock that contains important deposits of base metal and precious minerals. This discovery sparked a major exploration program by industry in an area once thought to have low economic potential.

GSC surveys also have long-term impacts. An aeromagnetic map of Prince Albert, Saskatchewan, published in the 1960s as the basis for understanding regional geology and deep structure of the area, directly resulted in the discovery of the Fort à la Corne kimberlites (diamonds) in 1988. This densely packed diamond-bearing kimberlite field is among the largest in North America.

Mapping of the country's surficial materials is necessary for effective land use planning, for identifying hazard-prone areas, and for the sustainable development of groundwater resources and aggregates (such as gravel). Mineral exploration companies rely on GSC's mapping of past glacier movements (and also on its geochemical data) to trace glacially transported ore minerals back to their bedrock source. The recent diamond discoveries in the Northwest Territories were made through drift prospecting stimulated by the GSC's surficial geology program.

Geoscience surveys also record the baseline or "natural state" of Canada's landmass and offshore, enabling us to detect how humans have affected the physical environment. They also provide information for evaluating native land claims, assessing proposed parks and wilderness areas, and evaluating the environmental sensitivity of particular areas.



New deposit attributed to GSC geochemical program

Cominco Ltd. announced in 1994 that it had discovered a major base and precious metal deposit at *Kudz Ze Kayah* ("caribou country" in the local Kaska Indian language) in south-eastern Yukon as a direct result of following up a GSC regional geochemical survey published in 1988. Drilling by Cominco has outlined a 13 million tonne deposit, grading 5.5% zinc, 1% copper, 1.3% lead, 125 grams of silver and 1.2 grams of gold per tonne of ore. The exploration program which led to this discovery was prompted by several geochemical anomalies observed in a GSC National Geochemical Reconnaissance survey conducted as part of the Canada-Yukon Mineral Development Agreement and published in 1988.

New light shed on Abitibi-James Bay mineral exploration

A new surficial map showing an old glacial flow direction in the mineral-rich Abitibi-James Bay region of Quebec has caused exploration companies to re-examine their exploration methods in the search for gold, base metals and diamonds. The failure to recognize older ice flow movements means that companies may be searching in the wrong direction as they trace glacially dispersed ore minerals toward their presumed source areas in the bedrock.

NATMAP: CANADA'S NATIONAL GEOSCIENCE MAPPING PROGRAM

SHIELD MARGIN PROJECT: Collaborative multidisciplinary studies carried out by researchers from the GSC, the Manitoba and Saskatchewan Surveys and a number of universities have resulted in a paradigm shift in our understanding of the 1.9 billion-year-old Flin Flon Belt, an important zinc-copper mining district supporting several mining communities. By linking the results of traditional geological mapping with specialized studies on the age, origin and plate tectonic significance of the rocks, a new framework was developed for sorting out the fragments of ancient oceans, volcanic arcs and continents that are caught up in the belt, only some of which contain the mineral deposits. The wealth of geoscience maps and databases incorporated in a GIS has created a "virtual" guidebook to the Flin Flon Belt (initial CD-ROM released in 1993: GSC Open File 2743), enabling users to study the signatures of nearly 2 billion years of Earth history in real time. Recent ore deposit discoveries and mine development in the area have extended the life of the mining communities and attracted new investment and exploration activity.

SLAVE PROVINCE PROJECT, NORTHWEST TERRITORIES: Research on the geology and tectonic history of the Slave geological province, a portion of the northwest Canadian Shield that contains the oldest rocks on Earth, continued to provide important new perspectives on the regional setting of its gold, base metal and diamond deposits. The Slave Province NATMAP project has pooled the efforts and resources of federal and territorial geoscience agencies and has involved scientific partners in the university community and the mineral exploration industry. GSC bedrock and surficial geology maps, spanning from the 1940s to new colour Open File maps produced just months after the field season, have been used extensively in the recent diamond rush. New and existing maps, as well as numerous other fully integrated data sets, have been released on a second CD-ROM for the project, entitled *Selected Geoscience Data for the Slave Province NATMAP Project, District of Mackenzie, Northwest Territories* (see page 27 for ordering information). SURVIEW, a data visualization package developed at the GSC, is included on the CD-ROM to enable clients to view the various maps and data sets without the requirement for any additional commercial software.

MAGDALEN BASIN PROJECT: This project in the Maritimes completed its first year of operation. Its objective is to further knowledge of the evolution of basins and to develop models for the exploration of base metals, industrial minerals, coal and natural gas in this type of geological structure. Partners in the project include GSC, the Nova Scotia and New Brunswick governments, and a number of universities in Eastern Canada. As with all NATMAP projects, new insight and synergy is brought to the project by the integration of diverse disciplines and areas of expertise such as cartography, sedimentology, paleontology, structural geology, geophysics and geochemistry. Results to date include a better understanding of the internal geological structures of the area and the subsequent evolution of the basin, and a new model to explain the origin of lead-zinc occurrences.

PARTNERSHIP LEADS TO EXPORT SUCCESS FOR PHOENIX GEOPHYSICS

Over the past 15 years, federal research grants and the transfer of GSC scientific and technical knowledge have helped elevate Phoenix Geophysics Ltd. of Toronto to the top of the world market in the design, manufacture and operation of magnetotelluric (MT) systems. Their success illustrates the results realizable from government/industry partnerships.

Phoenix has turned the government's initial \$500,000 research grant in the early 1980s into more than \$18 million worth of exports of MT equipment and services, significantly boosting Canada's share of the world market for geophysical exploration equipment. Phoenix-built MT systems are now used in some 75 countries, with potential for growth in such markets as India and China. MT instruments measure electrical and magnetic fields in the subsurface and are used primarily for resource exploration.

With GSC's help, the first generation of Phoenix MT instruments was technically superior to all other systems, enabling the company to capture a large share of the market. GSC is now a major domestic client for Phoenix's MT equipment and services, which are used widely in the GSC's research programs. For the future, Phoenix and the GSC are collaborating, under the Industrial Partners Program, on a project to explore innovative ways to analyze high-frequency MT data for mining and environmental applications.

New geological understanding of Lake Winnipeg

The first year of the Lake Winnipeg Project, which is being carried out in cooperation with the Manitoba Department of Energy and Mines and several other agencies, has already produced important results based on geophysical profiling, coring, and laboratory study of the lake's sediments. Bedrock maps will have to be revised to incorporate a 40 km repositioning of the edge of the Canadian Shield under the lake. Manitoba Hydro, which uses Lake Winnipeg as their most important reservoir, has co-funded the project. The work has implications for issues such as shoreline processes and basin tilting, monitoring of elements such as lead, cadmium and arsenic in the environment, and reservoir management.

Sustainable development of Toronto Area aquifers

The Oak Ridges Moraine Project, now in its third year of operation, is mapping the aquifer systems of the Oak Ridges Moraine, the major groundwater resource for the Greater Toronto Area. As part of its mandate, the project is promoting widespread public understanding of the groundwater resource and its geological controls. Before the groundwater can be fully developed in a sustainable

way, the geometry of the aquifers must be known, the history of groundwater levels must be estimated, and the public must be educated. The Oak Ridges Project is a model for hydrogeological research methods and for meeting public information needs and should have application for other similar projects in sensitive areas.

Navy test helps seismic research

In November 1994, GSC scientists took advantage of a rare opportunity to collect seismic data from a large detonation some 300 km southeast of Halifax. The GSC recorded one of the charges detonated by the National Defence Naval Forces as part of tests designed to monitor their patrol frigates' ability to withstand underwater explosions. The charge, recorded by 200 instruments over a 600 km profile from Nova Scotia to Quebec's Gaspé Peninsula, presented a unique and economical opportunity to obtain information from the Earth's deep crust and mantle about the northern Appalachians and their Atlantic margin. This information may lead to a better understanding of the region's resource potential and seismic activity.



Fieldlog: Computerized mapping in the field. For the past four field seasons, GSC geologists have been incorporating Fieldlog, a software package designed for the input of geological observations and data in the field, into their geological mapping programs. Fieldlog has been a key factor in enabling the GSC to release colour Open File maps in as little as three months following the field season, from map areas spread across the Canadian Shield. The use of Fieldlog is increasing in industry and academia as well, resulting in a demand for the latest upgrades that are being developed by the GSC, and for training sessions in the use of this software. In 1994-95, GSC staff gave five short courses and made seven presentations about Fieldlog to external users.

Drift prospecting

Geoscience surveys conducted by GSC in the Hudson Bay and James Bay areas revealed a phase of glacial flow towards the northwest that calls into question many concepts related to the dynamics of Quaternary ice sheets in North America — information of critical importance to geochemical and mineral prospecting in areas of high mineral potential in northern Quebec and Ontario. This discovery has resulted in the introduction of a new drift prospecting

concept that should have an impact on the design and follow up of exploration programs for precious metals, base metals and diamonds.

GSC instruments used for rockburst studies

Developed originally by the GSC for crustal scale seismic refraction surveys, Portable Seismic Refraction (PSR) instrumentation has found several new applications: in Canadian mines

for rockburst studies and in the evaluation of seismic activity related to enhanced oil recovery in Western Canada. The versatility and reliability of these instruments has led to their use in scientific endeavours that were not anticipated during the original development phase, demonstrating an important link between long-term research and spin-off technologies.

Aeromagnetic survey over British Columbia

A high resolution aeromagnetic survey was flown over the interior plateau of British Columbia. In the past, exploration has been inhibited in this area by extensive glacial drift cover and recent (Miocene) lava flows. The release of the aeromagnetic data set will help resolve some of the unknowns. Aeromagnetic data are also a very useful tool in the identification of kimberlites. The magnetic response of kimberlites can, however, be confused with other formations so the GSC has developed an automatic data scanning procedure that eliminates much of this ambiguity and targets kimberlites over other lithologies and structures.

MINERALS

Canada is one of the world's foremost mining nations. It is the leading producer of zinc, uranium and potash, ranks second for nickel, asbestos and sulphur, third for platinum metals and molybdenum, fourth for copper and cobalt, and fifth for gold, silver, lead and cadmium. In all, more than 60 mineral commodities are produced in Canada.

The minerals and metals industry makes an important contribution to the economic well-being of Canadians. The value of production was \$19.1 billion in 1994, equivalent to about 2.9% of Gross Domestic Product. Minerals and metals are even more significant in the context of international trade, accounting for 12.4% of total exports and making a net contribution of \$11.5 billion to Canada's balance of trade. In fact, Canada is the world's leading exporter of minerals.

The potential for discovery of new mineral wealth is as high in Canada as in virtually any country in the world. However, the discoveries that will transform this potential into reality will require increasingly innovative approaches to exploration. The goal of GSC's Minerals Program is to contribute to the sustainable development of Canada's mineral resources

by developing new concepts and methods to assist industry in exploration, and by providing government with the geoscience information needed to formulate policies on resource management, land use, trade and international competitiveness.

Aggregate resources of the Scotian Shelf

GSC's knowledge of the Scotian Shelf's glacial history proved useful in the first year of a three-year study of the area's offshore sand and gravel resources, funded by the GSC and the Canada-Nova Scotia Mineral Development Agreement. The research involved intensive surveys of targeted areas, and identified economically viable concentrations of sand and gravel at several locations. Strength testing has demonstrated the suitability of many of the deposits for construction purposes. Shallow water location and proximity to the shore suggest potential economic resources for future development.

New EXTECH project launched in New Brunswick

The GSC and the New Brunswick Department of Natural Resources and Energy launched the second EXTECH project in the Bathurst district. The Bathurst Mining Camp accounts for 31% of the zinc and 39% of the lead produced in Canada, but new ore



Beth McClenaghan

GSC scientists and colleagues from the Ontario government and the University of Waterloo worked together, under a federal-provincial regional development agreement, to prepare surficial geology maps and compile stratigraphic information in support of drift prospecting for precious and base metal deposits in the Timmins area. Fieldwork included the collection of till samples for gold analysis at exposed target areas such as Royal Oak Mines' Nighthawk Lake gold deposit.

reserves must be discovered if production is to be sustained at current levels into the next century. The federal and provincial governments will spend about \$7 million over the next five years to enhance the regional geoscience knowledge base, refine mineral deposit models and evaluate exploration technologies that might be applied in Bathurst Camp. This will include a \$1 million multiparameter airborne geophysical study of the entire Bathurst Camp.

GSC aids diamond exploration

A spectacular concentration of diamonds from a prospect northwest of Rankin Inlet, NWT, was announced in February by a partnership of three junior mining companies. The announcement acknowledged the dual role played by GSC scientists and their colleagues from the University of Western Ontario leading to the discovery. Over several years of regional geological studies in the Keewatin District, GSC staff defined and delimited a widespread assemblage of rocks that they believed could host diamond deposits. Of the three samples taken by the companies, one weighing 7.8 kg returned 6,680 microdiamonds and 3 macrodiamonds. This most astonishing yield led to the acquisition by industry of over 400,000 hectares in the area and further exploration in 1995.

New understanding of the Thompson Nickel Belt

The Thompson Nickel Belt in Manitoba accounts for about one third of Canada's nickel production. Collaborative research in the Thompson area has greatly increased the understanding of the ultramafic rocks which host the world-class nickel deposits found in this region. In particular, recognition of previously undocumented "spinifex" textures provides the long-awaited proof that

DIAMOND EXPLORATION RESEARCH REPORTS

GSC continued to publish a series of groundbreaking research reports on how to use glacial sediments in the search for diamonds. Before this, companies exploring in Canada's glaciated terrain had to rely on experience from non-glaciated countries, where indicator minerals carried in rivers are traced upstream to their source. Proprietary concerns within the diamond industry had prevented previous publication of exploration methods using tracing of minerals in glacial sediments. The first in the series published last year, *Distribution and Character of Kimberlite Indicator Minerals in Glacial Sediments C14 and Diamond Lake Kimberlite Pipes, Kirkland Lake, Ontario* (GSC Open File 2819*) became an immediate bestseller. New to the series:

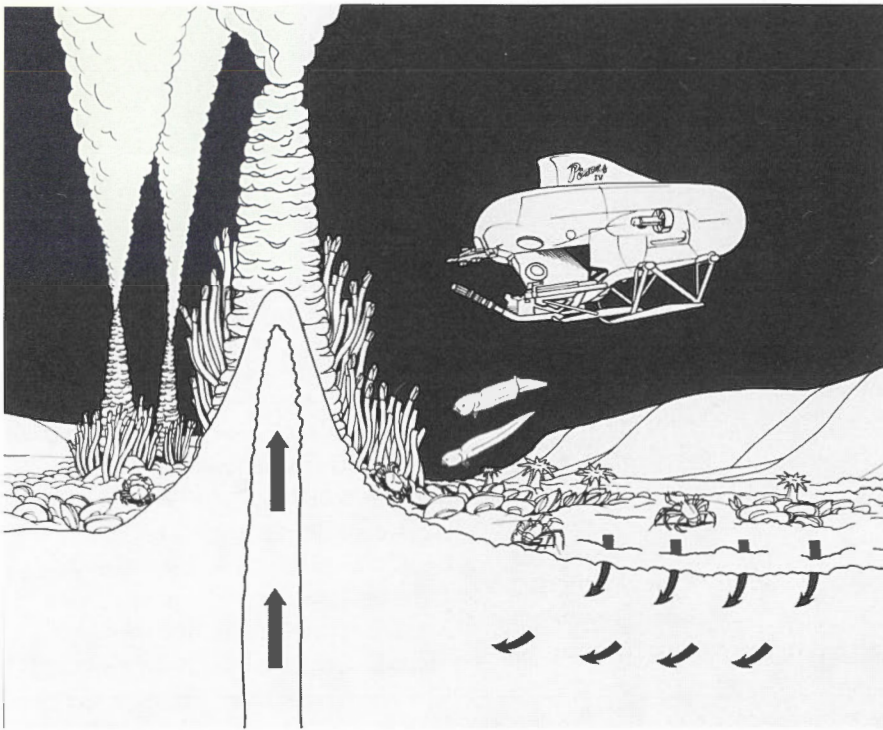
Prairie Kimberlite Study — Indicator Mineral Geochemistry by L.H. Thorleifson, R.G. Garrett and G. Matile (GSC Open File 2875**).

Biogeochemical Survey over Kimberlites in the Kirkland Lake Area, Northeastern Ontario by M.B. McClenaghan and C.E. Dunn. (GSC Open File 3005*).

Till Geochemistry, Lac de Gras, District of Mackenzie, Northwest Territories by B.C. Ward, L.A. Dredge and D.E. Kerr. (GSC Open File 2868*).

* Ordering information for these items available from Ashley Reproductions (613) 235-2115.

** Order from the GSC Bookstore, see page 31 for address.



Hot hydrothermal discharges at the seafloor produce dense clouds of "smoke" and form tall structures of metal-rich precipitates.

LESSONS FROM THE SEAFLOOR GUIDE MINERAL EXPLORATION ON LAND

The GSC has been involved in the study of hydrothermal systems and related mineralization on the modern seafloor since the early 1980s. The effort began as a resource potential assessment in support of Canada's claim of sovereignty over its offshore areas, but quickly blossomed into an internationally recognized program of research on the processes that form volcanogenic massive sulphide deposits.

Massive sulphide deposits are widely distributed in different geological environments in Canada, and they are our single most important deposit type in terms of value of production. Active hydrothermal systems on the seafloor provide a rare opportunity to study in "real time" the ore-forming processes that would have shaped the ancient, now land-based, deposits. Application of this improved understanding of how volcanogenic massive sulphide deposits form will enable us to develop better exploration guides.

The research has had many significant milestones including the discovery and exploration of actively forming massive sulphide deposits in Middle Valley on the Juan de Fuca Ridge, culminating in the drilling of these deposits by the international Ocean Drilling Program Consortium in 1991. Middle Valley now ranks as the world's principal "natural laboratory" for the study of submarine hydrothermal systems.

the nickel ores occur within an extensive ultramafic sequence and, moreover, two distinct belts of ultramafic volcanic rocks have been identified. These scientific advances provide an improved stratigraphic context for nickel exploration in the district.

Research should stimulate exploration in the Canadian Shield

The major copper mines of the Cordillera of North and South America are known as porphyry deposits and are usually linked to the Tertiary period. Research undertaken with the Ministère des ressources naturelles du Québec has provided definitive proof that porphyry mineralization in the Chibougamau district of northern Quebec is not only an integral part of the ore-bearing system responsible for the productive copper-gold vein deposits, but also is of Archean age. This demonstrates that contrary to conventional wisdom, Archean porphyry deposits can occur, a fact with wide-ranging implications for exploration in the Canadian Shield.

Keewatin gold similar to important Brazilian deposits

Research in the Keewatin district of the Northwest Territories has revealed that widely distributed gold mineralization is significantly younger than the iron formation in which it occurs. This so-called Meliadine Trend is comparable to gold districts

in the the famous Quadrilatero Ferrifero in Brazil and indicates that this part of the Canadian Shield has a higher potential for gold than previously appreciated.

Seafloor analogues for gold in Canada

During more than 10 years of research of hydrothermal systems on the modern seafloor, the GSC has focussed its efforts mainly on the massive base metal sulphide deposits which form in deep water environments. In the course of this work, GSC scientists have observed that volcanic and hydrothermal activity also occur in the shallow marine environment, but mineral deposits had not been recognized. In 1994, GSC scientists, working with colleagues from Germany, the United States and Australia, discovered the first known example of shallow gold bearing veins on the modern seafloor near the island of Lihir in Papua New Guinea. This will not only shed light on the origin of the giant Ladolam gold deposit on Lihir but, more importantly from the Canadian standpoint, provide new clues in the exploration for deposits similar to Selbaie in the Canadian Shield and to Eskay Creek in the Canadian Cordillera.

Exploration for nickel and copper on Victoria Island

The potential for important nickel, copper, platinum group metals and

diamond deposits has been recognized in mafic intrusions on Victoria Island, Northwest Territories, located in a region first mapped by GSC at a reconnaissance scale (1:1,000,000) in 1959. Victoria Island has a similar geological setting to the giant Ni-Cu-PGE deposit of the Norilsk area of Russia. Currently there are more than 20 million hectares in this area under permit for mineral exploration. To assist companies in targeting their prospecting ventures, GSC began geological mapping of the area in greater detail (1:50,000 scale), and data obtained this year from four highly prospective map sheets were released in colour Open File map format.

New technology for deep mineral exploration

To meet the challenge of developing enhanced geophysical tools for exploration to depths attainable with current mining techniques, comprehensive physical rock property studies of Canadian mining camps were conducted under the GSC's Industrial Partners Program. These studies provide the basis for three-dimensional seismic imaging, a technique similar to medical ultrasound imaging and originally developed for hydrocarbon exploration in sedimentary basins. Recent GSC studies indicate that 3-D seismic techniques can be adapted to the hard rock environment of the Canadian Shield — a premise that will be tested in the coming year.

A cost effective approach to geochemical exploration

Stream and lake sediments, soil and glacial till have been the most common sample media used for geochemical exploration in Canada. Advances in analytical chemistry are making it feasible to use water more routinely as a sample medium in geochemical exploration surveys. Water sampling and analytical protocols for use in permafrost terrains, developed under an Industrial Partners Program project with BHP Minerals Canada Ltd., effected dramatic savings in sampling time and field costs as compared to conventional lake sediment surveys.

Refining base metal exploration tools

GSC and Cominco Ltd. are jointly studying potential exploration tools that would identify new sulphide reserves around the Polaris lead-zinc deposit in the Northwest Territories. The immediate objective of the partnership is to perfect an exploration model applicable to the area based on petrographic, geochemical, and microthermometric criteria. This would not only help develop viable exploration strategies in this important Arctic mining district, but improve Canadian expertise in exploration technology.

Focus on: Marine Geoscience

Canada has one of the world's longest coastlines. Offshore territories (including the Great Lakes) comprise almost 40% of the country's total area. Valuable hydrocarbon, mineral and biological resources are located within the diverse, sensitive ecosystems of these offshore territories. Many coastal areas are densely populated: 80% of Canada's population lives within 100 kilometres of an ocean or a Great Lake.

Understanding the geoscientific properties of marine environments is a necessary starting point when making rational decisions about the management of these coastal and offshore areas. The basic and applied research of GSC's national marine geoscience program provides baseline knowledge, methodologies and assessments that are relevant to today's economic, resource and environmental issues. The program operates out of GSC Atlantic (formerly the Atlantic Geoscience Centre), located at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia, and maintains a regional presence at GSC Victoria (formerly the Pacific Geoscience Centre), located at the Institute of Oceanographic Sciences in Sidney, British Columbia.

Since the federal government has sole responsibilities for sovereignty and international obligations and is responsible for all marine areas beyond three miles from the coast, the GSC works in cooperation with other federal departments through the Interdepartmental Committee on

Oceans. There is also effective partnership between departments with complementary objectives through the National Action Committee on Ocean Mapping and the Federal Action Plan on Marine Environmental Quality.

Indeed, much of GSC's marine work is done in collaboration with various levels of government, industry, universities and other interest groups. This sharing of costs, data and expertise enables GSC to effectively and efficiently carry out its research. Marine geoscience work can be divided into three interrelated themes.

Marine Regional Geoscience

GSC collects baseline geological and geophysical data about the subsea bedrock and surficial materials of Canada's offshore territories. This contributes to an understanding of the evolution of the continental margins and the basins they contain. Scientists can use this information to develop new hydrocarbon and mineralization models, which can then be applied to analogous or adjacent settings on land.

In 1994, data gathered from GSC marine surveys were used in several significant projects. With its unique capabilities in handling and combining large sets of data, GSC brought together data collected from more than 1,000 aeromagnetic and ship-borne magnetic surveys conducted by 40 agencies

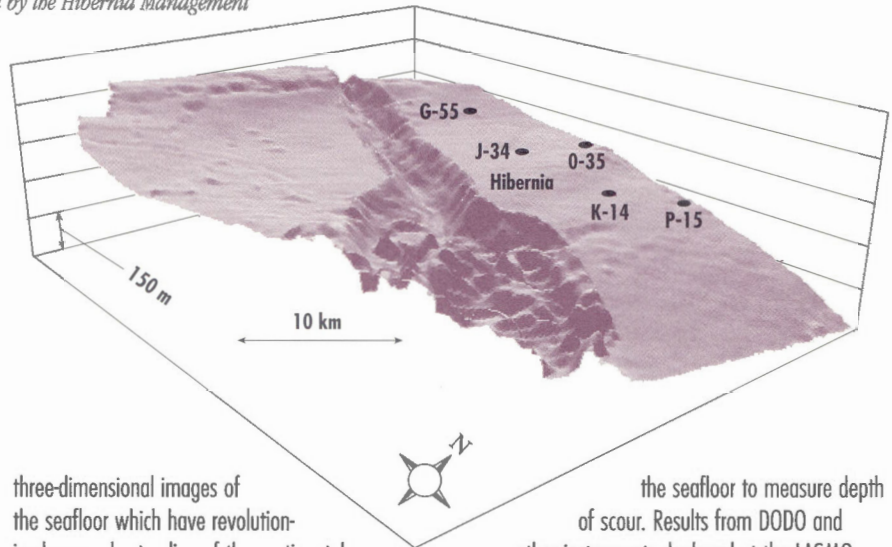
from 15 countries in order to produce the *Magnetic Anomaly Map of the North Atlantic and Arctic Oceans*, which will be released as a CD-ROM with an accompanying report. This reconnaissance scale image helps scientists reconstruct the history of plate movements and determine the location of sedimentary basins.

In another application, two decades of regional mapping of Canada's offshore territories were synthesized in a report that will help Canada formulate a position on its participation in the United Nations Commission for the Law of the Sea. The report outlined what is known about Canada's territorial boundaries and associated resources and what work still needs to be done. The Law of the Sea could potentially add new economic zones to Canada's territory totalling 1.75 million km² beyond the 200 nautical mile limit.

Marine Resources Geoscience

GSC investigates the geology, structure, tectonic evolution and hydrocarbon generation of sedimentary basins to evaluate their oil and gas potential. As the national repository for data about offshore basins (GSC recently received major data donations from Husky and Petro Canada), GSC scientists, often working in partnerships, use this information to develop a conceptual framework that stimulates exploration by industry.

Shaded relief image of a seismic horizon revealing a 60 million-year-old (Paleocene age) submarine canyon formed by mass movement processes on a paleoslope. The canyon was a major conduit for sediments moving from a stable shelf to the ocean floor. This surface, now buried approximately 1.5 km below the seafloor, lies above the oil producing horizons at Hibernia oil field. It was mapped on GSC Atlantic's client facility workstations using 3-D digital seismic data donated by the Hibernia Management and Development Corporation.



Basin modelling targets the details of individual basins, using combined industry and public domain data. The Hydrocarbon Charge Modelling Project, a joint industry/government/university effort, continues to develop data processing and visualisation technology for the analysis of sedimentary basins. Information and newsletters about the project were made available on the World Wide Web, giving the project an international presence. WWW users can also try out a demonstration of GSC's petroleum exploration database (BASIN), which contains a wealth of geological, geophysical and engineering information accumulated over 25 years of petroleum exploration off Canada's east coast. WWW access is <http://agcwww.bio.ns.ca/hcmp/hcmp.html>

Marine Environmental Geoscience

GSC scientists study geological processes and sediment properties along the coast, in the near-shore, and on the continental margin to determine environmental processes, and both the constraints to and impacts of development.

As part of the Ocean Mapping Program, GSC recently completed a four-year initiative to convert seismic, sidescan sonar and bathymetric acquisition systems to digital technology and has been applying these techniques to environmental and engineering questions. Combined resources of the GSC, the Canadian Hydrographic Service, University of New Brunswick and industrial partners have developed the ability to create high resolution

three-dimensional images of the seafloor which have revolutionized our understanding of the continental shelf. This technology has been applied to studies of mine subsidence in shafts extending under the sea off Cape Breton (working with CANMET) to provide knowledge necessary for mine safety and mine planning, with telecommunication (MT&T, Newfoundland Tel) and hydro companies (BC Hydro) to assist in cable routing and design, and with other government departments to assess impacts of trawling, dredging and dumping.

The unique challenges posed by the marine environment when it comes to gathering geoscience information often spur the development of new technology. Industry's need for sediment transport information to ensure the safety of structures such as oil rigs and pipelines combined with GSC's long-term sediment transport research has resulted in several innovative marine monitoring technologies. The latest is DODO (Depth of Disturbance Observatory), an *in situ* instrument installed at

the seafloor to measure depth of scour. Results from DODO and other instruments deployed at the LASMO Nova Scotia Ltd. oil production site on the Scotian shelf have been used by the company to monitor sediment transport around the production platform and by GSC to develop new sediment transport models for the Scotian Shelf. Ongoing work with LASMO, conducted under IPP and PERD (Program on Energy R&D), has kept GSC at the forefront of global research into seabed stability.

GSC, working in collaboration with many different partners, also provides baseline data of coastal and offshore areas that can be used for the development of concepts which help us understand marine geological processes over a variety of scales (ranging from the movement of sand grains to the movement of the continental margins). This knowledge can be applied to resource exploration, assessment of environmental hazards and environmental protection.

ENERGY

Fossil fuels (oil, gas, coal) are one of the key engines of Canada's economy and a fundamental support to the high standard of living Canadians enjoy. The GSC provides basic geological information and research on the nature and origin of structures and trends that may be prospective as fossil fuel deposits. This enhances exploration and development success in Canada's \$27 billion per year energy industry. Mapping and offshore seismic analysis on the west coast of Newfoundland, for example, led in 1994 to renewed drilling on the Port au Port Peninsula, with encouraging initial results.

GSC's objective assessment of Canada's undiscovered fossil fuel potential, much of it in the offshore continental shelves, is also useful for environmentally sound policy formulation and planning. For example, computer models and resource assessments of Canada's coal resources, built up over a period of 10 to 20 years, maximize the competitiveness of the industry and provide a sound basis for policy decisions to minimize the environmental impact of coal use.

The methodology developed by the GSC for geologically based, play-by-play assessment of petroleum potential — the Discovery Process Model, embodied in the PETRIMES technology — was released for general distribution in 1994. A number of

Canadian and foreign government agencies and private sector firms have picked up the technology and are using it for their specific applications.

Over 700 energy companies operate in Canada and they are the main users of GSC's energy resource information. They use GSC data and reports in more than 10,000 projects, studies or internal reports each year. Other clients include universities, environmental groups, the public and various levels of government. GSC's expertise is even called upon to solve forensic problems. The RCMP has used the GSC's organic geochemical expertise to identify sources of spilled crude oil.

Western Newfoundland petroleum drilling

Work done by GSC scientists, in cooperation with industry, the provinces and universities, contributed to the drilling of the Hunt-PanCanadian Petroleum Port au Port No. 1, a reported oil discovery well in western Newfoundland. The well may signal the beginning of a new Canadian petroleum province. The GSC work involved a reinterpretation of the structure of this area that showed it to be similar to some Alberta foothills hydrocarbon structures. It also included an examination of the area's

petroleum potential through an investigation of oil seeps and their source rocks.

Exploration in Laurentian Channel

As part of the Industrial Partners Program, GSC and Mobil Oil of Calgary carried out research to study the southern reaches of the Laurentian Channel between the Scotian Shelf and the Grand Banks. Until recently, under a moratorium to exclude petroleum exploration in an area of a now-resolved boundary dispute with France, this has been one of the least explored areas of eastern North America's continental shelf. The project's primary objective was to map and sample pockmarks (saucer-like depressions in the seafloor formed by the escape of liquids and gases from underlying sediments) that could indicate the presence of hydrocarbon deposits. Mobil approached GSC after seeing GSC's *Scotian Shelf Basin Atlas*, published in 1991, which showed pockmarks in the channel area.

LITHOPROBE survey in Peace River Arch

GSC and 25 industry partners conducted one of the most successful LITHOPROBE surveys ever. The Peace River Arch Industry Seismic

Experiment (PRAISE) extended 627 km from Dawson Creek, British Columbia, to Entwistle, Alberta. The goal was to better understand the role of the crystalline basement in the tectonic evolution of the Peace River Arch, a region of significant anomalous uplift and subsidence in the Western Canada Sedimentary Basin, and an area of very active hydrocarbon exploration. Data acquisition parameters were significantly enhanced relative to previous LITHOPROBE surveys, and the data were recorded for the first time to specific industry standards. In addition, leading edge integrations of multidisciplinary studies involving electromagnetics, potential fields, geochronology and geochemistry are being conducted throughout Alberta in cooperation with LITHOPROBE, university and industry researchers to unravel the tectonic evolution of the basin and underlying Precambrian basement.

Western Canada Sedimentary Basin research

Working with 13 industrial partners, GSC continued to collect, analyse and publish data that clarifies the relatively enigmatic relationship between the well-established Lower Paleozoic strata of the Rocky Mountains and the more poorly

INDUSTRIAL PARTNERS PROGRAM GETS TOP MARKS

A study conducted by an independent consultant showed that GSC's Industrial Partners Program (IPP) is highly effective in helping Canadian resource-based industries compete globally, in fostering working relations between GSC and industry, and in enhancing GSC's response to client needs.

The IPP began in 1992 as a way for GSC to undertake research projects of direct interest to one or more Canadian companies, with active participation of those companies in the research activities and a sharing of the project costs.

Economic impacts from the 26 industrial partners surveyed for the study include revenue generation for new product/service development, discoveries for exploration-related research, and cost reductions and impacts on revenues for environmental research. So far, \$3 million has been realized and a further \$144 million is anticipated over the next five years. These figures compare favourably to the \$3.96 million investment in the projects (\$1.99 million by GSC and \$1.97 million by the industrial partners).

Of the partners surveyed, 95% reported that the IPP enabled them to do R&D work that would not otherwise have been done, and 93% reported that GSC's participation was critical to the success of the project.

For more information on the Industrial Partners Program, contact:

Business Office
Earth Sciences Sector
615 Booth St.
Ottawa, Ontario K1A 0E8
Telephone: (613) 992-8916
Fax: (613) 992-9760

GEOSCIENCE LABORATORIES

Delta-Lab



The isotopic geochemistry laboratory of GSC's Québec Geoscience Centre analyzes stable isotopes of hydrogen, carbon, nitrogen and sulphur using PRISM-VG, Isotech, SIRA-12, GC-COMBUSTION-Prism, auto-water for oxygen and extraction lines for water, carbonates, sulphides, sulphates and organic matter.

With this equipment, the laboratory is able to cover the entire range of stable isotopic tracers applied to hydrogeological, environmental, metallogenic, diagenetic and sedimentological studies by analyzing the isotopes of water, reagent hosts and dissolved components.

For further information, contact:

Martine M. Savard
Québec Geoscience Centre
Geological Survey of Canada
2535, boul. Laurier
C.P. 7500
Sainte-Foy, Québec
G1V 4C7
Telephone: (418) 654-2634
Fax: (418) 654-2615
Internet: savard@gsc.emr.ca

Geochronology Laboratory

GSC's Geochronology Laboratory specializes in age dating and isotope microanalysis using U-Pb, Sm-Nd, Rb-Sr and Ar-Ar radiogenic systems. It is especially known for its development of innovative age-dating techniques to resolve new problems in geological mapping and timing of tectonic and mineralizing events. Advice from laboratory staff and use of its state-of-the-art facilities are available to clients in Canada and abroad.

A sensitive high resolution ion microprobe was installed in January 1995. One of only a half dozen in the world, the ion microprobe

broadens the spectrum of geoscience questions that the GSC can address. For more information about the services available and costs, contact:



Isotope analysis using a solid source mass spectrometer



Selecting zircon grains to undergo age determination

Geochronology Laboratory
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario
K1A 0E8
Telephone: (613) 995-8785
Fax: (613) 995-7322
Internet: ovanbreemen@gsc.emr.ca

Charges may apply

known strata of the subsurface of Alberta. The research provided a greater understanding of the nature and distribution of source rocks and reservoirs and their potential for hydrocarbon generation and preservation within the Middle Cambrian to Middle Devonian interval. No potential source rocks were found in the Cambrian, but the Middle Devonian was found to be extremely well-endowed with such rocks and new reserves will likely be found by explorers in the coming years. This work was funded under the Industrial Partners Program, and a new IPP project has been initiated to study the petroleum systems of the Devonian in the Western Canada Sedimentary Basin.

Another Industrial Partners Program project has GSC and Wascana Energy Inc. working together on a multi-phase regional stratigraphic study of the Basin's Mannville Group, an area of record-breaking land sales and increased drilling activity. The main objective of the study is to provide a consistent regional stratigraphic framework for this prolific oil- and gas-bearing interval. Wascana's contribution to the study is in the form of funds as well as the sharing of data, materials and technical expertise. The first phase of the study, located in the oil-producing trend of southwest Saskatchewan, has been completed and the results were presented in January to over 800 members of

the Canadian Society of Petroleum Geologists and at the GSC's Oil & Gas Forum in March. Open file reports for Phase I will be available in the coming year, Phase II is nearing completion and Phase III is well underway.

Coalbed methane in Western Canada

Coalbed methane resources in Western Canada represent a vast untapped source of energy that only now is starting to attract significant attention from the oil and gas sector. An Industrial Partners Program project involving GSC and eight industrial partners investigated the relationship between the characteristics of coals and the related coalbed reservoir permeability. Each company contributed \$3,500 and received in return both primary and interpreted geological data valued at more than twenty times their contribution. The data are being utilized by the subscribing companies to assist their ongoing coalbed methane exploration activities.

Coal study looks at environmental impact

GSC, in partnership with several operators of coal-fired power plants in Canada (including TransAlta Utilities Corporation, Edmonton Power Limited, Nova Scotia Power

Limited), is studying the types and levels of elements in emissions from the plants. Results contribute to a better understanding of the impact on the environment of the development and use of Canada's coal resources. It also supports government and corporate goals of the industrial partners, enabling environmentally responsible development of the coal resources. TransAlta credits the study with maintaining an option to extend the operating life of its Wabamun Power Plant beyond the year 2000. An alternative option of rebuilding the plant would cost about \$1 billion. The study also demonstrated that power plants such as TransAlta are committed to environmental concern, and it has been a significant factor in the company's business transactions in India and New Zealand.

Coal resources in Nova Scotia

GSC's coal program, through the National Coal Inventory, has developed databases and computer models of the Sydney, Cumberland and Pictou coalfields in Nova Scotia. The computer models have been used by industry and provincial government agencies for resource assessment, regulation, optimization of land use and exploration planning. They have also been used as a predictive tool for exploration stemming from renewed interest in the coalbed methane resource possibilities in Nova Scotia.

Geophysical Data and Services

The Geophysical Data Centre provides user access to national aeromagnetic and gravity databases and supplies digital data, data processing and plotting services.

The National Aeromagnetic Database contains more than 11,000,000 line kilometres of regional total field survey data and high resolution detailed surveys. The aeromagnetic data have been levelled to a common datum, and levelled profile and gridded data are now available for eight provinces and the Northwest Territories. The National Gravity Database contains 650,000 gravity observations and 5,500 gravity control stations. Data are provided in a variety of formats in consultation with clients. Contact:

*Geophysical Data Centre
Geological Survey of Canada
1 Observatory Crescent
Ottawa, Ontario K1A 0Y3
Telephone: (613) 995-5326
Fax: (613) 992-2787
Internet: infogdc@agg.emr.ca
WWW: <http://gdcinfo.agg.emr.ca>*

ENVIRONMENT

To live in harmony with the environment, we must understand how our actions affect it and how, in turn, natural environmental processes affect us. We must also learn to distinguish between natural and anthropogenic (induced by human activity) global change. There is a geoscience component to all environmental problems and solutions, and the GSC is one of Canada's main sources of this expertise at the national level.

GSC has been involved in environmental assessments of Canada's most significant large projects such as the St. Lawrence Seaway, pipelines in the Arctic and, more recently, the Prince Edward Island landlink. It also participates in programs of national importance, such as the evaluation of various geological structures as secure disposal sites for low- and high-level radioactive waste.

Each year, GSC receives more than 3,000 requests for information about environmental constraints on development, land use and public safety. It gives the construction industry advice on seismic hazards, produces seismic zoning maps for the *National Building Code*, and documents the Earth's changing magnetic field throughout Canada to ensure that aviators and navigators have up-to-date compass information. The GSC also strives for a thorough understanding of the natural processes that

are active or can be triggered in a given area. For example, GSC provides independent assessments of landslide hazards and their role in railway accidents for the Transportation Safety Board of Canada.

Work on permafrost has identified natural hazards and led to changes in the design of oil and gas pipelines and furthered our understanding of the distribution of natural "gas" sources (hydrates) in the north. Understanding natural levels of elements such as lead, cadmium and arsenic provides a baseline against which to establish pollution standards and monitoring procedures.

The GSC also provides information on the impact of human activity on the environment, responding to more than 2,000 requests each year from governments, First Nations agencies, national safety boards and industry. GSC scientists reconstruct the history, document the present status, and predict the future trends of land, lake and ocean environments. This knowledge is vital to the prevention and remediation of such environmental concerns as toxic waste disposal, air and water pollution, ozone depletion and global warming.

A future Cascadia megathrust earthquake

The location of a future megathrust earthquake along Canada's southern West Coast and extending as far as northern California has been defined by a multidisciplinary study. Many types of data obtained by GSC researchers and others were modelled to produce this location, the landward limit of which is just offshore but near enough to affect Vancouver, Seattle and Portland and, according to insurance industry estimates, to cause 300 billion dollars worth of damage. This year the modelling techniques and assumptions have been successfully tested by predicting the extent of previously recorded subduction earthquakes in Japan and Chile.

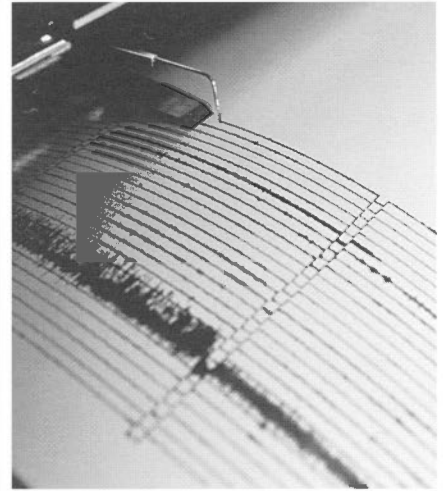
Fraser Delta research

GSC released for the first time details of the morphology of the (Tertiary) bedrock surface below parts of the Fraser Delta, an area that GSC research has shown to be periodically

subject to large earthquakes. The bedrock surface is much more variable and deeper than previously thought. This information is of critical importance for the evaluation of the ground-surface motion and the potential for ground liquefaction during earthquakes. The data are being used for detailed modelling and will improve building design and land use zonation in this densely populated area. They will also be important input to emergency preparedness planning. GSC marine surveys in the offshore Fraser Delta are aimed at definition of seafloor hazards to coastal infrastructure and seabed engineering.

Ice core circumpolar Arctic project

GSC has taken the lead in the creation of an international Ice Core Circumpolar Arctic Project. With our international partners, the first arctic glacier considered for this project (Penny Ice Cap, Baffin Island) was cored, and the first suite of snow and



Mineral Resources Canada

New seismic hazard estimates:

The GSC released new estimates of seismic hazard for Canadian cities. These update the third generation seismic hazard maps which the GSC supplied for the current National Building Code of Canada, and they are intended for trial use by the engineering community, prior to being recommended for the year 2000 building code. Providing earthquake-resistant design in new buildings is one of the most cost-effective ways of mitigating future earthquake damage.

ice samples from across the Arctic were collected. This project has already enhanced our understanding of pollutants and their movement, as well as our understanding of longer-term regional climatic/environmental variability through time. This work is an important contribution to the study of global change.

HONOURS

The Northwest Territories Association of Professional Engineers, Geologists and Geophysicists chose GSC to be one of two recipients of its 1994 Award of Merit (the

ship *MV Arctic* was the other), which honours individuals or groups that have made a significant contribution to the development of the Northwest Territories.



Bonni Hryciuk

Ground ice in the north is a important factor to consider in land use. This exposed ice ridge is near Tuktoyaktuk, Northwest Territories.

Drought research in the Palliser Triangle

The frequency and natural variability of droughts is of critical importance in some areas of the world, as in the agriculturally important southern Prairies or Palliser Triangle. A GSC-led team is unravelling the details of the past history of the area and finding that droughts are the norm and not the rare event that we once thought. This has implications for long-term agricultural practice and policy in this area.

Landslide hazards research

Many regions of Canada are prone to landslides, which can have devastating impacts on the economy and on lives. For example, the Vancouver to Squamish highway has been closed or partially closed by 14 relatively small failures since 1906. An understanding of the geological processes and controls on landslides is required

for proper land use planning. GSC provides the regional context for understanding and dealing with these failures. GSC expertise has been used in transportation agency enquiries on train derailments caused by landslides, routing of development away from high hazard areas, and assessing the overall hazard to enable sound development strategies. In cooperation with the provinces, GSC has expanded its landslide program.

National geological hazards synthesis

A new initiative, the National Geological Hazards Synthesis Project, will amalgamate the diverse range of GSC geological hazard data and present it in a single CD-ROM package. Geological hazards information will be presented at the national scale and will comprise catastrophic hazards (e.g. earthquakes and seismicity, landslides,

and volcanoes) and hazardous conditions (e.g. sea level change, permafrost). The CD-ROM will be of particular interest to groups from all sectors involved in emergency planning and preparedness and to land use planners.

Surveys look at the Great Lakes

A collaborative project to conduct high resolution geophysical surveys of the Great Lakes, involving GSC, the Atomic Energy Control Board (AECB), Ontario Hydro, industry and universities, was completed. The study examined faults running across the lake bottom to determine if movement on the faults was recent or active. The study helped Ontario Hydro and AECB make informed decisions about nuclear safety and about planned upgrades and retrofitting of nuclear power stations.

Hydrogeological project linked to sound land management

A hydrogeology project involving the GSC and the Quebec Department of Environment and Wildlife was launched this year in the Portneuf area of southern Quebec. Its goal is to demonstrate the importance of multidisciplinary knowledge of the physical environment to sound land management. For example, knowledge of the regional geology, hydrogeological units and their hydrological properties, and regional flow is essential for evaluating groundwater quality and for managing groundwater with a view to sustainable development.

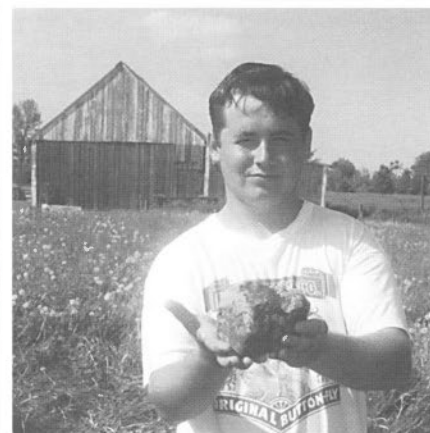
Defining climate change with geoscience

Canadians, including GSC researchers, and others have developed methods to use geothermal data from boreholes drilled hundreds of metres into the earth to obtain a record of past surface temperatures. Geothermal data were gathered in Canada initially to study crustal temperatures for other purposes such as tectonics, the maximum depths of earthquakes, the strength of the lithosphere, geothermal energy, detection of water flow and radioactive waste disposal. Now

they are being used to define past climate change. In eastern Canada temperatures a century ago were 1-2 degrees colder than average, and have increased until now they are 1-2 degrees warmer than average. Climatic warming varies across the country, decreasing towards the West Coast.

Gas hydrates in marine sediments

Some sediments on the ocean floor contain large amounts of methane, a clean fuel resource with potential for the future. Climatic warming, however, could release it to the atmosphere and because methane is such an effective "greenhouse gas", this would accelerate the warming trend. GSC studies of the nature and distribution of gas hydrates and the processes concentrating the gas, thus forming the hydrates, were carried out off Vancouver Island. Japanese interest in methane as a domestic energy source has resulted in their funding a joint project with the GSC and the University of Victoria.



Richard Heald

EXTRATERRESTRIAL EVENTS

Canadians were reminded that the Earth does not exist in isolation in the solar system, when fragments of a meteorite fell near Montreal on June 14, 1994. GSC scientists were involved in the highly publicized recovery efforts of what is now called the St-Robert meteorite. A piece of the meteorite, which was located within hours of its fall by Stéphane Forcier (above), was identified and acquired by the GSC for short-lived isotope determinations. The meteorite was subsequently added to the National Meteorite Collection, which is maintained by the GSC for scientific study and display.

On a larger scale, the spectacular impacts of pieces of comet Shoemaker-Levy into Jupiter in July emphasized that such large events could also pose a hazard on Earth. From studying the ancient record of impact cratering in Canada, GSC scientists have contributed to quantifying the hazard potential of impact.

In the same vein, cooperative studies with Mexican geoscientists continued at the approximately 200 km diameter Chicxulub crater, in the Yucatan, Mexico, which was likely responsible for a mass extinction within the biosphere 65 million years ago. These studies are co-funded with the Pan-American Institute for Geography and History and are focussing not only on how the impact event affected life, but also on how the crater affects the local water supply.

INFORMATION

A fundamental responsibility of the GSC is to make the results of its research available to all Canadians. By using the latest technology, GSC's Information Program delivers these results to clients and the public in a variety of formats and with increasing speed and efficiency.

A major scientific publisher, each year the GSC produces an average of 40 publications (totalling about 7,500 pages), 50 full-colour maps, over 150 Open File releases (averaging more than 12,500 pages, 500 map sheets and 120 geophysical plots), and digital files. Publications written for general audiences, such as the *Rocks and Minerals for the Collector* series, are also very popular.

GSC has a skilled cadre of cartographers whose work with the scientific staff and sophisticated mapmaking technology, allows for an increasingly faster turnaround of field research results into maps. This in-house cartographic capability is regarded internationally as a benchmark operation. Ireland, Sweden and Mexico are just some of the countries that have consulted GSC when setting up their own cartographic systems. Canadian mining exploration companies have also called on GSC for advice.

Making the most of new technology, GSC specializes in providing information in the format that most suits

clients' specific needs, including CD-ROM or customized data products. Information is also accessible through a number of channels. GSC's Information Centre, libraries, bookstores and service links provide the public with walk-in access to the GSC's resources and products. Databases, library catalogues and general information can also be accessed electronically via the Internet and other on-line services. Workshops, training courses, educational outreach programs and guided tours of Logan Hall (the GSC's museum at 601 Booth Street in Ottawa) are some of the many ways in which GSC scientists bring their knowledge directly to Canadians.

Coming soon: Virtual Geology

As part of the Industrial Partners Program, GSC worked with PCI Incorporated, a company selling remote sensing analysis software, to produce a three-dimensional fly-through software tool for use in the interpretation of geological field data. This method is especially useful for visualizing geological data when it is integrated with geophysical, satellite or contour information. The visualization technique was then extended using Virtual Reality technology, and will eventually be used to "explore" geological formations.

GSC-Links opened for Toronto and Winnipeg clients

In December following client consultations, GSC opened a service link in Toronto to better serve the large population of GSC clients in an area where GSC does not maintain an office. Co-located in the Ontario Mines and Minerals Information Centre, GSC-Link provides kiosk access to GSC information. It consists of a computer terminal linked to the GSC gopher and a display of current releases, maps and CD-ROM products of interest to Toronto-area clients. Consultations with Winnipeg clients have led to a second GSC-link there, and more are planned for other cities.

Communicating with the next generation

As an ongoing corporate commitment, GSC maintains a program of educational outreach to students. Twin goals are to encourage interest in the geosciences as a career option and to increase geoscientific literacy



Patricia Hunt

About 1,500 people took part in school tours, evening lectures and a family fun day put on at GSC in Ottawa to celebrate National Science and Technology Week in October 1994.

in young people. Funding for these activities is limited, but fueled by the enthusiasm and commitment of GSC staff across the country, the program meets with great success. Some highlights for 1994-95 include:

- the release of a new teaching poster "Gemstones"
- the sponsorship of an interpretative plaque about the geological evolution of the Fraser River Delta at the Fraser River Discovery Centre
- planning and leadership of intensive, hands-on geoscience workshops for teachers in Halifax and in the Outaouais region of Quebec as part of the national EDgeo program run by the Canadian Geoscience Council.
- two field trips designed to build teacher awareness of local geology organized by GSC Vancouver; the accompanying guidebook is available as a GSC Open File.
- celebrations of National Science and Technology Week and its Quebec equivalent, *La Quinzaine des sciences*, at GSC offices in Ste-Foy, Ottawa and Calgary.
- recognition by the publication, *The Canadian Internet Advantage*, of GSC Atlantic's "Geology in the Classroom" as an excellent Internet educational resource.



Improved access to GSC experts

GSC's Canadian Geoscience Information Centre created and maintains a database containing information on the experience and expertise of GSC scientists. The *GSC Directory of Specialists* is available on the Internet. Gopher: emr1.emr.ca, select: NRCan-Info/Geological Survey of Canada/Information Centre/Databases WWW: <http://www.emr.ca/gsc/gicd/cgic/dbases.html>



Acanite Design

CYBERSPACE CONNECTIONS

Access to library catalogues, databases and information about GSC products, services and scientific research is available through a number of different on-line channels.

World Wide Web: <http://www.emr.ca/gsc/>
<http://agcwww.bio.ns.ca/>
(for GSC Atlantic)

Gopher: <gopher.emr.ca>:1235

National Capital Freenet: Access available to registered users only. Type "go gsc" at the arrow prompt.

Telnet: <geoinfo.gsc.emr.ca> for access to the Canadian Geoscience Information Centre catalogue, log in as "opac" and select VT100 terminal emulation.

Dial-in: Access to GSC's Canadian Geoscience Information Centre catalogue requires a modem and communications software that supports VT100 terminal emulation. The telephone number is (613) 947-5722 and the modem setup is: full duplex, no parity, 1 stop bit, 8 data bits. Dial-in access supports modems of up to 9600 baud. Once the connection is established, select CGIC Online and choose VT100.

Focus on: International Connections

The GSC is recognized internationally for its earth science expertise and is regularly called upon to provide advice to other nations engaged in establishing their own geological surveys or to participate in bilateral and multinational collaborative projects. This involvement ensures Canadian geoscientific input and often leadership into social, economic and environmental issues of national and global concern.

Through good working relationships with other national governments, GSC is seeking to promote the products and services of Canada's geoscience industries abroad and stimulate contacts between Canadian companies and foreign governments.

The South American "Borders" project
GSC scientists, working with the British Columbia Geological Survey and private consultants, completed a \$200,000 feasibility study for the Interamerican Development Bank (IDB) to define a four-country geoscience mapping project in South America. The proposed \$(US)20 million Multinational Andean Program, to be funded by IDB, would be conducted over five years by the national geological surveys of Argentina, Bolivia, Chile and Peru in areas of shared national boundaries. The IDB invited GSC to develop the work plan based on its established record in carrying out similar mapping and resource assessments in Canada. GSC's involvement may mean

opportunities for supervisory and consulting contracts for public and private Canadian geoscience agencies.

Mining project in Brazil

GSC, CANMET (also part of Natural Resources Canada) and the Canadian International Development Agency (CIDA) developed a proposal for a multidisciplinary Mining Sector Project in Brazil to start in 1995. GSC's role will be to carry out training and technical assistance for the CIDA-funded project. Through consultations with counterpart institutions in Brazil, the three Canadian organizations have started to develop comprehensive project proposals. The objective is to develop long-term linkages between Canadian and Brazilian institutions and companies in the minerals sector and to promote cooperation in areas of mutual benefit.

Magnetic anomalies and tectonic elements of Northeast Eurasia

In a project sponsored by Oklahoma-based Conoco Inc. and managed by GSC Atlantic, a multinational team of geoscientists (representing Russia, China, Mongolia, the U.S.A., the U.K. and Canada) pooled their information to develop a combined magnetic and tectonic map of Russia, China, Mongolia and adjacent marine areas. Encompassing about 25% of the world's land area, the map offers an unprecedented illustration of major geological

FOCUS ON



Steve Evans

The Kobe Earthquake: As part of the assistance offered by Canada to Japan after the Kobe earthquake in January 1995, a GSC scientist worked in Kobe for three weeks immediately after the event. He provided an assessment of the landslide damage caused by the quake and offered advice on slope stability and further landslide potential in the area. All his expenses were paid by Foreign Affairs, with travel support donated by Air Canada.

structures and their magnetic expressions in a region with a complex crustal history. By outlining the scope of continent-wide processes that affected mineralization, it provides a broad framework for

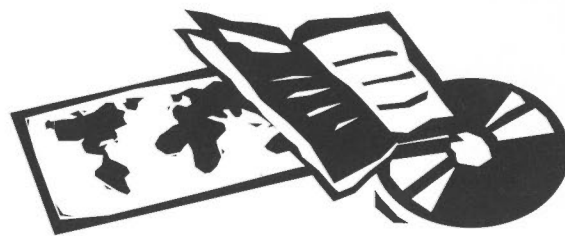
exploration and resource assessment. Prepared on the computer facilities of Conoco Inc. and GSC Atlantic, the map features textual material in Russian, Chinese and English and is available as a GSC Open File (No. 2574).

New bilateral agreements

New Memoranda of Understanding (MOU) under development or signed during 1994-95 were with the geological surveys or equivalent agencies in Poland, Ukraine, Brazil, Argentina and Mexico. The existing agencies in Argentina, Brazil and Mexico are in transition from a semi-commercial status with direct involvement in mining to a truly "national" geological survey. The GSC is being asked for advice and assistance in setting up the appropriate structures and procedures to accomplish this. The GSC also established new MOUs with two regional organizations with specific responsibilities in marine geoscience — SOPAC (South Pacific Applied Geoscience Commission) and CCOP (Coordinating Committee for Coastal and Offshore Geoscience Programs in East and Southeast Asia).

Swedish delegation "benchmarks" GSC

The Director General of the Geological Survey of Sweden and four senior managers visited the GSC in April 1994 to carry out a "benchmarking" review (i.e. to compare efficiency and productivity of their organization with the GSC). They were particularly interested in developments in geological mapping and cartography, and in how GSC has implemented digital methods to make substantial improvements in the efficiency of data collection, processing and output of the final product.



*The Geological Survey of Canada publishes its research in a wide variety of scientific journals and commercial publications. It also has an in-house publishing capability and sells both print and digital products. GSC's Canadian Geoscience Information Centre provides reference service to the complete output, including GSC's extensive annual map production (see *Cyberspace Connections*, page 24 and the *Directory*, page 31). A selection of priced products published by the GSC in 1994-95 follows.*

Geology and Geological Hazards of the Vancouver Region, Southwestern British Columbia

edited by J.W.H. Monger

This volume summarizes existing geoscience information on the Vancouver region and synthesizes it with newer research results. Topics include: the geology of bedrock and surficial deposits, earthquakes, volcanism and landslides, geological hazards associated with the Fraser River delta, and groundwater and trace element distribution in the region. (GSC Bulletin 481). \$23.95 in Canada, \$30.95 outside Canada.

Triassic Gas Resources of the Western Canada Sedimentary Basin, Interior Plains

by T.D. Bird, J.E. Barclay, R.I. Campbell, P.J. Lee, R.R. Waghmare, S.M. Dallaire, and R.F. Conn

Natural gas resource potential of Triassic strata in the Western Canada Sedimentary Basin (excluding the Foothills Belt) was evaluated using a combination of geological play analysis and statistical estimation. Triassic strata belong to a platformal succession of mixed siliciclastic, carbonate, and evaporite sediments deposited along the western portions of the basin. The thickest deposits, and most of the oil and gas, occur in the westward thickening and deepening depocentre called the Peace River Embayment. (GSC Bulletin 483). \$12.95 in Canada, \$16.95 outside Canada.

Composition of Glacial Sediments in Canadian Shield Terrain, Southeastern Ontario and Southwestern Quebec: Applications to Acid Rain Research and Mineral Exploration

by I.M. Kettles and W.W. Shilts

Basic geoscience data can have applications on both the supply side and environmental protection side of the sustainable development equation. This report can, at the same time, assist mineral exploration while providing a pre-mining natural baseline of metals in the environment and an evaluation of the landscape's sensitivity to acid rain. (GSC Bulletin 463). \$7.25 in Canada, \$9.45 outside Canada.

Contributions to Canadian Paleontology

by T.E. Bolton, B.S. Norford, S. Desbiens, H. Kurita, and D.J. McIntyre, J.M. White, L. Marinovich, Jr., and R. Higgs

This volume contains five papers with studies ranging from Late Ordovician to Late Miocene. Studies such as these are essential for determining the stratigraphic relationships between strata in different depositional basins in North America. Because many of these basins contain oil and gas deposits, precise correlation has important economic implications. (GSC Bulletin 479). \$11.75 in Canada, \$15.30 outside Canada.

Quaternary Geology, Cape Breton Island, Nova Scotia

by D.R. Grant

Cape Breton's unique landscape and natural resources make it an important target area for Nova Scotia's minerals industry and its prime tourist region. This report describes and explains the unconsolidated surface materials and landforms of Cape Breton Island. The information is of use for land-use planning, public education, mineral exploration in drift-covered areas, groundwater extraction, waste disposal and the assessment of the potential for large-scale reforestation. (GSC Bulletin 482). \$29.75 in Canada, \$38.70 outside Canada.

A Sampler of GSC Publications

Selected Geoscience Data for the Slave Province NATMAP Project, District of Mackenzie, Northwest Territories

compiled by C. Bowie

As described on page 5 (NATMAP Slave Province), this CD-ROM contains a collection of open files prepared and published by various authors. The data are provided in two common interchange formats (DXF and ARC/INFO.E00 format). (GSC Open File 2974). \$150.00 in Canada, \$195.00 outside Canada.

Stabilité relative des terrains meubles dans la région de la Petite rivière de la Baleine, Québec nordique

by C. Bégin, S.J. Paradis, M. Parent, and Y. Michaud

The relative stability of unconsolidated slopes in the region of the Petite rivière de la Baleine was assessed through the integration of geological and geomorphological data and information provided by the radial growth of trees. On the basis of that data, the area was divided into different environmental categories, which were assigned an instability index reflecting both current and potential situations. (Open File 2848). \$37.05 for report/\$48.15 outside Canada; \$15.00 for map/\$19.50 outside Canada.

Rocks and Minerals for the Collector: Northeastern Nova Scotia, Cape Breton Island, and Prince Edward Island

by A.P. Sabina

The latest volume in a popular GSC series, this book describes the occurrences of minerals, rocks, and fossils from 75 localities in northeastern Nova Scotia and Prince Edward Island. (GSC Miscellaneous Report 51). \$10.00 in Canada, \$13.00 outside Canada.

A Field Guide to the Glacial and Postglacial Landscape of Southeastern Ontario and Part of Quebec

compiled by R. Gilbert

This guide describes 20 sites between Peterborough, Lake Ontario and the Ottawa Valley. It sets the context with a general introduction to the geomorphic history and for some sites, particularly near Lake Ontario, the guide also deals with the impact of human activity on the environment. The descriptions are intended for a non-specialist audience and directions are provided for road travel to each site. (GSC Bulletin 453). \$8.50 in Canada, \$11.05 outside Canada.

Popular Geology, Québec

by T. Feininger, P. St-Julien and A. Bolduc

The geology of the Quebec City area, located at the crossroads of three major geological features and crossed by one of the largest rivers in North America, is unique. This brochure, which includes a geological map and description of sites of interest, invites the reader to discover the billion-year-old geological history of the area. \$4.65 (available from the Québec Geoscience Centre only, see Directory on page 31).

ORDERING INFORMATION

Publications and CD products may be ordered from the GSC bookstore in Ottawa or from our regional offices in Sainte-Foy, Calgary and Vancouver (see page 31 for addresses and inside back cover for order form). Prepayment is required by cheque or money order made out to the Receiver General of Canada. VISA and Mastercard are accepted.

All prices listed are in Canadian dollars.

ARCTIC LOGISTICS

Polar Continental Shelf Project

Polar Continental Shelf Project (PCSP) was created in 1958 in large part to help Canada establish, and subsequently to maintain, its sovereignty in the Arctic through peaceful means.

Over the years, it has done so by helping thousands of scientists work in otherwise inaccessible locations in the North and to learn about a region covering more than one-third of Canada's landmass and offshore — a region that stretches between Canada's borders with Alaska and Greenland up to the geographic North Pole. Those scientists have helped to define Canada's offshore limits and to establish Canada's claims to offshore hydrocarbon and mineral resources.

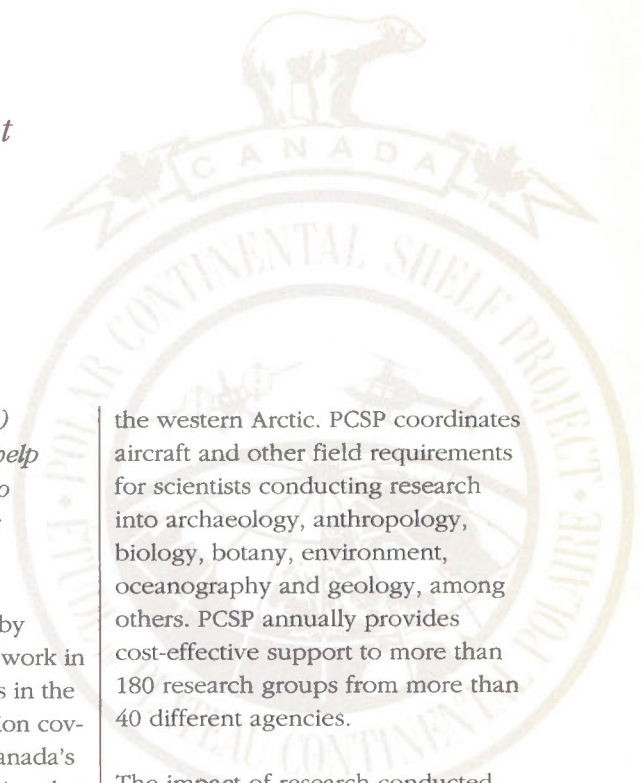
The knowledge gained by government and university scientists supported through PCSP's logistics network has also helped to identify safe shipping routes into northern communities, establish National Wildlife Areas and Migratory Bird Sanctuaries to protect and conserve wildlife habitats, identify pollution sources and their effects on the northern food chain, and to preserve and record the traditional knowledge of the North's aboriginal inhabitants.

The heart of PCSP's logistics system are its bases at Resolute Bay in the eastern Arctic and at Tuktoyaktuk in

the western Arctic. PCSP coordinates aircraft and other field requirements for scientists conducting research into archaeology, anthropology, biology, botany, environment, oceanography and geology, among others. PCSP annually provides cost-effective support to more than 180 research groups from more than 40 different agencies.

The impact of research conducted with PCSP support has been far-reaching.

- Canadian scientists have been collaborating with their circumpolar colleagues to map air- and water-borne contaminants, including PCBs, DDTs and acid rain, in the Arctic. Studies conducted in a "toxic corridor" beginning in Russia and extending over the North Pole into North America, have resulted in the discovery of high levels of PCBs in the breast milk of Inuit in northern Quebec.
- In 1994, government hydrographers completed the second year of a three-year survey of the Coronation Gulf to help identify safe shipping routes in support of the mining industry and Government of the Northwest Territories.





David Gray

In 1994, among the many government and university biology programs supported by PCSP were those examining Peary caribou conservation, polar bear populations, Canada geese migration and nesting areas, Arctic char distribution, wildlife habitat mapping in the Inuvialuit Settlement Region, and beluga and narwhal movements and behavior.

- PCSP has supported a wide variety of geological mapping programs throughout the Northwest Territories to assist and encourage mineral exploration. In 1994, it provided logistics support to large geological mapping projects of the Sverdrup Basin and of the Slave Province.
- Industry and government have joined forces to study the geothermal, geological and geotechnical conditions of frozen sediments in the Mackenzie Delta area. These ongoing studies contribute to the knowledge of the properties of permafrost, an issue vital to the future development of oil and gas in the area.
- Extensive experimental oil spill studies have been undertaken to monitor the effects of spills on regional ecosystems over the long term.
- Multidisciplinary, international teams of research scientists have been studying and continue to examine the well-preserved remains of a mummified tropical forest in the High Arctic. Dating back some 40 million years, the forest provides scientists with a rare insight into prehistoric, and possibly future, climates.
- Archaeological, anthropological and traditional knowledge studies involving community elders have been supported, contributing to the knowledge of past cultures and environments. In 1994, PCSP supported programs involving elders from Cape Dorset and Igloodik.

Applications

PCSP distributes its applications in September each year. The deadline for submissions is generally the end of October.

Non-government and non-Canadian applications are reviewed by a Scientific Screening Committee.

Those wishing to be added to PCSP's mailing list should send their name and address to:

Polar Continental Shelf Project
 344 Wellington, Room 6146
 Ottawa, Ontario
 Canada K1A 0E4
 Fax: (613) 990-1508

Geological Maps of the World

Three new world maps have been released in paper format, and the digital data used in their preparation are available on CD-ROM. The data are provided in formats that can be imported into a variety of Geographic Information Systems (GIS) software packages, allowing the flexibility to create a wide range of customized thematic displays.

Generalized geology of the world (1:35,000,000)

compiled by R.V. Kirkham, L.B. Chorlton, and J.J. Carrière

This wall-sized map provides an overview of the crustal makeup of the continents, their basic chronology and types of deposition. It is simple enough to be used as the backdrop for other data or as a resource for journal illustrations. Paper map. (GSC Open File 2915a). \$15.00 in Canada, \$19.50 outside Canada.

Global distribution of sediment-hosted stratiform copper deposits and occurrences (1:35,000,000)

compiled by R.V. Kirkham, J.J. Carrière, R.M. Laramée, and D.F. Garson

The first of several GSC global mineral deposit reports based on a geo-referenced digital database. Its accompanying global map is the first to use a simplified thematic map derived from the *Generalized geology of the world*. It summarizes the characteristics of many of the world's sediment-hosted stratiform copper deposits and occurrences, and their depositional settings. The database comprises mineral deposit/occurrence descriptions, grade and tonnage data where available, references, data definitions, and database structure. Report, paper map and diskette. (GSC Open File 2915b). \$82.00 in Canada, \$106.60 outside Canada.

Hydrothermal activity and associated mineral deposits of the seafloor (1:35,000,000)

compiled by M.D. Hannington, I. Peterson, I.R. Jonasson, and J.M. Franklin

This map also uses simplified geology from the *Generalized geology of the world*. It shows the settings of five separate classes of mineralization with respect to oceanic ridges, volcanic seamounts, volcano-sedimentary arcs and troughs, back-arc basins and abyssal plains, defined by bathymetric shaded relief. Paper map. (GSC Open File 2915c) \$16.00 in Canada, \$20.80 outside Canada.

Generalized geological map of the world and linked databases

This CD-ROM contains three directories representing the GSC data sets used to produce the global maps described above and a fourth directory containing the data sets prepared for viewing, querying, simple customization, and printing using SURVIEW, a Microsoft Windows 3.1 application available in limited form on the CD-ROM. (GSC Open File 2915d) \$200.00 in Canada, \$260.00 outside Canada.

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FINANCES

Geological Survey of Canada 1994-95 Expenditures (000\$)

GSC/CGC OTTAWA



OOG 03409521

	Salary	Operating	Capital	Grants and Contributions	Total
Assistant Deputy Minister	389	214	25	812	1,440
Polar Continental Shelf Project	1,024	4,953	296	—	6,273
Geoscience Information and Communications Division	4,652	2,108	704	—	7,464
Coordination and Planning Division	2,312	1,729	444	—	4,485
Geophysics, Sedimentary and Marine Geoscience Branch					
Director General	142	52	10	—	204
Institute of Sedimentary and Petroleum Geology	8,408	4,767	1,511	—	14,686
Atlantic Geoscience Centre	6,868	4,684	1,150	—	12,702
Geophysics Division	5,493	3,859	1,137	—	10,489
Pacific Geoscience Centre	2,429	1,418	907	—	4,754
Total	23,340	14,780	4,715	0	42,835
Minerals and Continental Geoscience Branch					
Director General	295	40	0	—	335
Québec Geoscience Centre	1,425	1,034	419	—	2,878
Cordilleran Division	2,519	1,280	167	—	3,966
Terrain Sciences Division	5,565	2,871	587	—	9,023
Continental Geoscience Division	5,878	2,473	953	—	9,304
Mineral Resources Division	8,583	3,352	996	—	12,931
Total	24,265	11,050	3,122	0	38,437
Sector Total	55,982	34,834	9,306	812	100,934

Note: Branch and divisional names reflect the GSC structure in effect March 31, 1995

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