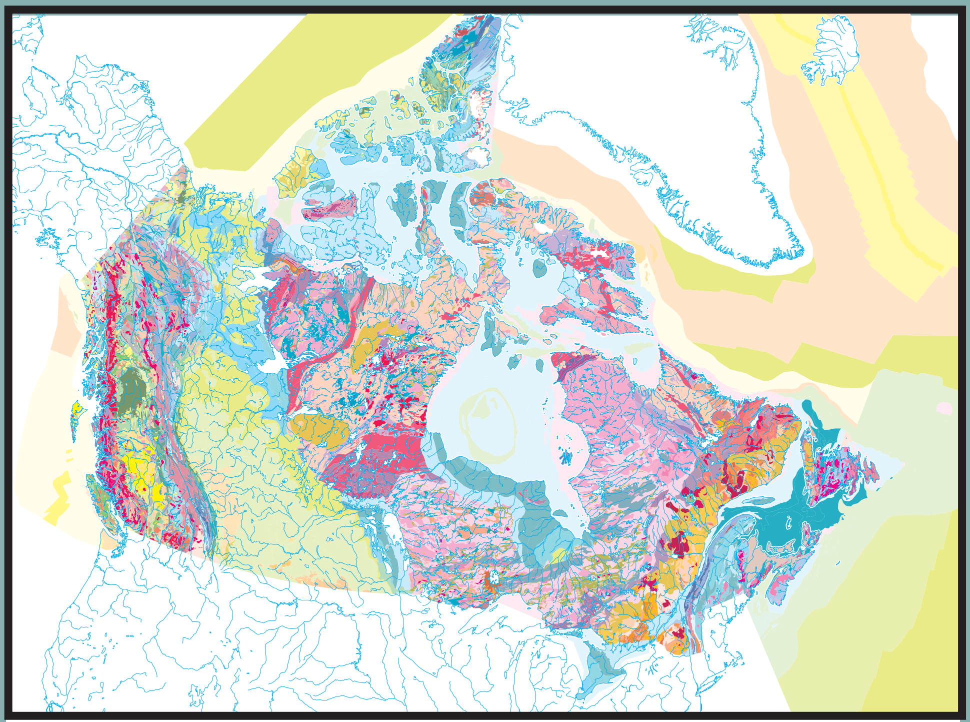
Geological Survey of Canada
Miscellaneous Report 65

FINAL REPORT ON THE GEOLOGICAL SURVEY OF CANADA BEDROCK GEOSCIENCE PROGRAM WORKSHOP FEBRUARY 23–25, 1997



Stephen Lucas (co-ordinator)

1999

Natural Resources Canada
Ressources naturelles Canada

Canada

GEOLOGICAL SURVEY OF CANADA
MISCELLANEOUS REPORT 65

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Geological map of Canada, from GSC Map D1860A

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FOREWORD

The Geological Survey of Canada (GSC) has always responded quickly and well to new challenges and opportunities. In the late 1970s, it met the energy crisis with new methods for assessing its energy resource potential. In the 1980s, it responded to regional development needs with a set of focused geoscience projects that delivered new knowledge, which is still being used by the private sector to generate wealth through new discoveries. The 1990s are a time of unprecedented change at the GSC, with restructuring and refocusing of its programs necessitated by major budget reductions. The GSC is meeting the challenge by providing new knowledge, in new formats, that supports sustainable resource development and good environmental stewardship. A major component of the required knowledge is obtained from the GSC's regional geoscience activities — bedrock and surficial mapping, geophysical mapping and process studies —, which will continue to underpin the broad needs for sustainable development. New scientific advances include, for example, high-resolution 'slices' of Canada's three-dimensional geological architecture, using LITHOPROBE deep sounding and the GSC's potential-field data. Increasingly precise information on the timing of geological events, derived from high-precision radiogenic isotope and biostratigraphic analyses, has revolutionized our understanding of Canada's geology. Process research has provided new information that in turn requires the GSC and its provincial partners to reinterpret, and in many cases, re-examine, the geology of Canada. New opportunities for resource discoveries, as well as new interpretations of Earth systems that underpin our ability to predict global changes, are the result of recent geoscience mapping and related research.

The challenge for GSC staff is to develop a more holistic, or 'Earth system science', approach to bedrock geoscience in an era of declining resources. Increasingly, the GSC's pool of highly skilled geoscientists must work together to define and prioritize the problems and apply the appropriate expertise to solving them. The GSC, with its partners, must develop a more integrated approach to regional studies. At the Bedrock Geoscience Program Workshop, GSC staff accepted this challenge, robustly debated the scientific challenges and directions, and examined methods of managing the 'way forward'. The plan herein will be a major influence on implementation of the GSC's management framework and will ensure that the quality of our work will improve, through the pooling of our expertise and through program planning and delivery from a national perspective. It presents a fundamental new way for the GSC to work in the future. It suggests that all research projects be proposal driven, integrating expertise and information as needed from across GSC divisions. Planning will involve all staff and the planning and management processes will ensure that the selection and delivery of the new program elements will provide the very best quality knowledge about Canada's geology for all potential users. This knowledge will be provided both in conventional ways and through digital access to fully interoperable information bases. We will link with our partners in universities, provincial surveys, and industry to plan and to share information. This report provides a blueprint for planning and delivering bedrock geoscience programs at the GSC that will optimize the quality of scientific work while maximizing the responsiveness to needs, in an era of much reduced resources.

Richard Grieve
Chief Geoscientist
Earth Sciences Sector

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OVERVIEW

The Geological Survey of Canada convened a workshop (February 23–25, 1997) on its Bedrock Geoscience Program to develop a long-term vision and future scientific directions. As outlined in the *Geological Survey of Canada Strategic Plan for Geoscience (1996–2001)* (Geological Survey of Canada, 1996), the Bedrock Geoscience Program comprises the following four principal activities undertaken by five GSC divisions (GSC Pacific, GSC Calgary, Continental Geoscience Division [CGD], GSC Québec, GSC Atlantic): bedrock and subsurface mapping; geophysical surveys; thematic (process-oriented) studies aimed at understanding the age, origin, nature, history, and resource potential of the landmass at all scales; compilation and synthesis of all information for the four principal geological domains of Canada (Canadian Shield, Appalachians, Cordillera; sedimentary basins [Western and Arctic Canada]; continental shelves; St. Lawrence Lowlands).

The workshop responded to challenges posed by recent and emerging changes in Canadian society, government policies, and geoscience, articulated in the *Geological Survey of Canada Strategic Plan for Geoscience 1996-2001* and the report *Future Challenges and Trends in the Geosciences in Canada* (Canadian Geoscience Council, 1996). Importantly, the idea for a GSC-wide bedrock geoscience 'futures workshop' stemmed from a grass-roots proposal to the GSC Science Program Committee, which was endorsed in August 1996.

A steering committee, comprising representatives from all GSC divisions, was tasked with translating the futures workshop concept into reality. Planning and participation in the workshop was GSC-wide, as the Bedrock Geoscience Program (delivered by GSC Pacific, GSC Calgary, GSC Atlantic, GSC Québec, and CGD) interrelates directly and indirectly with the other GSC programs (Surficial Geoscience, Marine Geoscience, Minerals Geoscience, Hydrocarbon Geoscience, and Geological Hazards and Environmental Geoscience programs). Planning for the workshop built on experiences and lessons learned from the two most recent GSC-wide 'futures' meetings (Gananoque, 1981; Mont Ste. Marie, 1987). GSC staff participated in preworkshop consultation through a variety of means, including staff meetings and an Intranet website that included a bulletin board for posting comments and ideas prior to the workshop.

The GSC Bedrock Geoscience Program Workshop was held February 23–25, 1997, at Merrickville (Ontario) and involved 60 scientists and managers (participating as scientists) selected from all GSC divisions and representing a broad spectrum of geoscientific disciplines. The workshop included stage-setting talks, short breakout sessions on five themes, and plenary gatherings to review discussions and meet the overall workshop objectives. Participants and organizers consider the workshop to have been a very positive event that generated a strong, team-oriented, dynamic, grass-roots participation and a renewed sense of optimism, belonging, and future and national purpose for the GSC. An interim workshop report was distributed to all participants and made available to all GSC staff in early May 1997 and was posted on the workshop website as well. It provided a complete assessment of all aspects of the workshop, including the preworkshop consultation processes. Its executive summary and recommendations were revised in light of comments and suggestions by GSC staff and management during summer 1997. The final workshop executive summary was submitted to the Chief Geoscientist on August 12, 1997, and was reviewed and accepted by the GSC Program Committee on October 29, 1997.

One measure of the workshop's success was the recognition by the Program Committee that it was in reality a GSC-wide science program workshop, with discussion on a future vision and directions for the GSC, rather than simply a workshop on the Bedrock Geoscience Program. A major recommendation stemming from the workshop was to implement the 'Vision for 2010' developed during the workshop. This recommendation states that "The GSC, in collaboration with provincial/territorial agencies, will strive to produce an integrated, digital, scale-independent, bedrock geoscience knowledge base of Canada, with coverage ranging from the biosphere to the mantle and through time (4D map of Canada)". The Program Committee requested that a proposal be developed to implement the workshop vision, under the working title 'National Geoscience Knowledge Base initiative' (NGKB). A pan-GSC team will co-ordinate input to this initiative, which will be developed in partnership with provincial and territorial geoscience agencies and universities. The other major decision taken by the Program Committee was to create an implementation task force to develop specific plans for implementing recommendations 2 to 4. These are 2) to develop mechanisms for interdivisional program planning, project formulation, review, and assessment; 3) to develop mechanisms for new thematic initiatives to meet government priorities and future societal needs; and 4) to improve internal and external communications and linkages at the GSC.

In summary, the workshop recommendations stress the importance of integrated, interdisciplinary science at all stages of a project life cycle and propose that all current and future GSC projects emphasize the third (depth) and fourth (time) dimensions through the integration of geology, geophysics, and chronostratigraphy (geochronology and paleontology). Considerable support was shown for a holistic team approach to mapping and thematic (process) research through integration across disciplines, GSC divisions, and geoscience agencies, as well as across geological time. The program should maintain a dynamic balance between national (thematic), regional, and discipline-based geoscience expertise and program activities in order to best meet the needs of present and future partners, clients, and stakeholders. Finally, strong support was indicated for developing new and innovative ways of doing and managing bedrock geoscience. Whereas regional and disciplinary expertise must be maintained, GSC scientists must be allowed a greater degree of interdivisional mobility (intellectual and physical) in order to provide expertise wherever and whenever it is most required.

Improved communication and the removal of barriers to effective co-operation and collaboration both within the GSC and externally are essential to the future success of the Bedrock Geoscience Program and the GSC in general.

The Workshop Steering Committee (Appendix 3) would like to acknowledge the support of Dr. Marc Denis Everell (Assistant Deputy Minister, Earth Sciences Sector), Dr. Jim Franklin (former Chief Geoscientist, Earth Sciences Sector), and the GSC Program Committee for their unwavering support of this endeavour. Dianne Paul (Continental Geoscience Division) is commended for her work in designing and maintaining the Intranet website, and Genevieve Allen (Chief Geoscientist's Office) and Mem Levesque (CGD) are gratefully acknowledged for their excellent administrative support.

EXECUTIVE SUMMARY: WORKSHOP RECOMMENDATIONS AND IMPLEMENTATION PLAN

The executive summary comprises four sections. The first is divided into general statements of vision, principle, and concept that set the stage for the future (general recommendations) and specific recommendations that can be translated into operational plans and initiatives within the GSC. The general recommendations are as follows:

1. Implement the vision for a 4D geoscience knowledge base (National Geoscience Knowledge Base).
2. Promote an integrated, balanced, relevant, and viable program.
3. Ensure program flexibility to meet future scientific and societal needs.
4. Improve internal and external communication and linkages at the GSC.

A number of scientific proposals were submitted before the workshop to the Intranet bulletin board for posting and comment and some were suggested during brainstorming sessions at the workshop. They are described more completely in the theme-session reports (*see* below).

Recommendations

1. Implement the vision for a 4D geoscience knowledge base

1.1 The GSC, in collaboration with provincial/territorial agencies, will strive to produce an integrated, digital, scale-independent bedrock geoscience knowledge base of Canada, comprising maps, process understanding, and expertise with coverage ranging from the biosphere to the mantle and through time (i.e. 4D map of Canada).

1.2 The 4D geoscience knowledge base (or National Geoscience Knowledge Base) will be an evolving and dynamic product that is consistent across the nation at a synthesis scale. It will be housed in components that will be distributed across Canada and in flexible formats, but must be easily accessible, on demand, to the Canadian public. The vision will not be realized at the expense of geoscience mapping, but rather through the co-ordination of existing digital knowledge base activities across the GSC and through an incremental approach involving the GSC and key partners (e.g. provincial/territorial geological surveys, universities).

1. Specific recommendations

- Initiate a National Geoscience Knowledge Base project. The project will require a pan-GSC team comprising geoscientists and geoscience information specialists working towards specific incremental goals and products.
- Consult with key partners (e.g. provincial/territorial geological surveys, universities, other government departments), users, and stakeholders to develop a national consensus on the proposed National Geoscience Knowledge Base.
- Develop a national geoscience metadata framework (index of geoscience information) and Internet map server as a first priority, in collaboration with provincial/territorial geoscience agencies.
- Where warranted, co-ordinate existing digital knowledge base work through the pan-GSC team, including generating, managing, interpreting, and publishing digital geoscience information. This can largely be accomplished simply by co-ordinating existing resources and initiatives, which in many cases are divisionally or regionally based.
- Integrate existing bedrock compilation projects to ensure consistent map coverage of the landmass and offshore regions at a synoptic scale.
- Implement, or where necessary develop, digital standards in collaboration with provincial/territorial surveys, universities and industry (e.g. current initiatives with Geological Association of Canada's GIS Division, United States Geological Survey).
- Link the National Geoscience Knowledge Base project to other initiatives when and where appropriate (e.g. Canadian Geospatial Data Infrastructure, GeoAccess, GeoExpress, NRCan Knowledge Initiative).

2. Promote an integrated, balanced, relevant, and viable program

2.1 Ensure the continued acquisition, interpretation, synthesis, and publication of bedrock geoscience data and information in a manner that is responsive and relevant to present and future government policy and societal needs, maintains scientific credibility through the peer review process, and addresses major gaps in scientific understanding and map coverage.

2.2 Promote integrated, interdisciplinary science at all stages of a project life cycle and ensure that all current and future GSC projects emphasize the third (depth) and fourth (time) dimensions. This requires the integration of geology, geophysics, and chronostratigraphy (geochronology and paleontology).

2.3 Develop an improved understanding of the interface between geology and geophysics by linking the geophysical parameters measured in the field to the processes that cause the variations in physical properties of the rocks.

2.4 Promote a holistic (Earth systems or 'geosystems') team approach to mapping and thematic (process) research by integrating across disciplines, GSC divisions, and geoscience agencies, as well as across geological time.

2.5 Develop and maintain a dynamic balance between national (thematic), regional, and discipline-based geoscience expertise and program activities to best meet the needs of present and future partners, clients, and stakeholders.

2. Specific recommendations

- Ensure interdivisional review of projects from proposal to completion.
- Develop a project review framework that encourages

  - interdisciplinary projects and research partnerships (NATMAP/LITHOPROBE philosophy);

  - a holistic, Earth systems approach (encompassing Earth, ocean, atmosphere, and biosphere science);

  - 3D and 4D study where appropriate;

  - thematic (process-understanding) research;

  - research on crossdiscipline integration (e.g. geology and geophysics);

  - scientific training and development (including exchanges within GSC and with universities);

  - links to government policy priorities and anticipated societal needs for bedrock geoscience information and knowledge.
- To foster innovative, grass-roots, pan-GSC project development, implement an Intranet website for posting of key scientific information and results for present and planned projects, with a bulletin board for scientific exchange. This could be broadened to an Internet site to inform partners, stakeholders, and clients (e.g. universities, industry) of project activities.
- Maintain and improve scientific expertise to provide identifiable, ready sources of geoscientific knowledge for all regions of Canada and for all key disciplines, and to ensure that the GSC can respond in a timely, impartial, and scientifically credible manner to issues concerning resource potential, environment, hazards, and land use.

3. Ensure program flexibility to meet future scientific and societal needs

3.1 Formalize a thematic approach to GSC bedrock geoscience by developing a National Geosystems Program of integrated mapping and process research that is proposal driven and interdivisional. Program themes would be tied to science goals, government policy priorities, and societal needs.

3. Specific recommendations

- Implement a National Geosystems Program of integrated mapping and thematic research on key geoscience themes.
- Select key geoscience themes, in consultation with public- and private-sector partners, stakeholders, and clients. The geoscience themes would promote understanding of Earth systems and would anticipate and respond to evolving societal needs (e.g. resources, hazards, environment, etc.). The proposals submitted to the workshop bulletin board and/or discussed at the workshop provide a number of possible themes and project ideas for discussion.
- Establish national working groups for each geoscience theme that include GSC participants and external partners as appropriate to provide the necessary scientific critical mass. Divisional and regional boundaries should become transparent to these activities in order to foster interdisciplinary research and mobility of expertise.
- Investigate opportunities for new partnerships, particularly in the area of Earth systems science, with national/international university researchers (e.g. Centres of Excellence, post-LITHOPROBE Natural Sciences and Engineering Research Council programs, Canadian Institute of Advanced Research programs).
- Develop a proposal-driven process to initiate and implement projects in the National Geosystems Program and devise review criteria for proposals.
- Nominate a steering committee, comprising GSC scientists and managers, to evaluate proposals and project progress, as well as overall program direction and progress on geoscience themes.
- Hold pan-GSC, science-based workshops where practicable to foster communication and discuss research progress and direction on the key geoscience themes.

4. Improve internal and external communication and linkages at the GSC

4.1 Facilitate new and innovative ways of doing and managing bedrock geoscience. Although regional and disciplinary expertise must be maintained, GSC scientists must be allowed a greater degree of interdivisional mobility (intellectual and physical) in order to provide expertise wherever and whenever it is most required.

4.2 Remove barriers to linkages within the GSC and with external partners by sharing expertise, project plans, and results.

4.3 Improve scientific communication from scientists to managers, from managers to managers, and from the GSC to policy makers.

4.4 Attach an outreach component to all projects at a scale appropriate to public interest in the project and provide better recognition for scientists involved in public outreach.

4.5 Raise public awareness of geoscience and the GSC.

4. Specific recommendations

- Remove barriers, such as short-term planning, division-imposed directions, and poor communication, to linkages inside and outside the GSC.
- Promote better communication and mobility of expertise and ideas inside and outside the GSC through scientific exchanges, visiting speakers, workshops, field trips, Intranet web pages, and video-conferencing.
- Entrench a commitment to public outreach in project plans as appropriate.
- Provide training opportunities for research staff in the communication of science to the media and general public.
- Explore better linkages with television to raise public awareness of science and of the GSC and its programs.
- Ensure that outreach activities are recognized as an important component of the program and of the work of individual scientists.
- Investigate the preparation of a popular 'Geology of Canada' publication.
- Promote communication with government decision makers in order to increase understanding of the significance of GSC bedrock geoscience knowledge and information to policy development and implementation as well as its long-term societal value.

Specific scientific proposals

The following scientific proposals are taken from the Intranet bulletin board and from the workshop itself.

National Geoscience Knowledge Base project

National geoscience syntheses

- queriable index map to GSC maps and reports
- digital interactive 4D Geology of Canada (1:1 000 000 scale)[1]
- Geological Atlas of Canada
- collection and archiving of industry seismic profiles

'Technical' initiatives for the Geoscience Knowledge Base

- standardization of digital products and databases[1]
- national metadata 'layer'[1]

National Geosystems Program

- LitMap: multidisciplinary study of the lithospheric mantle[1]
- systematic 3D, 1:250 000 scale mapping of the petroleum basins
- fluids in the crust: mapping and characterization of subsurface water resources[1]
- geology of major urban areas of Canada[1]
- multidisciplinary mapping of ancient and modern plate margins[1]
- mapping of Neotectonic deformation indicators
- studying paleoclimate–mountain building interrelationships
- chronostratigraphy: integration of biostratigraphic and geochronological time scales[1]
- multidisciplinary study of cratonic basins (e.g. Hudson Bay basin)[1]
- Late Cenozoic fluvial landscape evolution
- regional geology and dating of sediment-hosted mineralization
- early crustal evolution: tectonic processs in Early and Middle Archean crust/lithosphere[1]
- radar interferometry and high resolution plate motion studies
- landscape evolution (interferometric synthetic aperture radar, hazards, neotectonics)
- magma formation in different tectonic environments[1]

National outreach products

- geology of the national parks
- geological highway maps
- a popular geology of Canada

Implementation plan

A number of key steps are proposed in order to translate the recommendations of the final report on the Bedrock Geoscience Program Workshop into specific actions, options, and initiatives. A task force with representatives from all GSC divisions (including the Geoscience Information Division) should be established to scope out specific options for implementing

[1] Proposals that garnered broad-based support at the workshop.

the workshop recommendations. The task force should report to the GSC Science Program Committee within three months of its inception on the following:

- assessment and prioritization of the workshop recommendations in terms of
  - potential scientific/science management impact and relevance
  - operational requirements and viability
  - external considerations and impact
  - specific actions for implementation and who would be responsible for them
  - implementation timeframe;
- potential pilot projects and initiatives that address the four general workshop recommendations, with specific plans and time lines proposed;
- consultation plan: GSC staff, NATMAP Co-ordination Committee, National Geological Surveys Committee, Minister's National Advisory Board on Earth Sciences, Council of Chairs of Canadian Earth Science Departments, and industry liaison committees as appropriate;
- communications plan: GSC/Earth Sciences Sector staff (Intranet), Earth Sciences Sector/Sector Management Team, publications (e.g. GSC paper, Geoscience Canada article).

WORKSHOP RATIONALE, OBJECTIVES, AND PROCESS

The GSC must respond quickly and in a co-ordinated and effective fashion to the challenges posed by recent and emerging changes in Canadian society, government policies, and geoscience. The workshop was held to plan a long-term vision and future scientific directions for the GSC's Bedrock Geoscience Program in the context of these challenges.

Changes: the future will be different from the past

The GSC is at a crossroads and must adapt to substantial internal change, a new framework for federal-provincial relations, and a new approach to S&T in government.

Government geoscience must respond to evolving socio-economic needs, with demands for more information pertinent to issues such as the environment, natural hazards, and water, while still supplying information for traditional needs (e.g. energy and mineral resources).

Geoscience is undergoing major change, as described in the following quotation "The boundaries between component parts of the earth sciences...have become blurred...It is this profound change in the flow of information and ideas across traditional barriers that is liberating many fields of endeavour and instilling a new sense of excitement and opportunity" (Canadian Geoscience Council, 1996).

Challenges: be proactive in responding to change — identify and seize opportunities

Develop and implement mechanisms to foster an integrated, holistic, team approach to bedrock geoscience.

Balance national program goals and regional needs and opportunities in order to best serve our clients and stakeholders and to address the expectations of our provincial/territorial partners.

Develop program priorities that anticipate future needs for geoscience knowledge and thereby are able to both inform and influence policies in a timely and scientifically sound fashion.

Improve program, policy, and communication linkages within the GSC and Natural Resources Canada, and to other government departments, the Canadian geoscience community, and the public at large.

Workshop objectives

- To define a future (2010) vision for the GSC Bedrock Geoscience Program.
- To define the strategic steps that are needed to realize this vision.

Workshop process

The workshop Steering Committee was struck in fall 1996 and held its first meeting in mid-November. The workshop proposal was presented to and approved by the GSC Science Program Committee on December 4, 1996. GSC staff was informed of the Bedrock Geoscience Program Workshop in early January 1997 and their input was solicited prior to the workshop through meetings and access to an Intranet website with an electronic bulletin board (inaugurated on February 2, 1997). A comprehensive, preworkshop briefing package was provided to workshop participants and made available to all staff through the website.

The workshop itself was held on February 23–25, 1997, in Merrickville, Ontario. Participants included 61 scientists and managers (participating as scientists) selected from all GSC divisions and representing a broad spectrum of geoscientific disciplines. Invited participants included a scientist from Geomatics Canada (Marc D'Iorio, Canada Centre for Remote Sensing) and one invited speaker (Raymond Price, Queen's University). Facilitation was provided by Annette Bourgeois, Mike Cherry, and Robin Riddihough. The workshop plan fostered a sense of the GSC as a national organization and incorporated team building, a focus on the future, grass-roots participation, and consensus building.

The Bedrock Geoscience Program Workshop sessions comprised stage-setting talks, breakout sessions on the five themes, and plenary gatherings to review discussions and meet the overall workshop objectives. The theme sessions were designed to facilitate discussion on key aspects of the Bedrock Geoscience Program. Session chairs developed both background material for participants and a list of questions or issues for participants to discuss and debate as they cycled through their session. Theme sessions covered 1) bedrock mapping, 2) geophysical mapping (surface and subsurface), 3) thematic (or process-oriented) studies, 4) linkages (to other GSC programs and external partners), and 5) the National Geoscience Knowledge Base. Participants cycled through four of the five theme sessions (eight to ten participants in each session) for two-hour breakout discussions (twice on Monday, twice on Tuesday). Breakout sessions for the five themes were facilitated either by two or three preselected session chairs or by one of the facilitators. Theme-session chairs presented interim reports at plenary gatherings of all participants on the afternoon of Monday, February 24, 1997, and rough draft reports on Tuesday, February 25, 1997, respectively. Final reports on the theme sessions were submitted to the Steering Committee by April 1997.

INTRODUCTORY PRESENTATIONS

Bedrock Geoscience Program Workshop — Introduction (J.M. Franklin, Chief Geoscientist, Earth Sciences Sector)

Welcome all to the first ever bedrock mapping workshop.

Thanks to Steering Committee chair Steve Lucas, who pulled together a hard-working team of scientists, including Cathie Hickson, Chris Harrison, Don Cook, Alan Jones, Marc St-Onge, Ron Dilabio, Charlie Jefferson, Annette Bourgeois, Greg Lynch, Léo Nadeau, and Peter Giles. This group pulled together an impressive amount of information, challenged their colleagues in each of our divisions to offer some ideas and present some challenges to the participants.

The concept of workshops to consider the future directions of the GSC's programs is not new — we have had two major workshops in my time at the GSC, one in Gananoque and one in Mont Ste. Marie. In addition, divisions have retreats, workshops, and planning sessions from time to time that are all designed to pause and reflect on where we are going. This is, however, the first time in my recollection that we have assembled such a large group of GSC geologists to consider a single program element — bedrock geoscience.

In a workshop such as this, we could not, for obvious reasons, invite all our regional geoscientists. Divisions were asked to send representatives of their groups; as representatives, you have had the responsibility to encourage your colleagues to provide their input to the workshop, to collect their thoughts, communicate the activities of the planning group, and report back the results of the next two days. Judging from the e-mail traffic, you have all done an excellent job at this.

So what do we want to accomplish here in the next two days?

I have a few challenges, and a few 'ground rules'!

First off, the ground rules.

1. I hope that the discussions of the next few days focus entirely on the needs and future directions for regional geoscience in Canada. What I do not want is for you to spend any effort on geopolitical considerations — no talk of provincial borders, other than geological, no talk of office mandates, no talk of constraints imposed by budgets (although we must remain realistic), expertise, or any other such 'trivial' constraint. Focus on science, not politics. We employ others for the latter!

2. Secondly, the workshop participants consist of three groups of people. I have some directions for each of you.

   A. Regional geoscientists whose careers are dedicated to unraveling the architecture of the Canadian crust — mappers, stratigraphers, paleontologists, structural geologists, petrologists, paleo magicians, geochronologists, GIS experts, geophysicists, tectonicists — the list goes on. You represent the mix of scientific expertise needed today to begin to unravel the complex geological history of Canada. Your job is obvious — to describe and prioritize the geological problems that we should be attacking over the next 10 to 20 years, to tell us what expertise and technology is needed to do this, and to tell us how we are going to provide a legacy of our work for future generations — maps, reports, CDs, the Web, whatever.

   B. A small group of 'other experts'. You have a special job: to challenge the regional geoscientists to look beyond their favourite piece of Canadian geology, to look beyond the conventions imposed by your individual disciplines, to interject with the knowledge that you have about your areas of specialization — surficial geology, seismology, submarine fans, publication methodology, GIS systems, mineral deposits geology, and more. Challenge your colleagues, expose their weaknesses (but be nice), bring the frontiers of your research into their thought processes.

   C. Managers: who let them in here? For these folks, I have some special rules or challenges. Each of you has a strong scientific or technical background and now it's time to dust off those cobwebs, put away those TQM reports, burn those spreadsheets, forget those SMT meetings, and focus on a core activity of the GSC. Seriously, the managers are here to work for you. Give us the best ideas, the firmest direction on the geoscience needs of Canada, and it's our job to make the best of our resources, and keep pushing for more, to encourage you to continue to be the most productive geological survey in the world.

What's changed that will ultimately define our role and our program well into the next century?

I'll give you three examples: there are many more.

First off, in the context of delivering geoscience in Canada, we have clarified our role relative to that of the provinces via the Intergovernmental Geoscience Accord. We are defined as a research organization, one that will work with our provincial partners, but that gives GSC responsibility for understanding the total picture of Canadian geology.

The Strategic Plan lays out some very general directions and even these will be modified to meet new challenges. We must continue our work in the geological frontiers, we must look more deeply, both in the physical and intellectual senses, at those areas for which we have some detailed knowledge, and we must understand geological processes in a more quantitative way.

The (Geoscience Council) Barnes report challenges us to adopt the 'Earth systems' approach: a more holistic approach to solving geoscience problems, in which all our traditional disciplines are integrated in an appropriate way to give the answers.

Finally, I want to discuss a little bit more about your challenge. Ray will be giving us his vision of a geological survey in the next century and I want to give you a bit of mine. For its first 154 years, a major focus of the GSC was to support the economic development of Canada. We have done this well. We all know the statistics about the contribution of our energy and mining sector to our economy. In the last 20 to 30 years, new challenges have been taken up by the Survey! We greatly increased our marine programs, we developed a high level of expertise in process studies for mineral and energy resources, we found new and exciting uses for the surficial component of our geology — first in mineral prospecting, then in understanding terrain hazards, and most recently in documenting at an amazingly fine scale the climatic changes that we have experienced through the past tens and hundreds of thousands of years. Much of the new work has been focused on the immediate economic needs of the country and there has been for me at least a sometimes disturbing tendency to overjustify our existence on this basis. As a mineral deposits specialist, I cannot name any piece of work that we do that cannot be related to the quest for new resources — even the most esoteric, the most basic, the most abstract work can and should be used by those practitioners whose mandate and passion it is to help find new resources. It's the same for hazard analysis; the science that surrounds the need to reduce risk from natural hazards involves virtually all our disciplines.

But we should not always focus specifically on the applied aspects. Speaking as a mineral deposits specialist, I would ask you to tell me why the various terrains are where they are, why they are deformed the way they are, why they have granite bodies or reefs or monotonous amounts of clastic sediments, what they looked like two or three billion years ago, tell me what the terrain boundaries that we can so effectively map in the Cordillera are going to look like in the Grenville, tell me where and how the serpentinites formed, tell me how I can sort out the paleoatmosphere and paleowater depth in the Archean and Proterozoic, and then I may be able to tell you a bit more about why the resources are where they are, or more likely you will be able to tell me!

Let's look at the big picture over the next two days, let's understand what we need to know about the crust, in terms of processes and the results of these processes, that will provide the framework for the next 20 years of regional work. Let's look at our expertise as a pool to be drawn upon to solve problems wherever they may be, and our laboratories and our technical facilities as resources that must be challenged to provide data and methodologies that will help answer our problems. Let's publish our results in as timely and user-friendly a manner as possible, taking advantage of the newest technologies. Let's spread the word to our schools, to the public, and to the politicians, so that our work is more highly valued.

Finally, let's have fun!

National geological surveys: present and future role in a changing world (Raymond A. Price, Department of Geological Sciences, Queen's University, Kingston, Ontario)

(adapted with modifications from a presentation to the Jubilee Symposium of the Australian Geological Survey Organization, Canberra, 21 February 1996)

This evening I want to share with you some ideas that lead me to the firm conviction that governments need national geological surveys now and that in our rapidly changing world national geological surveys will become even more necessary in the future. I also want to share with you my concern about the challenges that national geological surveys face in coping with the uncertainty and the confusion associated with our present global political, economic, and social reordering. For an audience dominated by people who have a stake in national geological surveys, the good news is that our changing world presents new, long-term opportunities that will enhance the usefulness of national geological surveys; the bad news is that our changing world presents major, short-term challenges that undermine the capabilities of national geological surveys and that even endanger their very existence.

On the threshold of the twenty-first century, change is our watchword. Everywhere, individuals, organizations, institutions, and nations are striving to cope with the uncertainty and the threats that are inherent in change and they also are striving to create innovative changes that will help them to succeed in the competition for wealth and for scarce financial resources. Consider for a moment how our present situation is marked by the effects of

- the abrupt and unexpected end of the cold war, the arms race, and lavish spending on military R&D;
- the recent recession in many of the largest national economies;
- the burgeoning national debt in many countries;
- a growing emphasis worldwide on the competition of a noninterventionist, free-market economy;
- the globalization of the economy;
- the amazing growth in information technologies and in the Internet;
- widespread industrial 'downsizing', 'outsourcing', and 're-engineering';
- the emergence of new democracies in Europe, Asia, the Americas, and Africa;

- the rapid growth in the economies and affluence of many so-called ‘poor’ nations (the doubling time for the growth in China’s economy is five to six years);
- the unprecedented rate of growth and size of the human population (5.75 billion and growing by 1 billion every 10 years);
- the growing and alarming environmental degradation associated with the large-scale use of natural resources; and
- the looming prospect of global changes in the geosphere and biosphere that threaten our human habitat and the genetic diversity of the biosphere.

Our present situation is a kaleidoscope of rapid change. Although it stems in part from some of the ponderous events of recent history, it has its roots in the onset of the industrial revolution and the rapid growth in the human population and in the use of the Earth’s energy, mineral, soil, and water resources. A distinction should be drawn between the short-term perturbations, which are often unexpected, and the long-term trends, which generally can be recognized. National geological surveys are in turmoil as they struggle to meet the challenge of the rapid pace of the short-term changes in the political, economic, social, and technological environment in which they must operate now; but they also face challenges, and opportunities, arising from the long-term trends of accelerating growth of the human population, the demand for earth resources, the risks associated with geological hazards, and the degradation of the natural environment.

The relative importance of the various challenges and, therefore, the overall response to change vary greatly from one nation to another, as the following two examples illustrate. Two years ago, the United States Geological Survey was destined to be abolished as part of the Republican Party’s ‘Contract with America’, which was aimed at eliminating nonessential government spending in order to achieve a balanced budget and reduced taxes. However, the threat of the disappearance of the United States Geological Survey resulted in a reassessment of the importance of the various services that it provides for the nation and, on this basis, it has managed to survive, in part, with new strategic goals that are focused on natural hazards, water resources, availability of geographic data, and environmental issues. The Australian Geological Survey Organization also recently went through a major review, but under much less traumatic circumstances, and it emerged with a new definition of its mission that is focused on economic growth and on encouraging economically and environmentally sustainable management of mineral, energy, soil, and water resources. These differences in the focus of the mission of the two national geological surveys should not obscure a common basic purpose for national geological surveys, which has not changed significantly since the British Geological Survey was formed about 160 years ago and probably will not change significantly in the near future. And what is this basic purpose, you might ask? The answer can be found by posing and answering several other questions.

To plan strategically for success (or even survival) in our rapidly changing, competitive world, an organization should be able to provide clear, logical answers to three basic questions.

FIRST — What is our business? (Why do we exist? / Why should we exist?)

SECOND — Who are our clients? (Who pays for our services and products? / Why do they pay?)

THIRD — What is our competition? (Where else do our clients spend their money?)

And the answers are:

National geological surveys are in the geoscience information business. They exist to ensure that the geoscience information requirements of the nation, as defined and redefined from time to time by the government, are satisfied.

Although they work for the nation, their *de facto* clients are the government that decides what they will do and how much they will spend doing it.

Their welfare and their survival are contingent on their success in identifying and fulfilling the needs of their clients.

Their competition comes from the other demands that are made upon the same government — to provide other services and products for the public good and to reduce taxes (and the national debt!).

And what are the geoscience requirements of the nation, you might ask?

To govern, governments need information.

Geoscience information is required by governments for the development and the implementation of sensible public policies on, among other things,

- the management of risk due to geological and geophysical hazards such as floods, tsunami, earthquakes, and volcanic eruptions;
- the wise use of the national mineral, energy, soil, water, and ecological resource endowment;
- the protection of the environment and human health, nationally and globally;
- sovereignty and national security; and
- the geoscientific knowledge component of the nation’s culture.

Geoscience information also is used by governments as an instrument for the implementation of public policy. For example, it is made available by governments to the general public, as a public good, to reduce the risk due to natural hazards and to promote environmentally sound economic development. It is also made available to specific target audiences such as the mineral or petroleum exploration industries, in order to stimulate regional or national development of natural resources, the generation of wealth, and the creation of jobs.

The specific nature, amount, and scope of the geoscience information and expertise provided by a national geological survey depend upon the special circumstances and needs of the nation and also upon the national government's perceptions of those needs and of their relative priority. The national geoscience information requirements of Australia obviously are fundamentally different from those of both the United Kingdom and Japan because of fundamental differences in the relative importance of the mineral resource endowment, environmental issues, and the risks due to natural hazards.

Geoscience information and expertise are a special kind of national resource. Unlike many other kinds of scientific information and expertise, they have both specific, local significance and general, universal significance. They pertain to a specific place in a specific country, as well as to the global corpus of scientific knowledge. They are part of the knowledge base concerning the nature and present state of the nation. They also are part of what defines the nation as a sovereign state and as a cultural entity. Along with information on the rest of the natural environment, on the size and nature of the national population, on the economy, and on the national and international political environment, they form an integral part of the information framework within which governments govern and nations function.

Geoscience information and expertise may be obtained from many sources, but insofar as what is needed cannot be acquired more effectively, efficiently, and economically from nongovernmental sources, it must be assembled and/or generated within the government. National geological surveys do this by conducting field research and related laboratory research, compiling information available from state or provincial agencies, universities, industry, and various other sources, and integrating and synthesizing all this to maintain a national geoscience knowledge base from which the required geoscience information and expertise can be extracted as required.

The basic underpinnings of the national geoscience knowledge base are the geographically referenced geoscience observations and interpretations that normally are displayed as maps. These geological interpretations, together with the multiparameter arrays of geological, geophysical, and geochemical observations upon which they are based, are the modern counterpart of the simple geological maps of the nineteenth-century predecessors of our present-day geological surveys.

The multiparameter data record and portray various attributes of the rocks and, accordingly, the processes involved in their acquisition, interpretation, and presentation may still be referred to as 'geological mapping'.

In this sense, geological mapping has been, is now, and will continue to be a primary activity of national geological surveys.

Contrary to what may be implied by the colloquial use of the term 'mapping', geological mapping is scientific research, but scientific research in nature's laboratory. It can involve the use of a variety of techniques from the most mundane to the most sophisticated new technology, but whatever the technique, its basic purpose is to establish the nature, the three-dimensional shape and position, the age, evolution, and origin, and the regional or global significance of bodies of rock. It involves the recognition, description, analysis, and interpretation of experiments that have been conducted by nature and that hold the key to the wise use of the Earth by humankind.

The new frontiers for geological mapping are the subsurface and the third dimension — depth. In the past, most geological mapping has been essentially two dimensional: limited to what is exposed at the Earth's surface, revealed by scarce boreholes, and inferred by extrapolation into the subsurface. The continuing emergence of new technologies for geophysical remote sensing and imaging, like those that transformed the petroleum exploration industry, offers the prospect of dramatic advances in mapping the geology at depth, in three dimensions, and this offers the prospect of identifying major new Earth resources. For example, over vast areas of the continents, basement rocks like those that have provided much of the world's mineral wealth are buried beneath younger sedimentary rocks, regolith, and soils, but occur at depths at which they could be mined if the mineral deposits that they contain could be identified. One of the challenges for the emerging new technologies is to find those new mineral resources.

Public policy issues create a demand for specific, quantitative, 'derivative' geoscience information, such as assessments of the resource potential, or of the earthquake risk in a specific area, or the expected oil and natural gas endowment of the nation. Systematic, impartial, authoritative geoscientific studies provide the only rational basis for answering these questions. However, the time required to conduct the necessary research is commonly much longer than the duration of a public policy issue, or of a specific government. Accordingly, good strategic planning is crucial to the effective operation of national geological surveys.

In short, if these are the kinds of information that governments need and appreciate, they must make sure they are available when they are needed — not after the need has passed.

Strategic planning must be aimed at ensuring the availability of the knowledge and the expertise that will be required to address the policy issues that will emerge in the future. It must take into consideration new or emerging policy directions of governments and nations and new or emerging scientific concepts that may lead to a re-evaluation of existing scientific data or to the need for new data, and it also must involve providing for the availability of the professional expertise that will be needed in the future.

Feedback relationships between the national knowledge base and those geoscience activities that are instruments for the implementation of public policies offer important opportunities for maintaining, expanding, and strengthening the knowledge base. For example, geoscience information that is acquired specifically for one application, such as the stimulation of mineral exploration or the mitigation of natural hazards, becomes part of the national knowledge base and may have many other potential applications in areas such as the management of soil and water resources and land-use planning.

Geoscience expertise is generally developed through experience in studying specific areas or regions and, therefore, it is not entirely portable, nor can it be generated rapidly to meet new demands. Successful investments in the development of professional expertise require great foresight and careful planning. Consequently, it is vital that challenges, problems, and opportunities be anticipated and that financial and human resources be deployed strategically. The national geoscience knowledge base is an important national resource; however, it is a living, renewable resource that becomes depleted by the advancement of science, if not continually replenished.

To be effective in the public policy process, geoscience information and advice must be credible and user friendly. It must be timely, succinct, and completely understandable in terms of its significance, scope, and limitations; and, at the same time, it must meet the highest standards of scientific quality and reliability. This can only be achieved by maintaining a continuing dialogue between the scientists who generate the information and advice and the people who will use their information and expertise, by employing the best available scientific talent, by fostering scientific creativity, and by ensuring thorough scientific peer review of the science.

At the February 1997 meeting off the American Association for the Advancement of Science, Stephen Schneider (Stanford University climatologist) noted that we face difficult decisions that hinge on scientific expertise, for example, decisions about safe ways to manage nuclear waste or how worthwhile it is to scale back on fossil fuel use to prevent global warming. Every citizen in a democracy is capable of joining in those decisions because in the end, they are value judgments based on common sense plus an awareness of the risks and benefits of alternative strategies. To transcend the current 'dueling experts' scenario, in which two opposing sides deliver politically selected extremes instead of the current scientific consensus on a given technological problem, citizens should seek answers to three questions: What can happen? What are the odds? How do you know? The question "How do you know?" seeks assurance that the answers to the two preceding questions are based on the best available, evolving knowledge.

Geoscience information and expertise that are acquired to meet the needs of national governments for the development of policies can be made available to the nation as a public good at very little added cost. When geoscience information or expertise is used as an instrument of public policy, it is commonly supplied to specific target audiences, for example, citizens who are threatened by the risks associated with natural hazards such as earthquakes and tsunami, or to mineral and energy resource exploration companies that might stimulate regional economic development, or it may be treated as a marketable commodity, but sold at a nominal price to recover part of the cost of its dissemination. However, geoscience information and advice also may be treated as a potential source of national revenue and sold at competitive market prices to other government agencies, to resource development companies, to consultants, or to geoscience service companies. In some countries, the role for the national geological survey has been shifting away from a public-good function, which involves service to the government and to the general public, towards a revenue-generating function that is focused on the sale of professional services and geoscientific information on the open market, in competition with private companies. In a free enterprise society, this trend must inevitably lead to the demise of the national geological survey because a national geological survey cannot succeed in simultaneously fulfilling two conflicting missions, particularly when one of them involves using subsidies from the public purse to compete in the open marketplace with private enterprise.

What does the future hold for national geological surveys?

In a recent address to the U.S. National Research Council's Board on Earth Sciences and Resources, William Fisher, Director of the Texas Bureau of Economic Geology, offered the following cogent observations (and I quote):

> Change, as recorded in events and trends, seems to move steadily, incrementally, and almost predictably for sustained periods, but then seems to move by massive jumps. One event triggers another, and elements of change take on a synergy of their own.
>
> Most of the sciences and for sure the geosciences, are in the midst of such a world of rapid change.
>
> The future cannot be predicted. But trends, properly recognized, can be assessed for the implications they hold;...
>
> It is important to distinguish between the perturbations of the moment and long-term systematic trends. We react to the perturbations; we modify but mostly adapt to the trends....
>
> There are some things about change (that) we should keep in mind:
>
> - No trend or change moves exponentially — up or down — indefinitely, and if something cannot happen, it will not.
> - Change may be disconcerting for many; it is disastrous for the indolent, but change is fertile ground for the resourceful.

There are a number of clearly established trends in our changing world. These include the accelerating growth in the human population, in the risks associated with major geological hazards, in the demand for energy, mineral, soil, and water resources, and in the environmental impacts of human activities. They also include a parallel growth in technological capabilities for the acquisition, management, analysis, and dissemination of geoscience information. These trends involve important challenges and important opportunities for national governments and for national geological surveys.

The problems of geological hazards and the risk to human safety and health, and the question of environmentally sound resource development to meet the needs of the growing human population, are both important policy issues now and they most certainly both will be pre-eminent policy issues in the near future as growth of the human population and in the quest for sustainable development continues to increase.

In order to illustrate the nature and magnitude of these issues, I would like to point out that in 1958, when I completed my Ph.D. and began working as a geologist with the Geological Survey of Canada, the size of the human population was about 2.5 billion. Earlier this year, the World Population Institute reported that the human population had increased by 100 million during 1995 and is now 5.75 billion. During the first part of my professional career, 3.25 billion people have been added to the human population. This is substantially more than were added during all the preceding history of humankind and the rate of growth is still increasing. There has been a concurrent growth in the per capita use of mineral and energy resources and in the per capita contribution to human impacts on the global environment. According to estimates reported in 1989 in the International Union of Geological Sciences news magazine *Episodes* by Brian Skinner of Yale University (Skinner, 1989), worldwide consumption of mineral and energy mineral resources in 1988 was 60 billion tonnes per year (Table 1). This includes only what was extracted for processing and use and does not include material that was moved to facilitate extraction of what was used; nevertheless, it is approximately four times the total mass of sediment transported to the sea each year by all the world's rivers. As the rate of growth of the human population continues to increase, and as the level of affluence in some of the more populous countries continues to grow, the demand and competition for Earth's land, water, energy, and materials will continue to grow at an increasing rate. This will provide important opportunities for countries with a rich mineral resource endowment and new challenges to the concept of sustainable development. I am convinced that we have been living in a brief episode of human history that is remarkable for the magnitude and pace of change in the human population and in its relationships to the use of the Earth's mineral, energy, soil, water, and ecological resources.

The rapidly growing human population, and particularly the continued growth of megacities, will lead to new environmental problems and to dramatically increased risks from natural hazards. The ecological footprint of a megacity — the aggregate area required to support the population — depends on the level of affluence of the city, but normally is very large. It has been said that every city is a black hole that draws on natural resources and productivity of a vast and scattered hinterland, importing carrying capacity and exporting ecological degradation. Demographers seem to agree that, barring some global catastrophe, the human population will not level at less than about 10 billion people and there is no basis for concluding that the established trend towards increasing urbanization will be reversed. Evidently more and larger megacities are part of our future. This will substantially increase the magnitude of the risk from natural hazards such as earthquakes, tsunami, and volcanic eruptions. The 1995 Kobe and Northridge earthquakes brought home the message that in our new global economy, large natural disasters have far-reaching financial and social consequences. In 1924, a major earthquake leveled Tokyo, with disastrous social and economic consequences for Japan. In 2004, a comparable earthquake could be expected to have disastrous economic and social consequences globally.

Table 1. Growth in resource consumption. Per capita consumption of mineral resources in the United States of America, 1988 (Skinner, 1989).

Stone	4900 kg
Sand and gravel	3770 kg
Cement	383 kg
Clays	195 kg
Salt	170 kg
Phosphate	145 kg
Iron and steel	562 kg
Aluminum	22 kg
Copper	9 kg
Zinc	6 kg
Lead	5 kg
Petroleum	100 kg
Coal	2600 kg
Natural gas	1950 kg
Uranium	0.1 kg
U.S.A. total — (17.8 tonnes/person/year) x (245 x 10^6 people) = 4.4 x 10^9 tonnes/year Worldwide average annual consumption is about 10 tonnes/person/year. Worldwide total annual consumption is 10 tonnes/person/year x (5 x 10^9 people) = 50 x 10^9 tonnes/year. Compare with the estimated total mass of sediment transported to the sea each year by all the world's rivers — (14 x 10^9 tonnes/year suspended load) + (2.5 x 10^9 tonnes/year dissolved load) = 16.5 x 10^9 tonnes/year	

It seems inevitable that as we move into the twenty-first century, there will be continued growth in the demand for energy, mineral, soil, and water resources, in the risk from geological hazards, and in the threat to human health and to the environment for life on Earth. Meeting the growing demand for resources, reducing the increasing risk from geological hazards, and protecting human health and the environment will be an increasingly daunting challenge for governments. The need for a credible, reliable source of geoscience information and expertise will grow in the immediate future in every major country in the world and, accordingly, national geological surveys will face new challenges and new opportunities.

Rapid advances in the development of new technologies will also drive changes in the activities of geological surveys. New, rapid, relatively low-cost, high-precision, observational and analytical technologies have created new opportunities for the acquisition of geophysical, geochemical, and geochronological data that have transformed the geoscience of the continents. They offer the prospect of major advances on problems such as extending geological surveys down into the third dimension, depth, where they can address fundamental problems such as the search for deeply buried mineral resources, the storage of toxic wastes, and the clean-up of contaminated groundwater systems, and back into the fourth dimension, time, particularly Precambrian time, the first four fifths of Earth's history, which lacks adequate fossils for precise biostratigraphic dating. New technologies for the storage, retrieval, analysis, and display of data, particularly the geographically referenced data that are the main concern of geological surveys, offer extraordinary opportunities for improving the effectiveness of the geological surveys in performing their research and in communicating with their clients. Geographic information systems and high-speed digital data transmission capabilities are revolutionizing the way geological surveys operate.

International activities will become increasingly important for national geological surveys. International collaboration and co-operation are an essential activity for most national geological surveys now. Many geoscientific problems require a global data set for their resolution and international collaboration is a cost-effective strategy for meeting this requirement. Moreover, the globalization of the economy means that governments have new incentives for acquiring global geoscience knowledge and expertise. For example, international resource assessments provide a basis for analyzing the potential for meeting domestic resources requirements or the international competitiveness and export potential of domestic mineral resources. A national geological survey can assume responsibility for ensuring the availability of this knowledge and expertise.

The twenty-first century will provide new challenges and new opportunities for national geological surveys throughout the world. Emerging global challenges arising from growth in the human population and in the per capita use of resources, in urbanization, and in the resulting depletion of natural resources, deterioration of the environment for human habitation, and risks arising form natural hazards will present governments worldwide with urgent needs for geoscience information and expertise about areas both within and beyond their national borders. New technologies for acquiring and analyzing geoscience data and for disseminating geoscience information and advice will continue to enhance the capabilities of national geological surveys. The potential future role for national geological surveys is very large; the actual future role will depend on many factors, not the least of which will be the leadership displayed by the national geological surveys individually and collectively.

S&T in the federal government: the background
(R.P. Riddihough, Senior Advisor, Earth Sciences Sector)

A key element in the recent history of federal S&T activities was Program Review. Initiated in 1994 for the stated purpose of ‘reinventing’ the federal government, it ushered in some drastic cuts to federal expenditures across all departments.

Each program was subjected to six questions:

- Is this program in the public interest?
- Does this program reflect an appropriate role for the federal government?
- Does this program strengthen our federation?
- Can this program be delivered in partnership with others?
- Is this program being delivered in the most efficient, cost-effective way?
- Is this program affordable?

For the GSC, the exercise resulted in the ranking of scientific programs and a series of graded resource and salary cuts that will total overall 32 per cent by 1997–1998.

At approximately the same time as Program Review, the government began a three-pronged Science and Technology Review. This involved public consultation, a National Advisory Board on S&T, and an internal review of federal S&T programs. This S&T review looked at government S&T under three headings: quality of life, wealth and job creation, advancement of knowledge.

The review concluded with recommendations that the government should invest in S&T in a strategic way, should foster innovation, promote a science culture, develop partnerships, and make expenditures now to save later. The formal response of the government was published in 1996 in a new federal strategy for S&T entitled *Science and Technology for the New Century* (Government of Canada, 1996).

This document outlined some new mechanisms for managing S&T within the federal government and provided a series of directions that should be followed and in many cases reported upon by managers. In summary, these directions focus on increasing the effectiveness of S&T, partnerships, emphasizing prevention and sustainable development, building information networks, building international linkages, and promoting a science culture.

Simultaneously with the issue of the federal strategy, Natural Resources Canada issued a document entitled *New Directions in Science and Technology* (Internet publication, 1997, http://www.nrcan.gc.ca/dmo/spcb/newdir_e.html). This attempted to show how Natural Resources Canada was already implementing many of the directions of the overall federal strategy and featured examples such as the Ocean Drilling Program and NATMAP.

Looked at in hindsight, the years since 1994 have seen a lot of attention paid to S&T within the federal government in Canada. Unfortunately, it is far from clear that this attention will result in any significantly increased funding. What it has already produced is increased attention to the management of federal S&T with some positive indications with regard to training and recruitment of scientists. The lesson I have learned is that the science community must pay more attention to ensuring that the S&T it does has a clear, demonstrable impact and that this impact and the value of our S&T are communicated strongly and loudly to all Canadians.

Federal-provincial relationships (M.E. Cherry, Chief Scientist’s Office, Geological Survey of Canada)

Major changes have occurred in the relationship between the GSC and the provincial and territorial geological surveys since 1993, culminating in the signing of the Intergovernmental Geoscience Accord by mines ministers in Yellowknife on

September 17, 1996. The purpose of this presentation is to provide a brief review of the context in which the Accord was developed, outline its content, and comment on its significance for the bedrock mapping workshop.

Context

The impetus for a formal working agreement between the GSC and the provincial and territorial geological surveys arose from three actions by the federal government.

Overlap and duplication

Increasing concerns in both federal and provincial governments about deficit budgets and the size of government led in the early 1990s to efforts to eliminate overlap and duplication. Mining was identified as a sector for review and the heads of geological surveys were repeatedly called upon to explain to their ministers (and their ministers' political staff) the complementary nature of the mandates and programs of the GSC and the provincial and territorial surveys.

Termination of mineral development agreements

The mineral development agreements (MDAs), which were components of larger cost-shared regional development agreements (RDAs), had become an important funding source for both the GSC and the provinces and territories. As well, the planning and reporting requirements of the MDAs provided the provinces and territories with some influence over GSC activities and they expressed considerable concern about the loss of these communications mechanisms when the federal government announced in 1994 that no new RDAs would be signed after the expiry of existing agreements, most in 1996. In response to these and other concerns about future geoscience programs, the GSC proposed in 1994 that the National Geological Surveys Committee (NGSC) be used to develop national priorities for geoscience, and that bilateral agreements defining mechanisms for detailed program planning and delivery be developed between the GSC and each province or territory.

Program Review

Program Review, undertaken in 1994 by the new Liberal government, was an expansion of the overlap and duplication exercises of the previous government. It was, however, a much more comprehensive and more rigorous exercise and required the GSC to demonstrate how its programs matched six specific criteria for federal departments (*see* below).

Together, these decisions and initiatives generated a significant pressure within the geological surveys to develop a document for ministers that clearly explained the need for surveys in both levels of government and provided assurance that their activities were being undertaken in a co-ordinated, co-operative, and cost-effective manner.

The six tests of Program Review

The six tests of Program Review are still being used to evaluate the appropriateness of federal activities. It is, therefore, important that the bedrock mapping workshop apply these questions to any proposed bedrock mapping strategy. The tests are:

- Is this program in the public interest?
- Does this program reflect an appropriate role for the federal government?
- Does this program strengthen our federation?
- Can this program be delivered in partnership with others?
- Is this program being delivered in the most efficient, cost-effective way?
- Is this program affordable?

Intergovernmental Geoscience Accord

As previously outlined, the Intergovernmental Geoscience Accord was developed by the National Geological Surveys Committee in response to questions about overlap and duplication, efficiency, and cost-effectiveness of geoscience programs being carried out by the federal, provincial, and territorial governments. To accomplish this objective, the Accord defines the complementary roles and responsibilities of the federal and provincial/territorial geological surveys, outlines principles of co-operation that will optimize the utilization of resources among the geological surveys, and establishes mechanisms for co-operation and collaboration among the geological surveys.

The Accord recognizes the mandate of the GSC to conduct national programs to define Canada's geology and resources. These programs are typically thematic in nature and national or broadly regional in scope. The Accord contrasts that role with those of the provincial and territorial surveys, whose programs contribute to the systematic description of the geology and mineral and energy endowment of each jurisdiction. These programs are typically more focused on resource development, shorter in term, and geographically restricted. The agreement also acknowledges that some aspects of the GSC's program, including fundamental research, technology development, and information transfer, are unique in Canada.

The Accord defines three principles that will guide co-operation in geoscience:

All geoscience activities by the GSC within the provinces or territories will be planned in consultation and co-ordination with the appropriate provincial or territorial organization. This principle calls for open, timely communication to ensure that GSC and provincial programs reflect both national and local priorities, and to identify opportunities for collaboration in the earliest stages of program planning.

Geoscience activities proposed by the GSC within the provinces that are directly relevant to the provincial responsibilities for, and territorial interests in, mineral and energy resources and land management will be conducted with the agreement of the province and in a collaborative manner. This principle acknowledges the constitutionally defined provincial control over the development and management of its mineral and energy resources, and the lead role of the provincial geological survey in all activities related to those resources.

If a province requests the GSC to undertake geoscience activities with the characteristics of a provincial program, these activities will be undertaken through formal agreements with the province. This principle provides a mechanism for the provinces to request that the GSC undertake specific activities that would normally be outside its mandate.

Finally, the Accord establishes the following mechanisms to ensure that its objectives will be met:

Detailed, bilateral or multilateral agreements on program planning and delivery between the GSC and its provincial and territorial partners are encouraged. Negotiations toward these subsidiary agreements have been undertaken with almost all the provinces and territories. Agreements have been signed with New Brunswick, Nova Scotia, and Manitoba. The GSC anticipates that agreements will be signed in 1997–1998 with Newfoundland, Ontario, Saskatchewan, Alberta, and the Northwest Territories. British Columbia and the Yukon Territory have expressed satisfaction with previous agreements on program planning. GSC activities in Quebec are planned and delivered in close collaboration with the provincial ministère de l'Énergie et des Ressources, typically through project-specific formal agreements.

Workshops are to be convened at regular intervals by the NGSC to review the GSC's national programs. These workshops are to include all GSC client groups and are intended to review national geoscience priorities and provide input to developing strategies to meet those demands.

Joint work plans developed through the bilateral agreements are to be tabled annually with the NGSC. Tabling of these work plans will allow the NGSC to review progress in the implementation of the Accord and to compile the information required for the national workshops.

An annual written report on progress in implementation of the Accord will be prepared by the NGSC and submitted to the Intergovernmental Working Group on Mining. The annual report to the Intergovernmental Working Group on Mining, which comprises assistant-deputy-minister-level representatives from the provinces and territories and is the executive committee for mines ministers, will provide an accountability report to ministers on the effectiveness of the Intergovernemental Geoscience Accord.

Challenge to the bedrock mapping workshop

The development and signing of the Intergovernmental Geoscience Accord is representative of significant changes in the relationships between the GSC and its provincial and territorial partners. The Committee of Provincial Geologists has commented positively on the GSC's actions in proposing and developing the Accord, saying that the federal-provincial relationship is better in 1997 than it has been for over 20 years. The Accord provides some measure of protection to all geological surveys from erroneous perceptions of duplication that have risen at political levels in the past. At the same time, the Accord and the new relationships that it will develop present a challenge to the GSC. This challenge should be remembered during the deliberations of the bedrock mapping workshop and taken into consideration in any proposals from the workshop.

It is important that the workshop define a bedrock geoscience program that is

National	It must satisfy the criteria of Program Review and the principles of the Intergovernmental Geoscience Accord.
Defensible	It must produce results that fulfill government policy objectives.
Doable	It must provide mechanisms to make choices about activities within fiscal constraints.

THEME-SESSION REPORTS

Theme session 1: Bedrock mapping (M.R. St-Onge, M.P. Cecile, R.I. Thompson)

Vision

> By the year 2010, the bedrock mapping program aims to provide an integrated, multiscale, digital geoscience knowledge base of Canada comprising both maps and process understanding from the biosphere down into the mantle and through time (i.e. 4D map of Canada), easily accessed by the public of Canada in flexible formats and on demand. Towards this end, by 2010 we also aim to have 50 per cent of Canada's landmass and continental shelves covered by good quality, small-scale geoscience maps with many in integrated GIS digital format.

This statement reaches far beyond a two-dimensional presentation of the surface bedrock geology of the nation. It creates the opportunity and emphasizes the need for all scientists at the GSC to contribute their data and interpretations to a common geoscientific framework. The 2010 version of the 'map of Canada' is viewed as an evolving and dynamic vehicle for integrating and synthesizing the national geoscience database. Each of the phrases of this vision statement deserves amplification.

'Integrated' refers to the many different databases incorporated; 'multiscale' refers to the capability of viewing Canada at a variety of scales depending upon the needs of the viewer and the availability and quality of data for any particular area; 'digital geoscience knowledge base' refers to the flexibility of the emerging new technology that provides us with the ability to manipulate and compare independent databases and that will be the new scientific tool of the future; 'biosphere down into the mantle' refers to the four-dimensional approach — the third dimension being depth and the fourth being time — that emerges when surface data are combined with subsurface data; 'easily accessed by the public of Canada in flexible formats and on demand' refers to the need to ensure that both digital (CD-ROMs and the Internet) and hard-copy versions of the map of Canada, in one or more of its plethora of expressions, are within easy reach of all Canadians.

The 2010 version of the map of Canada should contain the capability to respond to the diverse demands that will be placed on it by those who use it. Better informed governance and policy, resource endowment, natural hazards, sustainable development, management and disposal of hazardous wastes, education of school children about the Canadian landmass, formulation of GSC scientific program, and anticipation of future geoscience needs by the nation are a few of the needs it will serve. At the same time, it is viewed as an important scientific tool that will enable geoscientists to interpret the evolution of the craton in four dimensions, thereby paving the way for scientific breakthroughs.

Scientific rationale

Our vision requires that we maintain a balance between regional expertise and the scientific themes that focus more specifically on problems and processes, clients demands, and the need for improved geoscientific map coverage of Canada. These approaches are not in opposition; however, the balance between them may vary depending on location and state of knowledge.

One means of characterizing the science demands on the mapping program is to show the interdependence of science themes, regional expertise, and geographic location of resources. This is portrayed in Figure 1, in which the 2010 map of Canada is shown embedded in an 'umbrella' spanning the nation. Regional expertise is represented beneath the umbrella as arrows pointing upward towards each of the office locations; the science themes common to the mapping program are overarching because they are the scientific context (and rationalization) within which mapping is done; the edge of the umbrella represents the scientific linkages that exist between offices, exemplified in this case by NATMAP. The map of Canada is portrayed in three dimensions and embedded into the umbrella to emphasize that it combines surface and subsurface maps and that it is the synthetic focus for all mapping activity; in other words, all geoscientists within the GSC have a responsibility to contribute their data to the 2010 version of the map of Canada.

Responsibility for creating and implementing individual mapping programs towards achieving our vision rests with each office. Priority setting will depend on the regional context and will be based on some combination of considerations. Figure 2 is an example 'tetrahedron' defining the decision-making space in terms of client needs, regional presence needs, scientific needs, and data gaps; it is recognized that no one set of priorities can be applied uniformly.

The seven scientific themes are viewed as the primary scientific 'driving forces' behind mapping activity. The theme 'urban geology, hazards, water' is crucial in areas with dense populations whether they be large urban areas such as the Lower Mainland of British Columbia or a population-industrial corridor such as the St. Lawrence–Great Lakes. 'Plate margin processes' provide scientific linkage through time, from the present-day Pacific and Atlantic margins that bracket the onshore geology, through the Phanerozoic and Proterozoic margins that are fossilized within and constitute a major portion of the continent. 'Intracratonic basins' are the repository of detailed stratigraphic information that describes episodes of uplift and erosion as well as subsidence and deposition across the continent; 'map of the mantle' acknowledges that we have the capacity and need to map the current geophysical nature of crustal and noncrustal lithosphere as well as the opportunity to map the geochemical evolution of the lithosphere through time, thereby adding to our understanding of the geometry and nature of the third dimension (depth); 'chronostratigraphy of Canada' recognizes the need to maintain the expertise and develop the tools that provide control on the fourth dimension (time); 'Archean crustal evolution' is highlighted because it is viewed as 'different' by many geoscientists and does not necessarily fit within the plate tectonic context that is so useful in explaining Proterozoic and Phanerozoic crustal evolution and dynamics; 'Earth systems science'

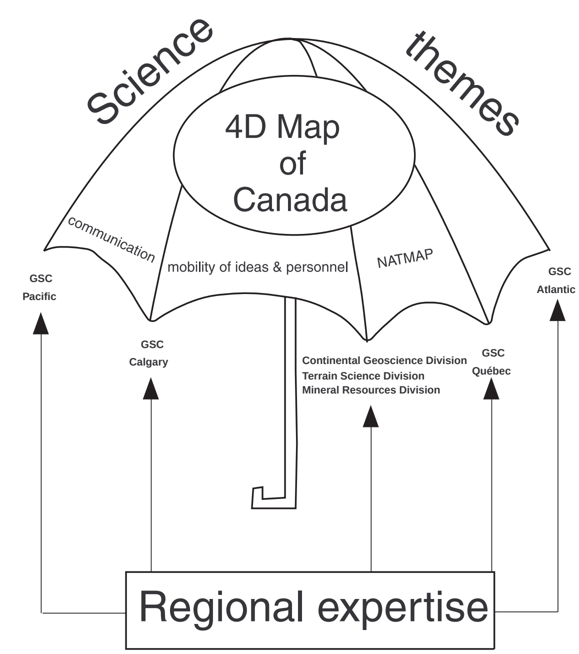

Figure 1. *Interdependence of science themes, regional expertise, and 4D map of Canada.*

acknowledges that we live within an integrated lithosphere-biosphere-atmosphere system and that our work impinges on and can be directly related to the study and understanding of environmental change.

Communication between offices at all levels is necessary if our vision is to be achieved. The collaborative, multidisciplinary principles of programs like NATMAP are viewed as a means of focusing resources from inside and outside the GSC onto specific areas and problems, thereby adding resources above and beyond the capability of an individual office; it is a means of evaluating the relative merits of large projects and ensuring they have an adequate and defensible conceptual framework; and it provides a national perspective on the state of and need for bedrock studies. It also provides a principle that should be followed by smaller projects.

Recommendations

- Initiate a national Geoscience Knowledge Base Project ('4D map of Canada') that will allow the Bedrock Geoscience Program to provide by the year 2010 an integrated, multiscale, digital, geoscientific synthesis of Canada comprising both maps and process understanding from the biosphere into the mantle and through time. The 4D 'map' is viewed as an evolving and dynamic product that would be consistent across the nation at a synthesis scale (e.g. 1:1 000 000). The project should be run under the auspices of the Office of the Chief Scientist and will require a pan-GSC team comprising geoscientists and geoscience information specialists working towards specific incremental goals and products. Project leaders need to be identified and given terms of reference.
- Ensure the development and implementation of a pan-GSC program of integrated research projects on key geoscience themes tied to Bedrock Geoscience Program goals such as the 4D map of Canada. The geoscience themes would promote the understanding of processes and would anticipate and respond to changing societal needs (emphasis on Earth systems interfaces such as crust-water, crust-mantle, crust-biosphere). The geoscience themes are viewed as the primary scientific 'driving forces' behind mapping activity.
- Establish interdivisional geoscience-theme working groups around the key geoscience themes and encourage mobility of ideas and staff as required. This will provide the necessary scientific critical mass for the exchange of ideas and information within the research themes. Promote and enhance pan-GSC communications by organizing annual field trips, GSC-wide scientific lecture tours, and websites.
- Initiate pan-GSC, science-driven reviews (workshop format) to foster communication and debate research progress and direction on the key geoscience themes.
- Maintain and improve regional expertise through the GSC division structure in order to retain identifiable, ready sources of geoscientific information for all regions of Canada and maintain the GSC's ability to answer questions pertaining to the public good (health and hazards), the search for mineral or energy resources, and land use issues. Regional expertise and activities as organized/channeled through the key geoscience themes will cumulatively contribute to the 4D geoscientific synthesis of the Canadian territory.
- Ensure that all current and future GSC projects emphasize the third (depth) and fourth (time) dimensions. This requires the integration of geology and geophysics, chronostratigraphy (conventional and SHRIMP

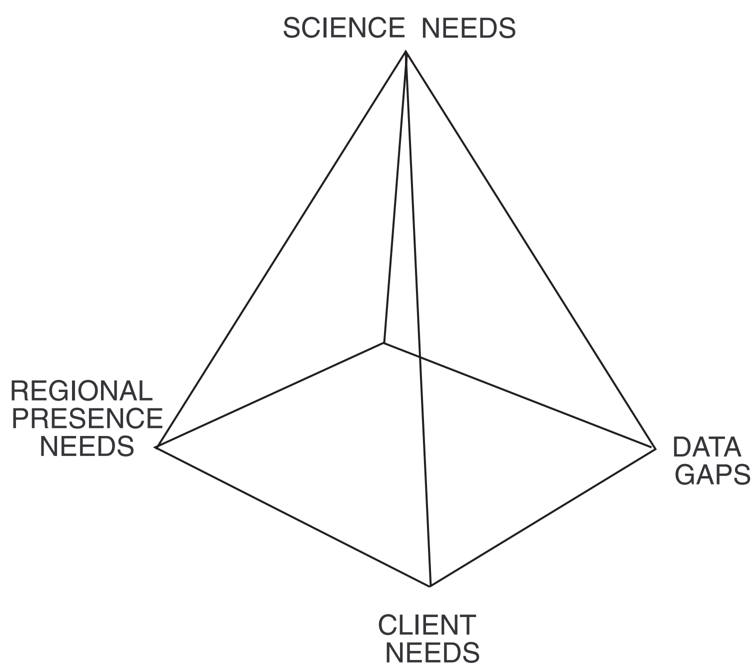

Figure 2.

Decision-making space.

geochronology, biostratigraphy, lithostratigraphy, sequence stratigraphy as applicable), as well as sound database management.

- By the year 2010, have 50 per cent of Canada's landmass and continental shelves covered by good quality geoscience maps at scales appropriate to the region and have a large number of these maps in a very high quality, integrated GIS digital format.
- By the year 2000, have metadata (data on what data we have) available in a user-friendly format that allows for geographically based inquiries of what geoscience data are available where in Canada including data of the GSC, the provinces and territories, universities, and industry.
- Improve the quality (internal consistency) of the recorded information within the GEOSCAN metadatabase in order to make it comprehensive and geographically searchable. Development work is required to allow a seamless link between database queries and GIS-registered output (maps). An improved GEOSCAN system would be of great use to research scientists, GSC management, and our clients for project planning.
- A status-of-geoscientific-knowledge map (database) should be compiled and updated as required from continental shelf to continental shelf. The knowledge evaluated should include all relevant geoscientific fields (e.g. bedrock and surficial geology, geophysics, geochronology, mineral and petroleum resources, hazards, etc.) at appropriate scales. The resulting integrated information is required for better project planning and for documenting what has been done and what remains to be done (identification of knowledge gaps). The compilation should include GSC and provincial/territorial contributions.
- Clearly establish a reference datum in terms of available, multiparameter compilations as starting points for the 4D geoscientific synthesis of Canada. This should include GSC and British Columbia Geological Survey compilations of parts of the Cordilleran Orogen, as well as 1:1 000 000 scale compilations for eastern and central Canada.
- Apply NATMAP principles (collaborative, multidisciplinary, and, as appropriate, multiagency approach) to all projects at the GSC, but restrict the NATMAP supra-management structure to major projects. In addition, the human and financial resources of major (NATMAP) projects should be held at their present levels and possibly reduced to allow the entrepreneurial A-base projects to continue to flourish following NATMAP principles.

Detailed report on the proceedings

Introduction

The following notes are from four different breakout sessions of the Bedrock Mapping theme session. The raw data are grouped into six major areas of discussion suggested by the Steering Committee. Virtually all ideas expressed by the participants are captured here. Some website submissions are included.

The session was co-ordinated by a facilitator using a very open format of introduction, presentations, discussion, and summary. The three co-chairs participated in the discussion. Results of the first two sessions were used as an introductory template for the last two. The final session ended with a review of visions for the future from all participants and from all breakout sessions.

Reaction to the sessions varied from very positive to good.

Theme-specific visions (list of ideas presented)

- Geoscience mapping is driven by a tetrahedron consisting of types of clients, science, need to know, and regional coverage. Presently, we lie in the tetrahedron towards the science and clients side. There was considerable discussion on how priorities in selecting areas to be mapped should be managed. Emphasis was placed on keeping a balance between all the driving factors and on the need for regional presence and maintaining regional expertise.
- NATMAP is an innovative method of driving major new initiatives. It should eventually be broadened into a new management style that incorporates the principles of collaboration, co-operation, multidisciplinary and intradivisional approaches, and GIS data management. The NATMAP formal committee structure is really only necessary and appropriate for large-scale projects. Its principles could be applied through the existing management structure to smaller projects. NATMAP's share of resources should be held at its present level and possibly reduced.
- Participants felt that national umbrella projects are needed to help us achieve national objectives and to strengthen our science, bring our efforts together, and alleviate our reduced human resource level. With this, staff mobility and widespread communications are needed.
- The third and fourth dimensions must be an integral part of any mapping program.
- There is a need to prepare for Canadians' future demands for mineral and energy resources and for information on environmental aspects of the geosciences including hazards, ground water, waste disposal, etc.

Umbrella themes suggested by participants

- a sedimentary-hosted mineralization mapping project with a least five different geological settings (Mississippi-Valley type, alluvial gold, Prairie type, unconformity-controlled, and shale-hosted nickel, molybdenum, PGE deposits);

- location of new sources of underground freshwater, undiscovered energy resources, blind ore bodies, aggregate and industrial minerals, safe sites for disposal of waste;
- consequences of catastrophic climate change;
- three-dimensional aspect of the crust, of the geology of the plains;
- identification of our Neotectonic features;
- chronostratigraphy of Canada to improve our understanding of the timing of basin fill and of sequence stratigraphy, using geochronology (SHRIMP), biostratigraphy, lithostratigraphy; this is considered an important tool in support of geoscience mapping;
- study of the origin and evolution of intracratonic, Phanerozoic basins and their basements (e.g. Hudson's Bay) in four dimensions, including their Precambrian geology under the Phanerozoic cover;
- a focus on studying the origin and evolution of Precambrian basins (e.g. Borden);
- study and origin of intracratonic uplifts in 4D (e.g. Severn Arch);
- systematic 4D compilation and production of 1:500 000 or 1:1 000 000 scale GIS maps of the Interior Plains; a similar concept may apply to offshore basin areas at a different scale;
- studies of processes relating to the evolution and destruction of continental margins starting with modern margins and working back to older, collisional zones in the Phanerozoic and the Precambrian; suggested titles included 'evolution of plate margins through time', 'Precambrian plate margins — how far back?', 'evolution and devolution of the proto-Pacific', 'comparison of continental collisions of all ages' (these zones are mineral-rich, which justifies focusing on them);
- a study of the enigmatic Late Paleozoic orogeny in the Cordillera;
- evolution of orogens and yoked sedimentary basins of all ages;
- a study of unroofing processes in orogenic belts;
- Archean assembly and crustal development; crust–mantle interaction, shield roots, plate tectonic processes, style of deformation;
- systematic geoscience (bedrock-surficial-geophysical) mapping at 1:25 000 scale of urban/populated areas — a project to prepare for future demands, similar to the Oak Ridges Moraine or southern Manitoba projects and including a study of near-surface processes, bedrock to surficial; further geophysical development needed;
- studies of the Tertiary to Recent such as 'transition and evolution from Tertiary to Recent from the Cordillera to the shield' and 'Late Tertiary to preglacial evolution of fluvial landscape across Canada';
- mapping programs to describe the lower crust, the mantle, etc., including mapping the mantle using regional basalt geochemistry and information derived from xenoliths as examples;
- more atlas compilations, such as East Coast, Beaufort–Mackenzie, in places like the Windsor–Québec corridor, parts of the shield, etc.; map compilations of tectonic entities like the Cordilleran map; mapping of national parks for both outreach and park management;
- goal of a new map of Canada at 1:250 000 scale;
- a more quantitative approach to geological processes, lithospheric-scale processes such as the generation of granites; even the basic quantification of granitic material has not been done;
- project to study the correlation of the Proterozoic subsurface from the Arctic to the northern Interior Plains;
- studies should be organized in an 'Earth sciences systems' format.

Theme-specific priorities

- A better understanding of the status of mapping is needed to establish priorities. A better database is needed to achieve this goal and to make the results more easily available to our clients.
- To maintain regional expertise over all our jurisdictional areas and to be prepared to address the demands of any client on subjects from resources to hazards.
- Allow for greater scientific staff mobility and communication.

Principal strengths and opportunities

- collaboration, multidisciplinary and interdivisional approaches, pooled resources as demonstrated by NATMAP;
- our present staff has broad-based experience, regional knowledge and expertise, and is open minded;
- strength exists in our 'raison d'être'; Canada needs the GSC and its maps because ours is a resource-based economy;
- strength in being able to do long-term programs with both short- and long-term benefits;
- breadth of our science including its infrastructure in geophysics, geochronology, geochemistry;
- recognized leadership role in concepts of the Canadian landmass for all clients;
- recognized nationally and internationally for our research ethics, the quality of work, and for being honest brokers.

Weaknesses

- The database of geoscience information is incomplete and some parts (geological maps and geoscience reports) are very user unfriendly. We cannot properly plan where to go next without it. In addition, clients have a hard time finding what is available.
- NATMAP favours large projects and commands significant resources and personnel, diverts a lot of grass-roots, A-base budget initiatives. It is unlikely that NATMAP can or should take on small projects. The solution is to reserve NATMAP for large projects and limit its size to allow for development of other projects.
- The NATMAP management structure is too demanding in that it is a management scheme built on an existing management scheme. Could it be build into the existing GSC management? Some believe that this type of special management is needed for large projects.
- The GSC is unfocused in not recognizing the need for regional maps. A map of Canada is needed at a scale of 1:250 000 or larger.
- We have a reduced number of mappers, we are at or below critical mass, and we have an aging staff that is not being rejuvenated.
- There is too much focus on short-term clients at the expense of our-long term clients.
- Management is becoming too politically oriented and is not allowed to properly address the science program.
- We need to make more use of and acquire more industry data, such as seismic lines in the Interior Plains.
- The infrastructure in geophysics, geochemistry, and geochronology is threatened and declining because of reduced budgets. It is under additional pressure because of the difficulty of managing cost recovery while trying to maintain national science programs.

Communication

- A top priority is to have proper-status geoscience maps, to undertake interdisciplinary and collaborative activities, and to let our clients and our colleagues know what we are doing and what we have done.
- The Assistant Deputy Minister should be asked to reorder priorities so that the science program is placed up front and given a higher priority than reforming management. The prioritization of management initiatives has resulted in senior management and division directors being less involved in steering science and in more of a response and political mode rather than a science leadership mode.
- There is a disconnection with the political level — we do not speak their corporate language and we have to learn it. We need a scientific lobbyist.
- Internal communication is a problem; Deputy Minister's highlights should be circulated.
- New field trips and staff exchanges are needed to show each other what we are doing. We need better communication among staff about the science program through field trips, web pages, etc.
- We need outreach programs or elements to educate the public — urban geology programs would have this element. We should work towards producing, for high schools, geological maps that are formatted for appropriate age groups.

Strategic visions (results of the final poll at the end of the last session)

- map products to meet society's needs
- bedrock maps that elucidate ore-forming processes
- 15–20 years full new map of the Cordillera in digital format at 1:250 000 scale together with resource maps, environmental thematic maps
- 1:1 000 000 maps of all of Canada across jurisdictions
- integration of biostratigraphic and radiometric data
- set of urban geology maps
- mapping in an Earth system sense
- much better access to the existing wealth of data and better use of it for multiple purposes
- national digital database of the geological and environmental data needed to manage Canada's energy resources
- full integration of geology and geophysics — one kind of map, unified effort
- models of igneous orogenic processes
- GSC moves to a theme-team, multidisciplinary approach to studying Canada in 3D computer format
- national leadership in co-ordinating work with industry and universities
- integrated, scale-independent map of Canada showing existing information from the biosphere to the mantle
- the above-mentioned map should be available in grade 9 textbooks across Canada

Theme session 2: Geophysics (Walter Roest and Don White)

Geophysics was the focus of one of five predetermined themes that were discussed during concurrent breakout sessions at the recent Bedrock Geoscience Program Workshop. The objectives of the Geophysics theme session were to provide information to the participants on the current status of geophysics at the GSC, to query a broad spectrum of GSC Earth scientists as to the role (perceived and/or realistic) of geophysics in the GSC, to stimulate discussion regarding collaboration amongst geophysicists and other Earth scientists, and to poll GSC geophysicists in particular concerning future directions for the GSC program.

Geophysics at the GSC

Within the science programs of the GSC, six divisions use geophysics and a significant number of geophysical subdisciplines (Table 2). Activities include baseline or systematic data acquisition, as well as targeted studies. With some exceptions, the geophysical programs in each of the divisions are planned and conducted under the general mandate of the division responsible for them or the program component they belong to. Thus, specific geophysical methods are most often associated with particular geographic areas and/or geological (depth) scales. Although there has been some interdivisional co-operation in geophysics, it seems to be limited.

What does geophysics have to offer?

Perusal of the activity list in Table 2 identifies the key strengths of geophysics and the contributions geophysics makes to the Bedrock Geoscience Program of the GSC. First and foremost, geophysical techniques provide the only means (apart from drilling) of quantitatively constraining subsurface geology. Secondly, geophysics provides systematic surface mapping capabilities that complement or replace conventional geological mapping techniques. Thirdly, geophysical techniques are inherently scalable, which allows methods developed for problems at one particular scale to be adapted for application at other scales. Finally, geophysics is capable of providing limited time constraints on geological processes, both historically, in real time, and predictively.

Vision

The GSC needs to work towards a truly integrated geoscience program that combines geology, geophysics, and other disciplines. The role and importance of each particular discipline in a project will depend on the scientific objectives. At the same time, it is important to strengthen or at least maintain geophysical expertise, in order to guarantee a healthy discipline that can maximize its contribution to understanding the third dimension of the Canadian landmass.

Workshop discussion themes and recommendations

Provided below are summaries of topics discussed during the Geophysics theme session, followed by recommendations from the theme-session chairs with crossreference to the vision and recommendations from the other workshop theme sessions.

Table 2. Geophysical methods in use at the GSC

Offshore mapping	GSC Pacific, GSC Atlantic
GPS (geodynamics)	GSC Pacific
Paleomagnetism	GSC Pacific, CGD
Potential field interpretation	GSC Pacific, GSC Atlantic, CGD
Heat flow studies	GSC Pacific
Structure-related earthquake studies	GSC Pacific /GSC Pacific–GSC Ottawa
Neotectonic studies (geodynamics)	GSC Pacific
Physical rock properties	GSC Atlantic, GSC Pacific, MRD
Sedimentary basin seismic interpretation	GSC Calgary, GSC Atlantic
Crustal-scale seismic reflection studies	CGD, GSC Pacific, GSC Calgary, GSC Atlantic
Mining camp seismic techniques	CGD, GSC Atlantic
Crustal-scale seismic refraction studies	CGD, GSC Atlantic
Controlled-source electromagnetic techniques	CGD, TSD
Magnetotelluric techniques	CGD
Borehole geophysics	MRD, GSC Calgary, GSC Atlantic
Airborne geophysics/radiometrics	MRD
Aeromagnetic data acquisition	CGD
Target gravity data acquisition	CGD
Shallow seismic methods	TSD, GSC Atlantic
Ground-probing radar	TSD
3-D seismic	CGD, GSC Atlantic
Teleseismics	CGD, GSC Pacific
Geodynamic modelling	GSC Atlantic, GSC Pacific
Geomagnetism	GSC Pacific–GSC Ottawa
Earthquake monitoring	GSC Pacific–GSC Ottawa
Quantitative geological modelling	GSC Atlantic
Note: CGD = Continental Geoscience Division; MRD = Mineral Resources Division; TSD = Terrain Sciences Division	

Theme I: Towards a fully integrated Geoscience Program

The third dimension

Mapping of the third dimension of Earth structure (i.e. depth) is becoming ever more important. The third dimension forms one of the cornerstones of the digital geoscience knowledge base of Canada (*see* Theme session 1: Bedrock mapping) and is critical for exploration, assessment, and exploitation of Canada's subsurface resources. Geophysical techniques provide the only means (apart from drilling) of quantitatively constraining subsurface geology and thus appropriate GSC resources should be available so that geophysical methods can be used to constrain subsurface geology.

Recommendations

- Appropriate GSC resources should be available for geophysical sounding of the subsurface. Currently, our primary efforts to constrain the third dimension using seismic and electromagnetic techniques are directed through the LITHOPROBE project. Following the completion of LITHOPROBE, those GSC resources should be maintained and used for imaging the third dimension of key geological targets identified by the GSC.
- In addition to acquiring new data, we need to continue/expand the use of industry databases on the Western Canada Sedimentary Basin and East Coast extensional basins.

Collaboration and integration

To fully address the complex geoscience issues that fall within the mandate of the GSC, it is increasingly recognized that co-ordinated, multidisciplinary programs are essential. Such programs require better interdisciplinary and interdivisional collaboration and integration, which ultimately will result in the delivery of a more efficient, complete, and scientifically sound program by the GSC. Programs of all scales would benefit from this approach, although the organizational effort required to achieve this goal should be kept in line with the size and scope of the project.

Recommendations

- A mechanism should be developed to facilitate the conception, development, and evaluation of integrated geoscience proposals at the GSC with established protocol for their acceptance and funding by senior management. Scientific review of proposed programs is essential to ensure the application of all relevant and essential geoscience methods required to address the specific problem.
- Multidisciplinary participation should be solicited at the start of project formulation rather than as an afterthought. Failure to do so results in inefficient and unfocused project-planning.
- Foster more extensive interdivisional collaboration by eliminating interdivisional barriers to funding of integrated proposals and to participation of personnel in extradivisional projects.

Communication

Effective geoscience within the Canadian geoscience community (GSC, provincial surveys, universities, industry) requires improved communication within and between the constituent agencies. In particular, if multidisciplinary planning and integration is the ultimate goal, then communication regarding proposed projects is essential. It is noted that GSC communication with industry, universities, and international academia is currently primarily on an individual basis, although at present LITHOPROBE plays an important role in communication with university Earth science research.

Recommendations

- EASY online acess to GSC program information should be provided to GSC scientists. This would ensure timely knowledge of relevant program activities.
- Website/bulletin boards should be instituted as a means of announcing and developing new projects, as well as communicating new results within existing projects. Their interactive nature is ideal for encouraging critical feedback and soliciting other relevant information. However, to be effective, websites must be well managed.
- Periodic scientific program review at the bench level (e.g. divisional program review) should be re-established. These review meetings should be modified so that in addition to reviewing existing programs, they provide a forum for planning upcoming programs.
- Reinstatement of the equivalent of Energy, Mines, and Resources Canada research agreements with Canadian universities should be considered as a method of forging closer ties with university Earth science programs.

Theme II: Geophysics the discipline

Geophysics research

The unique ability of geophysics to determine depth and its fundamental role in determining the depth dimension of the Canadian Geoscience Knowledge Base is recognized. The central role of geophysics within the successful LITHOPROBE project attests to the power of geophysical techniques. However, the success of applied geophysics as a complementary geological mapping tool is a direct outcome of a broader geophysical research and development program. Furthermore, geophysical subdisciplines examine geoscience problems that are uniquely addressed by geophysics (e.g. geomagnetism). To maintain/advance our expertise, geophysically driven research must remain a priority. Failure to promote vigorous, fundamental geophysical research will also result in the antiquation and eventual demise of GSC applied geophysics.

Recommendations

- Geophysical research must remain a priority. Geophysics will contribute to an integrated GSC geoscience program, but commitments to geological programs must be balanced by the need to maintain a thriving geophysical research program.
- Geophysics-based initiatives should continue as a fundamental element of the GSC Bedrock Geoscience Program. Geophysical leadership should not preclude the multidisciplinary nature of such initiatives.

Critical mass

The importance of maintaining critical mass (with regard to personnel) within the GSC geophysics program was a central theme of the session. It was emphasized that several geophysics subdisciplines at the GSC are already subcritical, whereas others are nearing the subcritical threshold. In the short term, this will have serious consequences that may not be immediately recognized. In the longer term, it will fundamentally alter the impact of geophysics within the GSC program. In this period of program reductions, it is difficult to argue that geophysics is unique in this regard. However, this does not discount the reality of the situation.

Recommendation

- The lack of critical mass within many of the geophysics subdisciplines at the GSC should be recognized and its impact on the delivery of the GSC program considered. A strategy for addressing this situation should be established.

Theme III: New opportunities and priorities for geophysics

The primary strength of geophysics is its ability to provide quantitative, subsurface information in a systematic fashion at a variety of scales. Consideration of the possibilities of this capability opens potential applications within an integrated GSC bedrock program and helps identify potential research topics where geophysical methods are uniquely suited to playing the lead role. A list of geophysical themes was assembled and posted on the website prior to the workshop as a means of stimulating discussion. In addition, the following list of geophysical applications and opportunities was assembled by participants during the Geophysics theme sessions:

- study of the overburden/basement interface and relationship to groundwater resources (e.g. Oak Ridges Moraine)
- exploitation of existing industry seismic data in sedimentary basins and calibration with other data, such as aeromagnetics and gravity
- geophysics for mineral exploration (e.g. downhole seismic imaging; 3D seismic, Sudbury; electromagnetic methods; high-resolution aeromagnetics, EXTECH New Brunswick)
- shallow (upper 5–10 km) foothills geology requires the acquisition of new seismic data
- crust-–mantle interaction studies using long-wavelength potential fields and deep-sounding magnetotelluric and seismic data
- lithospheric mantle processes and their relation to electrical and seismic anisotropy, gravity, and the formation of diamonds
- enhancement and exploitation of shear-wave seismic techniques
- improvement of interferometric synthetic aperture radar applications to ground motion.

Of the wide range of topics discussed under this item, two themes stood out in particular. They are described below.

1. An improved understanding of the interface between geology and geophysics

   The primary strength of geophysics is that it provides information on the subsurface and can do so in a systematic fashion. However, linking the geophysical parameters measured in the field to the processes that cause the variations in physical properties of the rocks is not easy. An effort has to be made to further the understanding of the interface between geology and geophysics through research on rock properties, surface geology, shallow geophysical imaging techniques (surface and borehole seismic and electromagnetics), and high-resolution potential-field data.

2. An improved understanding of the lithospheric mantle

   It is clear that lithospheric mantle processes and properties are important in the tectonic evolution of the Canadian landmass. Geophysics is well suited to taking the lead in a program to better understand lithospheric mantle processes and their relation to crustal processes and geodynamics. This theme combined with interest expressed in the formation of intracratonic basins suggests that a fully integrated study of Hudson Bay, from the lithospheric mantle to the surface, would be a suitable focus.

Proceedings of the Geophysics theme session

The Geophysics theme session comprised four separate breakout sessions conducted over the two days of the workshop. These sessions were chaired by Walter Roest and Don White (Continental Geoscience Division) with Mike Cherry acting as facilitator. A total of 26 workshop participants attended the four geophysics sessions.

Each geophysics session was conducted using a similar format that included an overview of geophysics within the GSC, strengths and weaknesses of geophysical techniques, presentation of a list of potential research themes, augmentation of the list by session participants with an open table discussion, break out into smaller discussion groups, and a final discussion and summary

The smaller discussion groups were abandoned after the first session, as this part of the exercise proved unproductive.

The discussions that took place during the breakout sessions were generally broad-ranging with some guidance provided by the preliminary lists and themes presented by the session chair.

Geophysical techniques

A list of geophysical techniques used at the GSC (Table 2) was prepared by the session chairs with additional items provided by session participants. Discussions based on this list included the following:

- What geophysical techniques are not used at the GSC?

  - little or no whole-earth geophysical methods (e.g. global tomography).

- What geophysical techniques are we not exploiting to their full potential?

  - geodynamic modelling,

  - modeling of geophysical data in general.

Opportunities for new geophysical applications

A list of opportunities was prepared by the session chairs with aditional items suggested by session participants.

- GPS: with full availability, GPS has in effect revolutionized our way of working
- geodynamic modelling: currently underutilized?
- technology development: essentially impossible with current resources
- interferometric synthetic aperture radar (IFSAR) (e.g. plans for a high-altitude ER-2 mission in the U.S.A. to measure accurate topography for the whole country)
- industry seismic databases: do we have resources to handle influx?

Strengths and weaknesses of geophysics in general and of the geophysics program at the GSC

<u>Strengths</u>

- Third dimension: geophysics is the primary means of mapping the third dimension and, through modelling, the fourth.
- Scalable: geophysical methods are inherently scalable, allowing methods developed at a particular scale to be modified to address larger or smaller scales.
- Only tool: geophysical methods are one of the only tools to look at deep, in situ properties and processes.
- Quantitative: the quantitative nature of geophysical data (sample rate and accuracy are generally known) allows the application of modelling techniques to maximize the information that can be extracted from the data.
- Systematic: several geophysical methods provide systematic coverage, not restricted by limited outcrop and accessibility.
- Predictive: using the physical constraints, predictive models can be developed that can be tested.
- Cost effective: many geophysical methods are becoming less expensive and/or are being improved through digital data acquisition, GPS, and improved computer power.

<u>Weaknesses</u>

- Expensive: geophysical methods are cost-effective, but nonetheless can be expensive and therefore surveys must be properly targeted to mitigate the costs.
- Nonunique: geophysical methods on their own can be suitable to address some specific questions, but in general they must be integrated with other information.
- Modelling: the quantitative nature of geophysical data is not being fully exploited within the GSC.

Geophysical themes

The following themes were presented for discussion. They were assembled prior to the workshop on the basis of discussion amongst geophysicists at the Observatory Campus. Their intent was to stimulate discussion. Specific discussions related to each of the themes can be found at the end of this section.

- understanding geophysical groundtruthing
- transitions in Earth evolution
- mapping the lithosphere
- intracratonic tectonics
- early crustal genesis
- Arctic studies
- strategic targets and hypothesis testing
- neotectonics: earthquakes in Canada's old and young geological terranes.

Other themes were added during the Geophysics theme sessions, including the following:

- extensional basins (east coast)
- intracratonic basins
- active plate tectonics (west coast)
- environment: geophysical mapping of the uppermost crust (nuclear waste disposal, metals in the environment [MITE], paleoclimates).

Summary of round-table discussions

<u>Session I</u>

The third dimension in bedrock geoscience is important and will only increase in importance. Geophysics will play a key role in establishing the third dimension.

In 10 to 15 years, we should have a fully integrated Earth science research program, have made a quantum leap in the understanding of the Canadian lithosphere, and developed at least one new geophysical technique.

Baseline geophysics and geophysics that is fully integrated with geology must be supported.

Session II

The importance of collaborative work and the integration of geophysics with the other Earth science disciplines is recognized. However, research time devoted to geophysics (technology and technique development, geophysically posed Earth science questions) must be maintained. It must not be eliminated by overcommitting to collaborative work.

The following highest priority geophysics initiatives were identified: 1) groundtruthing initiative (exploring the interface between geology and geophysics); 2) 3D imaging of the crust and lithosphere, particularly the shallow crust (upper few kilometres); 3) geodynamic modelling, hypotheses testing, looking at linkages among subdisciplines; 4) probing the subcrustal lithosphere.

Session III

Resources should be maintained/provided for the third dimension in the bedrock program.

A possible future endeavor could be to develop technology to further utilize shear-wave information in seismic investigations.

Targets for using seismic reflection methods to provide the third dimension must be assessed carefully knowing that the method is suboptimal in regions dominated by steeply dipping structures.

We should try to get access to existing industry data, although this will not provide the third dimension in most areas of the country.

Session IV

Geophysics and geology must be integrated from the planning stages.

Major project proposals should be posted to obtain input from scientists representing the various subdisciplines.

A proposal-based system should be implemented to accommodate proposals from the bench level, allowing access to scientific resources across divisional barriers.

Communication is essential.

Conclusions

The opinion was expressed that the contribution of geophysics to the bedrock program must grow. Understanding the lithosphere/upper mantle is suitable for a geophysics-driven theme, but determining the third dimension in the upper few kilometres is critical.

In order to accomplish this, we need better communication within the geophysics community and across the divisions, as well as improved linkages in project planning to successfully integrate geology and geophysics.

Theme session 3: Process-oriented research

(R. Hyndman, K. Osadetz, and T. Skulski)

Executive summary

Over the course of a two-day workshop, 41 GSC scientists in groups of ten participated in a theme session on process-oriented research at the GSC. Although many opportunities for process-oriented research could be identified, attempts at prioritizing these opportunities were generally difficult or were not attempted.

A number of common recommendations were made to facilitate process-oriented research and criteria were formulated for accepting process-oriented research projects and programs.

Preamble

Process-oriented research in Earth sciences reflects a transition from knowledge acquired by empirical observation (“what is this?”), to the field and laboratory testing of predictive theories (“why is this?”). This transition reflects the maturing of a natural science (e.g. taxonomy versus microbiology). Ideally, process-oriented research in natural sciences should act as a complement or adjunct to the sound collection of observable facts, rather than as a replacement for the careful collection of empirical observations.

Introduction

The workshop sessions were organized informally to gain feedback on the historic and current roles of process-oriented research at the GSC and to list and prioritize opportunities for process-oriented research, mechanisms of organization, criteria for accepting research proposals, and methods of facilitating research.

Feedback on the historic and current role of research was obtained through either round-table discussion or individual responses. The participants were asked to suggest research opportunities for each of the major geological settings in Canada including Archean cratons, Proterozoic orogens, Phanerozoic orogens, epicratonic basins, passive margins, active plate margins, and ocean basins. They were also asked to consider a wide family of geological processes including erosion, sedimentation and subsidence, structure and tectonics, magmatism and volcanism, diagenesis and metamorphism, and interactions between the atmosphere, geosphere, and hydrosphere. They were invited to organize research opportunities under common themes and to prioritize the proposals.

Information on organizational mechanisms and scale for process-oriented research were solicited or volunteered from a number of groups. Individual groups made suggestions for criteria with which to judge process-oriented research proposals. Each group was asked to make suggestions on facilitating process-oriented research and information was gathered on enhancing communication and types and availability of personnel.

This section comprises a first part that documents the results of the workshop proceedings and a second part that contains conclusions of the participants and recommendations of the chairs, based in large part on the workshop proceedings and on discussions arising from plenary sessions.

Theme sessions and preliminary discussions

Over the course of a two-day workshop on the future of the GSC Bedrock Geoscience Program, 41 GSC scientists shared their opinions on topics including the health and present status of process-oriented research, research opportunities, mechanisms for conducting research, criteria for evaluating proposals, and recommendations to facilitate process-oriented research. Information on these topics was gathered by open discussion, by soliciting individual responses, and by creating lists of opportunities. The structure of the sessions changed with each group to reflect individual interests and to build upon the strengths and weakness of the structure that were determined by each succeeding group.

With the first two groups, discussion began with a review of several historical and current examples of process-oriented research at the GSC. These discussions were successful, but they were modified in the last two sessions because the first two groups failed to reach a consensus during the subsequent discussion and analysis. The third and fourth groups presented historical and potential future models of how process-oriented research might play a role in scientific programs.

Participants in the first two sessions reached a general consensus that process-oriented research was ongoing and within the GSC's mandate. Although some process-oriented research was done in the current program on an 'as-needed' basis to solve problems on a map, in other examples, such as marine geophysics, process-oriented research was a significant consideration of projects and programs from their inception. Some scientists perceive that process-related studies are marginalized, although others are very comfortable with the present role of process-oriented research in their careers.

Discussion progressed to an examination and evaluation of process-oriented studies for the preparation of a list of opportunities. Some participants thought that process-oriented research should be involved in the mapping program, but that process-oriented research should not drive where mapping is carried out. In general, discussion showed that including process-oriented research did not exclude continuation of the existing program, rather that it was a possible augmentation of the program. A minority of participants expressed a concern that it was actually process-oriented studies that were now vulnerable in the return to traditional goals and integrated studies in a smaller organization. They called for more support for process-oriented studies from the broader managerial framework.

There was some discussion on the effects on mapping if the selection of map areas is model driven. The comment was made, and generally accepted, that regardless of where work is done, some level of current geological knowledge exists. Reference was often made to the new national map as an example of the basic level of knowledge. This appeared to satisfy participants who were concerned with the prospect that mapping would be model driven if a process-oriented research approach were adopted. A need for balance was recognized by all groups. GSC expertise should be available to solve problems on a national scale and across the country, but must be balanced by the preservation of local expertise to serve our national mandate.

One group considered the Mineral Resources Division model for process-oriented research. It was portrayed as combining three levels of effort including basic mapping and documentation, targeted mapping, and process-oriented research. Comments on the model saw strengths in combining all three levels of investigation, as long as the work was driven by scientists and scientific priorities. The following questions were then asked of the model: Is this new? Is the difference in the formality? Is there a different distribution of people and resources in such a model?

The third and fourth groups discussed two conceptual models of geological mapping. The first model is one in which bedrock mapping and geophysical surveys are conducted primarily with the goal of producing geological and geophysical maps. An alternate model was discussed in which process-oriented studies and integrated predictive and quantitative modelling performed by a team of 'specialists' were an additional component on a now integrated method of gathering geological and geophysical data. The result of such a new model was the production of multiparameter maps and an array of products, derivative data, and reports from multiple sources of geological and geophysical data. These two models elicited a variety of responses from the participants.

Participants in favour of a new paradigm for geological mapping suggested that we should focus a little more on process studies because of limited resources. We have done a lot of the basic mapping and we are now in a position to address large-scale problems. The products of process-oriented studies promote interpretive models. The evolution of processes through time is something that the national geological survey can do that neither the provinces nor the universities have the mandate or capability to do. It was proposed that the GSC is well equipped to take on the study of large-scale geological processes. However, this research should be conducted by a group that comes together to address a problem or program and is not just a fixed team of specialists. Some participants thought that a need exists for a fully integrated geosystems project. It was generally agreed that more process-oriented or thematic research should be included, but there was a great concern as to how and which topics will be chosen. There was general consensus that a method for the execution and synthesis of any given process-oriented research topic should include predictive and quantitative modelling as a technique for data analysis, integration, and synthesis (e.g. geodynamic modelling).

Considerable discussion was devoted to the role of process-oriented research in mapping. A feedback exists between the map and the process. The nature of geological mapping changes as geological paradigms change; however, we must still come back to outcrops each time the models or the set of processes change because we just observe what we are primed to observe. Some participants believe that new initiatives can be promoted on the merits of how process-oriented studies have changed bedrock mapping. Finally, the opinion was expressed that mapping is and always was fundamentally driven by process-oriented studies.

Some participants believe that the prime motivation for mapping new frontiers should reflect issues such as the needs and good of the public, resource industries, and the environment. The GSC has a long history of striking a balance between process-oriented studies and fundamental data collection or mapping. The minority opinion was that the choice of new areas to map should depend on where gaps exist in our coverage; process-oriented research will arise naturally. Multidisciplinary teams should not drive field geology.

There was also general discussion of the scale in process-oriented studies. The spirit of much of the discussion was captured in the third group. One participant proposed the following observations as to where we are with respect to scales. On the smaller scale, we exploit opportunistic contributions to process-oriented research in a general program driven by regional needs. There also exists a much larger scale that includes programs and disciplines such as LITHOPROBE, lithogeochemistry, geochronology, and geophysics. In the future, these two scales could be augmented by medium-scale projects oriented towards a team approach and scale-independent umbrella theme activities and projects that could be added to projects and programs.

Prior to listing opportunities for process-oriented research, all groups reached a consensus that we are, and have been, engaged in process-oriented research. It is part of our mandate. Some believe that we have been well served by the status quo and that, however, we should remain flexible and be able to embrace new initiatives as the need arises. There are both new process-oriented research opportunities and opportunities for synthetic studies that could satisfy the needs of large client groups.

Conditions that will facilitate process-oriented research

It was acknowledged that the need may arise for a new structure or framework, should process-oriented studies become more important. Some bedrock mappers feel constrained by the present organizational structure, especially since they perceive that it does not promote mobility. The participants felt that senior management should promote greater freedom in the workforce and allow more personal initiative.

A number of changes were proposed to facilitate process-oriented studies. The creation of working groups sharing common research interests might be fostered by additional activities including targeted field trips and team-building exercises and activities, all of which would contribute to the greater mobility of people within the organization. Many participants felt a need to improve communication amongst the scientific staff and that this could be promoted through video-conferences and other virtual conferencing techniques, greater use of the Internet, and meeting of working groups at national geoscientific meetings. These types of changes would promote the mobility of people and help ensure that the work is science driven, rather than management driven. Working groups will require structure and although specific proposals were not developed in this regard, it was widely recognized that working groups should be guided by a chairperson. Some participants believe that no crossreferencing of expertise occurs in the GSC. Management is not really aware of the complete set of skills available nationally. There is a great need for a national database of available expertise at the GSC. It was recommended that divisions should release experts to wherever the needs are in the national program. Working groups could be established across the GSC and could include experts from outside our organization. The GSC should have a number of, or the capability to form, umbrella projects, programs, and teams. These teams should be science driven and go beyond the traditional limits of GSC organization (e.g. the current divisional structure). Ideally, we should have the ability to call on talent anywhere in the GSC to address any problem that arises in a study conducted at any scale.

In summary, the various participants agreed that the following conditions would be favourable to process-oriented research:

- Science should be the driver for process-oriented research.
- Process-oriented research should be developed in an environment of increased linkages among divisions and more fluid communications, e.g. use of the Internet throughout the GSC.
- Process-oriented research should be carried out as umbrella projects by groups of the most suitably skilled individuals. This will require great flexibility in the assignment of staff across the GSC.

Potential process-oriented research

The four workshop groups were asked to identify opportunities for process-oriented research. There was a wide variety of responses to the attempt to prioritize the possible projects and programs, which are presented for each session.

Session I

- evolution of continental mantle lithosphere (six votes)
- crustal response to oblique subduction (three votes)
- water-rock interactions (five votes)
- refining the Phanerozoic time scale (zero votes)
- isotopic characterization of sedimentary rocks and their provenance (one vote)
- mechanisms of crustal deformation (zero votes)
- origin of the crust (four votes)
- evolution of orogenic processes through time (two votes)
- evolution of metallogenic processes through time (one vote)

- magma generation as a function of tectonic setting (five votes)
- meteorite impact (zero votes)
- seafloor spreading (one vote)
- subduction initiation (zero votes)
- intracratonic tectonics (four votes)

In addition to the list of process-oriented research opportunities, it was generally agreed that a method for the execution and synthesis of any chosen process-oriented research topic should include predictive and quantitative modelling as a technique for data analysis, integration, and synthesis.

An attempt to consolidate the list resulted in prolonged discussion. Although there were obvious common themes in the list, there were also very distinctive aspects to each of the proposals. Therefore, the group initially decided not to reduce the number of suggestions. An attempt to rate the suggestions was resisted very strongly; however, under considerable pressure from the facilitating chair, the participants agreed to a general indication of support for each suggestion. The group agreed to show support by voting for each suggestion. Each participant cast three votes. A total of 33 votes were eligible to be cast. Although the process was designed to attempt to identify the three most strongly supported proposals, the participants decided that the votes indicated five strongly supported proposals for process-oriented studies. The five most popular suggestions and their justification were as follows:

- evolution of continental mantle lithosphere (support expected from mining companies)
- water–rock interactions (general topic expected to be supported by all Earth science and Earth resource constituencies)
- origin of the crust (fundamental contribution to basic science)
- magma generation as a function of tectonic setting (support expected from mining companies)
- intracratonic tectonics (possible support from oil companies, with significant potential to have an impact on radioactive waste management and geological hazards).

Session II

- fluid flow in the crust
- subduction
- uplift, erosion, and exhumation
- linkages/feedback among tectonism, plutonism, and metamorphism
- climate–rock interactions
- deep crustal deformation
- mantle dynamics
- subsidence and basin fill
- paleoenvironmental consequence of supercontinents
- basement control on neotectonics
- accretionary processes
- evolution of Earth processes
- evolution of orogenic processes through time
- linkage amongst plate tectonics, deformation, and crustal subsidence
- far-field effects of plate boundary interactions through geological time
- coupled Earth processes

No attempt was made to consolidate the list as presented. The participants specifically did not want to rate the various suggestions. They commented that they could see very strong linkages amongst the opportunities and the types of processes in each of the suggestions that gave a holistic flavour to the list and prevented them from choosing one opportunity over another. They preferred to formulate a general statement of support for the increased support of process-oriented research.

Session III

- evolution of crust–mantle interactions
- fluid processes in the crust
- Earth system megatheme, study of geosystem processes
- foreland basin evolution
- evolution of orogens and yoked sedimentary basins
- improvement of geological time scales
- paleoclimate in the geological record
- constitution and tectonic response of the deep crust
- lower crustal deformation and tectonic response
- deformation and lithospheric rheology, structure, and state of stress
- fault processes
- emplacement of magma in the continental crust
- evolution of magmatic processes through time
- bedrock linkages to near-surface environmental processes
- evolution of continental margins through time
- evolution of facies models and depositional environments through time
- heat sources and heat transfer in the crust
- reactivation of structures in the continental crust

No attempt was made to consolidate the list as presented. The participants specifically did not want to rate the various suggestions. It was generally agreed that we currently do and will continue to do process-oriented research at many scales and in many ways. A minority of participants expressed a desire either to avoid process-oriented research in the bedrock program or simply to stick to the status quo methods of process-oriented research. The majority of participants suggested that process-oriented research would have a growing influence and that criteria for evaluating and accepting process-oriented research should be devised. At the request of the facilitating chair, the participants formulated the following criteria for the acceptance of process-oriented research projects and programs: What is the scientific value of the study and the return compared to the effort? What is the user value or client benefit expected from the study? Is such a study within the capabilities of the organization?

Session IV

- origin and evolution of intracratonic basins
- variations in plate margins through time
- modern analogues, e.g. sedimentary transport
- Earth system science (ocean, atmosphere, society, climate)
- chronostratigraphy of Canada
- metals in the environment (natural versus human sources)
- role of mantle lithosphere in tectonic processes
- geological controls on ore-forming processes
- fluids in basins (hydrocarbons, water, relationship of hydrogeology to mineral deposits)
- fluids in the crust

Participants decided to prioritize their suggestions because they were concerned that if they did not produce a grass-roots set of priorities, one would be imposed by management. The following two suggestions were rated by consensus as the highest priorities from this list:

- origin and evolution of intracratonic basins
- variations in plate margins through time.

In addition to these two projects, there should be an integrated study of the chronostratigraphy of Canada. The following projects were considered important, but were not rated, other than to be considered less important than the two topics given above:

- role of mantle lithosphere in tectonic processes
- modern analogues, e.g. sedimentary transport
- Earth systems science (ocean, atmosphere, society, climate)
- amalgamated process studies of fluids in the crust, including
  - metals in the environment (natural versus human sources)
  - geological controls on ore-forming processes
  - fluids in basins (hydrocarbons, water, relationship of hydrogeology to mineral deposits)
  - fluids in the crust.

Conclusions

Opinions on the current and historic status of process-oriented research at the GSC were provided.

- It was clear from the wide-felt interest in and importance assigned to process-oriented research by the participants and from the number and diversity of research opportunities compiled that process-oriented research is a fundamental aspect of current GSC activities.
- The majority of participants agreed that a general balance exists between research opportunities that are driven by the need to map or survey frontier regions of the country and those that are motivated by process-oriented goals.
- A minority opinion was that the status quo is acceptable or that process-oriented studies should not influence the choice of areas surveyed.

The following six topics were commonly raised by all or most of the groups in some form or another:

- intracratonic basins and tectonics
- fluids in the crust
- plate margins through time
- magma formation in different tectonic environments
- role of mantle lithosphere in tectonic processes
- crustal evolution.

A number of common recommendations were made for mechanisms for conducting process-oriented research.

- The majority of participants suggested that process-oriented research would become increasingly important and that criteria for evaluating and accepting process-oriented research should be devised.
- Process-oriented research should be carried out as umbrella projects by working groups of suitably skilled individuals. This will require greater flexibility in the assignment of staff at the GSC.

The following criteria were formulated for accepting process-oriented research projects and programs:

- What is the scientific value of the study and the return compared to the effort?
- What is the user value or client benefit expected from the study?
- Is such a study within the capabilities of the organization?

A number of common recommendations were made for facilitating process-oriented research.

- Science should be the driver for process-oriented research.
- Process-oriented research should be developed in an environment of increased and more fluid communications through the creation of working groups, the use of video-conferences and the Internet, targeted field trips, team-building exercises, the piggybacking on national meetings to gather working group participants, and the preparation of lists and categories of expertise at the GSC.

Recommendations

A general system has to be devised that would allow umbrella groups of researchers to form, devise, and submit proposals for process-oriented research. An initial set of criteria has been suggested to judge the suitability of proposals. To this list can be added other criteria including 'Does the proposed research fulfill the national mandate of the GSC?' and 'If the GSC does not have the immediate capabilities to conduct the research, can this expertise be found in outside geoscientific agencies (e.g. provincial surveys, universities, etc.)?' However, a mechanism for proposing and approving such projects or programs could not be decided upon at this meeting and further consultation is needed. Participation in process-oriented research should become a national priority, and divisional and regional boundaries should become transparent to these activities in order to foster multidisciplinary research and the mobility of both personnel and skills.

Theme session 4: Linkages (John Adams, Godfrey Nowlan, and Martine Savard)

Theme sessions

Four two-hour sessions were held. Each session started with a brief introduction on the variety of linkages that exist and participants were then invited to cite good and bad examples from their experience of linkages. After about 20 or 30 minutes of broad-ranging examples and discussion, participants were then asked to draw a single piece of paper from each of three pots labelled 'time', 'place', and 'theme'. The idea was then for a group of four or five participants to brainstorm a bedrock geoscience project based on these three parameters. For example, the papers drawn might say Mesozoic + a province + hazards or Paleozoic + the North + energy, and the participants were called on to devise a project using each of these sets of parameters. The idea was to draw upon as many linkages as possible, including other GSC programs, industry, universities, provincial governments, municipal governments, other federal government departments, international connections, general public, media, and any other that might be appropriate. The game produced some highly innovative projects and expanded participants' thinking about the range of possible linkages. Each group, usually two or three per session, was asked to report on the project they had proposed and these presentations led to a final discussion of all possible linkages and their importance. The sessions demonstrated that the GSC is endowed with some talented, original thinkers.

Report and recommendations

Internal GSC

<u>Introduction</u>

We were impressed by the range of knowledge and interest demonstrated by the participants about GSC-wide activities and expertise. Those contributing anecdotes and those involved in the task demonstrated an enthusiasm for trans-GSC linkages that belies any thought that GSC staff is insular. Examples of good linkage cited were between Precambrian and Quaternary glaciation experts, between scientists and the Geoscience Information Division to take data from field logs to cartography to make maps more timely, and the widely quoted, successful interactions spawned by LITHOPROBE, NATMAP, and EXTECH. In particular, the evolution of project style over the last decade from insular, money-driven mineral development agreement projects to interdisciplinary, transdivisional projects, strongly linked to external clients and collaborators, seems to have been deeply accepted as being in the correct direction. However, there were specific reservations about the Industry Partnership Program (*see* 'Industry').

<u>Barriers to linkages</u>

Although there was much discussion with respect to barriers to still more linkage, no single theme emerged. Inertia did not seem to be a barrier, at least to the staff at the workshop. It is clear that many researchers are overcommitted and that quality time for science is shrinking. Some projects might be slowed down by overcommitted or underenthusiastic people, or by their diversion into division-imposed directions. Management-forced linkages will not work, so clearly an effort must be made to understand the motivations that get staff enthused about linkages. Poor communication and too much short-term work to allow longer term planning were also cited as barriers. The loss of older staff's expertise (through retirement and layoffs) has reduced the mentoring base and the breadth of knowledge that encourages linkage.

Recommendations

- Understand the motivations favouring linkages.
- Remove barriers such as short-term planning and division-imposed directions where practicable.

<u>Internal communications</u>

The workshop was seen to be an excellent example of enhancing GSC scientists' ability to interact. The communication barriers to interaction are partly geographic, partly time and money constraints, and partly a lack of personal knowledge or contacts that would enable bilateral visits between offices. It was suggested that similar-sized, short, internal workshops, perhaps following one or another regional ‘forum’, be held annually for scientists to meet and improve communications. These workshops should involve some nonexperts for a sanity/communication check. Accidental discussions at these meetings are very important, as are good working relationships established through field involvement and science cruises. An internal network (Intranet) of web pages detailing the science program could be very productive and could enhance communications.

Recommendations

- Hold informal thematic workshops annually to bring GSC staff together and promote internal collaboration.
- Hold more field trips for internal project development and exchange of ideas.
- Post all current science activities on a website for internal and external use.
- Stimulate linkages through greater staff mobility.

<u>Project initiation and development</u>

There was a sense that projects should no longer be devised and approved within one single group or division, but that most projects would benefit from some GSC-wide input. It was considered important to achieve this input without unnecessary bureaucratic regulation and that, generally, less input should be sought for smaller projects. A preapproval period would allow posting of all projects on the (internal) website for scientific feedback and would add a broader context and extra linkages to most projects. For larger projects, the preapproval period should be longer and include internal development workshops followed by (external) web posting to encourage external collaboration.

Recommendations

- Post a website for internal project development.
- Encourage the holding of workshops for internal project development and evaluation.
- A process such as that used for federal-provincial agreements, NATMAP, and LITHOPROBE should be used for major project development.
- Aim for better advanced planning of projects.
- In the process of improving the system of project development, avoid bureaucratic regulation.

<u>Management activities</u>

There was considerable discussion about the role of management in promoting bedrock geoscience and the GSC science program in general. These grass-roots participants believe that a communication gap exists within the GSC and that compared with managers of a decade ago, today’s managers were less knowledgeable about their own and the GSC’s entire program and spent much more of their time reacting to demands from above. This ‘looking-up’ now occupies the directors and even subdivision heads. The position of Chief Scientist has also become upward-looking, whereas of all the management team, the chief scientist should be the most active among the grassroots. No one seems to be taking the high-level, downward-looking co-ordination role, even though management should be more proactive at encouraging interdivisional contributions.

It was clear from the grassroots that we believe that we manage our work exceptionally well, but since we cannot easily explain how GSC projects are devised, their priorities set, and the operations managed, we appear to be poor managers despite our results. In this regard, the vignettes presented to upper management were considered excellent, but some believed that they may have (falsely) given the sense that there are absolutely no problems in the GSC’s science, so the problem must (again) be in management.

Recommendation

- Find ways to improve scientific communication from scientist to manager and manager to manager.

External

<u>Canadian megaprojects</u>

Response was generally positive from those who had participated in the LITHOPROBE project. Many participants listed it as a positive example of linkage when asked for ideas on good and bad examples of linkages at the beginning of the session. People liked the method of project planning that includes workshops and special reports. Even nonparticipants in the megaproject recognized the value of LITHOPROBE’s ‘supporting geoscience’ program that funded much geological work. There was little or no discussion of what might replace LITHOPROBE in the future, even though it was pointed out in each session that LITHOPROBE would be phased out by 2003.

<u>Industry</u>

A particular point was raised concerning the oil industry’s collection and archiving of seismic data. Canadians and the GSC would benefit from better exploitation of existing seismic data. It is clear that many companies would like a well structured agency to archive the data because they are uncertain of their own capability to do so adequately. This could be a role for the GSC, but it involves significant costs. In order for seismic data to be required to be deposited with a central agency (as are cores and cuttings), a change in regulations is required.

Recommendations

- Revise federal and provincial legislation to ensure that seismic data are deposited in a way similar to cores, cuttings, and well-log data.

- Evaluate the possibility of tax relief for in-kind contributions and investigate means for incremental funding to support the GSC in its data-archiving role (e.g. per kilometre levy on seismic reflection profiles).

Although cases were presented where cost-sharing with industry (Industry Partnership Program) leads to greater efficiency, it was generally agreed that the timescale of industrial clients is not well suited to scientific research, because it is too short and reduces quality time for research. The experience of most GSC scientists was that the Industry Partnership Program projects were good to generate data, but involve too much paperwork, have very short deadlines, and have restrictions on data because of confidentiality.

Recommendations

- That the GSC limit the amount of short-term industry research it does in favour of longer term agreements.
- GSC scientists should not consider the availability of industrial funding as the sole basis for developing industrial partnerships; they should also evaluate the 'motivators' for such research and clearly identify the benefits of the partnership.

Existing good linkages between GSC and industry are annual workshops (e.g. Cordilleran tectonics) and short courses given by GSC staff (bring funding, allow personal contacts, and raise the GSC's profile). Such activities should be encouraged.

The recent reduction in personnel within the GSC mostly affected more senior staff and incidentally caused a significant loss of long-established links with industry. Some participants thought that GSC personnel should be more proactive in contacting industry. It seems that in most cases, letters get no response, although more persuasive methods, such as visits to mining camps, can be successful in establishing linkages.

Recommendation

- Encourage mobility of GSC staff as visiting scientists in industry laboratories/offices, and vice versa.

<u>Provinces</u>

Consensus was unanimous that federal-provincial relations are better than they have ever been. Overall, the format of provincial 'needs' workshops results in doable projects and constitutes time well spent on planning and project development (e.g. Yellowknife workshop; provincial agreement meetings). This format allows the GSC to recognize regional priorities.

Recommendation

- Better reporting of the 'needs workshops' within the GSC could improve linkages with the provinces.

<u>Other government departments</u>

There were mixed reviews of participants' linkages with other government departments. Positive examples such as the 'Memorandum of Understanding on Science and Technology for Sustainable Development in the Natural Resource Industries' on metals in the envirornment, signed by the four natural sciences departments (Agriculture and Agrifood Canada, Environment, Fisheries and Oceans, and Natural Resources Canada), and the agreement with Fisheries and Oceans on stream/bedrock geochemistry in salmon spawning grounds, were offset by examples of miscommunication. Clearly, many unanticipated linkages are possible and would make the government more efficient, but in most cases, linkages are hampered by a lack of knowledge of what is relevant and whom to ask.

Recommendation

- Explore better communications with other federal departments at the scientific level.

<u>Universities</u>

It was suggested that universities are not as well plugged into GSC programs as they could be. It was pointed out that universities needed a fair bit of lead time in order to frame grant proposals to the Natural Sciences and Engineering Research Council for work that might be related to a GSC program. Therefore, longer term planning on the part of the GSC was necessary. Others pointed out that some opportunities for collaboration were lost because of this lack of adequate long-term planning. Many cited the LITHOPROBE project as an example of good, well planned collaboration with universities.

Recommendation

- The GSC should do well publicized, long-term, advance planning so that co-operation with universities can be more effective.

The fact that some GSC scientists are adjunct professors was deemed to be a positive feature. It was thought that the main benefit to GSC scientists was the chance to mingle with and supervise students. Courses given at the graduate level were also thought to be of mutual benefit. Co-supervision of graduate students can work well, but it was pointed out that the trend towards shorter term projects in the GSC, especially those with contractual deliverables to industry, meant that it was more difficult to include graduate-student theses in project work. At the GSC, it is now easier to work with postdoctoral fellows because of the short time lines of many projects (postdoctoral fellows get up to speed more quickly and finish projects more quickly than Ph.D. students). The down side is that they are more expensive in the short term.

Recommendation

- Work to ensure that more graduate students can be brought into projects more effectively.

It was widely agreed that sharing specialized laboratories and expertise is a major advantage of well planned collaborative work with universities.

There was universal agreement that the GSC's Research Agreements Program, which was cancelled a number of years ago, was an excellent program that allowed the transfer of a modest amount of funds to universities for projects of interest to both professors and the GSC. The appraisal process for the Research Agreements Program was praised as a way of keeping university funding clearly visible and well directed. One participant pointed out that there can be a subtle form of patronage from the GSC when it holds most of the funds for projects.

Recommendation

- Reinstate the Research Agreements Program with universities after discussion within the science programs as to how best to fund the program without increasing the GSC's administrative burden or funding university overhead expenditures.

International

Opinions were mixed about GSC linkages at the international level. It was thought that because Canada is so large, many researchers work in relative isolation and it is difficult to establish teams to work on significant international questions in the geosciences. Our landmass is so big and our personnel and financial resources are so small that we have tended to focus on Canadian areas and problems. It was recognized that it is worthwhile to work on world examples and then apply the results to our understanding of Canadian problems.

The instability of long-term funding in Canada makes it difficult for our staff or other Canadian researchers to commit to international projects because of the long lead times required for collaborative international science (e.g. Germany schedules ship time two years in advance). Our potential partners want to know whether we will be in or out in order to properly plan international projects.

It was recognized that there are two levels of international co-operation in the GSC. One is high profile and expensive (e.g. Ocean Drilling Program), but with the prospect of great results, and the other is less expensive, comprising both formal collaboration through projects in the International Geological Correlation Program or informal, one-on-one collaboration on an *ad hoc* basis.

Recommendation

- That the GSC institute better planning for and knowledge of GSC participation in international programs.

Several participants pointed out that contracts for work through the Canadian International Development Agency or the World Bank permit more international work. Such arrangements can allow salary reimbursement for GSC staff. However, these international contracts make experienced scientists unavailable in Canada to meet Canadian needs. Many thought such contracts should be evaluated cautiously, as GSC researchers should avoid becoming just contractors.

All participants thought that mobility of GSC staff as visiting scientists in other foreign institutions (and vice versa) should continue because it is very useful for maintaining excellence and developing expertise.

Public outreach

Participants had a strong sense of the great importance of conducting public outreach programs and many excellent ideas were shared at each session. It was suggested that every project should include consideration of public outreach so that public education is built into the project development phase. Furthermore, the GSC public education program is too *ad hoc*, taking place wherever there were motivated scientists. It might be better if the GSC as a whole adopted a more consistent approach.

Recommendation

- That the GSC should have a much more consistent approach to public outreach.

Several participants raised good examples of what has been done in the past including Ann Sabina's books on mineralogy, posters of various types, and the rock and mineral sets. There was concern that some of these may now be out of date and considerable concern that production of the rock and mineral sets had been terminated.

A number of participants raised the possibility of reaching the public effectively through the question of global change and mentioned how paleoclimate studies can contribute to the knowledge base. Several participants, especially those from the Vancouver office, expressed pleasure at how their work on issues of societal interest (e.g. on earthquake risk in the Fraser River delta) had brought them into closer contact with their community. The setting of the new Vancouver office that fronts on a busy urban street was also deemed an excellent way for the GSC to become better known to average Canadians. A large number of people drop in to find out what the GSC does. This exposure has in turn fuelled a strong sense of the need for public outreach and the highly successful *Geoscape Vancouver* poster is an excellent example. The practice of what is, in essence, urban geology was viewed by many participants as an excellent way of building good community relations and support. The project on the Oak Ridges Moraine north of Toronto was cited as another example.

Recommendation

- That the GSC add an outreach component to all projects on a scale appropriate to public interest in the project.

Many of the participants who work in the northern parts of Canada noted that linkages to aboriginal communities were of primary importance. Involving northern peoples was deemed very useful for planning and logistics. An example was cited of the excitement and interest generated in a young aboriginal field assistant in the course of field work through the discovery of zinc mineralization. Another example was provided by a scientist who employed aboriginal field assistants in a mapping project. When asked what they would like to discover, they replied a stone for carving. As it happened, the project led to the discovery of a deposit of alabaster, an excellent carving stone. It was a good news story all around. In light of these many positive stories, participants thought that the kinds of linkages established in the North should be applied to southern projects as well. We should all consider delivering copies of maps and reports to municipalities or local governments in the areas in which we map and also offer to explain aspects of the work at a public lecture.

Recommendation

- Find ways to make common in projects elsewhere in Canada the kind of connections that are made with local (especially aboriginal) people in the North.

Several suggestions were made as to how the GSC could assist teachers. A strong presence on SchoolNet was advocated as an excellent way of exposing teachers and students to the GSC. Another idea was to involve teachers as summer interns in GSC laboratories, such as is done elsewhere (e.g. Alberta Research Council).

Several participants advocated closer ties and joint programs with national parks. One idea was to have GSC summer students work in national parks as interpreters because the level of interpretation of geology lags far behind that of biology and history. This would be a good way for the GSC to remedy the situation while increasing its profile with park visitors. The students so employed would learn a great deal about presenting science to the public and could return to a GSC office to write up educational material for use in the parks. A suggestion was made for the development of geological maps for national parks.

Recommendation

- That the GSC institute a program for summer students as interpreters in national parks.

One linkage cited as an opportunity for the GSC was a suggested popular geological atlas of Canada, and/or a popular ‘Geology of Canada’ in some form.

Recommendation

- That the GSC explore the preparation of a popular ‘Geology of Canada’.

Several participants thought that the importance and societal relevance of GSC work could be better explained to the public. Many believe that it should be made accessible by writing summary documents and/or preparing World Wide Web sites on significant aspects of the program. The example of the CD-ROM on the Palliser Triangle project was cited as a step in the right direction since it could be used at both a general and a detailed level.

In the area of products for the public, some participants thought that the GSC could partner with other organizations in Canada (e.g. scientific societies) to produce some of the required products. Others thought that products that are clearly associated with the GSC are needed to raise our public profile. All saw great value in the World Wide Web home page as a basic means of communication. One suggestion was for a WWW version of the recently cancelled magazine *Geos*.

Recommendations

- That the GSC develop some public outreach products jointly with other agencies (e.g. scientific societies) and other products that are clearly connected to the GSC.
- That the GSC establish a strong presence on the World Wide Web and consider preparing educational material along the lines of a web version of *Geos*.

It was pointed out that most Canadians get their science information from television, so several participants advocated stronger ties to television as a public education medium for the GSC. Many linkages were suggested including the Discovery Channel, Earthwatch, The Weather Channel, and Newsworld.

Recommendation

- That the GSC explore better linkages with television as a means of raising public awareness about science, the GSC, and its programs.

There was universal support in all sessions for building education and public outreach into the GSC culture and for a strong GSC role in popularizing science. However, concern was expressed that those who are involved in public outreach are not consistently supported or recognized.

Recommendation

- That the GSC develop better and more consistent recognition for scientists involved in public outreach.

<u>Municipal links and urban geology</u>

There was support for using urban geology to forge links with regional municipalities. This level of government is rapidly rising in prominence with the amalgamation of local communities into regional municipalities. A large fraction of Canadians, their homes, and their immediate concerns regarding hazards, the environment, and questions to be answered are found in the 10 or 20 largest municipalities. As described under ‘Public outreach’ a thirst for knowledge exists that could be exploited. Municipalities should be using reliable, relevant, and modern geoscience information as the basis for long-term urban planning. The GSC, in conjunction with the provincial surveys, has expertise in all the required aspects of urban geology.

Recommendation

- That the GSC investigate the establishment of a comprehensive urban geology program in conjunction with the provinces and seek municipal support for a pilot study.

Conclusions

GSC scientists who were present at the Bedrock Geoscience Program Workshop all agreed that the GSC can improve its internal and external linkages. Discussions during the four sessions led to a number of recommendations.

Theme session 5: National Geoscience Knowledge Base (John Broome, Kevin Coflin, and Phyllis Charlesworth)

Vision

The GSC should move to capture its geoscience knowledge, both data and expertise, in a consistent, scale-independent, digital geoscience knowledge base composed of individual, decentralized components. This digital knowledge base should be accessible to both internal and external users via network technology through easy-to-use visualization and query software.

Summary of discussion

Geoscience knowledge

The GSC Geoscience Knowledge Base comprises both expertise and geoscience data covering the full range of geoscience disciplines including geology, geophysics, and geochemistry. It was envisioned that this knowledge base should be captured in a Digital Geoscience Knowledge Base (DGKB) that should be decentralized, in the sense that components would exist across the organization, but be accessible everywhere. Increased accessibility does not imply universal access to information and data. Existing restrictions would be used to model future access; some knowledge would be publicly accessible, some would be restricted for a limited period of time, and some would remain restricted, e.g. confidential company information. The participants saw such a knowledge base as a tool to represent and preserve their work more efficiently.

It was agreed that the knowledge base must be accessible online (some of it public, some restricted), through easy-to-use visualization and query software. A level of consistency for the user is required. It must be easy to add information to the knowledge base to ensure that knowledge is captured routinely.

To maximize value, all GSC geoscience data and expertise should be described (metadata) and, if possible, contained in the the knowledge base. It was agreed that metadata are important and, furthermore, that gathering, organizing, and disseminating metadata are the first step in the development of the knowledge base. It was also put forth that metadata in the knowledge base should include not only GSC knowledge, but also Earth science knowledge from all Canadian sources (virtually and/or in reality where necessary)

It was agreed that standards are essential to achieve the necessary consistency in the Digital Geoscience Knowledge Base. There was considerable discussion about the level of detail at which this consistency must be enforced. Where appropriate standards exist, the GSC should move to adopt them. In other cases, such as geology, the GSC should develop standards with appropriate stakeholders. Adopted standards should incorporate generalization and drill-down capabilities. Standards must be clearly documented and communicated across the organization.

The creation of a consistent data set for Canada at some scale, 1:1 000 000 and 1:250 000 being suggested, received considerable support. It should be based on existing coverage. No support was given for a systematic new program to generate this coverage.

Quality issues were discussed. It was generally agreed that quality indicators are required in the Digital Geoscience Knowledge Base and that access to data that do not meet the standards of quality or consistency could be restricted.

The issue of whether the knowledge base should incorporate non-GSC data beyond metadata (e.g. university-generated maps) for public access was raised.

Field systems

Field systems are already extensively used, but further improvements were envisioned that would simplify the use and incorporation of field data into the knowledge base. Ideas included integrated deregulated GPS; voice capture; better sketching capability; more compact, fully functioned systems; and data integration capability in the field (GIS).

Publications

There was general agreement that our existing product lines are inadequate. A number of individuals questioned whether the distinction between A-series and other map products was understood by the public or even necessary. There was consensus that we need product lines for our digital products. Clearly, online access to our Digital Geoscience Knowledge Base could eventually become our primary product.

Recommendations

The following recommendations were compiled by the co-chairs from opinions presented during the four breakout session. Due to the wide variety of recommendations, all opinions cannot be presented; however, an attempt is made to capture the predominant views.

Digital Geoscience Knowledge Base

From discussions during the breakout sessions, the session chairs recommend that the GSC commence building a multi-disciplinary, scale-independent, digital geoscience knowledge base. The components of the knowledge base should be distributed throughout the GSC, in appropriate centres of expertise, but should be accessible through Internet-type networking. An easy-to-use, network-based visualization and query tool must be provided to users to ensure maximum utilization of the knowledge base.

The knowledge base should try to capture both the data and expertise of the GSC. Contents should include, in increasing detail, metadata, regional geoscience maps, compilations and interpretations, detailed mapping and modelling, and raw data such as geological and geophysical measurements and observations. At the metadata level, its goal should be to ultimately act as a detailed index to all Canadian geoscience data. Implementation of the metadata layer in the knowledge base for Canadian knowledge, including federal and provincial publications, should be a first priority.

The level of consistency of the knowledge base contents is an important consideration. Consistency facilitates the sharing and utilization of knowledge; however, when attempting to maintain consistency in increasingly detailed data, it is important to realize that the benefits of consistency diminish due to less frequent use, while the cost of maintaining consistency increases exponentially due to the increased volume of data. For this reason, consistency should be enforced initially only above a certain threshold of detail, possibly defined by the level of detail associated with 1:1 000 000 scale compilation maps. The GSC should move rapidly to implement, or where necessary develop, standards and data models for our knowledge base in co-operation with our stakeholders. For geological data, a good starting point will be GSC participation in the May 1997 Geological Association of Canada workshop on standards. For metadata, the Inter-Agency Committee on Geomatics (IACG) standards initiative will be a good starting point.

Knowledge should be delivered through the Internet or another network protocol that is accessible to both the public and the GSC. Easy-to-use, GIS-like visualization and query tools should be provided. The database design must incorporate the ability to define different levels of access for data with varying confidentiality requirements. Many new Internet map and data servers are being produced as commercial products. The GSC should investigate them and set up a pilot project to evaluate user needs and identify potential problems.

An individual or group must be identified to champion the construction of our consistent digital knowledge base and the establishment of systems to allow access to and use of the data. A regional/divisional representative should be identified to provide support and direction. Stakeholders must be consulted during the design process.

Field systems

Digital field systems are an important component of the GSC's integrated digital methodology for geological mapping. The GSC should continue to refine its digital field system technology through the use of emerging technologies, enhanced utilization of existing tools, and training.

Publications

Following from a consensus that the GSC's product lines are inadequate and not suited for digital products, an interdivisional group should evaluate our current product lines and recommend a more suitable set of product lines. Specific items that should be discussed are the role of the Digital Geoscience Knowledge Base as a publication tool and the distinction between A-series and other map products.

ASSESSMENT OF THE WORKSHOP PROCESS

General

Participants and organizers consider the workshop to have been a very positive event that generated strong, team-oriented dynamics and a renewed sense of optimism, belonging, and national purpose for the GSC.

Website

The workshop website provided preworkshop information to all GSC staff and a bulletin board for receiving proposals and comments. The idea was strongly endorsed by all participants and was held up as an effective mechanism for general project planning and the advertisement of interim or final results.

Negative comments included the perception that the workshop website was insufficiently promoted within the GSC and that many of the proposals and ideas submitted were either ignored at the workshop or were not discussed because of a lack of opportunity.

General workshop features

The general impression of the workshop was positive.

The workshop setting (away from the office) was very conducive to open discussion.

The time for unstructured communication between GSC colleagues was highly beneficial.

The focus on science planning was a refreshing change from the all-too-common discussions of program operation and program management.

The timing (after the recent period of downsizing and since the last workshops of this type) was appropriate.

The meeting was short enough to convey a sense of urgency on the proceedings, but not so short as to limit discussion of the principal issues.

There was some concern that the results of the first full day of the workshop could have been better utilized for building consensus on the last day.

Workshop size

The number of participants was deemed to be appropriate and there were sufficient opportunities for everyone to contribute during both the plenaries and the theme sessions.

Management attendance

Management participation in the plenary sessions was viewed as crucial. Although some believed that the presence of managers may have impeded open discussion during the theme sessions, the majority thought that the potential benefits arising from management attendance outweighed such concerns.

Opening session

The following comments were received about the opening session:

- The stage-setting presentations were generally well received, particularly that of the invited speaker.
- The introduction of participants was inadequate.
- The message conveyed by the invited speaker (i.e. future responsibilities of national surveys to society) was largely ignored by participants during most of the meeting.

Plenary sessions

The participants found the presentations by the session chairs at the plenaries to be very useful. The amount of time for discussion of common themes and issues was somewhat limited.

Theme sessions

Positive features of the theme sessions included the following:

- number of participants (10–15) in each session;
- spontaneity;
- broad scope of session topics — sufficient to encompass all geoscience disciplines;
- especially noteworthy was the ‘game’ devised for creative thinking in the Linkages session;
- there was some concern that session chairs were given insufficient opportunity for input into other sessions, that participants could not revisit specific sessions, and that some chairs imposed too rigid a structure on session proceedings; feelings were mixed about the use of facilitators.

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APPENDIX 1: WORKSHOP SCHEDULE

Sunday

ca. 3:00 pm — Arrival

4:00 pm — Meeting of Steering Committee, session chairs, facilitators

6:00 pm — Welcome to workshop participants (Jim Franklin)

6:15 pm — 1940s National Film Board film on the GSC

6:30 pm — National geological surveys: present and future role in a changing world (Raymond Price)

7:30 pm — Dinner

Monday

7:00 — Breakfast

8:15—9:00 — **Plenary session 1**

a) Welcome, Introduction (Steve Lucas)

b) S&T in the federal government (Robin Riddihough)

c) Federal-provincial relationships (Mike Cherry)

d) Introduction to theme sessions and workshop mechanics, including framework for reporting theme-session discussions (Steve Lucas)

Presentations by theme-session chairs

9:00 — Bedrock mapping (Mike Cecile, Marc St-Onge, Bob Thompson)

9:15 — Geophysics (Walter Roest, Don White)

9:30 — Process research (Roy Hyndman, Kirk Osadetz, Tom Skulski)

9:45 — Linkages (John Adams, Godfrey Nowlan, Martine Savard)

10:00 — National Geoscience Knowledge Base (John Broome, Phyllis Charlesworth, Kevin Coflin)

10:15–10:30 am — Coffee

10:30 –12:30 — Breakout session 1 (five concurrent sessions)

12:30–1:30 — Lunch

1:30–3:30 — Breakout session 2 (five concurrent sessions)

3:30–4:00 — Break

4:00–5:30 — **Plenary session 2**

a) Introduction (Robin Riddihough)

b) Reports from theme-session chairs

c) General discussion

5:30–7:00 — Social

7:00 — Dinner

Evening — Meeting of theme-session chairs, Steering Committee, and facilitators

Tuesday

7:00 — Breakfast

8:15–10:15 — Breakout session 3 (five concurrent sessions)

10:15–10:30 — Coffee

10:30–12:30 — Breakout session 4 (five concurrent sessions)

12:30–1:30 — Lunch

1:30–4:00 — **Plenary session 3**

a) Introduction (Robin Riddihough)

b) Reports from theme-sessions chairs

c) General discussion: Towards a future vision for bedrock geoscience at the GSC (facilitator: Robin Riddihough)

d) Concluding remarks, Next steps (Steve Lucas)

Departure about 4:15 pm (to airport, hotels, and Booth Street)

APPENDIX 2: PARTICIPANTS

Continental Geoscience Division

Steve Lucas (SC = Steering Committee)
Alan Menzel-Jones (SC)
Marc St-Onge (SC, Bedrock Mapping theme chair)
John Broome (Knowledge Base theme chair)
Tom Skulski (Processes theme chair)
Don White (Geophysics theme chair)
Walter Roest (Geophysics theme chair)
John Percival
Dave Boerner
Bill Davis
Cees Van Staal
Simon Hanmer
Rob Rainbird
Tony LeCheminant

Terrain Sciences Division

Ron Dilabio (SC)
Larry Dyke
Jan Bednarski
Mineral Resources Division
Al Galley
François Robert
Andy Rencz

Geoscience Information Division

Marie-France Dufour
Vic Dohar
Phyllis Charlesworth (Knowledge Base theme chair)
John Glynn

GSC Atlantic

Peter Giles (SC)
Charlotte Keen
David Piper
Kevin Coflin (Knowledge Base theme chair)

GSC Québec

Léo Nadeau (SC)
Greg Lynch (SC)
Martine Savard (Linkages theme chair)
Jean Bédard

GSC Calgary

Chris Harrison (SC)
Godfrey Nowlan (Linkages theme chair)
Terry Poulton
Don Cook (SC)
Mike Cecile (Bedrock Mapping theme chair)
Kirk Osadetz (Processes theme chair)
Tim de Freitas
Tony Hamblin
Dan Lebel
Dave Hughes

GSC Pacific

Cathie Hickson (SC)
Bert Struik
Steve Gordey
Jim Haggert
Bob Thompson (Bedrock Mapping theme chair)
Roy Hyndman (Processes theme chair)
Carmel Lowe
John Adams (Linkages theme chair)
Murray Journeay

Chief Scientist, directors, directors general

Jim Franklin
Janet King
Gina LeCheminant
Annette Bourgeois (SC)
Grant Mossop
Aïcha Achab
Sandy Colvine
Jean-Serge Vincent
Murray Duke
Richard Haworth

Facilitators

Mike Cherry
Robin Riddihough

Geomatics Canada

Marc D'Iorio (Canada Centre for Remote Sensing)

Invited speaker

Raymond Price (Queen's University)

APPENDIX 3: STEERING COMMITTEE MEMBERS

The Steering Committee comprises the following members and alternates/colleagues:

Chair: Steve Lucas (CGD)
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GSC Pacific: Cathie Hickson
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GSC Atlantic: Peter Giles
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Chief Geoscientist: Jim Franklin (ex officio)
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