

Summary Report, Canadian Geoscience Council Review Committee on the Minerals Geoscience Program of the Geological Survey of Canada

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Résumé de l'article

En 1999, un comité de révision externe nommé par le Conseil géoscientifique canadien a étudié la portée, la pertinence, les choix de projets, la planification stratégique, la gestion et le mode d'évaluation des programmes du Programme des géosciences minérales (PGM) de la Commission géologique du Canada. Il en ressort que le PGM a été affecté négativement par les politiques du gouvernement et les changements organisationnels, incluant une diminution du budget de 50 % au cours des six dernières années, conséquence des coupures gouvernementales systémiques. Le comité de révision a formulé un certain nombre de recommandations visant à renforcer la mission de recherche minérale au sein de la CGC. Les plus importantes d'entre elles soulignent la nécessité de définir clairement des axes stratégiques d'intervention, coordonner les divers projets et en préciser l'ordre de priorité en fonction des objectifs stratégiques, et miser sur une approche synergique en visant une collaboration accrue, aussi bien à l'intérieur de la CGC, qu'à l'extérieur, avec les services géologiques provinciaux, les universités et le secteur privé de l'industrie.

ISSUES IN CANADIAN GEOSCIENCE

Summary report Canadian Geoscience Council Review Committee on the Minerals Geoscience Program of the Geological Survey of Canada

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SUMMARY

An external review committee, appointed by the Canadian Geoscience Council in 1999, has investigated the scope, relevance, project selection, strategic planning, management, and program evaluation of the Minerals Geoscience Program (MGP) of the Geological Survey of Canada. The MGP has been negatively impacted by government policies and organizational changes, including a

decline in funding of almost 50% in the previous 6 years as a consequence of government-wide cutbacks. The review committee has made a number of recommendations to strengthen minerals research at the GSC. The most important of these are setting clear strategic directions, aligning and prioritizing projects with strategic goals, and taking advantage of new opportunities for greater collaboration and synergy, both within the GSC and with provincial surveys, universities and industry.

RÉSUMÉ

En 1999, un comité de révision externe nommé par le Conseil géoscientifique canadien a étudié la portée, la pertinence, les choix de projets, la planification stratégique, la gestion et le mode d'évaluation des programmes du Programme des géosciences minérales (PGM) de la Commission géologique du Canada. Il en ressort que le PGM a été affecté négativement par les politiques du gouvernement et les changements organisationnels, incluant une diminution du budget de 50 % au cours des six dernières années, conséquence des coupures gouvernementales systémiques. Le comité de révision a formulé un certain nombre de recommandations visant à renforcer la mission de recherche minérale au sein de la CGC. Les plus importantes d'entre-elles soulignent la nécessité de définir clairement des axes stratégiques d'intervention, coordonner les divers projets et en préciser l'ordre de priorité en fonction des objectifs stratégiques, et miser sur une approche synergique en visant une collaboration accrue, aussi bien à l'intérieur de la CGC, qu'à l'extérieur, avec les services géologiques provinciaux, les universités et le secteur privé de l'industrie.

INTRODUCTION

In late 1998, the Canadian Geoscience Council (CGC) was invited by Dr. M.D. Everell, Assistant Deputy Minister of the Earth Sciences Sector (ESS) of Natural Resources Canada (NRCan), to perform an external review of the science-related activities of the Geological Survey of Canada's (GSC) Minerals Geoscience Program (MGP). The review was conducted between July 1999 and March 2000 by a committee composed of Robert J. Cathro, P.Eng., retired mineral exploration consultant, Bowen Island, British Columbia (Chair); A. Lynton Jaques, Ph.D., Chief Scientist (Minerals), Minerals Division, Australian Geological Survey Organization, Canberra, Australia; C. Michael Leshner, Ph.D., Professor of Economic Geology and NSERC Senior Industrial Research Chair in Mineral Exploration Research, Laurentian University, Sudbury, Ontario; and H. Scott Swinden, Ph.D., Executive Director, Minerals and Energy Branch, Nova Scotia Department of Natural Resources, Halifax, Nova Scotia (Fig. 1).

The Terms of Reference directed the Review Committee to:

- Determine and document the current level and type of scientific activities within the MGP;
- Assess the relevance and adequacy of these activities to a) users in industry, university and government sectors, and b) the sectoral and departmental national responsibilities and mandates;
- Assess the timeliness, relevance, quality and quantity of publications arising from the science activities within the MGP;
- Assess the range, adequacy and quality of research infrastructure available to support the science activities within the MGP;

- Examine the methods and procedures used in originating, implementing, assigning priorities and managing research projects within the MGP;
- Identify new potential initiatives and opportunities for the MGP.

Because the GSC is the heart of the national geoscience community, any report dealing with its health, future role, and direction should contribute to an informed debate on the future of Canadian geoscience research and delivery. The entire 96-page report, which includes 19 tables and 1 figure, as well as 55 recommendations, was submitted to Natural Resources Canada in March 2000 (Cathro *et al.*, 2000, unpublished) and may be available as a link to the CGC Home Page. In the following summary of the full report, we have highlighted the major findings. The full report contains a complete discussion and a listing and review of all recommendations.

The Review Committee believes that redirection and rebuilding of the Minerals Geoscience Program is necessary if the GSC is to continue to make a meaningful contribution to the health of the Canadian minerals industry. This rebuilding will be difficult, if not impossible, without additional funding. In addition to more funding, the committee believes that a viable and strong MGP must be rebuilt through enhanced integration and synergy with other GSC programs, notably the Bedrock Geoscience and Surficial Geoscience (Mapping) Programs. In our opinion, future projects to address minerals objectives should be multidisciplinary and draw on relevant expertise across the existing Divisions in GSC. Much of the focus of the report and its recommendations is aimed at defining appropriate priorities for the MGP and identifying ways in which the GSC and the MGP can best implement change in order to continue to fulfill an important national function.

The Committee believes that a clear mandate exists for the continuation of a strong Minerals Geoscience Program at the Federal level. Various aspects of this mandate are set out in the 1996 Minerals and Metals Policy (particularly the commitment to discovery of new resources as part of a "sustainable development" strategy), the 1996 Intergovernmental Geoscience Accord, and the 1996-

2001 GSC Strategic Plan (Franklin, 1996). Nevertheless, while the GSC suffered a 32% decline in funding during the last 6 years, expenditures by the Minerals Geoscience Program were cut by almost 50% (Table 1). There are various reasons for this sharp decrease, including the results of the government-wide "Program Review" and a new federal science policy, a major departmental reorganization, and the termination of the federal-provincial Mineral Development Agreements (MDA) program. While the GSC has adopted a range of measures to try and lessen the impact, this sharp cutback in funding has unavoidably resulted in a serious decline in the amount of scientific research being performed in the field of minerals geoscience.

In order to ensure that the country's mineral endowment is sufficiently well understood to replace diminishing reserves in the future, we believe that GSC management must continue to strongly support and promote the

national need, and assume a national leadership role, for Canadian minerals geoscience. Full advantage will have to be taken of opportunities for developing cooperative synergies both across divisions within the GSC and with outside agencies in order to maximize the impact of minerals-related work in the future.

ORGANIZATION AND ROLE OF THE MINERALS GEOSCIENCE PROGRAM

The Geological Survey of Canada is organized into two operational branches, Minerals and Regional Geoscience and Sedimentary and Marine Geoscience, each of which is headed by a Director General, and seven divisions, each of which is headed by a Director. Three of the divisions are based in Ottawa, whereas the others are located at regional centers in Dartmouth, Quebec City, Calgary and Vancouver/Pat Bay.

Since the mid-1980s, GSC's scientific work has been defined in terms of six programs, each with a series of



Figure 1 Meeting of the External Review Committee on the Minerals Geoscience Program of the Geological Survey of Canada and GSC staff in Ottawa, 27 September 1999. Left to right: **John Wood**, Director, Mineral Resources Division, GSC; **Richard Grieve**, Chief Geoscientist, GSC; **David Boerner**, Acting Director, Continental Geoscience Division, GSC; **Ron DiLabio**, Acting Director, Terrain Sciences Division, GSC; **Bob Cathro**, Chairman, Review Committee, retired Consulting Geological Engineer; **Scott Swinden**, Committee Member, Executive Director, Nova Scotia Minerals and Energy Branch; **Murray Duke**, Director General, Minerals and Regional Geoscience Branch, GSC; **Lynton Jaques**, Committee Member, Chief Scientist (Minerals), Minerals Division, Australian Geological Survey Organization; **Mike Leshner**, Committee Member, Professor of Economic Geology, Laurentian University. **Missing:** Gina LeCheminant, Head, Applied Geochemistry and Mineralogy Subdivision, Mineral Resources Division, GSC; Aicha Achab, Director, GSC-Quebec; Charlie Jefferson, Acting Head, Resource Exploration Research Subdivision, Mineral Resources Division, GSC.

subprograms, which transcend the branch/division structure. Under this modified-matrix management system, program delivery has been the responsibility of the divisions, but no program has been the sole responsibility of any one division. The Minerals Geoscience Program has had the main responsibility within the GSC for conducting non-hydrocarbon minerals research and for provision of minerals geoscience advice to the federal government. Primary responsibility for the delivery of this program resides within the Mineral Resources Division (MRD), although elements of the program are delivered elsewhere within the GSC organization.

In order to carry out our review of the Minerals Geoscience Program, we interviewed scientists from four divisions: Mineral Resources (38 people), Terrain Sciences (6), Continental Geoscience (3), and GSC – Quebec (4). After careful review, the Committee eventually concluded that it could not evaluate the work of the MGP without also considering the role of the divisions and assessing policies that affect the entire organization. For that reason, many of the recommendations in the report are of a systemic nature.

The goals of the Mineral Resources Division, as stated in the Division Business Plan, are:

- To assist the minerals industry to sustain employment and prosperous mining communities;
- To provide the federal government

with required geoscience information for policy formulation and implementation;

- To promote the international technological capability of the exploration services industry.

The goals of the MGP, as also stated in the GSC Strategic Plan for Geoscience 1996-2001 (Franklin, 1996) are:

- To assist the industry to discover ore reserves required to sustain employment and prosperity in Canada's mining communities and minerals industry, and to increase metal export revenues;
- To ensure that the federal government has the geoscience information it requires to formulate and implement minerals-related policies in areas of federal jurisdiction;
- To promote the technological capability of the Canadian exploration services industry in an increasingly competitive global market.

Key Strategies

The key strategies of the MGP for pursuing these goals, as stated in the 1996-2001 GSC Strategic Plan (Franklin, 1996), are:

Mineral Deposit Research

- To pursue a national program of thematic studies of significant deposit types for Canada's principal trading commodities in order to develop more precise guidelines for exploration, and to establish a more quantitative basis for assessing resource potential.

Mineral Exploration Research

- To focus on those areas where the GSC has unique capabilities or a critical mass of expertise. There will be an emphasis on partnerships and cost-shared research to promote technology transfer.

Mineral Resource Assessments

- To be undertaken, as required, to respond to federal government policy and legislation.

State-of-the-Art Laboratories

- To be maintained for mineralogy, analytical chemistry and petrophysics in order to meet increasingly complex demands both in traditional program areas and in environmental applications.

International Perspective

- To be enhanced to keep abreast of the increasingly global outlook of the Canadian exploration industry. The GSC will continue to assist Canadian firms to obtain a foothold in foreign markets although these opportunities will be pursued on a cost-recoverable basis. These activities will also provide scientific benefits and improve knowledge of foreign mineral potential for GSC scientists.

PROJECT SELECTION AND STRATEGIC PLANNING

Project planning in the GSC has traditionally consisted of a project proposal system driven largely by individual scientists, and contained largely within

Table 1 Change in Geological Survey of Canada program funding between fiscal year 1994-1995 and fiscal year 1999-2000 (table 1.2 in Cathro *et al.*, 2000, unpublished). Numbers are in the thousands of dollars.

Program	Funding Components	1994-1995	1999-2000	% Change
Marine	Abase/OERD/MDA	6719	4866	-27.6
Hydrocarbon	Abase/OERD/MDA	8492	5691	-33.0
Minerals	Abase/OERD/MDA	11,003	5536	-49.7
Mapping, Bedrock, & Surficial	Abase/OERD/MDA/NATMAP	20,926	13,890	-33.6
Environmental/Hazards	Abase/OERD/MDA/MITE	10,772	9290	-13.8
Total Science Program Spending		57,912	39,273	-32.2

Data provided by GSC. 1994-1995 includes NATMAP, co-operative national geoscience mapping program (\$1280), and other funds from the following sources: Office of Energy Research and Development (OERD), Mineral Development Agreements (MDA), Industrial Partners Program (IPP), and distributed revenue (\$823); excludes Capital, Employee Benefits Plan (EBP), Green Plan, and Grants and Contributions. Source of 1994-1995 data: GSC Year-End financial report 1994-1995, Table XVIII-A and B, and GSC Notionals 1994-1995. Source of 1999-2000 data: GSC Notionals 1999-2000; NATMAP and Metals in the Environment (MITE) funds included. Revenues and Special Purpose Accounts not included.

Divisions. While this traditional approach has contributed to staff empowerment and scientific excellence, it has operated without the benefit of a comprehensive, long-term strategic plan. This has led to both overlaps and gaps in coverage. We believe that *cultural change* is needed if the GSC is to develop strategic direction and leadership, respond effectively to the current fiscal environment, and continue to meet its mission.

The project selection process is currently evolving to a more open and competitive approach named the Proposal Approval System (PAS). The Committee agrees that a new planning system is necessary in order to refocus the GSC programs, align them with corporate priorities, and match them with available funding. The PAS is still in its infancy and it remains to be seen whether this system will provide the necessary strategic direction to ensure the long-term health of the GSC's minerals programs.

In order to be effective, the new project selection system must ensure that all potential minerals geoscience projects are tested against a strategic plan and not judged merely on scientific merit. We recommend that a long-term strategic Minerals Geoscience Program plan, based on national needs and priorities, should be developed as a matter of urgency. This new MGP strategic plan should be used as the basis for rationalizing the current program into fewer, better-funded projects with a more balanced ratio of salary to operational funding levels. The GSC should use this opportunity to terminate those projects and activities that do not clearly align with corporate priorities and to capture "stranded assets" resulting from recent downsizing. In order to monitor the progress of strategic planning on an annual basis, we believe that an industry advisory committee, representative of both major and junior companies, should be established.

MANAGEMENT

Concurrent with the introduction of a new project selection system and strategic plan, we are convinced that the GSC should review its Divisional organization with the intent of simplifying the management and reporting structures. Any new management plan should recognize and support the project as the most

effective mechanism for delivery of team-based research outputs. The committee commends the extension of "best practices" observed in some MGP projects to all future projects. These "best practice" characteristics include scoping and planning of projects (especially outputs) in consultation with stakeholders and clients, as well as monitoring, reporting and evaluation. There is an urgent need to accelerate the staff rejuvenation program in the MGP through strategic hiring of younger scientists in priority areas. The GSC should support and encourage the development of team-based, multi-disciplinary research and broaden the current reward/promotion criteria to recognize productivity and excellence in all contributions to the GSC program.

PROGRAM EVALUATION

Because of decreased funding, the Minerals Geoscience Program has been left with more ongoing projects than it can fund or adequately support. At the time of the review, the MGP was divided into four subprograms that were closely aligned with the five key strategies. Approximately 30 active subprogram elements, including laboratories, were identified to the committee as contributing to the MGP. For the purposes of evaluating the scope and relevance of the MGP program, we found that the programs were too broad to provide a useful framework at the activity level, while subprogram elements were generally too detailed.

One of the tasks faced by the Committee was to review these projects and activities, and evaluate and rank them according to a standard set of criteria. In order to evaluate the types of science activities within the program, we reclassified the 30 subprogram elements into 20 scientific "program areas" or "activities" that we felt should logically be grouped together. We then developed a priority ranking of these activities by considering three questions about each activity:

- Is it a core function of the GSC, as the national geological survey?
- Can only the GSC do it?
- Does it contribute to the MGP mission?

Each question was applied to all 20 activities in a zero-sum exercise by assessing the relevance, diversity, current

delivery levels, and adequacy of each activity against the stated goals and strategies of the MGP. The results of this analysis represent the considered opinion of the Committee members as to the relative priority of the various MGP activities, weighed against the GSC and MGP mandates.

Highest Priority Activities

The activities assigned the highest priority by the Committee are:

Digital Databases

Form the basis of the GSC's knowledge base to meet the present and future needs of its clients. We acknowledge that the primary role of geological surveys is the provision of geoscientific advice and information to Government, industry and the community, and view the lack of systematic archiving of all data into corporate databases as a serious gap. We recommend that a review and audit of all data collected by the MGP should be carried out to determine which data should be archived corporately. We also feel that a system of corporate archival and timely release of digital databases should be implemented as a matter of priority.

EXTECH-type Mineral Deposits Research

Has been widely praised because of a) its collaborative style, b) its tight management structure, c) its ability to meet goals in a timely manner, and d) its socio-economic basis through strong community involvement. The Committee believes that projects of this type should be encouraged with priority funding and expansion into former producing camps and well-mineralized districts that have never achieved commercial production.

Regional Geochemical and Surficial Surveys

Provide basic data that are highly relevant to a wide variety of users, and which we believe are becoming increasingly important as environmental baseline information.

Regional Airborne Geophysical Surveys

Provide basic regional information and are an essential component of modern

geoscientific mapping. A systematic mapping program is best coordinated under a national plan to develop a consistent national database.

Regional Metallogenic Studies

Provide the basis for resource inventory assessment to meet Government needs and stimulate private sector exploration. These are carried out, particularly in the northern territories, in conjunction with regional multidisciplinary mapping projects. We consider these studies to be an essential part of a national minerals program but are concerned about a recent decline in the level of activity.

Lower Priority Activities

We attached a slightly lower priority to the following activities because parts could be performed outside the GSC. However, these are still important components of the MGP mandate:

Analytical Laboratory Services

Provide high-quality, specialized, geochemical analyses that most scientists consider essential for their work. We concluded that the laboratories are generally well-equipped but that their operational integrity is being threatened by inadequate levels of technical support and capital replacement. Given the funding shortfall, we believe that decisions will have to be made about which analytical services should be maintained, which can be provided by alternative means (e.g., outsourcing, collaboration with universities) and which should be terminated.

Thematic Mineral Deposit Studies

Are very important to Canada at a regional and national scale. The GSC is a recognized world leader in this type of work. Because thematic mineral deposit research is so fundamental to the role of the MGP, the Review Committee made a special effort to measure the severity of the decline in resources and the extent to which the present MGP has the resources to meet the national needs. This analysis, which is found in table 3.3 of the full report, clearly points out a number of important aspects of the state of mineral deposit expertise within the present MGP.

The program's present strength resides in

the area of high-temperature hydrothermal deposits. There is resident world-class expertise for most deposit types with the exception of W-Cu-Sn skarns, which represent a significant reserve and exploration potential, particularly in the north. Expertise is very thin for porphyry type deposits. However, the expertise exists to allow all of these deposit types to be covered.

There is substantially less capability to deal with the wide range of magmatic deposits, low-temperature hydrothermal, and very low temperature deposits, although marginal capability does exist for some deposit types. The MGP would be hard pressed to provide an adequate level of expertise to deal with national needs related to most of these deposits. There is also very little capability to deal with alluvial deposits.

The Committee concluded that the capacity to carry out the necessary range of thematic mineral deposits has been seriously curtailed by downsizing and little or no capability now exists for many deposit types, a matter of particular urgency in the northern territories. Strengthening this activity could play a key role in government efforts to arrest the continuing decline of the Canadian minerals industry.

Rock Collections

Comprise the archive of rock and mineral specimens collected during fieldwork, as well as the national meteorite collection. We regard these as an important national resource for future research and reference.

International Mineral Deposit Research, and Technology and Knowledge Transfer

Provide opportunities to apply information gained from overseas minerals research to Canadian deposits. Overseas projects aimed at supporting export of Canadian knowledge and technology are consistent with Earth Science Sector goals but, in our view, these could be largely performed by the private service sector.

Laboratory Technology Development

Focused on new analytical methods to aid in exploration and environmental geochemistry, this activity is considered by the committee to be particularly useful.

Other Activities

We believe that three other activities deserve continued strong support, but we assigned them a somewhat lower rating than the others because some of this work is being, or could be, conducted elsewhere in Canada.

Genetic Mineral Deposit Research

While we do not believe that these studies should be a primary focus of MGP research programs, there is a significant opportunity to pursue them as adjunct research to larger multidisciplinary projects that are more closely aligned with strategic priorities.

Geochemical and Surficial Process Research

This consists mainly of drift dispersal studies that are of particular importance in the northern territories.

Environmental Process Research

This is a topic which we acknowledge is of great importance to other government departments, and in which the MGP has taken a leadership role in the study of the movement of metals in solution.

Lowest Relative Priorities

The lowest relative priorities assigned to MGP activities by the Committee were in the areas of Analytical Research, Geomathematics Service, Geomathematics Research, Geophysics Research, Geophysics Technology Development, and Geochemical and Surficial Technology Development.

It should be emphasized that the Committee is presenting, through this exercise, a relative prioritization rather than an absolute assessment of the usefulness or value of individual activities: it is not necessarily recommending the elimination of low priority activities. If decisions have to be made about adjusting the program to accommodate decreased levels of funding, however, this ranking may provide guidance to management as to our assessment of relative priorities.

PUBLICATIONS

The GSC has a well-deserved international reputation for the scientific excellence of its geoscience research, and this is also true of minerals geoscience. Overall,

MGP scientists are highly productive with a publication rate equal to or greater than that of personnel within many university departments. However, in order to ensure more timely release of information to clients, we urge the GSC to speed data dissemination and reduce publication costs by use of modern digital technologies, especially the Internet. Coupled with this is a need to adopt a more corporate approach to data acquired through GSC programs. We believe that the MGP should develop an explicit policy that all data generated by GSC project work belong to the Survey and ensure that it is all captured in corporate archival databases. Moreover, procedures should be developed for releasing these corporate databases to the public as soon as practical, after the accuracy of the data has been verified.

The Review Committee found less tangible evidence regarding the relevance of MGP products to its clients. While there is clear evidence of the uptake and application of some GSC outputs, a significant proportion of MGP publications are now in the national and international literature, where their impact and uptake is less certain. Closer attention by the GSC to the needs of its clients and closer monitoring of the uptake and application of its outputs will ensure that the GSC continues to provide a relevant, high-quality program.

RESEARCH INFRASTRUCTURE Analytical Laboratories

The mineralogical and geochemical analytical laboratories in the Minerals Geoscience Program represent a very large component of the MGP budget in terms of salaries (25% of MRD staff) and capital expenditures and operating and maintenance expenses (15% of program resources). The Committee recognizes the importance of the labs to the research projects, but feels the primary focus of the MGP research program must be field-based rather than laboratory-based.

The MGP laboratories appear to be very comprehensive, well maintained, and generally fully functional. Most are equipped with current, but not state-of-the-art, technology. The principal exception is the Sensitive High Resolution Ion Probe (SHRIMP) facility, which is a major strategic research tool maintained

by the Continental Geoscience Division.

We believe that the top priority for analytical activities in the MGP should be the provision of specialized services that: a) are not available elsewhere, b) require (further) in-house development and/or a high degree of communication between scientist and analyst, or c) require direct (hands-on) analysis by the scientist (*e.g.*, certain microbeam analytical methods). The GSC should actively seek university partnerships to address cutting-edge analytical needs. Analytical research priorities should be determined in the context of program needs, focusing on collaborative research that is closely aligned with the strategic goals and objectives of the MGP.

Information Technology (IT)

The Review Committee concluded that computer facilities are generally adequate, but that there appears to be a lack of access to IT support and Geographic Information System (GIS) expertise, especially at the project level. In addition, it appears to us that the need for support in this area is a corporate necessity and not a divisional or program need. The requirements of individual projects should be addressed at the project planning stage.

FUTURE INITIATIVES AND OPPORTUNITIES

The Review Committee believes that the process of change that has taken place in the MGP in recent years is not over and is not reversible. It seems likely that scientists who are able to identify new research opportunities that are aligned with the broader Departmental and Sectoral policies will continue to find new and challenging opportunities for their research. We see future initiatives and challenges in four important areas.

Changing Needs of the Minerals Industry

Canada's share of world production in most metals has been falling steadily for two or three decades and the country has lost its former position as the leading global metal producer (Fig. 2). This trend appears to be increasing at an alarming rate because new mines are not being found at a sufficient rate to offset the depletion of the major deposits that have sustained the Canadian minerals industry in the past. Increasing levels of Canadian exploration (and development) funds as well as expertise are being directed overseas as Canadian companies have adopted a global approach to exploration and mining. At a time when positive action is needed to reverse these trends,

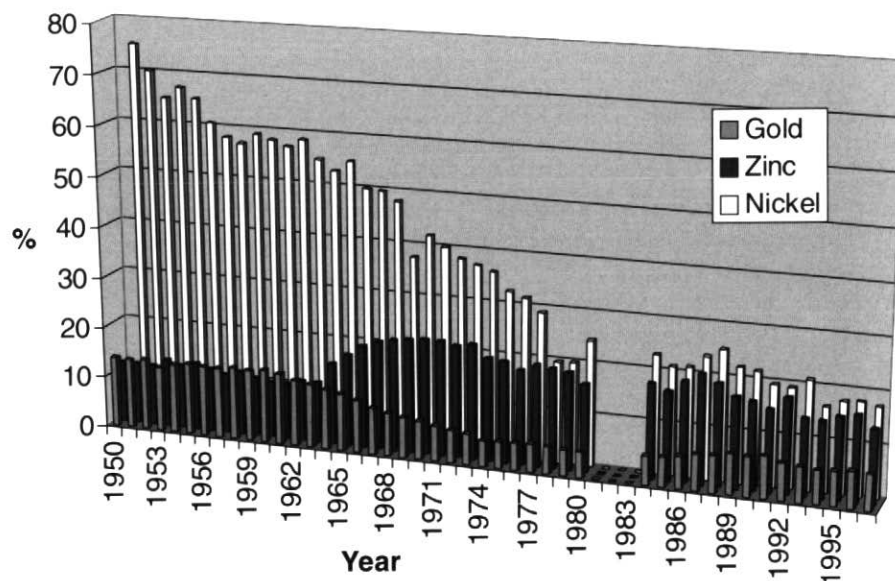


Figure 2 Chart showing Canadian share of global gold, zinc, and nickel production for the period 1950-1997 (source: mineral statistics group, Natural Resources Canada, Ottawa; figure 7.1 in Cathro *et al.*, 2000, unpublished).

federal policies have resulted in a cutback on the necessary research funds.

There is a need for increased research to support future exploration in areas covered by thick overburden, water, ice or barren rocks. This will require deeper geophysical penetration, more sophisticated geological and geophysical interpretation, a better understanding of glacial and fluvial history, more sensitive geochemical analyses, and improved mineral deposit models. The scientific leadership needed for this effort must, in our view, be fostered at the national level, within the GSC. Regional metallogenic studies, EXTECH-style projects, and northern development will be particularly important in future mineral programs. The northern territories will continue to provide enormous opportunities for new minerals programs within the MGP.

Increased Emphasis on Collaboration

The broad spectrum of knowledge and the multi-disciplinary approach to modern science requires a collaborative approach. Synergies resulting from the melding of diverse areas of expertise have been responsible for significant advances in science. Although collaborative research has always played a role in GSC research programs, it has blossomed in recent years, prompted in part by the need to work jointly with Provincial and Territorial surveys in order to work in their jurisdictions. The Review Committee has concluded that this collaboration with sister surveys, university researchers, and industry must increase in order to make better use of the shrinking resources and to capture the best research opportunities.

New and Emerging Technology

We see two areas of clear opportunity presented by new technology. One of these is better analytical capability for an increased range of elements at lower concentrations. New geochemical applications could be particularly significant in, for example, detecting geochemical dispersion in bedrock or the surficial environment, tracing metal transport in the environment, developing sophisticated methods for tracing indicator minerals in surficial materials, and developing more detailed ore deposit

models from case studies.

The second area of opportunity is in the field of information technology. The importance of the growth of computers in science cannot be overestimated. Computer technology is constantly providing new opportunities for data accumulation, processing, analysis, visualization, publication, and archiving. There is tremendous opportunity for the MGP to conduct sophisticated data analysis and to incorporate large volumes of related data in ways that are beyond the means of many of their clients. The Internet provides new opportunities for publication and dissemination of research results and information to a wider client base.

Applying Existing Skills in New Directions

MGP scientists have expert knowledge and skills that can be applied in areas other than mineral deposit research. The geochemical expertise that is critical for exploring the surficial environment for new mineral deposits can be applied to understanding the environmental effects of metal transport in other areas. We feel that the application of MGP data to environmental matters will be an increasingly important part of the program. It is critical that good science be brought to bear on the environmental issues raised by metals in the environment and that this science be communicated, not only to the geoscience community, but also to those concerned with public health and safety.

CONCLUSIONS

The Review Committee recognizes the important contribution that the GSC's minerals program has made to the development of Canada's mineral wealth over the years. There is still vast scope for contributions of this nature and there is a clear mandate in legislation, policy, and Federal-Provincial agreements for the GSC to carry out this work. A strong minerals program within the GSC is a prerequisite for Canada's continued leadership in the field of minerals geoscience and will continue to be a major factor in attracting mineral investment to Canada.

The GSC's minerals program has reached an important crossroads. Budget

reductions referred to earlier (see Table 1) have severely impaired the ability of the Geological Survey of Canada to carry out its traditional range of minerals-related activities and have triggered changes to the nature of the program that we consider to be irreversible. It seems likely that at least some minerals-related activities carried out by the GSC in the past will have to be scaled back or dropped in order to adjust the program to the current fiscal realities. Although budget reductions and the resulting need for program adjustments are causing severe strains within the Minerals Geoscience Program, they also provide an opportunity for strategic planning and realignment of the GSC program. The scope and breadth of the minerals program must be rethought and recast in terms of the GSC's mandate, priorities, and resources, and the nation's needs. The re-alignment of the Minerals Geoscience Program should also maximize the integration and synergy with other GSC regional mapping programs that contribute to sustainable development issues. We believe that change to the Minerals Geoscience Program is both inevitable and necessary to reinvigorate and optimize the Program, so that it will retain its ability to make a major contribution to Canada's key position in the global mining sector.

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