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GEOLOGICAL SURVEY OF CANADA

OPEN FILE 2366

Report of the External Advisory Committee to the Geological Survey of Canada for geophysics

H.O. Seigel

1991

Energy, Mines and Resources Canada Énergie, Mines et Ressources Canada

Canada

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H.O. Seigel,
Chairman

July 1989

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REPORT OF THE EXTERNAL ADVISORY COMMITTEE TO THE GEOLOGICAL SURVEY OF CANADA FOR GEOPHYSICS

1.0 EXECUTIVE SUMMARY

The merger of the Geological Survey of Canada with the Earth Physics Branch of the Earth Sciences Sector of the Department of Energy, Mines and Resources in April 1986, the division of the new organization into four branches, and shifts in emphasis in the type of work being conducted have justified the creation of a Committee to review the status of geophysical activities presently being conducted.

This report covers the general aspects of geophysics in the GSC, geophysical discipline related issues, those related to organization, management, and output products, and finally, suggests new or expanded initiatives for the future. A summary of the major findings is presented below, in the form of both primary and secondary recommendations.

The abridged versions of the recommendations in this summary are referenced with the section numbers from the body of the report. Complete recommendations, including supporting discussions are found only in the body of the report.

THE ROLE OF GEOPHYSICAL RESEARCH IN THE GSC (2.2)

Primary Recommendation

The GSC should continue to engage in geophysical research activities which are pertinent to its mission. Whenever possible, these should complement activities in the private and academic sectors. Collaborative research should be encouraged.

Secondary Recommendations

1. In general, the GSC should undertake R&D projects in geophysics relating to new technology (methodology) development, new methods of data processing, interpretation and presentation, and in the conduct of experimental surveys intended to test the application of new instrumentation or technology under known geological conditions in Canada.

2. The GSC should work in consort with private sector parties to facilitate geophysical instrument development of common interest, through acting as a catalyst in support of funding from other government and governmental sources. The GSC should only engage unilaterally in instrument development as required to support its primary research programs and then only if the appropriate capability does not reside within industry.

BALANCE OF GSC ACTIVITIES RELATED TO GSC MISSION (2.3)

Primary Recommendation

The GSC should evaluate and, if necessary, redirect its activities so that there is a balance in emphasis in the geoscience fields related to support of the various resource based industries.

Secondary Recommendations

1. Except where special arrangements with other agencies are made, mapping projects should not be conducted at a scale that will allow direct and immediate use in exploitation of resources.

2. The GSC should establish a series of guidelines for geophysical mapping scales for routine surveys. Guidelines for more detailed mapping projects, including appropriate scales and criteria to be met to justify such projects, should also be developed.

EARTHQUAKE SEISMOLOGY (3.1)

Primary Recommendation

The National Seismograph Network must continue its 24 hour per day, 365 day per year monitoring function. Also, this National Program should be exempt from the 10% 'sunset' item recommended by this Committee (see Section 5.2).

Secondary Recommendations

1. The Committee recommends that the National Seismograph Network be provided with the resources to continue and enhance its plans for upgrading the network to digital standards.

2. The balance of seismological research and monitoring effort between GD and PGC is not appropriate to the balance of seismic activity, hazard and risk; this should be rectified. Reallocation of personnel and funds in seismology is recommended.

3. The "West Coast Megathrust Earthquake" project has been proposed, to launch a major research effort related to possible subduction thrust earthquakes with magnitudes greater than 8. The Committee fully endorses this initiative and its need for new resources.

4. The Committee recommends that the GSC address the lack of continuing Canadian expertise in earthquake seismology by providing incentives to graduate students and by supporting university research.

GEODYNAMICS (3.2)

Primary Recommendation

Strengthen the western Canadian geodynamics program by transferring appropriate personnel from eastern Canada to PGC and recruiting qualified young scientists whenever possible.

Secondary Recommendations

1. Increase the effort in local geodynamics programs by transferring some resources from the global program.

2. Continue coordination of activities with the Geodetic Survey of Canada and expand such activities as required for crustal deformation measurements, particularly on the west coast, but including also other earthquake prone areas in eastern Canada.

3. Maintain the GD's VLBI effort and its collaborative research with two universities and the Geodetic Survey; focus the principal global geodynamics effort on VLBI.

4. Phase out optical efforts in geodynamics (with the possible exception of leveling to study post-glacial rebound).

GRAVITY (3.4)

Primary Recommendation

The national program of regional gravity measurements should be continued, with at least the current level of resources, until the Gravity Anomaly Map of Canada is complete.

Secondary Recommendations

1. All budget items associated with these regional surveys should be consolidated within the GD to ensure effective and efficient use of the resources.

2. The program of absolute gravity measurements should be maintained to ensure the viability of the national gravity network; however, there needs to be improved integration with problem-oriented studies such as geodynamical crustal deformation.

3. Personnel in the Applications Section should continue to strive for, and be assigned, more scientific problems to address, including acting as research collaborators with scientists in other divisions who could utilize their expertise.

4. Remote access to the computer facilities in the GD data centre should be improved for its effective utilization from remote sites.

PALEOMAGNETISM (3.5)

Primary Recommendation

The two paleomagnetic laboratories, one at LCSD and one at PGC should be maintained. However, the two separate laboratories within LCSD should be combined and located on Booth Street where there are opportunities for close interaction with geologists.

Secondary Recommendations

1. The group at PGC should be expanded. The Committee recommends that the two vacant paleomagnetic positions and one technical support position in Ottawa should be transferred to PGC.

2. The advances in automation of paleomagnetism measurements made at PGC should be implemented in the LCSD group to increase the efficiency of the latter.

3. The Committee recommends that, if a comprehensive rock properties laboratories laboratory is established, the paleomagnetic group in Ottawa should form one component of it.

4. The GSC should address the problem of recruitment in paleomagnetism by providing incentives to graduate students and, whenever possible, supporting university research involving students.

THE SKYVAN AEROPLANE (3.7.1)

Primary Recommendation

The Skyvan aeroplane should be retained as a platform for the purposes for which it is currently being utilized.

Secondary Recommendations

1. Its complement of geophysical instrumentation should be broadened to include a vertical magnetic gradiometer, and possibly an airborne gravity meter.

2. The Skyvan should not be used for systematic surveys of large areas; these should be contracted out to the private sector.

3. To ensure that the Skyvan can be quickly mobilized as a quick response tool in the event of a nuclear incident to map the distribution of radioactive contamination, an annual "fire drill" should be called without warning.

THE TERRAIN GEOPHYSICS SECTION (3.7.2)

Recommendation

The Terrain Geophysics Section should be moved into the Exploration Geophysics Sub-Division of the MRD to relate closely with the Electrical Methods Section in respect of solving problems of interest to natural resource development.

THE RADAR GROUP (3.7.3)

Primary Recommendation

The Radar Group should be transferred to the Exploration Geophysics Sub-Division of the Mineral Resources Division, to be combined with the shallow seismic group of the Terrain Geophysics Section.

Secondary Recommendation

The combined technical resources of the Terrain Geophysics Section and Radar Group should be utilized in multidisciplinary programs relating to the GSC's mandate.

THE ELECTRICAL METHODS SECTION (3.7.4)

Primary Recommendation

If the GSC becomes involved in "geosphere" problems associated with Global Change (problems in groundwater and toxic waste disposal), the expertise of this section should be utilized toward the study and resolution of such problems.

Secondary Recommendation

If this does not occur, the PY and budget resources should be transferred to LCSD. The electrical methods specialists should be integrated into the Potential Field Section; the personnel in the rock properties laboratory should be combined with those in the Paleomagnetism Section to form the nucleus of a national Rock Properties Lab.

THE INSTRUMENT DEVELOPMENT SECTION, MRD (3.7.5)

Primary Recommendations

1. The current programs relating to instrumentation development should be terminated as soon as possible.

2. The instrumentation capabilities of this section should be devoted to the maintenance and improvement of the Skyvan airborne installation, and the maintenance of ground equipment owned by the Exploration Geophysics Sub-Division.

Secondary Recommendations

1. This section should cultivate and establish closer ties to the Canadian industry for instrumentation development, and to the universities for basic research. They could provide a useful catalyst for the development of funding from other governmental agencies for support of research in industry, e.g., through the IRAP program.

2. This section should cooperate with industry in the testing of new geophysical instruments, to determine their effectiveness over areas of known geology.

ORGANIZATIONAL ISSUES (4.0)

MISSION OR DISCIPLINE-BASED ORGANIZATION (4.1)

Primary Recommendation

In order for the GSC to maintain technical competence in many diverse geophysical disciplines, the Committee recommends that a basic, matrix style of organization be created, through the addition of a discipline-oriented network.

Secondary Recommendations

1. A key element in the maintenance of technical competence will require that the position and title of Chief Geophysicist be revived.

2. To support the Chief Geophysicist, Consultants in each major technical area would be appointed to monitor the quality of the science carried out in their speciality.

GEOPHYSICS IN FOUR (SUB) DIVISIONS (4.2)

INSTITUTE OF SEDIMENTARY AND PETROLEUM GEOLOGY (4.2.1.)

Recommendation

Increase the geophysical staff of ISPG to a level which is more appropriate to the needs of its scientific programs.

CORDILLERAN AND PACIFIC GEOSCIENCE DIVISION -VANCOUVER (4.2.2)

Recommendation

In keeping with the GSC's stated objectives of multidisciplinary studies and the scientific needs of the programs within the Cordilleran Subdivision, the Committee recommends that its geophysical staff be increased to a level commensurate with the needs of the group.

CORDILLERAN AND PACIFIC GEOSCIENCE DIVISION - PACIFIC GEOSCIENCE CENTRE) (4.2.3)

Primary Recommendation

Raise PGC to the status of a Division with its own Director.

Secondary Recommendations

1. Resources from other divisions should be reallocated to PGC such that its scientific role will be enhanced.

2. Encourage closer cooperation in all aspects (technical, equipment, scientific, personnel) between AGC and PGC.

THE QUEBEC GEOSCIENCE CENTRE (4.2.4)

Recommendation

The ratio of geologists to geophysicists at QGC should be similar to that in the GSC.

AEROMAGNETICS (4.3)

Primary Recommendation

Retain the responsibility for contracting out, data processing and presentation of the aeromagnetic surveys in the Geophysics Division.

Secondary Recommendations

1. Take positive steps to promote good technical communication between those staff members involved in magnetic analysis and interpretation, and their counterparts in all other divisions who are involved in magnetic analyses and interpretation.

2. The dollar budgets for completion of the regional aeromagnetic coverage of Canada should be administered by the Geophysics Division.

MULTIUSER GEOPHYSICAL EQUIPMENT (4.4)

Recommendation

The Chief Geophysicist, after consultation with all interested geophysicists, should approve the purchase of all major geophysical equipment and, on an annual basis, create a schedule for usage of such equipment.

MANAGEMENT RELATED ISSUES (5.0)

MAJOR PROJECT MANAGEMENT (5.1)

Primary Recommendations

1. Formal project management should be established as a routine policy in the GSC. Each project should have clearly stated objectives, a target date for completion and milestones against which progress is measurable.

2. For multidisciplinary projects a project manager should be designated as responsible for the entire project, with clearly defined lines of authority and responsibility.

Secondary Recommendations

1. The Project Manager should have defined supervisory authority. He should prepare an overall plan and, if necessary, a plan for the year, for approval by GSC management.

2. The resources required should be made available by the Divisions involved with the Directors assisting the Project Manager in ensuring that the personnel and equipment assigned are available when required and that data analysis, interpretation and the final report are completed in a timely fashion. All personnel assigned should be made responsible to the project manager for their part of the project.

3. The Directors General should be charged with the responsibility of reviewing the status of each project at regular intervals to ensure that the goals are being met.

DOLLAR AND PERSON-YEAR BUDGETS (5.2)

Recommendation

With the exception of certain national programs, such as the seismograph and geomagnetic observatory networks, as well as the national aeromagnetic and gravity mapping programs, each year 10% of the dollar and PY budget of each division should be "sunsetted", for possible reallocation to other projects and/or other divisions.

EFFECTIVE UTILIZATION OF RESOURCES (5.3)

Primary Recommendation

Establish a policy for maximum utilization of human and material resources across the GSC through mobility of these resources on a project/need basis.

Secondary Recommendations

1. Individual DG's, directors and subdivision heads, should be encouraged to borrow or second personnel and equipment in order to get better utilization thereof, across the GSC, to avoid duplication of specialization and scarce resources, and to improve communication, team spirit and technical standards.

2. As part of general technical communication, the Chief Geophysicist should prepare a detailed listing of human resources (with areas of expertise) and material resources in geophysics, and circulate these to all GSC personnel.

PERSONNEL RECRUITMENT (5.4)

Primary Recommendation

The GSC should become more proactive in development Canadian expertise at the Ph.D. level, particularly in fields which have been identified as lacking qualified applicants.

Secondary Recommendations

1. The GSC should expand its Research Agreements programs in geophysics, paying particular attention to those fields where it perceives a distinct need; and the grants should be advertised more widely, so that students are more aware that the research is being supported by the GSC.

2. The GSC could initiate a Ph.D. Fellowship program and enhance its postdoctoral fellowship program, "Visiting Fellowships in Government Laboratories".

3. GSC geophysicists who are good speakers and have exciting topics should regularly give talks at university earth science departments, particularly to undergraduate groups, to demonstrate the excitement and opportunities that are available; and also give talks of a more research nature to graduate students and faculty, as is frequently done now.

4. The GSC should continue and enhance its visibility at international conferences through appropriate presentations in order that young foreign scientists continue to be aware of the quality of research in geophysics and the opportunities offered by employment with the GSC.

PERSONNEL REVIEW AND ADVANCEMENT (5.5)

Primary Recommendation

The Chief Geophysicist should be involved in all reviews of geophysical staff.

Secondary Recommendation

The GSC should examine its current criteria for advancement to ensure that all types of professional activities are considered, including those which would not be expected to produce publications.

MANAGEMENT TRAINING (5.6)

Primary Recommendation

The GSC should develop a comprehensive training and replacement plan for supervisors at all levels.

Secondary Recommendations

1. The desirability of supervisory jobs should be enhanced by increased management communication, increased authority, personal perks, etc.

2. Training in project management, management theory, human relations and other supervisory skills should be provided to all scientists acting as project managers or supervisors.

LACK OF SUPPORT STAFF (5.8)

Recommendation

Determine the percentage of time that each Research Scientist spends on support staff type activities, establish desirable ratios of scientist/support staff for specific groups of scientists, and modify present hiring policies to attain these ratios.

PRODUCT RELATED ISSUES (6.0)

PUBLICATION OF DATA (6.1)

Recommendations

GSC should ensure that the highest quality is maintained for all published data, not just written reports and maps, through internal review procedures which should provide critical assessment and positive suggestions for betterment.

BASIN ATLASES (6.2)

Primary Recommendation

The Basin atlas format of GSC publication is strongly recommended.

Secondary Recommendations

1. Each Division should review its current inventory of information with the object of publishing a continuing series of atlases over the next decade.

2. In the interest of expediency, (unless prohibited by official government policy), these atlases should be published in either of the official languages while the translation into the second language is undertaken.

ARCHIVING OF DIGITAL DATA (6.3)

Recommendation

The Chief Geophysicist should review the present procedures for cataloguing and archiving of digital data and, in cooperation with the Divisions, establish thorough cataloguing procedures and designate proper archiving locations.

DIGITAL INFORMATION STANDARDS (6.4)

Primary Recommendation

Standards for computer and software acquisition and software development, and digital data bases should be set up and maintained. A committee with representatives from each Division and the Chief Geophysicist should be formed to establish these standards.

Secondary Recommendations

When standards are established, this Committee should review all proposals for purchase, development or output in the digital area to ensure that they are being followed.

NATIONAL DATA BASES (6.5)

Recommendation

Specification for collection and distribution of data for national geophysical data bases should continue to be reviewed periodically by a group representing the GSC and outside experts, to ensure that they meet the needs of the end users.

HIGH SPEED DATA TRANSMISSION (6.6)

Recommendation

The GSC should study its data communication requirements with the view to setting up high capability transmission facilities to serve the needs of its earth scientists, should the study prove to be cost-effective.

HIGH CAPACITY COMPUTER SUPPORT (6.7)

Primary Recommendation

The digital standards committee should also study computer needs in the GSC and devise a cost effective plan that will provide computer support required by GSC geophysicists.

Secondary Recommendations

1. The use of the Convex computer already owned by the GSC for geodynamic, gravity and magnetic modelling, etc., should be evaluated.

2. It is suggested that the Lithoprobe Seismic Processing Facility be utilized, at least on an interim basis, for processing seismic data.

NEW DIRECTIONS AND CHANGING EMPHASIS (7.0)

CONTINENTAL DRILLING PROGRAM (7.1)

Recommendation

Extensive surface geophysical work should be done around any area on which such drilling is contemplated. After the drilling, the hole should be logged using a variety of standard logging tools and offset VSP measurements should be made.

MEGATHRUST EARTHQUAKE (7.2)

Recommendation

The Committee strongly endorses the proposal to evaluate the risk of a mega-earthquake in southwestern B.C.

GLOBAL CHANGE (7.3)

Recommendation

The GSC should evaluate the application of its present geophysical resources to the problems posed by "Global Change".

REMOTE SENSING (7.4)

Recommendation

In order to more fully utilize remote sensing techniques in GSC mapping projects, a formal liaison committee should be established, through the office of the Chief Geophysicist with the Remote Sensing Branch to review geological mapping projects to see where these techniques could be of value.

BASE METALS EMPHASIS (7.5)

Recommendation

This Committee strongly supports the initiative recently taken by the GSC, to devote 10% of the annual budget of the Mineral Resources Division to the advancement of the science of mineral exploration. The studies undertaken must be multidisciplinary and should be done in consort with the private sector and universities.

ROCK PROPERTIES (7.6)

Primary Recommendation

The GSC should establish a national data base of rock properties to serve the needs of all earth scientists.

Secondary Recommendations

1. The initial task should be to catalogue and archive existing data.
2. The rock properties lab could be combined with the Paleomagnetic Section of LCSD.
3. The assistance of the Canadian geoscience community should be solicited in the establishment of this function.

STANDING EXTERNAL ADVISORY COMMITTEE FOR GEOPHYSICS (8.0)

Recommendation

The Committee recommends that a standing External Advisory Committee to the GSC for Geophysics should be established. Its constitution should provide for the rotation of members (e.g., 1/3 to 1/2 each year) and a sunset clause for the Committee as a whole.

1.1 INTRODUCTION

In April 1986, the 'new' Geological Survey of Canada was formed through the amalgamation of the 'old' Geological Survey of Canada Branch and the Earth Physics Branch of the Earth Sciences Sector of the Department of Energy, Mines and Resources. Following that amalgamation, in April 1987, the previous Earth Sciences Sector was dismantled and the 'new' Geological Survey of Canada was raised to the status of a Sector, with its head being an Assistant Deputy Minister. Simultaneously, the GSC Sector was divided into four branches (Sedimentary and Marine Geoscience; Continental Geoscience and Mineral Resources; Geophysical Surveys, Hazards and Terrain Sciences; and Programs, Planning and Services), each with its own Director-General. Within each Branch, the major units are Divisions, each headed by a Director. Further subdivisions occur within each division. A brief review of these developments is given by Price (Geotimes, December 1987, p. 4).

Just prior to the amalgamation, the Earth Physics Branch had undergone a review by the "Garland Committee", resulting in a report published through the Canadian Geoscience Council (Garland, 1987). However, the report was published after the amalgamation. As such, the first five pages of Paper 87-24 include a section titled "Response to Report of the Canadian Geoscience Council on the Earth Physics Branch" in which replies to the 26 recommendations of the Garland Committee are given.

Since the Earth Physics Branch has been incorporated into the present Geological Survey of Canada, the contents of GSC Paper 87-24 provide a detailed consideration of the state of much of EMR's geophysical effort to about 1986. The paper provides some background history and includes a major section resulting from a survey of users. It also presented consideration of the linkages between EPB, government institutions, industry and university. This Committee has made no effort to duplicate the contents of the Garland report and recommends it to the reader for an earlier perspective of the major component of geophysics at the present GSC.

1.2 THE EXTERNAL ADVISORY COMMITTEE TO THE GEOLOGICAL SURVEY OF CANADA FOR GEOPHYSICS

The Garland report recommended that:

> ". . . a committee, of similar structure to the present Review Committee but with the addition of representation from mining geophysics, be established to have ongoing missions of assisting the Branch to develop programs and review progress." (Garland, 1987)

The GSC response to this recommendation was:

> "The principle of establishing an External Advisory Committee to the GSC for Geophysics has been accepted and invitations will be issued in late 1986. Representation from industry, universities and international agencies will be sought." (Garland, 1987)

The External Advisory Committee to the Geological Survey of Canada for Geophysics (hereinafter referred to as "the Committee") was appointed in 1987 by Dr. R. A. Price, Assistant Deputy Minister, Geological Survey of Canada Sector using the following guidelines:

The Committee will consist of 9 members, 3 representing Canadian industry, 2 representing Canadian universities, 3 representing the international geophysical community, and 1 representing provincial government agencies. The members of the Committee, including its Chairman, will be nominated by the Canadian Geoscience Council and appointed by the Assistant Deputy Minister responsible for the Geological Survey of Canada. The members of the Committee and their affiliations are:

Dr. H. O. Seigel, Chairman
Scintrex
Concord, Ontario

R. B. Barlow
Ontario Geological Survey
Toronto, Ontario

Dr. R. M. Clowes
University of British Columbia
Vancouver, B.C.

W. E. Davitt
Chevron Canada Resources
Calgary, Alberta

Dr. W. Kaula
University of Los Angeles
Los Angeles, California

Dr. J-P. Mareschal
Universite de Quebec a Montreal
Montreal, P.Q.

Dr. R. Masse
United States Geological Survey
Denver, Colorado

Dr. J. E. Oliver
Cornell University
Ithaca, New York

M. C. Jobin
Dighem Surveys & Processing Inc.
Mississauga, Ontario

1.3 COMMITTEE TERMS OF REFERENCE

The purpose of the Committee is to advise the Geological Survey of Canada Sector of the Department of Energy, Mines and Resources, on the scope and effectiveness of its geophysical activities, including observatory networks, national surveys, exploration geophysics, terrain geophysics and other fields of applied geophysics, international liaison, geophysical instrumentation and technology development. Recommendations should be limited to areas in which the Assistant Deputy Minister is empowered to act, but observations and comments on broader issues would be appreciated.

The Committee will examine: a) the products or outputs of the geophysical activities of the Geological Survey of Canada, both published information and internal reports; b) the research facilities at Dartmouth, Nova Scotia; Ottawa, Ontario; Calgary, Alberta; Vancouver and Sidney, B.C., and perhaps some of the other observatory facilities as well; c) the program planning and management system for the geophysical activities in the Geological Survey as a whole; and d) the human resources development plans and practices. It will submit, within two years, a report suitable for publication by the GSC and CGC, to the Assistant Deputy Minister. It will consider the advisability of establishing a Standing External Advisory Committee on Geophysics to the GSC.

The Committee will recommend changes that may be necessary to best respond to the needs of the Canadian government and the users of the services supplied by the GSC.

1.4 OPERATION OF THE COMMITTEE

The first meeting of the Committee was held in Ottawa on December 1-2, 1987 in Ottawa. A comprehensive review of the geophysics activities of the GSC was presented by the Assistant Deputy Minister, the Directors General and the Directors. The Committee toured the geophysical laboratories and viewed the displays at 601 Booth Street, 401 Lebreton Street, and at the Geophysics Division on Observatory Crescent. The Committee held its first organizational meeting to formulate a plan of attack and examine the technical expertise resident within the Committee.

The major elements of the review plan developed were:

- Visit all sites of significant GSC geophysical activity to evaluate programs being conducted and to solicit voluntary contributions from all GSC scientists either in writing or through personal interviews with Committee members during these visits.

- Utilize previous user surveys such as those conducted by Slind (1988), Devenny and Jardine (1986) and Garland (1987) to evaluate the user community response to the work being carried out by the GSC in the area of geophysics.

- Examine the activities of the GSC within each Division by major project, and evaluate the contribution and relevance of the geophysical component.

- Examine relationship of GSC geophysics component with external organizations including federal departments, provincial geological surveys, international organizations, Canadian industry.

- Obtain statistics on the utilization of products produced by the GSC. Examine a random sample of these.

- Obtain internal planning documents relating to individual projects involving geophysics.

The Committee also developed some additional guidelines:

- The final report must conform to the GSC mandate. According to the GSC Long Term Plan for 1987/8 to 1991/2, the Activity Objectives of the GSC are defined as follows:

  > "To ensure the availability of comprehensive geological, geophysical and geochemical knowledge, technology and expertise concerning the Canadian landmass, including the underlying solid earth, offshore areas, mineral and energy resources and the conditions affecting land and seabed use, as required for effective exploration of mineral and energy resources, estimation of the resource base of Canada, land use, public safety and security and formulation of policies." (Internal GSC document)

- The report should have a high probability of being implemented. This will mean getting prior agreement, insofar as possible, with the ADM, DG's and Directors.

- Insofar as possible, recommendations should entail a re-allocation of resources, not an increase of resources.

- The special nature of geophysics as a discipline within the GSC should be clearly documented.

A schedule of visits to sites outside of Ottawa was also developed, and a coordinator for each visit appointed.

1.5 SUMMARY OF COMMITTEE ACTIVITIES

The Institute of Sedimentary and Petroleum Geology was visited by W. E. Davitt (Coordinator) and Dr. R. M. Clowes on February 8, 1988; the Atlantic Geoscience Centre, by Dr. J-C. Mareschal (Coordinator), Dr. R. M. Clowes, W. E. Davitt, Dr. R. Masse, and Dr. H. O. Seigel on April 25 and 26, 1988; the Cordilleran and Pacific Geoscience Division and the Pacific Geoscience Subdivision, by Dr. R. M. Clowes (Coordinator), W. E. Davitt, Dr. W. Kaula, Dr. R. Masse, Dr. J-C. Mareschal, and Dr. H. O. Seigel on May 12 and 13, 1988; and the Divisions utilizing geophysics in Ottawa, by the entire Committee except R. B. Barlow on June 22-24, 1988.

Additional Committee meetings to review the information gathered, to discuss preliminary recommendations with GSC management, and to prepare and present this report were held in Ottawa from October 13-14, 1988 and in Toronto January 17, 1989. A preliminary draft of the final report was reviewed by the Committee on May 15, 1989 and the final report was submitted to the ADM and the Canadian Geoscience Council in July 1989.

It will be obvious to those reading this report in its entirety that it was written by a committee. An effort was made to maintain a standard format for each section but it was decided that editing and rewriting the entire report in order to maintain consistent writing style would be too much effort for too little benefit.

1.6 A MOVING TARGET

It should be noted that continual changes have affected the GSC during the year and one-half tenure of this Committee. At the time of the Committee's first meeting in December 1987, the GSC had a staff of about 1000, and an annual budget of $105 000 000. The head of the GSC, the Assistant Deputy Minister, was Dr. R. A. Price, and the Minister responsible for EMR was the Hon. Marcel Masse.

There was general concern about the declining A-base budget, and the reliance on "soft money" to support much of the field activities of the GSC. The Mineral Development Agreements with the provinces were scheduled to terminate and the most significant soft money source, the Frontier Geoscience Program, was under review. Lack of adequate office space at several locations was also a concern. Pressure was mounting for the GSC to become more involved in multidisciplinary projects. This was one of the reasons for the merger of the Earth Physics Branch with the GSC.

By early 1989, a little over a year later, a new Assistant Deputy Minister, Dr. E. A. Babcock, has been appointed to head the GSC and the Hon. Jake Epp had become the Minister responsible for EMR. The establishment of a joint Quebec government/GSC facility in Quebec City had been announced and the Pacific Geoscience Centre was awarded "Division" status. The extension of the Frontier Geoscience Program had been approved, with these funds forming a part of the A-base budget. With the termination of MDA's and possible downsizing in other areas, the GSC was struggling to cope with the changes.

1.7 ACKNOWLEDGEMENTS

The cooperation of the GSC management at all levels greatly assisted the work of the Committee. The Directors General and Directors were most helpful in supplying the information requested and in assisting with the Division visits. The Committee offers its thanks for their complete cooperation. The Committee particularly wishes to thank the many geophysicists and other earth scientists who appeared before it to discuss their concerns and their ideas, and to present their recommendations on ways to improve the function of geophysics within the GSC.

2.0 GSC GEOPHYSICAL ORGANIZATION AND ACTIVITIES, CIRCA 1988

Through its many meetings and visits to all geophysical groups within the GSC, the Committee was made aware of the great diversity of geophysical activities and the extent to which geophysicists are spread throughout the organization. This situation is in keeping with the GSC's management policy of a multidisciplinary approach for its scientific programs. To summarize geophysical activities within the GSC, the Committee has prepared a "GSC Geophysical Organization and Activities, circa 1988" chart (Figure 1). The information contained in this chart has been extracted from the many submissions presented to the Committee. It is not intended to be definitive and will undoubtedly include errors and have omissions; nevertheless, it does provide a compact overview.

2.1 GEOPHYSICS IN THE GSC

Following amalgamation of the Earth Physics Branch and (old) Geological Survey of Canada, geophysics was established as a major component of the (new) Geological Survey of Canada. There are several functions originally conducted by the EPB that provide data required beyond the original GSC mandate to "study the rocks of Canada". These include seismicity monitoring and its use in developing building codes, the terrestrial effects of atmospheric magnetic fluctuations, operation of the Yellowknife seismic array for detection of nuclear explosions, compilation of the Gravity Map of Canada for purposes ranging from geological structures to the geoid ("figure of the Earth"), geodynamic investigations for regional tectonic problems and continental-scale motions, and geothermal studies ranging from permafrost to heat flow (the Earth's heat engine), among others.

Geophysics is an earth science discipline in its own right and needs to be nurtured as such. At the same time, Geophysics represents the geologists' "telescope" into the earth, a means through which subsurface "images" can be obtained for the purpose of extrapolating surface geology to considerable depths. This dual scientific role, discipline and application, is an important one that is well represented within Geophysics at the GSC.

Under the umbrella of the original GSC charter, geophysics has a major role to play. Only a minuscule amount of the "rocks of Canada" are observable on the surface or in scattered penetrations of the subsurface by wells. Geophysics is required to bridge the gaps in accessible geologic observations, and to explore elements of the earth that geology cannot study, either due to inaccessibility or to the unsuitability of geologic techniques. Each science has contributed greatly to the understanding of the Canadian landmass and, with higher levels of interaction, these contributions will multiply.

While much of this report will deal with the issues and problems which have been the focus of its activities, the Committee recognizes that there are many areas of strength within geophysics at the GSC. As such, we consider that it is important to highlight a number of these.

The Canadian Seismograph Network has been a stable and reliable component of the world-wide network for decades; it has always provided high quality data and maintained standards of the highest order. The (now) Geophysics Division (with a former component at PGC) is a world leader in digital seismic networks, such as the Eastern and Western Canada Telemetered Networks, and continues to provide enhancements in this field. They were the first to develop probabilistic hazard maps which were, and continue to be, incorporated into the Building Code of Canada.

The Canadian Geomagnetic Network also has been a stable and reliable component of the world-wide network. With Canada's large land area and northerly range of latitudes, such information is essential for tracking variations of the magnetic field, information that is essential to a number of 'clients', from communication, hydroelectric power and exploration companies to groups investigating fluid motions in the earth's core. Only a government agency can maintain the continuity and high standards that are necessary for such programs.

The two National Mapping Programs (Gravity and Aeromagnetic) are considered amongst the most complete and highest quality of any in the world. They provide an unmatched coverage for regional studies and the aeromagnetic data are particularly relevant for mineral exploration and geological mapping below overburden. The recent efforts in image processing and color displays are excellent. The outputs of the programs are used by a wide range of 'clients'.

Instrumentation Development, undertaken in support of GSC geophysical programs, has a history of innovation and excellence. Garland (1987) noted that the Earth Physics Branch "achieved its worldwide reputation for outstanding geophysical research and scientific leadership partly because it employed a number of outstanding instrumentalists". In the field of airborne magnetometry, the GSC has made significant contributions in instrumental development, including some aspects of proton precession magnetometers, self-orienting, optically-pumped magnetometers, and magnetic gradiometers. In the latter case, the GSC has been the leader in promotion of the increased geologic resolution inherent through airborne magnetic gradient measurements.

One of the highly successful developments has been the portable seismic refraction recorders designed and built for Lithoprobe and other projects. After extensive design criteria involving scientists from the universities and government, prototype instruments were developed and tested in the instrumentation section of the Geophysics Division. A market for the instruments was identified and the technology transferred to EDA Instruments of Toronto, who have proceeded with further R&D.

Two instrumentation developments on the marine side have enabled researchers at the GSC to obtain critical information that otherwise would never have become available. The development at AGC of a relatively inexpensive and easily deployable ocean bottom seismograph, together with a large air gun array, has resulted in the acquisition of marine refraction data of very high density, enabling geological interpretations that were previously unattainable. One university (UBC) was provided with their design and constructed six instruments for use on the west coast; another (Dalhousie) has followed the same design and is now extending it. Similarly, the

collaborative development of the ocean bottom magnetometer at PGC and GD has enabled the acquisition of data to determine the electrical structure of the earth below the oceans, again a capability not previously available.

The marine multichannel crustal reflection studies and continuing interpretations carried out at AGC through the FGP program and Lithoprobe are as good as any in the world. The data have been widely used by industry for the regional framework within which the offshore sedimentary basin have developed. In particular, Husky Oil and Petro-Canada have prepared their own interpretations of the data and presented these at conferences. The Marine Geophysics Group at PGC have made scientific contributions out of proportion to the size of their small group. Their work (with some others) off the west coast has resulted in the most comprehensively studied subduction zone in the world. Their excellence and expertise is recognized internationally.

The Seismology and EM Section in LCSD have achieved worldwide recognition in their fields for their work in crustal reflection/ refraction and magnetotelluric data acquisition and interpretation and relation to geotectonics. Unique and effective software for specialized processing and analyses in both areas have been developed, and recognized by the peer community for their excellence.

The Terrain Geophysics Section doing shallow seismic work out of the Terrain Sciences Division have been at the forefront of developments in the acquisition and processing of such data. They were the first to develop a simple and effective reflection profiling procedure with multichannel enhancement seismographs. Interaction with industry, other government agencies and universities is well established through advice, information and publications.

The Regional Reconnaissance Subdivision at AGC provides a good example of integrating geophysical results with geological information through basin modelling studies. Their work represents the fundamental last step to regional basin studies and they are doing it as well as any group in the world.

The degree of collaboration with university researchers is another very positive aspect of Geophysics at the GSC. On the east coast, AGC geophysicists interact well with scientists at Dalhousie and Memorial universities; on the west coast, PGC geophysicists have carried out many joint programs with UBC and other universities in Canada and the U.S.A. Similarly, geophysicists in the Seismology and EM Section of the LCSD have collaborated actively with geophysicists at many universities across Canada. In all cases these collaborations have mutually benefited both sectors, government and university, and more importantly have produced high quality scientific results.

2.2 ROLE OF GEOPHYSICAL RESEARCH IN THE GSC

Issue

What is the proper role of research in geophysics in the GSC?

Background

The Geoscience community in Canada has three main constituents - government (federal and provincial), university, and private sector. All three constituents conduct research in their various areas of special interest.

As befitting a free enterprise economy, the private sector (resource companies, consultants, contractors and instrument manufacturers) is market driven in determining the nature and extent of their research activities. By and large, their research programs are those which are expected to yield relatively short term benefits of an economic nature. They are rarely of a fundamental nature, where the uncertainties of technical and economic success are usually large.

Geoscience research at Canadian universities is focused on areas of special interest to influential professors at these universities. As a result, there are research topics that are well covered by the university community and others which are not at all under investigation.

Based on the guidelines for government research (Dept. of Science and Tech., 1987), the proper role of research in the GSC has been defined by the ADM as that which is pertinent to the mission of the GSC, but is not being done (or cannot be done) by the universities nor by the private sector. Because of academic freedom in the universities and of total freedom in the private sector, the qualifier "cannot be done" is hardly material.

More specifically, the role of geophysics in the GSC is defined to be:

> "To ensure the availability of comprehensive . . . geophysical knowledge, technology and expertise concerning the Canadian landmass . . . as required for effective exploration . . ., estimation of the resource base of Canada, land use, public safety, security and formulation of policies."

In pursuit of this objective with regard to geophysics, the GSC undertakes comprehensive geophysical surveys appropriate for establishing an understanding of the fundamental geological framework of the Canadian landmass including its offshore extension; and conducts geophysical surveys and operates geophysical observatory networks appropriate to mapping natural hazards in Canada on a regional scale. Analysis of data so obtained, its interpretation and relation to regional geology and tectonics comprise the complementary geophysical research component. Thus, research in geophysics at the GSC encompasses a wide range of activities which are essential to fulfilling the GSC's governmental mandate:

1. Operation of national observatory networks for monitoring of earthquakes and the geomagnetic field; and analysis of the data so obtained

2. Acquisition, analysis and interpretation of seismic reflection, refraction and electromagnetic data

3. National mapping programs in gravity and aeromagnetics; analytical developments (e.g., "sun angle" aeromagnetic maps); and analysis and interpretation of the data

4. Methodology developments, particularly related to applied geophysics (airborne and ground gamma ray spectrometry, shallow seismic common-offset profiling, establishing of standards for aerial surveys, and calibration of equipment)

5. Paleomagnetic studies to determine past tectonic motions

6. Geothermal studies to understand one of the primary driving forces for geological phenomena (the Earth's heat engine)

7. Test surveys (multichannel radiometric surveys, magnetic gradiometry, etc.) to establish the applicability of these methods to known geological conditions

8. Instrument development which has included, among others, airborne proton and optically pumped magnetometers, magnetic gradiometers, portable seismographs, digital observatory networks, multichannel gamma ray spectrometry, ground probing radar and multipurpose electrical receivers.

The Committee considers that detailed surveys appropriate to the exploitation of Canadian resources is generally the responsibility of the appropriate resource industry. Similarly the detailed mapping of natural hazards on a site-specific basis is the responsibility of other governmental agencies (provincial or municipal) or the proponent of a particular project.

Instrument development as such should be undertaken in support of GSC programs and is considered legitimate only when the instrument cannot be purchased. When development is necessary, it should be undertaken either by industry or in cooperation with industry, whenever possible and economic. The Canadian geophysical instrument manufacturing industry is now quite mature in its development capability and in its marketing and distribution facilities. However, some in-house GSC instrument development capability is necessary to maintain a suitable core competence level and to enable the very special developments that are sometimes necessary to fulfil the scientific programs that are part of the GSC's mandate.

Nevertheless, it would be appropriate for the GSC to advance instrument developments within industry by acting as a catalyst for meritorious research projects, through the support of applications to established sources of federal R&D funding, e.g., IRAP and UP. The operation of the Aeromagnetic Research Fund by the Geophysics Division is precisely effective in this fashion.

GSC management generally accepts the viewpoint that in order to attract and stimulate geoscientists of high calibre, the GSC must offer them the opportunity to engage in research.

Recommendations

The GSC should continue to engage in the wide range of geophysical research activities which are pertinent to its mission. Where possible, these should complement activities in the private and academic sectors. Collaborative research should be encouraged.

In general, the GSC should undertake R&D projects in geophysics relating to new technology (methodology) development, new methods of data processing, interpretation and presentation, and in the conduct of experimental surveys intended to test the application of new instrumentation or technology under known geological conditions in Canada.

The GSC should work in consort with private sector parties to facilitate geophysical instrument development of common interest, through acting as a catalyst in support of funding from other governmental sources. The GSC should only engage in instrument development as is required to support its primary research programs and then only if the capability does not reside within industry.

2.3 BALANCE OF GEOPHYSICAL ACTIVITIES RELATED TO GSC MISSION

Issues

Are the geophysical activities of the GSC directed in a balanced manner to fulfill the objectives of the GSC mission? Where do the boundaries between regional surveys conducted by the GSC and detailed surveys conducted by industry lie?

Background

". . . Since the release of the maps in October 1987, over 300 claims have been staked in the area; 138 of these have been staked directly on the results of the potassium map because of the known relationship between gold and potassium enrichment . . ."

". . . mine in the NWT was discovered on the basis of a GSC gamma- ray spectrometry anomaly . . ."

". . . A major gold occurrence . . . was found as a result of following up an airborne anomaly . . ."

(Internal GSC report)

It has been accepted that one of the legitimate activities of the GSC is to assist in the exploitation of Canada's mineral resources. If the foregoing had read:

> "On the basis of seismic reflection studies conducted by the GSC, six major oil companies have leased large tracts of land and drilled a number of successful wells. Proven reserves of 100 000 000 barrels have been discovered."

Would this also be perceived as a legitimate GSC activity?

There is one obvious question of balance: should the minerals industry receive this level of GSC support to assist it in exploiting Canada's mineral resources? Should the petroleum industry, or the coal industry, or the building aggregates industry receive the same level of support?

Another related question is one of scale. Should the GSC be conducting surveys that permit their direct use in the exploration for specific resources? In joint projects with provinces under Mineral Development Agreements, such a level of detail may be justified, the funds being made available to further political aims in addition to any scientific value.

Cooperative surveys with industry could be undertaken with the GSC funding data acquisition adequate for regional control and the industry funding infill acquisition for detailed analysis. The publication of the higher resolution component of the survey could be deferred until the industry participants have had an opportunity to utilize these data.

And there is a more general question. What level of survey detail is required in order that the GSC will have fulfilled its original charter:

> ". . . to make an accurate and complete Geological Survey of this Province, and furnish a full and scientific description of its Rocks, Soils and Minerals, which shall be accompanied with proper Maps, Diagrams, and Drawings, . . ."

If 1:250 000 mapping is completed, should remapping with additional data for 1:100 000 be undertaken? 1:50 000? 1:10 000?

In general, except where calibration surveys are conducted over known features, it would be expected that regional mapping would be completed before more detailed surveys are undertaken.

Recommendations

In the geoscience fields related to resource exploitation, the GSC should evaluate and, if necessary, redirect its activities so that there is a balance in emphasis in support of the various resource-based industries.

Except where special arrangements with other government agencies or industry are made, mapping projects should not be conducted at a scale that will allow direct and immediate use in the exploration for resources.

The GSC should establish a series of guidelines for geophysical mapping scales for routine surveys. Guidelines for more detailed mapping projects, including appropriate scales and criteria to be met to justify such projects, should also be developed.

3.0 DISCIPLINE-RELATED ISSUES

The Committee has examined the range of geophysical activities in which the GSC is currently engaged, in order to be able to judge their scope and effectiveness. In this section, we will present our comments on the salient features of these activities, for each major specific geophysical discipline.

3.1 EARTHQUAKE SEISMOLOGY

Issue

What is the present status of GSC's earthquake seismology program in:

1. Seismograph network recording, analysis and risk assessment?

2. Earthquake forecasting?

Background

As noted previously, the Canadian Seismograph Network is one of he many very positive aspects of geophysics within the present GSC. It is an essential element for seismic risk assessment, government policy re building codes and underground nuclear detection, and understanding the nature and type of earthquakes in Canada. Garland (1987) cited the high quality of the activity:

> "The Canadian . . . seismological networks are models of efficient operation. The quality of the seismograms is very good . . .". The (now) Geophysics Division "deserves special credit for the excellence of its seismological bulletins, including seismicity catalogues and maps. These are fundamental data whose value increases with time . . . Seismological studies related to the identification, location and discrimination of underground nuclear explosions, along with participation of Canadian experts in disarmament discussions, also represent an important contribution to the country and to all mankind."

The network is run primarily within the Seismology Section, Seismology & Geomagnetic Subdivision of the GD (13 PYs directly assigned to network aspects plus 8 research seismologists); with a component for western Canada operated from the Pacific Geoscience Centre Subdivision of CPGD (3 PYs assigned, including the Subdivision Chief, and some technical support from the Program Support and Instrumentation Group). The program is well organized, well run and meets Canada's international obligations to global earthquake studies. The telemetered arrays, Eastern Canada Telemetered Network (ECTN) and Western Canada Telemetered Network (WCTN) provide high quality digital data in real time; some technical assistance is provided by GD to PGC. The GD, in consultation with PGC, also has well formulated plans to maintain a state-of-the-art capability for the networks ("A new generation of seismograph networks operated by the Geological Survey of Canada"; internal GD document, December 1987).

Because of past history and contacts, the separation of responsibilities between groups has not been a problem. However, during interviews the Committee was informed that problems may arise, particularly for the PGC group, as personnel change and resources of all types are tightened. In the case of a moderate or large event, the GD has the manpower to rapidly deploy portable stations to record aftershocks, but PGC does not have that capacity and depends on resources from a different branch in Ottawa. Thus the merger may have had a negative impact by severing the link between the understaffed group on the west coast with major problems and the GD which has focused on less severe problems in eastern Canada.

Seismic analyses include development and use of state-of-the-art techniques for interpreting data and determining earthquake source parameters. The GD has a number of personnel devoted to this aspect while PGC has one overworked staff member. The previous EPB had a good reputation for these types of studies but the present personnel have not kept up with international developments in the field, possibly due to a lack of qualified young scientists.

Seismic hazard assessment concerns estimation of future strong ground motion that may be expected in a region or at a site; risk assessment concerns estimation of the consequences (lives lost, damage caused) of the strong ground motion. Within this context, the west coast region has a much higher hazard; the risk may be comparable as a result of greater population in the east. However, the division of resources between PGC and GD does not equate with the relative hazards or risk. Both groups carry out some research involving integration of neotectonic studies in their assessment of seismic hazard, but it is limited by personnel.

Earthquake forecasting concerns attempts at predicting future earthquakes that include information on location, time and magnitude. Research in this field is difficult; the problems have no evident solution and there is no guaranteed return on the effort. Earthquake research in general, and prediction in particular, has an extremely low profile in Canada, not only at the GSC but also in universities. This contrasts with the U.S.A. where USGS, NOAA and the universities are continuing a major effort (initiated in the early 1970's) in earthquake prediction; and from which studies (and others) it is known that the problems are extremely difficult.

The EPB (prior to merger) had a multidisciplinary earthquake precursor monitoring program centred on the Charlevoix region of Quebec, but it was cut to absorb reductions necessitated by the merger. No other similar program is in place at GD.

At PGC, there is an attempt to address the earthquake forecasting problem by measuring crustal deformations. Associated with this and other seismic studies, a proposal ("West Coast Megathrust Earthquake" - internal GSC document; see also Dragert and Rogers, 1988) has been formulated to launch a major research effort to prove or disprove the hypothesis concerning the past occurrences of megathrust earthquakes (greater than M = 8) in the Vancouver Island region, establish the current position in the cycle and estimate the hazard for incorporation into the National Building Code. The Committee fully endorses the Megathrust proposal. Regardless of the political decision that will be made concerning this program, the

Committee considers that the present balance of resources committed to seismicity and related studies is not adequate to address the problems in western Canada.

A reallocation of GSC resources to the most urgent problems should result in an active and successful program in earthquake seismology with few additional resources (the addition of one or two international level earthquake source specialists; and excepting the Megathrust proposal where additional resources are required).

Recommendations

The National Seismograph Network must continue its 24 hour per day, 365 day per year monitoring function. It **must be exempt** from the 10% 'sunset' item recommended by this Committee (see Section 5.2).

The Committee recommends that the National Seismograph Network be provided with the resources to continue and enhance its plans for upgrading the network to digital standards. This should be done following appropriate peer review and comment. The balance of seismological research and monitoring effort between GD and PGC is not appropriate to the balance of seismic activity, hazard and risk; this should be rectified. Reallocation of personnel and funds in seismology (and geodynamics, part of which is closely related) is recommended.

The "West Coast Megathrust Earthquake" project has been proposed to launch a major research effort relate to possible subduction thrust earthquakes with magnitudes greater than 8. The Committee fully endorses this initiative and its need for new resources.

The Committee recommends that the GSC address the lack of continuing Canadian expertise in earthquake seismology by providing incentives to graduate students (see Section 5.4) and, whenever possible, by supporting university research through the Research Agreement or other programs.

3.2 GEODYNAMICS

Issue

Is the current GSC geodynamics program appropriate to the national needs?

Background

Geodynamics - the measurement of contemporary motions in the solid Earth - can be roughly defined as having two scales: global and local.

Global geodynamics is concerned with the motion of the solid earth as a whole, or the motion with respect to each other of points thousands of kilometres apart. It is of great scientific interest because there are significant broad scale effects -- plate tectonics, ocean and atmospheric loading, core-mantle interactions, tides, post-glacial rebound, etc. -- that are becoming more and more measurable by the new techniques, while becoming more amenable to theoretical interpretation. Although plate

tectonics is the essential framework to global geodynamics, and although the effects of climate changes are becoming perceptible in the data, the practical implications of global geodynamics are limited mainly to monitoring earth rotation and polar motion, a task Canada shares with other nations. The accuracy of this monitoring required for navigation is routine; the drive for high precision is purely scientific.

Local geodynamics is concerned with the relative motion of points in the solid earth from a few kilometres to hundred of kilometres apart. This is also a problem area of great scientific interest, but more difficult (and hence less attractive to some) because of the complexity of tectonic behaviour. At present, measurement of contemporary motions to the precision, detail and frequency needed for significant advance are becoming feasible, through GPS, only in particularly active zones. These zones are characterized by earthquakes and are associated, to varying degrees, with margins of the global plate tectonic system. Local geodynamics has great practical potential through its contribution to earthquake hazard alleviation. The understanding of the tectonic setting requisite to effective prediction will probably require precise geodetic networks that are dense and repeatedly measured.

The development of quantitative models of the earth as a dynamical system, the principal objective of geodynamics, should provide information to assist in:

1. Quantitative assessment of present earth system trends and significant global change by providing globally integrated effects due to atmospheric and ocean circulation, sea and ground water level changes, seasonal or permanent biomass redistribution, deglaciation, etc.

   e.g., a) monitoring of sea level requires the careful separation between vertical crustal movement in coastal areas and global rise in sea level,

   b) monitoring of length of day provides information on the dynamics of the atmosphere and oceans,

   c) changes in the position of the pole of rotation provides information on the changing distribution of mass within the earth (plate tectonics, earthquakes, etc.) and on its surface (receding glaciers, changing sea level).

2. Improvement in accuracy of surveying and navigation systems, maintaining standards and long term continuity.

3. Better understanding of the earth's structure and properties, in particular the mechanics of crustal processes and plate tectonics with direct impact on earthquake hazard assessment.

In Canada, the greatest earthquake hazards exist on the Pacific Coast, associated with the underthrusting of North America by the Juan de Fuca plate. While an earthquake hazard also exists in the St. Lawrence zone, the probability of an >8.0 magnitude shock of severe economic and human impact is appreciably lower, and the tectonic setting is less understood and thus less amenable to diagnostic scientific programs.

The current geodynamic activities of GSC (approx. 12 PY, $1.4M) are allocated about two-thirds to the global and one-third to the local. It is only a part of the Canadian effort in geodynamics. The Committee is not informed as to the magnitude of the geodynamic efforts of the Geodetic Survey and the universities. However, at PGC there is collaboration with the Geodetic Survey on relevelling on Vancouver Island for crustal deformation. The Geodynamics group in the GD have worked closely with scientists at the Geodetic Survey and the universities of Toronto and York in the development of the Canadian Very Long Baseline Interferometer (VLBI) system.

The GD provides one important part of a team approach to working on the VLBI development which can be used for high precision distance measurements on a continental or large regional scale. The program has been in progress for about five years during which time substantial hardware and software developments have been made.

At PGC, there is a small geodynamic effort (approx. 1 PY) which is well-focused and well coordinated with the PGC work on seismicity. Similarly, there is a small local geodynamics group (approx. 3 PY) within Geodynamics at the GD which works closely with the seismologists. However, this distribution of limited manpower (and presumably financial) resource is not consistent with the greater national needs re seismic hazards and risk on the west coast.

Recommendations

Strengthen the western Canadian geodynamics program by transferring appropriate personnel from eastern Canada to PGC and recruiting qualified young scientists whenever possible.

Increase the effort in local geodynamics programs by transferring some resources from the global program.

Continue coordination of activities with the Geodetic Survey of Canada and expand such activities as required for crustal deformation measurements, particularly on the west coast, but including also other earthquake prone areas in eastern Canada.

Maintain the GD's VLBI effort and its collaborative research with two universities and the Geodetic Survey; focus the principal global geodynamics effort on VLBI.

Phase out optical efforts in geodynamics (with the possible exception of levelling to study post-glacial rebound).

3.3 CRUSTAL SEISMOLOGY AND ELECTROMAGNETIC GEOPHYSICS

Issue

Are the current GSC activities in crustal seismology and crustal electromagnetics appropriate to the national needs?

Background

Throughout the world, studies in crustal seismology and electromagnetics (particularly magnetotellurics) are being recognized for their contributions to the understanding of the formation of sedimentary basins and the regional framework of tectonic structures within which mineral deposits are located. The GSC, through the work of scientists at AGC, PGC and LCSD, has gained international recognition for its participation in, and contributions to, such studies. These scientists have defined key problems in tectonics and have been very innovative in using a variety of geophysical methods to resolve these problems. Their success has been due partly to a multidisciplinary approach and effective collaboration with their colleagues from academia and industry. This is particularly manifest in the research programs of Lithoprobe and similar Frontier Geoscience Program projects. These have provided regional crustal information in several areas of Canada and have received wide support and recognition from industry, universities and other governmental agencies. It is worth noting that these multidisciplinary programs were initiated prior to the merger between GSC and EPB; indeed, it is reasonable to assume that their success influenced the present emphasis on multidisciplinary studies within the GSC.

Through Lithoprobe and the Frontier Geoscience Program, Canada has become recognized as a world leader in crustal studies. These two programs have been cited as models of multidisciplinary geoscience research by many scientists outside of Canada. A few brief examples illustrate the socioeconomic significance of these research programs. On the west coast, the current structure and tectonic history of the Cascadia subduction zone has been better defined than at any subduction zone in the world; and led to a much improved understanding of seismic risk in the region. Seismic reflection and refraction data collected in the Beaufort- Mackenzie Delta region in northwestern Canada have resolved crustal structure, indicating among other aspects that structures within Mesozoic and younger sediments may be controlled by features within the Proterozoic crystalline crust. The deep seismic reflection, refraction and other geophysical data obtained around Newfoundland have confirmed the thin-skinned tectonic environment across the northern Appalachian orogen and discovered that a number of major half-grabens on the Grand Banks extend to a great depth. The Arctic and East Coast results are of primary significance to the petroleum industry. Following from the highly successful Lithoprobe preliminary program (including GSC contributions) in the Abitibi sub-province of the Canadian Shield, the mining industry is being awakened to the value of, and showing considerable interest in, such regional tectonic studies.

Recommendation

Following the old cliche "if it ain't broke, don't fix it!", the Committee recommends that these programs be maintained and supported at no less than their existing levels of activity.

3.4 GRAVITY

Issue

Is the current GSC gravity program appropriate to the mandate of the GSC?

Background

There are two distinct, but related GSC activities in measuring gravity: (1) the National Gravity Mapping program consisting of regional surveys to give the spatial variations in the field; and (2) absolute measurements at selected monumented sites for calibration and other purposes. These are carried out through the Aeromagnetic, Gravity and Geodynamics Subdivision of the GD.

1. The National Gravity Mapping program is based on an approximate grid of 8 km and is a continuing program. Much of the remaining data required to complete the Gravity Anomaly Map of Canada must be undertaken with aircraft and helicopter logistical support. Almost all of this work is carried out by private industry through contracts. Gravity maps are a valuable reconnaissance tool in support of geophysical exploration, particularly petroleum but also including minerals. They form an important component of lithospheric studies, which are being applied increasingly due to the more recent emphasis on the modeling of tectonic evolution as essential to understanding structures such as basins and underthrust belts.

2. A standard gravity network is carefully adjusted, maintained and calibrated using absolute gravity measurements which are made using the GD's one absolute gravity meter. In addition to providing calibration for the standard network, absolute gravity measurements can be applied to monitoring temporal changes in the gravity field (relevant for earthquake hazards such as exist on the west coast), and supporting the adjustment of geodetic control networks.

These measurement programs appear to be proficiently operated. The only problem brought to the attention of the Committee was the fact that due to the historical situation, not all of the gravity survey budget was under the control of the GD, who planned and carried out the surveys.

Within the Subdivision, an Application Section carried on development of analysis methods and modeling of the anomalous gravity field. A good example is the horizontal gravity gradient map of North America recently published (Sharpton et al., 1987). Concern was expressed that there was insufficient research of this type available to members of the section; this has a detrimental effect on attempts to hire highly qualified and motivated scientists when positions are available.

Recommendations

The national program of regional gravity measurements should be continued with at least the current level of resources until the Gravity Anomaly Map of Canada is

complete. The completion of the gravity data base is a national priority, and should not be affected by the 10% clause (see Section 5.2).

All budget items associated with these regional surveys should be consolidated within the GD to ensure effective and efficient use of the resources.

The program of absolute gravity measurements should be maintained to ensure the viability of the national gravity network.

Personnel in the Applications Section should continue to strive for, and be assigned, more scientific problems to address, including acting as research collaborators with scientists in other divisions who could utilize their expertise.

Remote access to the computer facilities in the GD data centre should be improved, for its effective utilization from remote sites.

3.5 PALEOMAGNETISM

Issue

Is the current GSC activity in paleomagnetism adequate and cost effective for the GSC's current needs?

Background

Paleomagnetic studies can contribute critical information to the understanding of past positions, and hence subsequent motions, of major rock units and thus are an important component of geotectonic studies. In order to make these contributions, concurrent disciplinary studies of the magnetism of rocks is essential.

At the GSC, the study of paleomagnetism is carried out in two divisions, the Paleomagnetism Section of LCSD in Ottawa and the Paleomagnetic Group in the PGC Subdivision of the CPGD in Sidney, B.C. The Ottawa group has 9 PYs allocated - 5 RS, 2 PS and 2 TS - but 2 of these are now vacant. However, they are physically located in two places - Booth street and the laboratory on Anderson Road. The PGC group has 1 RS, 1 PS and presumably receives some technical support through the Program Support and Instrumentation Group. The Committee was impressed with the advances in automation of paleomagnetic measurements which have been made at PGC. The one RS at PGC is nearing retirement and there is concern about what happens following his retirement. In this regard, several GSC sources have identified the lack of Ph.D. graduates in paleomagnetism and thus the difficulty of recruitment in this area.

The Ottawa scientists are working on problems in the following regions: eastern Arctic, NW Greenland, Labrador, the central Canadian Shield, the Mackenzie Mountains, and the Canadian Appalachians. The PGC scientists concentrate on studies related to the Canadian cordillera and the western Arctic, although they have worked elsewhere through collaborative projects. The Committee considers that the size of the Canadian landmass and the range of problems to be addressed can justify

two sites for paleomagnetic research within the GSC. However, a more equitable distribution of manpower and financial resources between them is required.

It should be noted that PGC has one of Canada's most distinguished earth scientists who has made immense contributions to the science of paleomagnetism and its relevance to geotectonics. The Ottawa group, in spite of its much greater size, has not made the same impact. They produce good quality information and seem to publish regularly; but based on our limited knowledge, we would rank them as below average in their field; this is not a strong scientific group within the GSC.

Recommendations

The two paleomagnetic laboratories, one at LCSD and one at PGC should be maintained. However, the two separate laboratories within LCSD should be combined and located on Booth Street where there are opportunities for close interaction with geologists.

The group at PGC should be expanded. The Committee recommends that the two vacant paleomagnetic positions and 1 technical support position in Ottawa should be transferred to PGC.

The advances in automation of paleomagnetism measurements made at PGC should be implemented in the LCSD group to increase the efficiency of the latter.

The Committee recommends that, if a comprehensive rock properties laboratory is established (see Section 7.6), the paleomagnetic group in Ottawa could form one component of it.

The GSC should address the problem of recruitment in paleomagnetism by providing incentives to graduate students (see Section 5.4) and, whenever possible, supporting university research involving students.

3.6 GEOMAGNETISM

Issue

Is the GSC geomagnetic program appropriate to Canada's needs?

Background

Among the Earth sciences, geomagnetism is unique in taking for its province the whole sequence of concentric zones from the Earth's core to the outermost limits of the magnetosphere. Communications and guidance technologists, researchers in geophysical and space- science disciplines, navigators, exploration geophysicists, land surveyors, and the military services require a strong national program in geomagnetism.

The Canadian magnetic observatory network provides data routinely used by approximately 100 mineral exploration companies. The Canadian satellite operations

depend on magnetic activity reports and forecasts. Canadian utility companies depend on daily magnetic activity forecasts for rebalancing power grids. Oil companies use current magnetic data for directional drilling operations. The Canadian military services require updated magnetic data for many purposes.

The Canadian geomagnetic network has been a stable and reliable component of the worldwide network. It produces data critical to the development of International Geomagnetic Reference Fields (IGRF's). IGRF's are global magnetic field models used to remove regional trends in exploration and research survey data to delineate magnetic anomalies. Reduction in continual collection of Canadian magnetic data would destroy validity of this reference field for use in Canada.

Ongoing operation of geomagnetic observatories provides information on delineation and secular variation and the ability to service needs of users noted above. These needs would not be met by international models (IGRF) which would themselves be seriously degraded if Canadian data, vital for the regional components in these models, was not included.

Canada has a special responsibility because of its large area and extensive coverage of the auroral zone, important to the study of disturbances that have adverse effect on radio communication. Continuity is important in this monitoring, since some important oscillations of the field have periods of more than a decade, and the large events most damaging to communication occur at several year intervals. This effort is one of appreciable international collaboration. Only a government agency can provide the continuity and maintain the standards that are necessary for such programs.

Timely data and forecasts result in decreased users' costs, and improved services to their clients and the public. For example, electric power utilities have a continual risk of power transmission breakdowns (such as the recent power blackouts suffered by Hydro Quebec), with consequent costs and hazards for the public and industry. Exploration companies reduce the costs of having to re-do unsatisfactory surveys. With increased solar activity during the next several years, problems related to geomagnetic activity will be at a maximum.

The Canadian observatory network will be a major part of the developing INTER-MAGNET program, a program in which many countries will participate in a near-real-time magnetic data exchange by satellite telemetry. For the Canadian region of the globe, this new program will greatly enhance studies for exploration of the crust and upper mantle of the Earth and will be of great significance in studies of magneto-spheric and ionospheric processes.

The application of geomagnetic data that is most significant economically is communication. The U.S. Air Force regularly & distributes forecasts that are widely used in radio communication. Longer range forecasts of peak magnetic storm activities impact appreciably the cost of the fibre optic cables now being installed as the main means of long range communication. The main determiner of the power level, and hence the facilities to maintain it, in these cables is the noise from induction caused by magnetic storms. The cable being installed from the west coast

of North America to Japan, costing about $500 million, follows a great circle route that passes through magnetically noisy high latitudes. This induced noise also affects the design of power transmission lines.

The current effort (13 observatories, 16 PY, $1.6M) seems minimally adequate to do the job. The division of this effort - roughly one-half to operations, one-fourth to interpretation, one-fourth to instrument improvement - seems appropriate. The program appears to be proficiently operated. No problems or dissatisfactions were brought to the attention of the Committee. There do not appear needs to expand or redirect the effort. Additional observatories in support of space research are appropriately supported largely by the U.S., but it is in the interest of Canada to share the data and participate in the interpretation.

In an almost unnoticed way, to many people, the Canadian magnetic observatory program makes critical contributions to a very broad spectrum of the whole population. The program is vital to the country's welfare in many ways.

Recommendations

1. The present level of activity in the geomagnetism program should be maintained.

2. The geomagnetism program should be exempted from the provisions of any general "sunset clause" (see Section 5.2).

3.7 APPLIED GEOPHYSICS

Prior to 1987, there existed in the GSC a strong Resource Geophysics and Geochemistry Division which included most of the geophysicists who were engaged in airborne and ground geophysical mapping related to mineral resources, surficial deposits and permafrost investigations. (The EPB also had included a group which dealt with permafrost investigations.)

The creativity of the critical mass of geoscientists of common objectives in this division fostered numerous advances in geophysical instrumentation, field technology, data processing and data presentation. Many of these advances have since been incorporated into standard field practice by the Canadian geophysical industry and, indeed, by their colleagues around the world.

The 1987 reorganization of the GSC resulted in the dissolution of the Resource Geophysics and Geochemistry Division, and the dispersal of its geophysical personnel into four of the newly created Divisions, namely Lithosphere and Canadian Shield Division, Geophysics Division, Terrain Sciences Division, and the Mineral Resources Division. One of the stated objectives of this dispersal was to create multidisciplinary groups, united by a community of mission, rather than of discipline. Unfortunately, as we have seen, this grouping of disparate disciplines has not always resulted in a fruitful union - or even a productive cooperation among geoscientists.

We shall now comment on individual aspects of the practice of Applied Geophysics at the GSC.

3.7.1 SKYVAN AEROPLANE

Issue

What is the justification for the maintenance of the Skyvan geophysical mapping aeroplane in the GSC? If justified, what is its proper role and function?

Background

The Skyvan aeroplane of the Exploration Geophysics Sub-Division is the sole remaining GSC facility for experimental airborne geophysical surveys, now that the Queenair has been sold. The operation of this aircraft requires five person years and an annual expenditure of about $450 000. Its stated functions include: the conduct of experimental geophysical surveys; the testing of new geophysical methodology and instrumentation; and the provision of quick response means for nuclear surveillance in the event of a release of nuclear radiation into the atmosphere.

The latter function is part of the commitment of Energy, Mines and Resources Canada, to the Federal Nuclear Emergency Response Plan, administered by the Department of National Health and Welfare. Under this commitment, EM&R is to provide "remote sensing capabilities for radiation and environmental imagery".

In accordance with this commitment, the Exploration Geophysics Sub-Division "will provide scientists, technicians and equipment to conduct surveys to locate radioactive contamination and to analyze and interpret survey data". The Skyvan and its computer-based, high sensitivity, gamma ray spectrometer system is specially designated as a resource to be employed for this purpose.

Recommendations

The Skyvan should be maintained for the purposes stated. In particular, we support its uses related to natural resource development especially for minerals and groundwater.

The Skyvan's complement of geophysical instrumentation should be broadened to include a vertical magnetic gradiometer, provided that an appropriate location on the aircraft can be determined. In addition, it may be a suitable vehicle on which to install an airborne gravity meter, with stabilized platform and a GPS navigation system, for experimental gravity surveys.

The Skyvan should not be used for systematic surveys of large areas (1 000 square km or more), as such production type surveys should be contracted out to the private sector, whenever the competence exists or may readily be acquired by that sector.

For truly effective use of the Skyvan as a quick response tool in the event of a nuclear incident to map the distribution of radioactive contamination, an annual "fire drill" should be called, without warning, to ensure that the equipment and personnel may be very quickly mobilized should a nuclear emergency actually arise.

3.7.2 THE TERRAIN GEOPHYSICS SECTION (Terrain Science Division, GTSB)

Issue

Is the organization of the Terrain Geophysics Section conducive to its optimum utilization under the GSC mandate?

Background

The Terrain Geophysics Section is a group of four scientists and three technicians working primarily in high resolution seismic survey work.

This small section has been at the forefront of developments in the acquisition and processing of such data. They were the first to develop a simple and effective reflection profiling procedure with multichannel enhancement seismographs. Interaction with industry, other government agencies and universities is well established through advice, information and publications.

Prior to the GSC reorganization, this Section was part of the Exploration Geophysics Sub-Division. In this previous structure, the Section was able to pursue a wide variety of seismic-oriented problems in mining and oil exploration, as well as engineering geophysics. They operated as part of multidisciplinary teams which crossed Division and Branch administration boundaries.

Their immediate managers were geophysicists who could grasp the significance of their work and thus could speak effectively for their programs at Division and Branch level.

Under the present organizational structure, the DG of the Geophysics and Terrain Sciences Branch does not see a useful link between the Section and the Quaternary Scientists Group with whom they are grouped in the Terrain Sciences Division. He finds seismic surveys too expensive and therefore not practical in the present context. He is of the opinion that it would be more appropriate for his purposes, if surveys were contracted out to the private sector, when required.

Much of the work done by the Terrain Geophysics Section, in recent years, has been more of interest to "clients" outside of the Terrain Sciences Division than within, e.g., shooting CDP seismic reflection from the Canadian Ice Island for delineation of the sedimentary stratigraphy on the Arctic Continental shelf, of interest to the ISPG; high resolution reflection shooting for coal structures in the Cumberland Basin in aid of the Nova Scotia MDA program, of interest to NSDME geologists; and development of the shallow high resolution reflection technique for mapping of the occurrence of basal tills as an aid to drift prospecting for gold, of main interest to the Ontario Geological Survey.

It is, therefore, apparent to this Committee that the Terrain Geophysics Section is a resource which is making a valuable contribution to the GSC in the fulfillment of its mandate, but is inappropriately positioned under the present organization.

Recommendation

It is recommended that the Terrain Geophysics Section be moved, together with their PY's and budget, and incorporated in the Exploration Geophysics Sub-Division of the MRD. In this structure, they will be able to relate closely with the Electrical Methods Section in respect of solving problems of interest to natural resource development (minerals, coal, hydrocarbons and groundwater (see also Section 7.3).

3.7.3 THE RADAR GROUP (Permafrost Research Section, Terrain Dynamics Subdivision, Terrain Sciences Division, GTSB)

Issue

Is the organization of the Radar Group conducive to its optimum utilization under the GSC mandate?

Background

The Radar Group consists of five scientists and technicians working in the development and application of radar probes for the high resolution of shallow geology. Specific applications to which this technology has been applied include regional permafrost studies and other problems relating to the nature of the near surface unconsolidated sediments. The group has been working closely with a Canadian industrial partner (A-Cubed Inc.) on the development of hardware and software for the radar probes and for their interpretation in terms of the near surface geology. In the opinion of this Committee, this group has not been as actively employed nor as well supported as it might be, and that its technology could have greater potential application outside of its current branch.

This group appears to suffer from the same set of problems which has been observed for the Terrain Geophysics Section, especially the lack of interest at the Director General level in multidisciplinary programs which might utilize this technology.

Recommendations

1. The Radar Group should be transferred to the Exploration Geophysics Sub-Division of the Mineral Resources Division, to be combined with the shallow seismic group of the Terrain Geophysics Section.

2. The combined technical resources of the Terrain Geophysics Section and the Radar Group should be utilized in multidisciplinary programs relating to the GSC's mandate. Examples would include permafrost studies and seabed characteristics in the Arctic, and near surface geological studies related to Global Change.

3.7.4 THE ELECTRICAL METHODS SECTION (Exploration Geophysics Sub-Division of the Mineral Resources Division, CSMRB)

Issue

Is the Electrical Methods Section a useful facility in the GSC?

Background

The head of the Electrical Methods Section has a staff of four person years and three persons in the physical rock properties laboratory.

This section is involved in ground investigations, test site and contract surveys, and physical rock properties, but does not seem to have the funds necessary to effectively carry out this mandate.

The head of this section has not been successful in implementing new applications research programs (field surveys or instrumentation) since he joined the GSC, about five years ago. There is no reason to expect that this situation will change in the near future. There is a strong feeling within this section that they suffer from a lack of direction, interest and funding. In addition, the Rock Properties Laboratory in this section appears to be working on projects of little relevance to any particular multidisciplinary programs of the Mineral Resources Division.

It is clear that this section represents technical and human resources which are currently being inadequately utilized by the GSC.

Recommendations

If the GSC becomes involved in "geosphere" problems associated with Global Change (problems in groundwater and toxic waste disposal), the expertise of this section should be utilized toward the study and resolution of such problems.

If this does not occur, the PY and budget resources should be transferred to LCSD. The electrical methods specialists should be integrated into the Potential Field Section; the personnel in the rock properties laboratory should be combined with those in the Paleomagnetism Section to form the nucleus of a national Rock Properties Lab (see Section 7.6).

3.7.5 THE INSTRUMENTATION DEVELOPMENT SECTION (Exploration Geophysics Sub-Division, MRD)

Issue

Is there justification for the Instrumentation Development Section of the Exploration Geophysics Sub-Division, MRD?

Background

There is a group of eight engineers and technicians who concentrate on the development of geophysical instrumentation for mineral exploration purposes. The major areas of investigation, at present, appear to be in the field of borehole logging and the development of data acquisition systems for airborne surveys. Regrettably, their activities in these areas appear to be conducted without any close interaction with industry and may well be duplicating work, either already done or currently underway in industry, either Canadian or foreign.

The Committee is of the opinion that, at the present time, these instrumentation development programs are neither needed because of their availability from other sources, nor justified in terms of the current GSC mission.

Recommendations

The development programs relating to instrumentation development should be terminated as soon as possible.

The instrumentation capabilities of this section should be devoted to the maintenance and improvement of the Skyvan airborne installation, and the maintenance of ground equipment owned by the Exploration Geophysics Sub-Division.

This section should cultivate and establish closer ties to the Canadian industry for instrumentation development, and to the universities for basic research. They could provide a useful catalyst for the development of funding from other governmental agencies for support of research in industry, through the IRAP program. They could cooperate with industry in the testing of new geophysical instruments, to determine their effectiveness over areas of known geology.

3.8 INSTRUMENTATION SECTIONS (Geophysics Division)

Issue

Is there a justification for two separate instrumentation sections in separate subdivisions within the Geophysics Division?

Background

The value of capabilities in instrument development were exemplified in Section 2.1. In particular there is a need for continuing expertise for maintenance, development and enhancement of the seismograph and geomagnetic networks; for development of new instrumentation to address requirements of scientific programs (e.g., portable seismic refraction recorders, ocean bottom magnetometers); for general instrumentation requirements that are a fixture of any data gathering and processing function (e.g., absolute gravity meter); and for maintaining a state-of-the-art knowledge of technical developments such that externally available equipment can be evaluated. Within the GD, there are two sections dealing with instrumentation: the Geophysics Instrumentation Section of the Seismology and Geomagnetic Subdivision and the

Instrumentation Section of the Aeromagnetic, Gravity and Geodynamics Subdivision. The largest group (23 PY) is in the Geophysics Instrumentation Section and is located at the Anderson Road laboratory, separate from the Observatory location of the main GD. This separation reflects some scientific requirements for being away from electromagnetic interference associated with a large city and lack of space available on Observatory Crescent. The function of the section is service and development related to the national seismic and geomagnetic networks and the Yellowknife array for nuclear detection purposes, and support for the equipment needs of other divisions (e.g., LCSD and PGC Subdivision) to enable them to effectively carry out their own programs. The section thus forms an integral part of other programs which are part of the GSC's mandate.

The Instrument Section in the Aeromagnetic, Gravity and Geodynamics Subdivision is much smaller (8 PY) and is physically situated at the Observatory location. The principal functions of the section are the maintenance of the equipment required for the gravity mapping program, calibration and absolute gravity measurements. The VLBI development is carried out in collaboration with university based groups and the Geodetic Survey of Canada, by the Geodynamics Section. Both functions are carried out in close cooperation with the scientists involved in the programs.

No strong expressions of concern about either section were expressed to the Committee. They appear to function well within their respective subdivisions and provide the expertise that is needed to meet the needs of the specific scientific programs. In the case of the larger Geophysics Instrumentation Section, they also seem to be serving well the other divisions, but to maintain or enhance this needed cooperation the Division Directors (or their delegates) will need to remain aware of the interdependence that each has for the other and continue to foster the existing collaboration.

Recommendations

The Geophysics Instrumentation Section in the Seismology and Geomagnetic Subdivision and the Instrumentation Section in the Aeromagnetic, Gravity and Geodynamic Subdivisions are serving their intended function well and should be maintained per the status quo.

The instrumentation component of the Geodynamics Section should continue and enhance its focus on the VLBI system development as it relates to global and regional geodynamical problems. If replacement or additional PY positions become available within the Section, they should be applied to this component (providing the gravity component is not compromised).

3.9 GEOTHERMAL

Issue

What is the future of geothermal research at GSC?

Background

The EPB had a very strong geothermal (heat flow) research group that had received international recognition. Because of the declining interest in geothermal energy and the limited potential in Canada, the merger of the GSC with EPB resulted in the dismantling of the geothermal group. Under these circumstances, the scientists involved in the heat flow program have done extremely well and kept a relatively high profile but they feel that the relevance of their work is not well appreciated and that they are isolated in different facilities (PGC, Calgary, Ottawa) and Divisions (Terrain Science, LCSD, CPMD, ISPG). Regardless of the present low interest in geothermal energy, there are strong arguments for a good geothermal research program at the GSC: the geothermal regime drives tectonic processes, mineral deposit formation, basin evolution and hydrocarbon formation. In the Arctic, permafrost and its geotechnical aspects are important problems. Some of these broad-ranging research programs can and will be conducted by the university community, and in special cases, by industry. However, if the GSC is to keep or expand its expertise in tectonics, mineral deposit formation, crustal evolution, sedimentary basin evolution and permafrost studies, it will need an active geothermal research group.

Within the present GSC, there is at least one expert in geothermal work in each division that needs such expertise (except AGC and in this case there are professors at east coast universities with such expertise). This represents a minimum allocation of human resources. To help maintain their scientific discipline, GSC geothermal specialists have formed an informal specialty group wherein they exchange information and ideas related to their discipline.

Recommendations

Support geothermal research at the GSC at least at its current manpower and budget levels.

The informal specialty group should be supported in their efforts to maintain and enhance their disciplinary expertise.

3.10 TECTONIC MODELLING

Issue

Is the present level of activity in tectonic modelling appropriate to the needs of the GSC?

Background

The ever increasing power of supercomputers has provided geoscientists with the possibility to test hypotheses with geophysical modelling. In the GSC, such expertise in geophysical modelling has been developed at the AGC with very strong interaction with Dalhousie University. The quality of the work done by this group has been internationally recognized and is exemplary in several ways. Geophysical modelling brings together all the different disciplines in Earth Sciences and requires the

participation of applied mathematicians and physicists as well. Also it has fostered a good working relation between geoscientists at the GSC and in academic institutions. The results of geophysical modelling have had impact on the data collection. These exchanges have worked extremely well at AGC.

Much of the expertise developed at the AGC should be used by the other divisions of the GSC, in particular ISPG. Such need was recognized at ISPG where one RS, who is to leave shortly, was actively involved in modelling basin evolution. The AGC has experience in modelling the evolution of rifts and passive margins, intracontinental and foreland sedimentary basins, and is developing experience in collision zones. It is not desirable nor feasible to replicate the unique competence that exists at AGC, but other divisions should have the opportunity to use that expertise for their problems.

Recommendations

Support tectonic modelling research in the GSC at the current level with the present personnel.

Improve high capacity computer support (see also Section 6.7).

4.0 ORGANIZATION RELATED ISSUES

It has been the experience of this Committee that most of the problems uncovered in the course of their discussion with GSC staff, were related to the recent organizational changes, firstly the amalgamation of the Earth Physics Branch with the GSC, followed shortly by the reorganization of the GSC.

These ongoing changes have had a serious impact on the morale of many geophysicists within the GSC. In addition, unless preventative steps are taken it appears likely that there will be deterioration in the level of geophysical expertise, and in the uniformity and quality of the practice of geophysics within the GSC.

We will present below the details of the individual issues which we have uncovered and which are related to the present GSC organization. We will also suggest appropriate remedial action in respect of each issue.

4.1 MISSION OR DISCIPLINE-BASED ORGANIZATION

Issue

Should the structure of the GSC, particularly as it concerns geophysics, be organized according to technical discipline or according to multidisciplinary mission?

This issue is inseparable from its companion issue, viz "Is there adequate, formal, discipline-oriented communication within the present mission-based GSC organization?"

Background

The GSC traditionally operated under long term stable budgets on long term, individual scientist generated projects. A very limited range of scientific disciplines was brought to bear on any one project. Output was in the form of comprehensive maps and occasional papers. The Division Directors controlled the activity in their areas and required minimal outside support.

The Earth Physics Branch operated observatory type recording equipment, recorded data for national geophysical data bases, carried out various types of geophysical surveys, and developed specialized geophysical instrumentation. Data were compiled and published in large quantities over fairly short time frames. Many scientific publications and conference papers were produced.

The absorption of the EPB by the GSC was designed to "reduce the potential for duplication of geophysical activities, to reinforce scientific programs, and to achieve economics of scale." (Geogram No. 24, April 1986). By having geologists and geophysicists in the same Branch, cooperation on multidisciplinary projects was to be improved with new technology being available to provide better tools for increased understanding of the Canadian land mass. The traditional A-base budget has been effectively decreasing and has been supplemented by several short term "soft" budgets, the most notable being the Frontier Geoscience Program. These soft budgets provided funds and personnel for particular types of projects and made new demands on the GSC organization. Each project had specified deliverables and completion time frames. Personnel and funds were made available for limited times and in specified amounts. The amount of funds allowed for the acquisition of significant amounts of geophysical data.

The main direction taken by the GSC in response to these changes was to maintain the traditional operating style. EPB influence in management was minimized by having only two geophysicists appointed Directors and one appointed "Chief Scientist." The latter is so heavily burdened with administrative duties that he has no time to review science. An additional level of bureaucracy was instituted with the addition of four Directors General. Geophysicists were assigned to work in geologist dominated Divisions.

Although Directors at CPGD and ISPG identified the need for additional geophysicists as one of their highest priorities during discussions with this Committee, four openings in these Divisions were recently filled with geologists.

The Geophysics Committee, as it is currently constituted, is not a committee of geophysicists and is not equipped to provide technical communication across the GSC.

With the creation of multidiscipline-based, mission-oriented divisions, and the dispersal among them of what were once centrally directed discipline-oriented groups, there is no longer a central technical authority coordinating common standards for the hardware and software for geophysical data gathering, data processing and data base management. There is a consequent danger that the technical standards, in certain geophysical activities, may deteriorate in certain geographic areas. There is also the

problem of non-interchangeability of hardware or software between groups, thus impeding the ready flow of personnel, equipment and software developments among these groups.

In some cases, organization along disciplinary lines is appropriate because the nature of the problem is primarily unidisciplinary. For example, forecasting of magnetic field variations requires little interaction with other types of scientists. Some aspects of earthquake seismology such as, say, core topography, are purely seismological. Discipline-oriented organization is adequate. For other problems such as, say, mineral or hydrocarbon prospecting or resource evaluation, clearly a spectrum of disciplines is essential. In such areas, a spectrum of scientists should be assigned to a project.

Communication between geophysicists and geologists on particular projects ranges from good to non-existent depending on the group of scientists and the personal qualities of the project leader and is quite independent of whether participants are in one division or many. Communication between geophysicists performing similar work in different Divisions is erratic at best.

Team research has many points in its favor. Most research problems today are too complex to be solved by one individual. When researchers work as a team, a symbiosis occurs and the whole is more productive than the sum of the parts. On a team, young staff profit from their interaction with experienced researchers.

Flexible and economic attacks on problems require a problem orientation, with projects organized in response to identified problems and opportunities. However, the development of expertise, the fostering of long-term understanding of how things are done, and the career motivations of scientists and engineers require a discipline orientation.

The requirements for management of multidisciplinary projects coupled with the need to maintain a high level of scientific capability in a group of scientists in diverse disciplines exist in many science based companies. Various organizational styles have been tried with varying degrees of success. In particular, the Boeing Company has developed a successful approach that is being used by many science-driven companies and appears to be applicable to the GSC.

In the Boeing Company approach, the scientific personnel spend the <u>majority</u> of their time working on a project under the direction of a project manager. They also, however, spend a <u>small</u> amount of time in their technical discipline, reviewing their work with their peers and maintaining and enhancing their competence. It is of particular importance in the GSC, because of the geographical separation of many of the scientists, to have formal, discipline-related lines of communication and interaction with fellow scientists in order to maintain a "critical mass" for development of the science.

<u>Recommendations</u>

The establishment of a type of matrix organization designed to suit the particular needs of the GSC is recommended (see Organizational Chart, Figure 2).

To this end, we recommend that the position and title of Chief Geophysicist be revived, and his responsibilities be redefined as will be stated below. This may imply that the companion position of Chief Geologist will be created. They would report directly to the ADM.

The Chief Geophysicist should be involved with all geophysicist assignments, evaluations, promotions, transfers, etc. To provide authority commensurate with his responsibilities, he would approve all significant projects utilizing geophysics.

The Chief Geophysicist should appoint, with the concurrence of the appropriate DG, geophysicists in the divisions to act as Consultants in their specific disciplines. The functions of the Consultants would include discipline related communication through personal meetings with peers, and involvement at seminars, meetings, and the like. They would monitor the quality of the science in their area of speciality and assist in setting standards in instrumentation, data acquisition, processing, analysis and presentation. On request, they would assist in personnel performance reviews and could be called upon to provide expert information to the Geophysics Committee.

The Chief Geophysicist should review, with each individual geophysicist, the progress of his work at least once each year. The appropriate Consultant would be present at this review and, if convenient, scientists from other Divisions in the same discipline may also attend. The use of invited external experts in this review process would also be encouraged.

He should be chairman of the Sector Geophysics Committee where, with the Directors General and Directors, the planning of all major geophysical programs would be reviewed. This committee would utilize the knowledge of the Consultants as required.

Note:

The above recommendations are designed to reduce some of the problems observed with the present organization. During our discussions with individual scientists, recommendations were put forth, in one form or another, that would create a stronger, line oriented Geophysics Division within the GSC. This type of organization worked well in the EPB and could perform in a similar manner in the GSC. The Committee, however, feels that the joining together of the GSC and EPB will lead to more and more multidisciplinary projects to the mutual benefit of the geophysicists and geologists involved. An improved project management structure (Section 5.1) will be required to make these combined projects work more effectively. The need for critical masses of scientists in individual disciplines to provide stimulating interaction is recognized. The creation of a matrix style organization with the establishment of the Chief Geophysicist position and of Consultants in each discipline, all being charged with communication and liaison duties, should provide this needed support.

4.2 GEOPHYSICS IN FOUR (SUB) DIVISIONS

Of the five currently operating or proposed sites of major GSC geoscience activity outside of Ottawa, only the Atlantic Geoscience Centre was relatively problem free

in the area of geophysical disciplines. Three of the remaining sites suffer from an extreme lack of geophysical personnel; the fourth from an awkward administrative arrangement. The problems observed are discussed below.

4.2.1. INSTITUTE OF SEDIMENTARY AND PETROLEUM GEOLOGY

Issue

Is the level of geophysical staffing at ISPG appropriate to its mandate?

Background

The major objectives of the ISPG are (according to the Division's booklet published in 1982) to describe the bedrock geology of the land and offshore areas of the sedimentary basins of western and northern Canada, to further the discipline of paleontology, to maintain a knowledge base about the coal resources of Canada, and to identify and assess the oil and gas resources of western and northern Canada.

With a total staff of 165 person years, half of which are scientists and other professionals, and being located in the principal city of the oil industry in Canada where geophysics is a significant component in most exploration programs, the Committee was amazed that the total number of staff with geophysical backgrounds is three. In interviews with both geophysical and geological staff members, this extreme imbalance was mentioned as being inappropriate. However, the projects that the geophysical staff have participated in have been of very good quality and well received by industry.

Through FGP, the ISPG has had, and presumably will continue to have, responsibility for contracting to industry the acquisition of seismic multichannel reflection data worth hundred of thousands of dollars and for regional seismic refraction programs, both directed to better understanding the structural evolution of sedimentary basins and the underlying crystalline basement. In spite of these responsibilities, ISPG does not have a seismologist familiar with acquisition and processing of seismic reflection data nor one who is experienced with the complexities of seismic refraction processing and interpretation. As a result, ISPG has involved scientists from the university sector and other GSC divisions in their projects. This will likely continue to be needed but in-house expertise is also required.

ISPG has acquired, or has the opportunity to acquire, thousands of tapes of seismic reflection data from the Arctic for the cost of storage. These tapes contain tens of thousands of kilometres of valuable seismic data, data which cost hundreds of millions of dollars to acquire. This is a unique opportunity to establish an unprecedented data base and one that should not be missed. Yet ISPG does not have any geophysicists qualified to reprocess such data and take maximum advantage of the unique data set.

In a similar fashion, potential field geophysics can play an important role in the scientific mandate of ISPG; and some of the data yet to be acquired as part of the national gravity and aeromagnetic mapping programs are in regions of interest to ISPG scientists. Yet there is not a single scientist dedicated to such research.

Collaboration, for example with the Applications Section at GD, will clearly be required, but again some in-house expertise is needed.

Although management has indicated that staffing of geophysics at ISPG was a priority item, the Committee was informed that when staff vacancies become available, they were filled with more geologists, not geophysicists. Thus there appears to be a discrepancy between what is stated and the action that is taken.

Recommendations

Increase the geophysical staff of ISPG to a level which is more appropriate to the needs of its scientific programs. Specifically, the following minimum needs should be addressed:

- 2 reflection seismologists with capabilities and experience in both processing and interpretation of seismic reflection data;
- a specialist in the processing and interpretation of crustal seismic refraction data; and
- a specialist in the processing and interpretation of potential field data.

These staffing needs could be met partially by transfer of one or two key personnel and, with time, replacement of retiring staff in other fields where the need is not so critical. Even so, the requirements of the scientific programs will require continuing collaboration with such specialists from other GSC divisions and with university scientists.

Seize the opportunity to acquire the Arctic set of multichannel reflection data available on digital tape.

Note:

Nowhere in the national objectives of the GSC was the furthering of the discipline of paleontology mentioned. Did the Committee miss something?

4.2.2 CORDILLERAN SUBDIVISION (CPGD - VANCOUVER)

Issue

Is there adequate geophysical expertise in the Cordilleran Subdivision to support its scientific programs?

Background

This subdivision specializes in Cordilleran geological mapping programs, tectonic syntheses and support for the local mining industry. When visited there were no geophysicists located in this Vancouver office, although the Committee was informed that one RS in potential field analyses was in the process of moving from PGC.

Although it is associated administratively with the Pacific Geoscience Centre subdivision, the interaction of geophysicists from PGC on Cordilleran problems was minimal.

Although the geologists from the Cordilleran Subdivision have attained a deserved international reputation for their Cordilleran studies, the Committee is of the opinion that research involving tectonic syntheses and support for the local mining industry would be enhanced through the addition of geophysicists, perhaps when staff openings become available through retirements. Disciplines that would seem valuable are crustal seismology, potential field methods, geothermal studies and electromagnetic studies.

Recommendation

In keeping with the GSC's stated objectives of multidisciplinary studies and the scientific needs of the programs within the Cordilleran Subdivision, the Committee recommends that geophysical staff be increased to a level commensurate with the needs of the group. The following positions should be considered:

- a crustal seismologist, with expertise in either seismic refraction, seismic reflection or both; and
- a scientist specializing in crustal or regional electromagnetic studies; and
- a geothermal specialist.

4.2.3 PACIFIC GEOSCIENCE CENTRE SUBDIVISION (CPGD - SIDNEY)

Issue

There is a serious organizational and morale problem existing at PGC.

Background

The west coast of Canada offers an exceptional geological situation and a variety of tectonic processes from plate creation to subduction and terrane accretion. The study of geological processes that occur near the west coast has potentially strong social and economic impact. The Pacific Geoscience Centre (PGC) is Canada's national marine geoscience presence on the west coast; it is the western counterpart of the Atlantic Geoscience Centre. As such, part of its mandate is to carry out national geological and geophysical programs both offshore and along the coast. PGC includes the western facilities of the GSC's geophysical establishment, at which certain geophysical programs of national importance are carried out; for example, monitoring of earthquakes in western Canada, geodynamic studies, contributions to the gravity map of Canada and seabed resource studies. PGC also serves as a regional geophysical centre to which are assigned certain specialized tasks for which expertise exists. These tasks are designed to carry out, to coordinate, and to supplement research of socioeconomic importance; examples include crustal geophysical studies such as seismic reflection and heat flow to help determine evolution of sedimentary basins,

paleomagnetism to aid understanding of the long-term kinematics of the Cordillera and its relevance to mineral deposition, and definition of geophysical standards.

At PGC, a small and active group of scientists has achieved international recognition for their studies of the western margin of North America. However, the present administrative structure resulting from the merger of EPB and GSC and subsequent reorganization has done immense damage to morale at PGC. In turn, this is having a detrimental effect on the quality of the scientific activities being carried out. Throughout its interviews, the Committee was surprised to hear the high degree of dissatisfaction expressed by GSC geophysicists; this was probably most intense at PGC. There is clearly a problem which must be addressed directly.

Recommendations

Raise PGC to the status of a Division with its own Director. In so doing, the GSC would be recognizing the necessity of maintaining a marine geoscience centre on the west coast of Canada, a logical complement to AGC on the east coast.

Resources from other divisions should be reallocated to PGC such that its scientific role will be enhanced (with time); some specific recommendations are noted below:

- Some seismicity personnel should be transferred to the west coast where the seismic hazards and risk are higher than in eastern Canada. In this regard, the PGC Director would have to be more sensitive to the needs of this national program and continuing collaboration of all types (financial, scientific, technical and personnel) with the Geophysics Division Director. We note that no recent appointments have been made in this field at PGC; one question might be "Why?".

- Some personnel from the geodynamics and related groups (e.g., neo-tectonics) and applications research related to plate motions could be moved to PGC. (See also Section 3.2, Geodynamics Program.)

- Over time, the marine geophysics group should be augmented and develop capabilities for working in the western Arctic Ocean, just as AGC has been doing in a limited way for the eastern Arctic. Another marine seismologist, with interests in refraction, is required to complement the single reflection seismologist. More of the latter are needed; note that AGC has 3-4 such personnel. Transfer of one quality reflection seismologist from AGC to PGC would help in the short term. Other marine geophysicists also are needed. This recognizes the continuing and enlarging role of Canada's offshore responsibilities for management, monitoring and scientific study.

Closer cooperation in all aspects (technical, equipment, scientific, personnel) between AGC and PGC must be encouraged.

4.2.4 THE QUEBEC GEOSCIENCE CENTRE

Issue

Is the geophysical staffing proposed for the Quebec Geoscience Centre appropriate in light of the GSC thrust towards multidisciplinary projects?

Background

The Geological Survey of Canada (GSC) and the Insitut national de la recherche scientifique (INRS) signed an agreement in 1988 to establish jointly a centre for geoscientific research, to be called the Quebec Geoscience Centre.

The GSC's Continental Geoscience and Mineral Resources Branch will assign to the Quebec Geoscience Centre a 25 person-year team consisting primarily of specialist scientific and professional personnel. This team will be made up of permanent employees of the GSC and will be called GSC-Quebec. The 25 person INRS team to be know as INRS-Georesources will include administrative support staff, plus specialist scientific and professional personnel.

The thrust of the new GSC is towards multidisciplinary projects bringing together geophysicists and geologists to consider common geoscience problems and goals. This approach seems to have been forgotten when the Quebec Geoscience Centre was established as no provision was made to hire geophysicists. By the third year, the staff of 50, mostly geologists, will have to rely on geophysicists based in Ottawa for assistance in their research programs.

The GSC will have its own specific science programs aimed at a better understanding of the origins and evolution of sedimentary basins and their associated mineralization processes, geoscientific modelling and, in the longer term, the preparation of regional geological syntheses for selected target areas, particularly in eastern Canada. Through its research programs, which will complement provincial and territorial programs under the various mineral development agreements, GSC-Quebec will disseminate information, methods and skills relating to the geology and geochemistry of the bedrock, surface deposits and mineralization in selected target areas in eastern Canada. INRS-Georesources will seek to better understand the origins and evolution of sedimentary basins and to assess and strengthen their mineral and oil potential.

The presence of geophysicists on a permanent basis at the Quebec Geoscience Centre is required to assure good communications among researchers and integration of the various disciplines. This initiative will also contribute to improve the Quebec expertise in geophysical scientific research which has been limited in universities during the past ten years.

Recommendation

Geophysicists should form part of the QGC staff so that the ratio of geophysicists/geologists is similar to that of the GSC, i.e., in the range of 10 to 15%.

4.3 AEROMAGNETICS

Issue

Is the present responsibility for the supervision of the aeromagnetic coverage of Canada an optimum one, in view of the relationship to groups of similar interest and industrial clients?

Are the human resources with special competence in aeromagnetic survey technology being optimally utilized for this purpose?

Background

The Exploration Geophysics Division of the GSC was established in the early 1950's, primarily to carry out a systematic aeromagnetic coverage of Canada. The fruits of this program have been of enormous value to the mining industry in particular, in helping to unravel the drift covered geology of Canada and, in many instances, in defining geological environments favourable to the localization of ore deposits.

In addition to setting standards for overseeing federal and federal/provincially funded aeromagnetic programs, the staff of the Exploration Geophysics Division (later merged into the Resource Geophysics and Geochemistry Division 1972), helped to develop novel aeromagnetic instrumentation (e.g., self-oriented optically pumped magnetometer and vertical magnetic gradiometer).

The standards for aeromagnetics, developed by the GSC, have now been adopted by many countries as their standards.

In the reorganization of May 1987, the RGG was disbanded and its personnel and facilities dispersed among the various divisions of the new GSC. The Queenair aeromagnetic equipped aeroplane, with its equipment, was sold and the aeromagnetic instrumentation group was dispersed.

The aeromagnetics program was transferred, together with the bulk of its operational personnel, to the Geophysics Division of the Geophysical Surveys, Hazards and Terrain Sciences Branch.

The Geophysics Division is primarily concerned with the seismicity, geomagnetism, gravity and the geodynamics of the earth's crust. It includes many of the essential functions of the old Earth Physics Branch, now incorporated into the GSC. The Geophysics Division only has contact with the mining industry as the primary external client of the aeromagnetic program and as a lesser client of the gravity program.

The primary internal clients of the aeromagnetic program are the Continental Geoscience and Mineral Resources Division and the Sedimentary and Marine Geoscience Branch.

The Exploration Geophysics Sub-Division of the Mineral Resources Division has an aeroplane, the Skyvan, and operational personnel devoted to experimental (that is,

research-oriented) surveys, an instrumentation R&D section, which in part is devoted to airborne instrumentation, and close contact with geologists devoted to mineral exploration. Clearly, their contacts and familiarity with the mining industry are much better than those of the Geophysics Division. From the standpoint of forming mission-oriented divisions, it may be argued that the Aeromagnetic Group should reside in the Exploration Geophysics Sub-Division of the CG and MR branch, rather than in the GSH and TS branch.

On the other hand, it may also be argued that it would be logical that the contracting out of the aeromagnetic surveys and the incorporation of the resultant data, together with the gravity coverage, into the national geological data base, be left with the Geophysics Division.

Recommendations

Leave the responsibility for contracting out, data processing and presentation of the aeromagnetic surveys with the Geophysics Division. The GD will thus maintain its responsibility for incorporating the aeromagnetic data into the national data base.

Take positive steps to promote good technical communication between those staff members involved in magnetic analysis and interpretation, and their counterparts in all other divisions, for example, the Exploration Geophysics Sub-Division of the MRD, to improve the inter-relation with other geoscientists sharing common interests in natural resource development.

In this way, there will also be better communication with their natural resource industry clients, in particular, the mining exploration industry.

The dollar budgets for completion of the regional aeromagnetic coverage of Canada should be administered by the Geophysics Division.

4.4 MULTIUSER GEOPHYSICAL EQUIPMENT

Issue

Are major items of GSC geophysical equipment generally accessible to and utilized by all Divisions?

Background

Major pieces of geophysical equipment such as the Skyvan aircraft, lunch box refraction seismographs, electromagnetic recording stations, Convex computer, etc., are or could be utilized by geophysicists in more than one Division. Having control of such equipment centred in the same Division where users are located reduces, either in fact or in perception, the availability of this equipment to potential users outside that Division.

The Skyvan aeroplane has been used for a limited range of remote sensing applications. No effort has been made to utilize it for other applications.

There is a perception among some geophysicists that certain equipment, such as the new electromagnetic recording system, is not as accessible to them as it is to geophysicists in the Division owning this equipment.

Significant items of marine equipment located at either AGC or PGC could be shared in an equitable fashion.

A Convex mini supercomputer was purchased by one Division without agreement with possible users in other Divisions. This machine may not run the software available in these Divisions so it may not be utilized fully.

Other similar examples exist.

Recommendation

In order to ensure availability of major geophysical equipment on an equal basis for all geophysicists to maximize utilization on the most significant projects, the Chief Geophysicist, after consultation with all interested geophysicists, will approve the purchase of all major geophysical equipment and, on an annual basis, create a schedule for usage of such equipment.

5.0 MANAGEMENT RELATED ISSUES

Introduction

Organizational changes related to the merger of the GSC with the Earth Physics Branch and the thrust towards multidisciplinary projects have been two of the major factor affecting management at all levels. The requirements to coordinate projects involving a wider range of scientists with diverse skills; maintain effective communication, control and individual motivation; and ensure timely completion of deliverables has placed new demands on the management system. In certain areas, it has worked very well; in others, documented below, it has not.

This Committee has isolated a number of issues which are related to these current GSC management practices. These will be presented below, together with the recommendations of the Committee for remedial action thereon.

5.1 MAJOR PROJECT MANAGEMENT

Issues

a. There is a need for proper project management structure for major GSC projects.

b. Major projects involving more than one division are not being effectively managed.

Background

The GSC is undertaking certain multidisciplinary projects which may require contribution from, and participation by, more than one division or branch. In such instances, each group which contributes personnel and equipment may be operating independently from other groups and may be concerned only with its segment of the project, in respect of schedule, of data processing, and of medium of presentation.

The typical project that has functioned well in the GSC has been one initiated by a small group of scientists who work on a project of limited scope. Major projects involving more than one Division such as the DNAG and Ice Island projects have been poorly managed. These projects, initiated as major GSC initiatives, have come in conflict with the scientist initiated/Director supported style of traditional GSC management. The Directors have often not given their full support, and the project leader has never been given any authority to obtain the necessary equipment and staff.

Problems seem to arise because of a lack of project control and tracking which seem to be compounded in the publication state. In some instances, where projects have been funded so as to interlock with others a year later, they have not linked for up to three years, and some earlier results seem to have vanished completely. In most cases, individual tasks to be undertaken or the survey methods and activity schedules have not been set, thereby making the project undefined and untraceable in the end.

There appears to be a lack of attention to the need for an organized project management structure, to be established at the commencement of such projects, wherein there is one project manager who has full responsibility for the execution of all aspects of the project, and of the synthesis and presentation of all data in a final report or reports, on a pre-determined schedule. In practice, individual contributors to the project are not committed and seconded to the project manager for the duration of the project and the submission of the reports thereon.

In some cases, problems arise because of a reaction to an effective team approach at the beginning of projects, thereby eliminating any effective communications regarding the data and the publication thereof.

Planning of many of these projects has been erratic and communication among the various participants often has been poor. The outputs have been slow in coming and varied in quality.

Recommendations

Establish formal project management as a routine policy in the GSC. Each project should have clearly stated objectives, a target date for completion and milestones against which progress is measurable. Projects should be completed in human rather than geologic time.

For multidisciplinary projects, whether within one division or involving more than one division, establish a proper project management structure, with one project manager

responsible for the entire project, with clearly defined lines of authority and responsibility, clearly defined objectives, including budget, time and technical content, appropriate milestones and a pre-determined review procedure to ensure adherence to these objectives. Written project job descriptions should be drawn up for each participant in such a project.

Major projects involving several disciplines and/or Divisions should have a Project Manager appointed with defined supervisory authority. An overall plan and, if necessary, a plan for the year, should be prepared for approval by GSC management. This plan should include detailed descriptions of the objectives of the project, the costs of the various components, and, in particular, a detailed list of the equipment and personnel required. A flow chart should be prepared showing the timing of the various components of the project and the scheduling of the scientists' time including planning sessions, field work, data reduction and analysis, and completion of final report.

The resources required should be made available by the Divisions involved with the Directors assisting the Project Manager in ensuring the personnel and equipment assigned are available when required and that data analysis, interpretation and the final report are completed in a timely fashion. All personnel assigned should be made responsible to the Project Manager for their part of the project.

The Directors General should be charged with the responsibility of reviewing the status of each project at regular intervals to ensure that the goals are being met.

5.2 DOLLAR AND PERSON-YEAR BUDGETS

Issue

Except for changes related to "soft" budgets, the GSC has a static budgeting policy that does not allow for changes in programs and objectives to accommodate changes in national priorities.

Background

GSC budgeting philosophy is illustrated in the Long Term Plan, Total Resource Allocations, for 1987-88 to 1991-92 where, except for changes related to soft money programs, the dollar and PY budgets are absolutely static over this time interval. It is recognized that this is a planning document and that changes in resource allocations could be made. However, given the previous history of attempts to re-allocate budgets and the "fortress mentality" of the various Divisions, such reallocation under the present operating plan is likely to be minimal.

> "We know from experience that it takes probably 2-5 years, depending on circumstances, to seriously shift (scientific) gears in response to changing external factors and client demands." (Internal GSC report)

The rigidity of dollar and PY budget distribution does not reflect the requirements of short-term, multidisciplinary, high-cost projects. It is recognized, however, that a

level of stable A-base budgeting is required to maintain continuity in staff and facilities planning. The recent shift towards soft money funding required much greater flexibility.

Attempts to shift budgets between Divisions have had limited success. For example, FGP dollar and PY budgets were established based on the activity levels of the various Divisions at the initiation of the Frontier Geoscience Program. The dollar budgets have been changed over the course of the first four years of FGP, the PY budgets have not. Even though there has been a shift in dollar budgets from the East Coast to the West Coast, the present allocation of PY's generated by FGP does not reflect the present level of FGP activity in each Division.

Budgets for national gravity and aeromagnetic programs are currently allocated to individual divisions because that is the way it has always been done. This allows interference in the national programs by the divisions, with sometimes detrimental effects.

Recommendation

If a more flexible budgeting plan cannot be introduced, it is recommended that an arbitrary reallocation scheme be implemented, possibly as follows:

Each year 10% of the dollar and PY budget of each Division will be "sunsetted" for possible reallocation to other projects and/or other Divisions.

Notes:

The reallocation of person years would result from both attrition and physical moves, possibly 5% from each source. The Executive Committee, made up of the ADM, the DG's and the Directors, would reallocate these resources. This would provide staff and money for new thrusts, emergency programs, contingencies, project enhancements, and would, of course, permit downsizing of low priority projects or those entering their final stages.

Certain national programs, such as the seismograph and geomagnetic observatory networks, as well as the national aeromagnetic and gravity mapping programs, should be exempted from these "sunset" provisions.

5.3 EFFECTIVE UTILIZATION OF RESOURCES

Issue

There is no listing and sharing of the human and material resources of the GSC whereby anyone in one part of the GSC, may determine to whom to refer for assistance, when in need, for a specific project.

Background

The GSC is a large and diverse organization with divisions spread from coast to coast. Within its ranks, there are centres of competence (both human and equipment) in specialized technical areas. These centres of competence should be drawn upon, when needed, to support projects requiring their special abilities, whenever and wherever they may occur in Canada, for maximum utilization of these resources.

There does not appear to be a well understood and practiced policy within the GSC that personnel and equipment belonging to any division may be seconded, on a project-by-project basis, to another division. More commonly, such resources are guarded by the owner division.

Recommendations

Establish a policy for maximum utilization of human and material resources across the GSC through mobility of these resources on a project/need basis.

Individual DG's, directors and subdivision heads, should be encouraged to borrow or second personnel and equipment in order to get better utilization thereof, across the GSC, to avoid duplication of specialization and scarce resources, and to improve communication, team spirit and technical standards.

As part of general technical communication, the Chief Geophysicist should prepare a detailed listing of human resources (with areas of expertise) and material resources in geophysics, and circulate these to all GSC personnel. In this way, every GSC scientist will be aware of the resources to which he may refer in case of need, either for use on a particular project, or simply for information purposes.

5.4 PERSONNEL RECRUITMENT

Issues

How can the GSC obtain scientists of the highest quality at a time when there is a lack of such scientists in some fields, particularly within Canada?

Background

To maintain its high scientific standards, the GSC needs continuing renewal of retiring or departing staff with high quality young scientists poised to meet the challenges of the future. Yet most managers with whom the Committee met noted the lack of geophysicists being educated to the Ph.D. level in Canadian universities, particularly in some specialty fields. According to Ghent (1988), only 7 Ph.D's graduated in the field of geophysics in 1986-87 from a total of 102 Ph.D.'s in the earth sciences. At the M.Sc. level the breakdown was 28 of 272; and at the B.Sc. level 98 of 826 graduates in the earth sciences were in geophysics. A clear lack of geophysics graduates and, by implication, a lack of suitably qualified Canadian Ph.D. graduates, is evident. On an international basis, both universities and government agencies can expect strong competition for good young geophysicists.

The GSC (including the former EPB) has been able to attract many good quality young scientists, partly because of its reputation and the opportunities that are provided to carry out meaningful research without undue interference (but still consistent with GSC's mandate). Recently, in a number of cases, they have successfully recruited from the international community because qualified Canadians were not available. The situation of hiring both Canadians and non-Canadians will likely continue, but the GSC needs to be more pro-active in promoting geophysics at the post- graduate level in Canadian universities.

While recognizing that the GSC has considerable collaboration with universities, the Committee considers that improved and enhanced communication with, and support for, Canadian university departments with graduate programs in geophysics would produce a long-term benefit to the GSC. In some cases, this might just mean "up-front" promotion of existing support. Lectures by GSC staff, more collaborative research in which such collaboration is clearly known by students, and similar activities would ensure a higher level of awareness among students of the programs and opportunities in geophysics at the GSC. Clearly, carrying out and publishing exciting research at the GSC provides a means of attracting outstanding personnel. The present program of "Visiting Fellowships in Government Laboratories" which is administered through NSERC is an excellent one.

Recommendations

The GSC should become more pro-active in developing Canadian expertise at the Ph.D. level, particularly in fields which have been identified as lacking qualified applicants. This could be done by implementing a plan of support such as a Ph.D. Fellowship program at Canadian universities in which the fellowships are provided to qualified Ph.D. students (through a competition) to obtain their degrees in research areas of critical importance and assure them of a position upon graduation (pending an acceptable peer review of their accomplishments).

The GSC should expand its Research Agreements programs in geophysics, paying particular attention to those fields where it perceives a distinct need; and the grants should be advertised more widely so that students are more aware that the research is being supported by the GSC. In this the GSC will require cooperation of university faculty members.

The GSC should at least maintain and, if possible, enhance its postdoctoral fellowship program, "Visiting Fellowships in Government Laboratories".

GSC geophysicists who are good speakers and have exciting topics should regularly give talks at university earth science departments, particularly to undergraduate groups, to demonstrate the excitement and opportunities that are available; and also give talks of a more research nature to graduate students and faculty, as is frequently done now.

The GSC should continue and enhance its visibility at international conferences through appropriate presentations in order that young foreign scientists continue to

be aware of the quality of research in geophysics and the opportunities offered by employment with the GSC.

5.5 PERSONNEL REVIEW AND ADVANCEMENT

Issue

Personnel advancement criteria.

Background

Performance appraisals and advancement criteria for geophysicists are now commonly administered, in most divisions, by geologists who occupy the management roles. The ability of such managers to adequately judge the performance of their geophysical subordinates is open to question. In addition, the common practice of judging the performance of a GSC scientist by the volume of his publications is deemed to be unfair to certain individuals whose work does not naturally provide material for publication.

The USGS has recently established criteria other than publications for evaluating performance. The USGS is searching for ways to take account of service activities to the Survey or to the scientific community.

Recommendations

The GSC should examine its current criteria for advancement to ensure that it covers all types of professional activity equitably, including those which would not normally be expected to produce publications.

If the supervisor of a particular geophysicist is non-expert in the latter's field and therefore is unable to adequately judge the technical merits of his work, he should call in the "consultant" in that field for assistance in this aspect of his performance review. The Chief Geophysicist should be involved in all reviews of geophysical staff.

5.6 MANAGEMENT TRAINING

Issue

GSC scientists are reluctant to take on jobs as project managers, supervisors and managers.

Background

It was mentioned by a number of scientists that it is difficult to develop suitable supervisory staff and managers from within the GSC. Most scientists preferred to remain in scientific roles seeing little benefit and many problems if they shifted into more administrative functions.

Since it is highly desirable that those scientists who are technically competent and knowledgeable, and have the potential for supervisory work, be encouraged to take on such assignments, ways should be tried to make supervisory jobs more rewarding. The main rewards a supervisor receives is the knowledge that his efforts are appreciated by those he supervisors and by those who supervise him. GSC management can enhance this satisfaction by maintaining a high level of communication with supervisors at all levels and by monitoring the progress of their projects so that timely recognition of successful results is forthcoming.

Responsibility and authority should be delegated to the lowest effective level (see also Section 5.1). First line supervisors should receive more personal perks, such as attendance at international conferences, and have a significant input into the selection of members of their staff attending meetings, workshops, conventions, etc.

Within the limits imposed by government policies, financial incentives should be given to supervisors. It would be logical, for instance, to temporarily increase one step the salary grade of any scientist functioning in a supervisory position. The corollary to this, of course, would be to reduce by one step the grade of any supervisor returning to scientific work.

Supervisory skills could be upgraded through formal schools in project management techniques, human relations and management theory. Training assignments in other locations in the organization, special projects and industry/academic rotations could be used to help further develop such skills.

Recommendations

The GSC should develop a comprehensive training and replacement plan for supervisors at all levels.

The desirability of supervisory jobs should be enhanced by increased management communication, increased authority, personal perks, etc.

Training in project management, management theory, human relations and other supervisory skills should be provided to all scientists acting as project managers or supervisors.

5.7 MORALE OF GEOPHYSICISTS

Issue

What is the current status of morale among geophysicists at the GSC since merger of the EPB and (old) GSC?

Background

Some geophysicists, for example those now in LCSD Seismology and EM Section, expressed considerable satisfaction with their situation, while others, for example those previously within the GSC at AGC, were neutral concerning advantages or

disadvantages of the merger. However, the degree of disgruntlement evidenced by GSC geophysicists in interviews with the Committee was surprising. This varied appreciably among and within different groups, but was most intense at the Pacific Geoscience Centre and, in Ottawa, among the exploration geophysicists and some of those in GD. Certain themes were similar throughout their comments:

- Reorganization within recent years has subordinated geophysicists to geologists, separated them from support elements, reduced their voice in the making of decisions; and de-emphasized some traditionally important geophysical activities such as development of exploration techniques and seismological monitoring.

- Many geophysicists are in elements too small to constitute a "critical mass", thus not affording them as stimulating an environment and often leading to their work being evaluated by non-geophysicists.

- Most significant, work believed important by the geophysicists is not adequately supported, so they feel their talents are not being effectively used, and that excessive time is spent getting the means, often improvisatorially.

Such problems are common in government agencies everywhere, under the decline of budgets and shifts of agency goals toward matters identified as more significant to the commonweal (Perestroika has undoubtedly caused much groaning in Novossibirsk). The need is to address them properly.

The GSC has one main orientation that is properly in support of the mineral and petroleum industries, providing the mapping background, regional framework and long-range technical development to aid free enterprise in those aspects where returns on investment are unlikely or difficult to foresee, or where industry-wide standardization is desirable. This emphasis on resource rather than environmental concerns, compared for example to the USGS, arises from the greater dependence of the Canadian economy on mineral exports. It is worth noting that this is changing (see also Section 7.3).

From a geophysical perspective, the further shift in emphasis from technical development to addressing geological problems leads to a greater influence of geologists compared to geophysicists. Another main GSC orientation in geophysics, operation of observatory networks and national gravity and aeromagnetic mapping programs, is properly excluded from such considerations.

In the past, geophysics in the federal government has had a good level of support and considerable freedom to decide what to do, within the context of mission-oriented programs. With tighter budgets, shifts of emphasis, and the inflexibility of civil service rules, this leads to some individuals and small groups languishing with decreasing support for their traditional activities and no great pertinence to the new emphases. This will cause morale problems for which little can be done except to encourage shifts in activities. Fortunately, this situation applies to a minor fraction of GSC geophysicists.

Recommendations

Management should make all effort possible to keep informed those, who may be disgruntled, of policies affecting them and to consult with them as much as possible about how policies should be modified and implemented. (The difficulties of so doing when harassed by squeezed budgets, delayed guidance from above, increased paperwork, etc., are recognized.)

The Committee considers that the recommendations made in Section 4.0 would address many of the problems related to morale of the geophysicists.

5.8 LACK OF SUPPORT STAFF

Issue

Technician and Physical Scientist support staff is in short supply at many locations, so Research Scientists spend a significant portion of their time performing lower level functions.

Background

In the GSC a PY is a PY regardless of the training or capabilities of the individual. The hiring policy has, therefore, been biased towards getting the biggest bang for the PY, to hire the more qualified candidates such as Research Scientists, and minimize hiring of lesser trained support staff.

The actual payroll cost is of no direct concern to the Directors, and the effects on Research Scientist morale when faced with the need to undertake numerous mundane jobs appears to have little impact on providing a better balance in staffing.

Recommendation

Determine the percentage of time that each Research Scientist spends on support staff type activities, establish desirable ratios of scientist/support staff for specific groups of scientists, and modify present hiring policies to attain these ratios.

6.0 PRODUCT RELATED ISSUES

6.1 PUBLICATION OF DATA

Issue: Maps, Reports, Presentations

Is there an adequate review policy in place within the GSC to ensure that there is the same level of quality control on oral presentations and dissemination of data in digital format as there is on written reports and maps?

Background

It is essential that the GSC, as a scientific organization, and its scientists have the respect of the national and international scientific community. Publications and presentations are an essential component of the effort to assure recognition and furthermore are an important element of communication in science to which GSC should contribute.

The GSC has had a well deserved reputation of producing very high quality written documents and exceptional quality maps. See the section on "Basin Atlases" for additional comments.

There is an overall need to compress as much information into a format that is easy to use. The maps traditionally produced by the GSC fulfill this requirement and are in great demand. Written material, if current, is useful but usually reaches a fairly small select audience. A presentation at a conference may be attended by 100 or more earth scientists with a wider range of interest. Digital information is becoming more and more significant as a means of publishing geoscience information.

The quality control exercised by the GSC on these four areas of publication range from extensive to minimal. The traditional map and written publication modes receive intensive review; oral presentation and digital output receive minimal quality control.

The results of much GSC work are published in scientific journals after being carefully reviewed and edited to maintain the high GSC standards. Prior to publication, much of this material is presented at conferences and seminars. The quality control exercised over these presentations is minimal. Because the standards of the individual GSC scientists are high, most of these presentations are well prepared and well presented. There have been recent cases, however, of duplicate papers from different Divisions being presented at the same conference, poor quality slides being used, disorganized talks, and the like. Since earth scientists are being inundated with more and more written material which is being read less and less, the reputation of organizations such as the GSC will be increasingly appraised by those attending these presentations.

Recommendation

GSC should ensure that the highest quality is maintained for all published data through internal review procedures which should provide critical assessment and positive suggestions for betterment. In particular, the importance of peer and supervisory review and criticism of conference presentations should be recognized.

The increased output of geoscience information in digital format requires standards as discussed elsewhere in this report.

6.2 BASIN ATLASES

Issue

Are basin atlas compilations an appropriate form of GSC publication?

Background

The Slind report evaluating the Frontier Geoscience Program produced statistics based on 112 responses from government, universities and industry. The rating of "Very Useful" as an output format of FGP work was ranked by percentage for the following types:

Atlases	61%
Maps	51%
Papers	45%
Open Files	44%
Memoirs	43%
Technical Journals	32%
Current Research	26%

Slind's report also contains the following observations.

> "All of the Geological Surveys formats are useful, but some are more appropriate to certain projects than others:
>
> An Atlas would be a fine piece of work and is favoured by all except the contractors. It is, however, an expensive and time consuming publication which could be too dated by the time it is released.
>
> Memoirs share the same advantages and disadvantages with the Atlases.
>
> Current Research and the Technical Journals are the least popular formats, largely because the data tends to be scattered and back-up and illustrative material skimpy.
>
> Maps, Open Files and Papers are popular because they allow the results of research to be published in a timely fashion.
>
> A major criticism of the Geological Survey is that it takes so long for material to be published. The users do not want the quality of the research compromised, but publishing deadlines should be set and met. We realize that much delay often occurs in the official printing offices. A keen management should be able to overcome that problem." (Slind, 1988)

The compilation and publication of Basin Atlases was initiated and is being carried forward primarily by the Atlantic Geoscience Centre. Preparation of these atlases has brought together a variety of geologists and geophysicists on these multidisciplinary projects in a manner that conforms to the new direction that the GSC has mandated.

The atlases themselves will provide the users with concise and comprehensive information and bibliographies, and will become the standard references for each basin.

In order to publish these in a timely fashion, AGC will be utilizing local services for printing and binding. Since many of the scientists providing data will have an active role in the final atlas preparation, they should feel a high level of pride in the final product.

Basin atlases covering the Labrador Shelf, Grand Banks, Scotian Shelf, Hudson Bay, Gulf of St. Lawrence, and the Beaufort Sea are planned.

The Cordilleran and Pacific Margin Division is conducting a large scale multidiscipline project in the Queen Charlotte Basin which may lead to a Basin Atlas publication.

Multidisciplinary projects require a departure from the traditional view that each scientist's data is his own to publish. Joint publications, particularly in the Basin Atlas type of format, are to be encouraged.

Recommendations

The basin atlas format of GSC publication is strongly recommended.

Each Division should review its current inventory of information with the object of publishing a continuing series of atlases over the next decade.

In the interest of expediency (unless prohibited by official government policy), these atlases should be published in either of the official languages while the translation into the second language is undertaken.

6.3 ARCHIVING OF DIGITAL DATA

Issue

More and more data are being gathered and/or stored in digital form. Standards for cataloguing this data and proper archiving need to be established and maintained.

Background

Large volumes of digital field recorded data, such as that recorded by seismic surveys, are being added to the GSC's information base. Systems for cataloguing and archiving these data are poorly defined at present so there is a risk that some data may get lost or, due to faulty storage practices, become unusable.

It is standard practice to store digital tapes in temperature controlled environments, rotate the reels in their racks periodically to equalize the stress and stretching of the backing material, and to periodically rewind the tapes to maintain uniform tension. This has been deemed necessary for digital tapes to ensure that the data will be readable for several decades.

It was not clear to the Committee that there was anyone at the GSC responsible for monitoring the cataloguing of these data and ensuring that proper archiving procedures were being carried out.

Recommendation

The Chief Geophysicist should review the present procedures and, in cooperation with the Divisions, establish thorough cataloguing procedures and designate proper archiving locations.

6.4 DIGITAL INFORMATION STANDARDS

Issue

The GSC has no coordinated policy regarding purchase of computers and packaged software programs, standards for software development, for digital information acquisition, transmission, processing, distribution or storage.

Background

As a source of standards in the earth sciences in Canada, the GSC has played a major role over the years in setting standards for geologic classifications, mapping and the national gravity data base.

Unfortunately, this thrust has not extended into the general areas of geoscience data bases, computer hardware and computer software. Each GSC site visited is meeting its own needs in its own way, resulting in a proliferation of data base systems, digital formats, software packages and an absolute zoo full of different types of computers.

Purchasing a variety of computers leads to inefficiency and higher costs. Software purchased for a VAX will not usually run on a CONVEX, a CDC workstation or an IBM PC. Software developed by the GSC on one machine will require modification before it will function on other brands of computers. Data stored on one data base system can be accessed only by other machines with similar systems.

Some of these problems have been recognized:

> "Opportunities exist to acquire industry seismic data, but GSC has to set priorities, budgets and develop an **archival system**. Such acquisition and development of data bases necessitates improved interchange of data between scientists throughout the GSC. It follows that there needs to be better ways to present such data to the public (e.g., atlases, sale of disks)."

> "You will note that a consensus is emerging around the increased importance of digital technologies to the delivery of geoscience data, the need for greater emphasis on syntheses in our data bases, customization of our products, renewed vigour for our National geoscience mapping program, and the vital importance of effective communication of our expertise to the full range of client we serve."

"The list of S&T developments . . . was headed . . . by **digital equipment for acquisition, storage, distribution** of all forms of geoscience information." ". . . this technology is essential if GSC is to deliver its mandated service of information and expertise to its clients and users in the near future. These users need and want digital data, rapid access, accurate positioning, etc., etc., and unless the GSC retools to deliver, we will become increasingly irrelevant."

[GSC Internal Report]

The data archiving and distribution group at the Atlantic Geoscience Centre has studied USGS digital cartographic data standards and is adopting DLG3 as the standard for some of their maps. This is being done independent of other groups within the GSC or EMR.

The Minister of State for Forestry and Mines has recently (1988) announced a $16 000 000 program called the Geographic Information System to produce computerized maps. Without proper coordination, the GSC will not be able to make maximum use of this system.

The American Association of Petroleum Geologists has a data base standards committee with representatives from American, English, French and Dutch oil companies, major computer service and information companies, state geological surveys, and the USGS. An example of the work performed by this committee was published in the May 1988 issue of Geobyte. The GSC is not represented on this committee. There is no group within the GSC charged with the responsibility of developing standards for internal use and external distribution of most geoscience digital information.

Recommendations

Standards for computer and software acquisition and software development, and digital data bases should be set up and maintained. A committee with representatives from each Division and the Chief Geophysicist should be formed to establish these standards. The use of outside experts on this committee is recommended.

When standards are established, this committee should review all proposals for purchase, development or output in the digital area to ensure that they are being followed. The GSC should have representatives present at international standards meetings such as those held by the AAPG.

6.5 NATIONAL DATA BASES

Issue

The specification for collection of gravity and aeromagnetic data require review to ensure that the needs of the end users are being met.

Background

The specifications for the collection of high quality geophysical data require input from a cross section of the users of the data. Standards acceptable to a scientist studying large scale processes in basin development may not be suitable for another scientist studying more local features. It is usually possible to accommodate the needs of a variety of end users provided that they are consulted in the survey design stage.

Obtaining a wide range of input can significantly improve the quality of the data obtained, often with no increase in cost. An example of such positive benefits is the aeromagnetic survey conducted over the East Newfoundland Basin by a joint GSC/petroleum industry group in 1984, where the Global Positioning System was used for the first time, at the request of the industry group. The quality of the navigation far surpassed that of previous surveys and GPS has now become the standard specification for navigation. A controversial example is another aeromagnetic survey flown in 1987 over the Queen Charlotte Islands. Instead of flying at a constant elevation, this survey was flown at a constant height above average ground elevation. This type of recording technique provides reasonable profile data for interpretation of local anomalies, which may satisfy the needs of some users but cannot readily be combined to form a grid of lines that allow areal processing and interpretation.

The National Gravity Data Base is much used by earth scientists in Canada. The data supplied does not presently include all the inner terrain corrections so is not as accurate as it could be. After consultations with the user community, the format of the gravity data file is being changed to include this additional information where it has been documented.

The Geophysics Division is currently developing a National Magnetics Data Base that parallels the Gravity Data Base. It is recognized that a great deal of work will be required to level the data from survey to survey. The end result should be an excellent data set that will allow computer assisted interpretations over large areas.

It is recognized that the Geophysics Division has two committees existing at the present time to consider standards for aeromagnetic surveys and for data exchange and archiving. Both of these are sub-committees of the Natural Geological Surveys Committee.

Recommendation

Specifications for collection of data for the national geophysical data bases should continue to be reviewed periodically by a group representing GSC and outside users.

6.6 HIGH SPEED DATA TRANSMISSION

Issue

High speed digital data transmission from observatory sites and from users to remote computer facilities is required.

Background

The GSC presently supports several observatory data gathering and transmission systems using land based telecommunication facilities.

The need for scientists to process seismic data from remote sites increases the need for high capacity transmission capabilities. The present telecommunication system used by the geodynamics modelling group at AGC is substandard.

Other government departments, such as the NRC, are evaluating satellite communication systems. Would the acquisition of a satellite communication network be cost effective for the GSC for communication of data from monitoring stations, field parties and from outlying divisional offices? The GSC may be able to cooperate in a joint system.

Recommendation

The GSC should study its data communication requirements with the view to setting up high capacity transmission facilities to serve the needs of its earth scientists, should the study prove to be cost-effective.

6.7 HIGH CAPACITY COMPUTER SUPPORT

Issue

GSC geophysicists have ever increasing needs for high capacity computer support in areas such as geodynamic modelling, seismic processing and three dimensional gravity and magnetic modelling.

Background

The geodynamic modelling group at AGC leases time on a CRAY computer at Dorval with access via a low capacity telecommunications line. Micro Vax based seismic processing systems for small scale seismic reflection and refraction processing exist at three locations. These are not suitable for large volume seismic processing. A Convex computer is located in one division in Ottawa but has only limited throughput seismic processing capability. The Lithoprobe Seismic Processing Facility is fully operational in Calgary with excellent commercial seismic software and excess capacity during some time periods.

The lack of an overall plan and coordination of developments in the digital area discussed elsewhere in this report extends into this area also.

Recommendations

The digital standards committee (see Section 6.4) should also study computer needs in the GSC and devise a cost effective plan that will provide the computer support required by GSC geophysicists.

The use of the Convex computer already owned by the GSC should be evaluated for geodynamic, gravity and magnetic modelling, etc.

7.0 NEW DIRECTIONS AND CHANGING EMPHASIS

Within the broad mandate of the GSC its activities must evolve in emphasis as well as kind, in response to changes in national needs and priorities.

The Committee has selected, for highlighting, a few GSC activities for which it would recommend increased emphasis, or new directions which the GSC might take in light of current national conditions and trends in Canada.

7.1 CONTINENTAL DRILLING PROGRAM

The Canadian Continental Drilling Program (CCDP) is a major initiative in the Earth Sciences. It is aimed at complementing with drill hole information geological and geophysical data concerning the nature of the continental crust, in particular to complement the data collected by Lithoprobe. If it develops as planned, CCDP will have an impact on geoscientific research in Canada and thus on the GSC. At least one scientist in the GSC is actively involved in the Planning of CCDP; several scientists are involved in some of the preliminary proposals for drilling.

The development of CCDP will have an impact on geophysics at the GSC. The drill holes will provide test sites where geophysical experiments can be conducted. The data collected in the holes will help provide calibration of geophysical interpretations. There will be a definite need for preliminary geophysical studies before any drilling can be conducted. The logistical support of the GSC will facilitate the development and elaboration in the program. As this initiative develops, it will be appropriate for the GSC to support the CCDP, both financially and by encouraging participation of its scientists in the program. Also, there will be a need for a major core samples library and for measurements of physical properties. The GSC would be the logical place to locate these national facilities.

Recommendations

Before any drilling is undertaken, extensive surface geophysical studies should be carried out in the region of the planned drill hole. Grids of 3D seismic reflection, gravity, magnetic, electromagnetic and magnetotelluric data should be included. Upon completion of drilling, the hole should be logged with all available geophysical downhole logging tools plus offset vertical seismic profiling using both compressional and shear waves. If available, downhole sources and surface receivers also should be employed.

If CCDP becomes established, the GSC should establish the national core sample library as it is the only appropriate national institution with the mandate and experience to do so. Concurrently, the need for measurements of physical properties of the samples will require the establishment of a rock properties laboratory (see also Section 7.6).

7.2 MEGATHRUST EARTHQUAKE RISK

The potential for a megathrust earthquake (magnitude 8 or greater) associated with the Cascadia subduction zone off southwestern Canada is a controversial topic. Scientific evidence is accumulating that such an earthquake is a realistic possibility (Dragert and Rogers, 1988). Such a major seismic event on the west coast would have dramatic social and economic consequences. In response to this, the GSC has prepared a Memorandum to Cabinet (a version dated 14 January 1988 was made available to the Committee) recommending "a new geoscience program to assess the potential of a catastrophic earthquake in southwestern British Columbia".

Recommendation

The Committee strongly endorses the proposal to evaluate the risk of a mega-earthquake in southwestern B.C. **New financial and personnel resources would have to be allocated.** This recommendation complements others related to PGC.

7.3 GLOBAL CHANGE

The Committee has examined the theme "Global Change" as it applies to geophysical activities and are suggesting several potential program areas which are growing in social importance. The first of these areas involves the development of methods which would be effective in defining the subsurface geometry and temporal growth of electrolytic pollution plumes. As well, buried contaminants, are closely related. The second area involves the establishment of a multidisciplinary study team to improve geophysical methods for the exploration of groundwater. Groundwater regimes in many populated areas are changing at an increasing rate due to increased development. Water supplies are becoming strained and in some areas, the availability of water resources or lack of them effects development adversely.

Anthropogenic changes of major proportions are taking place at a rapid rate in our global environment. These include the pollution of our rivers, lakes and oceans by the dumping of toxic waste, the spoilage of our land surfaces by the dumping of municipal and chemical waste, the acidification of our lakes by airborne concentrations of sulfurous and nitrogenous gases, the destruction of the ozone layer in the stratosphere through interaction with chlorinated fluorocarbons, the introduction of saline groundwater through irrigation-based farming in semi-arid areas and the over-pumping of fresh water aquifers in coastal areas, and the "greenhouse" effect of the enormous release of CO_2 into the atmosphere through the combustion of fossil fuels and the simultaneous destruction of vast tracks of tropical and temperate forests.

Although the GSC cannot directly attack the sources of these changes, it can help both to monitor their extent and to assist in their accommodation and even circumvention.

A good discussion of environmental changes and the possible role of the GSC in regard thereto, may be found in Sections 5.5, 5.6 and 5.7 of Mapping the Landscape (Church, 1987).

Most of the above mentioned effects of global change are felt through deterioration in the quantity and quality of our surface and groundwaters. Within the GSC, there exists geophysical expertise which would be appropriate to bring to bear on these problems.

Most engineering or environmental site studies of the subsurface make extensive use of drilling for testing purposes. The application of geophysical methods to these are not considered a "standard practice" in Canada. In other countries they are seeing increasing use in these fields. Underwriters for projects involving the subsurface are becoming increasingly unable to insure the risks involved with these projects at reasonable rates; at the same time environmental regulations are focusing the liability for damages on contractors. There is a strong need to increase our ability to examine the subsurface with improved methods and to demonstrate these in multidisciplinary projects in order to introduce effective methodologies to larger engineering firms and municipalities so as to encourage the development of "standard practice" in this field.

The Electrical Methods Section of the Exploration Geophysics Sub-Division of the MRD has expertise required for the mapping of the conductivity of near-surface materials. The conductivity of such materials is largely a function of the ionic content of the surface waters and the ionic content and amount of the groundwaters in these areas. Thus, the conductivity of standing water reflects its acidity and/or degree of pollution, and mapping the conductivity of near-surface sediments reflects the amount, salinity and/or degree of pollution of the groundwater therein.

Conductivity mapping of large areas may be readily carried out by means of commercially available airborne electromagnetic survey systems (fixed-wing and helicopter), in which ample expertise resides in the Electrical Methods Section. More detailed conductivity mapping, using standard and newly developed ground electromagnetic methodology, would yield information of a scale appropriate to such problems as toxic waste dumps.

The shallow seismic and ground probing radar expertise in the Terrain Sciences Division of the LCSD could also contribute to the solution of problems relating to waste disposal effects and groundwater distribution.

This Committee suggests that a proper role for the GSC in the solution of these problems is to launch multidisciplinary programs, including geologic, geochemical and geophysical components, with the object of developing the appropriate methodology for the investigation of these problems.

There should be no need to develop new instrumentation for any of these programs, as adequate instrumentation (airborne or ground) already exists within either the GSC or the private sector in Canada. It may be necessary, however, to develop improved methods of data processing and interpretation.

In order to be incorporated into a remedial action or monitoring plan regarding a pollution site, geophysical methods must be able to produce a representative image of the subsurface target zone in relation to non-contaminated areas. Because the objective often involves complex overburden stratigraphy for which physical properties

are often unknown, it is recommended that drilling, logging and in situ measurement together with surface surveying be integrated and case histories prepared and published.

Some experimental techniques, for example, using airborne lasers, may also be appropriate for determination of additional information relating to the surface water quality, for example, their organic content. The organic content of lakes is a direct reflection of their ability to support aquatic life.

The emphasis for groundwater activities should be placed on method development and it is strongly recommended that this activity be jointly involved with the Provincial geological surveys. A multidisciplinary team of specialists should be organized for this activity as well.

This Committee is not aware of the extent to which the GSC is free to undertake programs relating to such environmental problems without infringing on the territory of the federal Ministry of the Environment and provincial ministries. It is clear, however, that geophysical expertise appropriate to such problems does reside in the GSC and should be brought to bear thereon.

It is also significant that the very geophysical groups within the GSC who would be most appropriate to be employed on these programs are currently being under-utilized due to lack of suitable multidisciplinary programs (see Section 3.7.4).

Various geological studies could also be undertaken. Many Mesozoic age formations underlying the Canadian prairie provinces have very low salinity formation waters. Excellent sandstone reservoirs are present and there is a continual recharge of these waters due to a west to east hydrodynamic gradient. If these waters are of sufficiently low salinity and are producible in adequate volumes from shallow depths, a potential renewable source of irrigation water could be available for exploitation. The data and the scientific skills are presently available within the GSC to readily evaluate the feasibility of this proposal.

Recommendation

The GSC should evaluate the application of its present geophysical resources to the problems posed by "Global Change".

7.4 REMOTE SENSING

Issue

Remote sensing expertise is located in another Sector of EMR and these techniques do not appear to be much used by the GSC.

Background

Remote sensing techniques were not mentioned by any scientists interviewed. Given the difficulties in promoting multidisciplinary projects when all the scientists are

working for the GSC, it appears likely that little, if any use, is made of these techniques to assist in geologic mapping.

> "Research on the use of remote sensing in mineral exploration now includes joint projects with industry. Landsat images are providing promising results in identifying bedrock lineaments related to mineralized zones in northern Saskatchewan. The possibility of using Landsat data to monitor vegetation stress related to debris from ultramafic rocks is being studied in the asbestos belt in the Thetford Mines area of Quebec. Image processing and analysis methods were used to integrate Landsat data, digitized geological information, catchment basin geochemistry and other parameters to predict tungsten skarn mineralization associated with buried intrusions in the Nahanni area of the Yukon." [GSC 1986-1987 Annual Report]

Future plans may or may not make mention of remote sensed data. The proposed 1:250 000 geological remapping project in the NWT for mineral exploration makes no mention of these techniques. It is noted, however, that the minerals resources planning group has stated:

> "Data integration and image analysis (including more widespread integration of **satellite** sensed data) is seen as providing an important **future** direction in the derivation of more sophisticated exploration and regional mapping methods." (Internal GSC report)

Recommendation

In order to more fully utilize remote sensing techniques in GSC mapping projects, a formal liaison committee should be established, through the office of the Chief Scientist, with the Remote Sensing Branch to review geological mapping projects to see where these techniques could be of value.

7.5 BASE METALS EMPHASIS

The depletion of Canada's known reserves of most base metals over the past decade has been highlighted by numerous sources. For example, EM&R's Annual Science and Technology Plan Update, May 17, 1988, takes note (page 15) that "the discovery of base metal deposits in Canada has recently fallen to a point where projected demand may exceed supply in 3-5 years".

The course of this run down of reserves is easy to see. The very low metal prices which have prevailed from 1982 to 1987, provided neither the incentive nor the funds for base metal exploration in Canada during that period.

Another casualty of the lack of interest in base metal exploration during this period has been the science of mineral exploration. At the very time when existing means of exploration for base metals had been rather exhaustively applied to the more accessible and more geologically promising areas of Canada, we ceased to develop new means for this purpose.

A prime example of a successful means for base metal exploration which was quite mature in its development and application by 1982, is the airborne electromagnetic method. This method discovered its first mine (Heathe Steele, New Brunswick) in 1953, and has been extensively applied across Canada ever since, resulting in the discovery of many important polymetallic deposits (for example, Mattagami, Poirier, Kidd Creek, Thompson) and even entire new mining camps.

Whereas base metal discoveries will continue to be made with the primary guidance of airborne electromagnetics, it is not very likely that any more "elephants" of the scale of the Kidd Creek or Mattagami Mines will be found in reasonably accessible parts of Canada. Clearly we need new tools and technology as we renew the search for base metal deposits in Canada, or else the law of diminishing returns will set in and the search will not be cost effective. Mining geophysical technology would provide an important ingredient in this new GSC initiative, as the search for new base metal deposits will require the ability to find these at ever greater depth.

Recommendations

This Committee, therefore, strongly supports the initiative recently taken by the GSC, to devote 10% of the annual budget of the Mineral Resources Division to the advancement of the science of mineral exploration. The studies undertaken must be multidisciplinary (geology, geophysics and geochemistry) to be truly effective. In addition, they should be done in consort with the private sector, who can provide test sites, detailed geological information (in 3 dimensions) and with universities, who can be responsible for ancillary laboratory studies.

Some aspects of mineral exploration research in which the GSC should participate include:

- Multidisciplinary studies of known deposits to establish their parameters and typical signatures, using current methodology and instrumentation.

- Development of methods of data processing and presentation which may utilize the totality of the multidisciplinary data, to enhance the effectiveness of the whole (that is, cross- correlation type approach).

- In consort with the private sector and university, the development of new techniques of mineral exploration and their testing on suitable sites with known geology.

- The integration into the exploration environment of the regional tectonic framework in which mineral deposits formed.

7.6 ROCK PROPERTIES LAB

High quality seismic reflection, seismic refraction, gravity, magnetic and radiometric data are routinely being acquired by GSC scientists, both within the organization and in collaboration with others. Thorough analysis and interpretation of such data is aided substantially when the physical properties of rocks at or near the surface are

known. Such properties include density, magnetic susceptibility, remnant magnetization, seismic velocities for shear and compressional waves, electrical conductivity, radioactive heat production, porosity and anisotropy (the variation of properties with direction of measurement). Many of these must be available for conditions (pressure, temperature, wet, dry, saturated, unsaturated) appropriate to the depths of investigation.

Within Canada, there are only limited facilities for carrying out some of the needed measurements. There is no centralized location at which such information is archived. Yet such information is almost as important for the geophysicist as rock samples are for the geologist. The GSC is the logical national institution with the mandate, the continuity and the resources(?) to establish and maintain a physical properties laboratory and data base.

The Committee is aware of three GSC laboratories which measure physical rock properties. These include two paleomagnetic laboratories (see Section 3.5), one at the PGC and one in Ottawa under the Paleomagnetic Section of the LCSD. The third laboratory is under the Electrical Methods Section of the Exploration Geophysics Sub-division of the MRD (see Section 3.7.4).

In the recommendations under the latter section, it was suggested that the two rock properties laboratories in Ottawa could well be combined into a more general rock properties laboratory. This laboratory could provide the full range of physical properties listed above, for use by both GSC and outside scientists.

Recommendations

The GSC should establish a national data base for rock properties oriented toward the national needs of all scientists (much like the gravity and magnetic mapping programs) and specifically toward the needs of GSC's multidisciplinary programs.

In line with other Committee recommendations (e.g., Section 3.7.4 and 3.7.6), underutilized resources within the Electrical Methods Section and Borehole Geophysics Section of the Exploration Geophysics Subdivision of MRD could be assigned to this task. Initially, it could act as an archiving/information centre for all of Canada; as it matured, facilities for the needed measurements could be improved or added.

The rock properties laboratory could logically be combined with the Ottawa Paleomagnetic Section in LCSD.

The GSC should inform the Canadian geoscience community of this redirected task, set standards for measurement information and request existing data bases to start the program.

8.0 STANDING EXTERNAL ADVISORY COMMITTEE FOR GEOPHYSICS

The Committee recommends that a Standing External Advisory Committee to the GSC for Geophysics be established.

It should, for maximum effect, consist of two members from each of the university community, the petroleum industry, the mining industry and the provincial surveys in Canada. There should be a good geographic distribution and a francophone representation.

Some members could be nominated by appropriate professional societies (e.g., CSEG and KEGS, for the petroleum and mining representation). There should be a rotating two or three year tenure for each member, staggered, so that one-half or one-third are rotated each year.

There should be a sunset clause for the Standing Committee, so that it would automatically terminate, at a certain time, unless it appeared to be serving a useful purpose.

The primary function of this committee would be to evaluate and comment on the effectiveness, relevance and technical viability of geophysics in the GSC. It could foster support and provide guidance for geophysical projects and improve communication between the GSC and its clients in Canada. Information on technical innovations developed outside of the GSC could be supplied as well as suggestions for future projects. This committee should become familiar with the present report and monitor the implementation of its recommendations.

The Committee should meet at least once per year, preferably during the project planning cycle, to review recent accomplishments and future project plans.

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