



CANADIAN
GEOSCIENCE
COUNCIL

REPORT OF THE CANADIAN
GEOSCIENCE COUNCIL
ADVISORY COMMITTEE ON
MINERAL EXPLORATION
GEOCHEMICAL ACTIVITIES AT
THE GEOLOGICAL SURVEY
OF CANADA

Published for the Council by the
Geological Survey of Canada as
Paper 91-13

Advisory Committee
J.A. Coope (Chairman), M.A. Bouchard, P. Davenport,
I.L. Elliott, K. Fletcher, A.H. Green



OCT 29 1992

\$10.75

\$13.98



Energy, Mines and
Resources Canada

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Canada

GEOLOGICAL SURVEY OF CANADA
PAPER 91-13

**REPORT OF THE CANADIAN GEOSCIENCE
COUNCIL ADVISORY COMMITTEE ON
MINERAL EXPLORATION GEOCHEMICAL
ACTIVITIES AT THE GEOLOGICAL SURVEY
OF CANADA**

Prepared by the
CANADIAN GEOSCIENCE COUNCIL

Advisory Committee

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1992

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Available in Canada through
authorized bookstore agents and other bookstores

or by mail from

Canada Communication Group – Publishing
Ottawa, Canada K1A 0S9

and from

Geological Survey of Canada offices:

601 Booth Street
Ottawa, Canada K1A 0E8

3303-33rd Street N.W.,
Calgary, Alberta T2L 2A7

100 West Pender Street,
Vancouver, B.C. V6B 1R8

A deposit copy of this publication is also available for reference
in public libraries across Canada

Cat. No. M44-91/13
ISBN 0-660-57480-2

Price subject to change without notice

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PART I

PREFACE

The geochemical exploration program within the Geological Survey of Canada commenced in 1949 with the work of Dr. R.W. Boyle in the Yellowknife mining district in the Northwest Territories. The research program rapidly became widely acclaimed and, over the years, has attained international status as a research and methods development center in geochemical prospecting.

GSC geochemical work has significantly stimulated mineral exploration activity across Canada and the developed expertise has made important contributions to the natural resource development of other nations.

The following are Conclusions and Recommendations prepared by the Advisory Committee charged with reviewing the Geochemistry Activities at the Geological Survey of Canada. The Committee was appointed in July 1988 by the Canadian Geoscience Council at the request of the Geological Survey.

Part II of this report contains a summary of the Committee's activities and findings leading to the Conclusions and Recommendations that are presented.

CONCLUSIONS

- C1. Scientists at the Geological Survey of Canada have made significant contributions to exploration geochemistry over the past 40 years, and their work has received world-wide recognition.
- C2. The successful application and adaptation of geochemical exploration techniques in a wide variety of conditions, the rapid development of analytical and computer technology and improvements in field transportation have made geochemistry one of the more effective and widely applied mineral exploration disciplines in Canada.
- C3. Over 40 important mines and mineral deposits have been discovered by the application of geochemical prospecting methods in Canada since 1938.
- C4. Regional Geochemical Surveys and exploration geochemical research completed by the Geological Survey of Canada has significantly stimulated mineral exploration across Canada. With this developed expertise, the GSC has made contributions to the natural resource development of other nations through CIDA and other foreign-aid programs.
- C5. The mineral exploration geochemical output of the Geological Survey of Canada originates from within the Mineral Resources and the Terrain Sciences Divisions.
- C6. In 1986 and 1987 a series of organizational changes were instituted in the Geological Survey which affected the administration of exploration geochemistry as

scientific activity. Scientific and technical personnel have experienced, to different degrees, changes in working relationships, disruptions of communication, diminished morale and other anxieties. The Exploration Geochemistry Subdivision has lost considerable professional momentum, and there is a perceived de-emphasis of applied geochemical exploration research within the Geological Survey.

- C7. Following reorganization in 1986, the staff and resources of the Applied Geochemical Laboratory of the predecessor Resource Geophysics and Geochemistry Division were regrouped into the Analytical Methods Development Unit of the Mineralogy and Chemistry Subdivision with expanded responsibilities in support of all Divisions of the Geological Survey of Canada. With some personnel, professional satisfaction and productive interaction has declined.
- C8. The effectiveness of the Mathematical Applications in Geology Section has not been diminished by its reorganization into the Geochemical Exploration Subdivision. The group is successfully integrating its expertise with scientists in other subdivisions through well developed interpersonal skills.
- C9. Geochemists joining the Exploration Geochemistry Subdivision either during or immediately after the reorganizations have not been significantly affected and work effectively, commonly in close coordination with scientists in other subdivisions.
- C10. The Committee finds, despite the generally favorable client response to past output and performance, internal problems of management, organization and morale are such that the exploration geochemical activities at the Geological Survey of Canada are at a critical crossroads.
- C11. Approximately 52% of the \$3.30 million budget of the Exploration Geochemistry Subdivision and 42% of the \$3.48 million budget of the Quaternary Geology Subdivision were expended under Mineral Development Agreements (MDA) and other joint programs with the provinces in the 1988-89 financial year.
- C12. Scientific philosophical differences relating to regional geochemical exploration between the Quaternary Geology and Exploration Geochemistry Subdivisions have been perpetuated to the present time, and, with few exceptions, have resulted in somewhat negative competitive rather than positive cooperative attitudes between both scientists and administrators in the two groups. These differences have, no doubt, been heightened through the competition for additional, available funding under MDA programs.

- C13. The target signatures and the sampling strategies most suited to the resolution of provenance of the Quaternary deposits contrast significantly, in the majority of situations, with the sampling strategies and metal associations necessary for effective mineral exploration in the same terrain. Thus, to strive for both of these objectives in the same reconnaissance program is to compromise effectiveness.
- C14. Within the Exploration Geochemistry Subdivision (and, more generally, within the Mineral Resources Division), there is a dangerously low level of technical support and a perceived ceiling on advancement due to existing limitations on the number of senior research scientists.
- C15. The high level of response obtained from a questionnaire survey (63.2%) reflects the concern and interest of the client communities in the geochemical activities of the GSC.
- C16. The principal purpose of the geochemical exploration activities of all the groups polled is the discovery of new mineral deposits.
- C17. Geochemical techniques most commonly used by GSC clientele are lithogeochemical methods, soil sampling, heavy mineral and drift (including till) surveys and regional stream sampling.
- C18. Although not as widely used, there is a significant expression of interest by some interest groups in other sample media requiring more sophisticated collection, analysis and interpretation. There is a clear role for the GSC not only to interpret current geochemical practices but to evaluate new ideas and techniques.
- C19. There is a significant lack of awareness of the GSC's geochemical exploration activities within the client community.
- C20. Printed output is by far and away the most favored and most often used medium in the geochemical exploration user community. Formal publications, outside publications and open files are, in aggregate, the most frequently consulted sources of GSC geochemical information. Information on microfiche and computer tapes is rarely used. The popularity and use of computer discs for data transfer is increasing.
- C21. The most frequent communication between the client community and the GSC geochemical staff occurs at workshops and conferences and over the telephone.
- C22. The user public rates the reliability and scientific quality of GSC geochemical exploration published output highly and client needs are acceptably well satisfied.
- C23. The timeliness of geochemical output is rated satisfactory although there is a vocal minority who claim timeliness of some geochemical output can be improved.
- C24. There is strong support in the industry and university sectors for the geochemical activities of the GSC. Regional exploration surveys including the National Geochemical Reconnaissance program are strongly supported.
- C25. Disciplines considered appropriate for GSC geochemical research include lithogeochemistry and mineral deposits research, biogeochemistry, analytical method development and data management and interpretation techniques. The least favored activities relate to non-exploration aspects of geochemistry.
- C26. Research into the geochemistry of the sample media used in regional surveys with the intent of improving methodology and interpretation procedures is considered by industry and government groups to be a highly appropriate area of GSC research. This is in sharp contrast with questionnaire responses a decade ago when the user public was surveyed on the Uranium Reconnaissance Program.
- C27. Generally speaking, the geochemical work of the GSC closely matches the need of the client community. There is no strongly indicated area of deficient or inappropriate activity identified in the questionnaire response relative to the current geochemical practices of the groups polled. The Advisory Committee has, however, cited lithogeochemistry, gas geochemistry and electrogeochemistry as areas of GSC neglect.
- C28. University and government groups express a high degree of satisfaction with the Survey's work in the geochemistry of mineral deposits although the industry group is less satisfied.
- C29. Provincial governments in Canada, collectively, have considerable geochemical capability, but individually none comes close to matching the resources of the GSC in number and diversity of geochemists.
- C30. Geochemists in most provinces and territories (6 out of 11) favor joint federal-provincial regional geochemical surveys. Four provinces favor provincial delivery. Two thirds of the provinces and territories indicate that there is a significant degree of cooperation with geochemists at the GSC in implementing regional geochemical surveys.
- C31. The greatest perceived benefits extended to the universities and university students by the GSC are help with literature search, job opportunities, field logistics and provision of co-supervisors of research projects.
- C32. The most significant relationship between the commercial laboratory community and the GSC centers on extensive contracting out of analytical services and provision for the development of analytical techniques. The laboratory group do not believe that analytical method development activity by the GSC has contributed to raising the general standard of geochemical analysis in Canada.

However, the Committee's observation of the literature indicates several significant contributions have been made by GSC scientists to the development and understanding of geochemical analytical procedures.

- C33. While acknowledging the response of the user community, the Advisory Committee believes that the overall geochemical exploration effort of the Geological Survey of Canada can be significantly increased by improved integration of personnel and resources through management, organizational and attitudinal changes within the relevant Divisions and Subdivisions.
- C34. There is near-unanimous consensus among GSC scientists and management that Geological Survey input into the study of environmental problems through geochemistry is desirable. A majority of respondents support this activity but the field is acknowledged to be of only moderate relevance and importance to the constituencies polled.
- C35. The interests and needs of environmental scientists are often not served by the sampling and analytical strategies currently employed by the GSC for routine regional mineral exploration surveys. Arbitrary modification of effective mineral exploration procedures to accommodate the needs of environmental scientists will lead to compromises which will undermine the quality and usefulness of the data for both environmental assessment and mineral exploration.
- C36. Geoscience information, and particularly geochemical information, is an important resource, and is of greatest value when it is readily available in a digitized form, for general use. Restrictions to the flow of this information beyond the need to ensure its quality and integrity are detrimental to total effectiveness. The establishment of a computer system to facilitate this utilization is a necessary investment in any geochemical program.

The GSC lacks a coherent strategy for input, quality control, storage and output of geochemical data.
- C37. The SPANS/GIS system, being advanced by the Mathematical Applications in Geology Section is a valuable application adaptable to spatial data. It has proven to be a positive stimulant to the added utilization and improved interpretation of regional geochemical data.
- C38. The increased use of geographic information systems will necessitate the integration of all GSC geoscientific data base systems.

RECOMMENDATIONS

- R1. The Advisory Committee strongly recommends that the Geological Survey of Canada reaffirms its important role in sustaining a vigorous and active program of research and development of exploration

geochemical concepts, technologies and methodologies directed towards expanding Canada's geochemical database in support of the mineral exploration industry and as an aid to government resource and environmental assessment.

- R2. The Advisory Committee recommends that activities pertaining specifically to the development of mineral exploration concepts, technologies and methodologies be the responsibility of the Mineral Resources Division of the GSC, and all activities pertaining to exploration geochemistry be the responsibility of the Exploration Geochemistry Subdivision.
- R3. The future geochemical programs of the Quaternary Geology Subdivision of the Terrain Sciences Division and the Exploration Geochemistry Subdivision of the Mineral Resources Division should be critically evaluated in terms of Subdivisional and Divisional priorities. Personnel with developed expertise in the determination of provenance and genesis of Quaternary deposits as applied in geochemical exploration should be transferred to the Exploration Geochemical Subdivision.
- R4. The Exploration Geochemistry Subdivision should take full advantage of the opportunity and setting following the reorganizations within the Geological Survey of Canada to revitalize the overall geochemical exploration program within the framework of a long-term national mapping program and, through integrated involvement in the investigation of exploration problems, advance the development of exploration science and technology in support of the mineral industry.
- R5. Specific management problems deserving attention in the short term are the current adverse ratio of technical support staff to research scientists and the perceived ceilings on advancement due to limitations on the number of senior research scientists.
- R6. The GSC should continue to exercise active and determined management of projects and resources rather than passive direction of studies initiated by scientists. Geochemical prospecting activities are significantly influenced by initiatives and the interests of individual geoscientists and the Committee urges a management environment that while encouraging initiatives from below maintains a firm direction to the overall thrust of geochemical research.
- R7. It is recommended that GSC management encourage interdisciplinary research among geoscientists by inviting joint-collaborative proposals that would compete for funds already allocated to carefully conceived integrated programs.
- R8. The GSC should also beware of diverting an inappropriate amount of scarce resources into areas of fundamental geochemical research with only long term potential application to the timely development of

Canada's mineral resources. Such research should be done in universities with GSC support and supervisory involvement.

- R9. In order to compensate for the critical shortage of both professional exploration geochemists and geologists knowledgeable in exploration geochemistry, the GSC should expand programs and initiatives for the dissemination and presentation of data that can readily be used as case history and instructional material for training in geochemical methodology.
- R10. The GSC should continue to encourage presentation of this geochemical output at regional meetings focussed either by topic or area. This would also present increased opportunities for subsequent personal contacts in the field.
- R11. Because the geographic areas of interest and the sampling and analytical strategies for environmental surveys conflict, in many instances, with existing geochemical exploration programs and procedures, the Committee does not recommend that the GSC should become proactive in environmentally-related geochemical activities since this will divert considerable resources from the established and important missions of providing data pertinent to mineral exploration and resource assessment.
- R12. It is recommended that the GSC initiate a working group of GSC, DOE, Health and Welfare and other appropriate personnel from government and the private sector which would:
- (a) be appraised of the extent and the purpose of the current geochemical database generated through GSC and other programs.
 - (b) define the value of this existing geochemical database to environmentally oriented scientific groups, and
 - (c) examine how existing exploration geochemical sampling and analytical protocols can be supplemented to provide useful environmentally-related data without compromising in any way the quality and quantity of output and the resources needed to sustain and continually improve the GSC's contribution to the mineral exploration industry through geochemical mapping and research.
- R13. The Committee advocates, based on its observations of world-wide geochemical research, that the proposed working group should consider and recommend a two-tiered approach to geochemical mapping in Canada to include an ultra-low density multi-media, country-wide survey coverage that would provide a rapid, multi-faceted overview of landscape geochemistry providing the basic regional geochemical database for separate, follow-up applied environmental and mineral resource surveys.
- R14. The Committee emphasizes that any applied environmental program established by the federal government is destined to become highly visible politically and publicly and its effectiveness will be dependent on a long term commitment and new funding for equipment and facilities and highly qualified personnel dedicated to a comprehensive program.
- R15. The Geological Survey of Canada should continue to support its established exploration geochemistry research and methodology program at the same levels, but should increase or initiate programs in lithogeochemistry, gas geochemistry and electrogeochemistry to meet the needs of its clients and investigate more comprehensively methods applicable in areas of deep transported overburden.
- R16. The Committee strongly supports the continuation of National Geochemical Reconnaissance programs and strongly recommends that additional A-base funding be made available to research those aspects of the NGR database that will lead to a better understanding of geochemical processes in surficial environments and the development of better methodologies for effective mineral exploration and regional surveying.
- R17. It is recommended that the archives of geochemical sample materials that have accumulated through the National Geochemical Reconnaissance be supported and maintained as a valuable national resource.
- R18. The Committee recommends that the routine determination of the trace element content of geochemical materials continue to be contracted out with the employment of quality controls that will ensure long term consistency and reliability of the resulting database. Contracting-out procedures should be carefully reviewed with DSS to minimize dissatisfaction among commercial geochemical analytical laboratories.
- R19. The GSC should make every effort to expedite the release of standard reference samples to the Canadian analytical community.
- R20. It is recommended that management at the GSC should continue to examine the effectiveness of their public relations activities and seek cost-effective ways to make the public at large, and the mineral industry in particular, more aware of GSC geochemical activities.
- R21. It is apparent that there are wide disparities in productivity among individuals as measured by the number of publications and other written output per year. The average annual output of, for example, papers in refereed journals by research scientists involved in exploration geochemistry is less than two per year. It is recommended that frequency and timeliness of published output be important criteria for funding research by GSC scientists.
- R22. It is recommended that the Analytical Chemical Laboratories unit be given responsibility for sample preparation preceding chemical analysis and that the

Analytical Methods Development unit also extend its responsibilities to the development of new and improved sample preparation techniques for specific exploration analytical problems.

- R23. Quality controls should be improved by supplementing the established Analytical Chemical Laboratory's procedures with wider utilization of standard reference samples and the inclusion of field duplicates chosen and inserted by the GSC geologists and geochemists.
- R24. The Advisory Committee endorses the earlier Naldrett Committee recommendation 4.3.2.2.3 that a realistic costing of internal analytical work be instituted with costs to be charged against the budgets of individual projects.

Careful consideration should also be given to establishing internal cost recovery for a proportion of analytical development costs.
- R25. To avoid unrealistic expectations on the part of research geologists and allow adequate time for analytical development, an internal analytical liaison committee, allied to the existing Analytical Priorities Committee, should evaluate the probable commitment required to take any development to a successful conclusion.
- R26. It is essential that GSC operating budgets include a realistic component to cover maintenance costs of laboratory analytical equipment and, whenever possible and appropriate, practical maintenance contracts should be established with instrument manufacturers.
- R27. In order to ensure high standards of analytical quality and analytical development and further increase its productivity, the GSC must make full use of advances in analytical technology and maintain state of the art laboratories. Inadequate funding in the early 1980s resulted in a serious deterioration in analytical standards and a realistic capital cost budget is necessary to avoid such a recurrence.
- R28. "Routine" analytical work within the Analytical Methods Development unit should be minimized by transferring newly developed or established procedures to the Analytical Chemistry Laboratories or to commercial laboratories more promptly.
- R29. The Committee is not convinced that process oriented geochemical studies requiring clean room and isotope laboratory facilities are of sufficient priority in mineral deposits research at the GSC to warrant the expense involved in retrofitting old laboratory facilities or building new ones. GSC scientists needing sensitive water analyses and isotope determinations should establish close coordination and necessary arrangements with appropriate well established and well regarded laboratories capable of providing prompt and accurate results on GSC sample materials.
- R30. The GSC should move expeditiously and deliberately but carefully into distribution of its geochemical data by electronic media.

- R31. It is the Committees observation that geochemists within the GSC should be taking fuller advantage of the computer revolution to facilitate communication within the Survey and in the service of its user clients.
- R32. Although the adaptation of the SPANS/GIS system has proved successful in presentation of geochemical data, the GSC should make timely evaluations of other GIS systems to enable effective presentation and interpretation of GSC geochemical data while, at the same time, facilitating the utilization of GIS analysis by GSC clients.
- R33. A computer system structure with centralized storage and information integration capability is recommended for GSC geochemical data handling.
- R34. Immediate planning should be instituted within the GSC to accommodate the ready collection of geophysical, geological, geochemical and other earth science data as part of geographic data packages.

COMMENTARY ON THE REPORT OF THE CANADIAN GEOSCIENCE COUNCIL ADVISORY COMMITTEE TO THE GEOLOGICAL SURVEY OF CANADA ON MINERAL EXPLORATION GEOCHEMICAL ACTIVITIES

Introduction

The Report of the Advisory Committee on Mineral Exploration Geochemical Activities at the Geological Survey of Canada forms part of the formal evaluation process in use in the Department of Energy, Mines and Resources. The report was commissioned by the Assistant Deputy Minister of the Geological Survey in July of 1988. Its purpose was to contribute to departmental requirements for program evaluation and to help the Sector meet its responsibilities as a research organization serving clients in the mineral sector, in other federal and provincial government agencies and in the geoscience community in the universities and elsewhere.

At the time of commissioning of this CGC study, there were a number of questions concerning exploration geochemical activities at the Geological Survey that needed to be addressed through an independent peer review process. In part some of these questions flowed from the results of an earlier CGC study on Mineral Deposits Research at the Geological Survey (GSC Paper 85-6, Part II). There were three questions of particular concern to management at the Geological Survey. Not necessarily in order of importance, they were:

1. In the client's view(s), was there an appropriate balance between geochemical survey activities and geochemical research (e.g. process geochemistry) at GSC?
2. Was the organizational and structural distribution of exploration geochemistry activities within GSC appropriate?

3. Was the National Geochemical Reconnaissance program viewed in a generally positive light by clients or were there changes that could be made in the structure and delivery of the program that would improve its usefulness to the mineral community?

The Advisory Committee report addresses these questions and many more, of course. On the matter of balance (Question 1) the report is generally positive, although it makes some recommendations that would serve to increase the research component, however, not necessarily at the expense of survey activities. On Question 2, the Committee makes recommendations concerning the transfer of drift prospecting geochemical activities from Terrain Sciences Division to Mineral Resources Division; these recommendations are generally contentious within the Survey and their implications will have to be carefully evaluated by GSC management. On NGR (National Geochemical Reconnaissance) the Committee provides a strong endorsement of the existing program but recommends adding to it a low-density survey component. The latter (low density surveys) are a matter of considerable debate in the geochemical community at the moment and GSC's response to this recommendation will be to proceed cautiously until such surveys have demonstrated their utility in Canadian terranes. A pilot project to evaluate the desirability of low density surveys is being planned.

A fourth important question began to come into focus during the time that the Committee was conducting its study. This concerned the matter of environmental geochemistry and the proportion of effort in this relatively new area that might be developed in tandem with more traditional exploration-oriented geochemistry activities. Initially, the Committee was generally of the view that GSC should proceed cautiously here, because of the danger of diluting resources available for exploration geochemistry through reallocations to environmental geochemistry. The GSC view on this matter is unambiguous; it is assumed that because of the high political and social profile of environmental matters that environmental geochemical activities will play a key role in GSC geochemistry in the future. During the two years that the Committee spent in its investigations, G.S.C. began to move seriously into environmental geochemistry activities on a number of fronts, including through participation in international projects with other national geological surveys.

The Committee's 34 recommendations are discussed in the following section. The GSC is in substantial agreement with the majority of these and, in fact, many have already been implemented or are in the course of being implemented.

Discussion of recommendations

Recommendation 1:

The Geological Survey is fully cognizant of the role that geochemistry has played in mineral exploration in Canada and of the significant contributions that its staff has made to the discipline over a period of 40 years. Furthermore, the

Survey intends to maintain its position at the forefront of geochemical research in Canada and to continue to contribute to expansion of the national geochemical database.

Recommendations 2 and 3:

For GSC these are the two most contentious recommendations in the report. At the heart of the problem is the longstanding Survey administrative structure which has separated geochemical activities associated with waters, soils, stream sediments and lake sediments (Exploration Geochemistry Subdivision, Mineral Resources Division) from the drift prospecting geochemistry associated with Quaternary geology/till sampling activities (Terrain Sciences Division). For historical as well as technical reasons there is considerable logic to the present arrangement, particularly because of the necessity to have surficial geology interpretations and expertise of Terrain Sciences Division firmly linked to the geochemical aspects of drift prospecting activities. This question is further complicated by other factors, including the development of an integrated geochemical data base in the Survey that can accommodate geochemical data generated within the two divisions in a compatible format. It is noted also that the new Program Structure now in place within GSC permits easier development of cross-division and cross-discipline projects, and this may be considered as an alternate to the actual transfer of staff and expertise from Terrain Sciences Division to Mineral Resources Division, as recommended by the Committee. For the moment, a working group involving staff of the two divisions will investigate these and related matters, but any decisions on organizational changes in response to the Committee's recommendations will be deferred.

Recommendation 4:

The GSC is in full agreement and has already implemented EXTECH, an integrated, multidisciplinary project aimed at improving concepts and technologies applicable to exploration for volcanogenic massive sulphide deposits. Exploration geochemistry and drift prospecting are key elements of EXTECH: indeed, the project leader is an exploration geochemist. The early results of EXTECH have been extremely promising and it is hoped that it will serve as the prototype for other exploration science and technology initiatives.

Recommendation 5:

Survey management shares the Committee's concerns with respect to the ratio of research scientists to technical support staff, and the limited promotion opportunities for research scientists. Unfortunately, both of these problems will take some time to remedy. With respect to the proportions of research scientists and support staff, it is important to realize that the person-year allotment of Mineral Resources Division has declined by about 15% over the past 3 years, meaning that there have been few staffing opportunities. This notwithstanding, it should be noted that all new staff taken on by Exploration Geochemistry Subdivision since the Committee's visits have been in the technical and junior professional categories.

The quotas which restrict research scientist promotions apply throughout the Public Service and are not subject to unilateral modification by either the Geological Survey or the Department of Energy, Mines and Resources. However, the system is currently under review and some improvements may be forthcoming.

Recommendation 6:

The Geological Survey will continue to exercise active and determined management of scientific projects.

Recommendation 7:

Two major integrated projects involving exploration geochemists have been implemented since the Committee's visits. These are the EXTECH project alluded to above and environmental geochemistry initiative. Both have yielded promising early results and are likely to give rise to other interdisciplinary research efforts.

Recommendation 8:

Survey management agrees that an "inappropriate amount" of resources should not be diverted to fundamental research. However, it is not clear what proportion the Committee would consider appropriate or, indeed which, if any, of the current exploration geochemistry research activities the Committee believes to be too fundamental.

Recommendation 9:

The Survey has already taken steps to make its expertise in exploration geochemistry more accessible to its client community. The Exploration Geochemistry Subdivision staff participated in three workshops during 1990 and presented a one day short course at the 1991 Prospectors and Developers Association Convention. As well, Terrain Sciences Division staff participated in two of these. A further workshop, in biogeochemical exploration, is being planned for 1992.

Recommendation 10:

The results of geochemical surveys and research are routinely presented at the open houses of each of the provinces and territories where such work is undertaken. This form of communication with clients is given a very high priority by management.

Recommendation 11:

This recommendation, as written, would appear to be at odds with the two that follow. In any event, management strongly believes that the Geological Survey has an important part to play in providing some of the knowledge essential to the solution of Canada's environmental problems. Clearly, geochemical expertise and data will play a key role and, to this end, an environmental geochemistry project has been initiated under the management of Exploration Geochemistry Subdivision. Nevertheless, the GSC will make every effort

to reconcile the sometimes conflicting requirements of exploration and environmental geochemistry without compromising either.

Recommendation 12:

Although a formal working group has not been established, numerous and repeated discussions have been held with officials of health and environmental departments at both the federal and provincial levels to inform these agencies of the existence and scope of GSC's geochemical database and to explore potential areas of cooperation. Several cooperative studies have already been initiated. In addition, cooperative studies in environmental geochemistry with other national surveys are under discussion (e.g., the British Geological Survey and the Geological Survey of Prague).

Recommendation 13:

The Geological Survey is aware of international developments with respect to ultra-low density geochemical surveys and will evaluate the feasibility of such an approach in Canada. However, in the event that such surveys were judged to be both feasible and desirable, it is unlikely that GSC would be able to fund a country-wide program in the near future. A more likely scenario would involve one or more pilot projects, probably in cooperation with provincial surveys.

Recommendation 14:

This statement is not so much a recommendation as an observation. In any event, it is recognized that any significant increase of environmental geochemistry activities beyond the current level would require both significant new funding and new expertise.

Recommendation 15:

The Geological Survey will maintain and, where possible, enhance its established research in surficial geochemistry, biogeochemistry and lithogeochemistry. In the current climate of restraint, it is unlikely that it can embark on significant programs of in-house research in "new" subdisciplines such as electrogeochemistry and gas geochemistry given that each of these would require not only additional operating funds but also new staff at both the research scientist and support levels. The Survey will, however, take advantage of partnership opportunities as exemplified by its current participation in an industry consortium evaluating electrogeochemical methods.

Recommendations 16 and 17:

The Geological Survey is committed to maintaining and, where possible, strengthening the National Geochemical Reconnaissance program. Over the short and medium term, new surveys will be funded almost exclusively from external sources such as the Mineral Development Agreements, while priorities for the A-base component of NGR funding will be digital database development (already well underway), maintenance and re-analysis of archived samples,

methodological research, and interpretation. The Survey is committed to continued support of the National Geochemical Reconnaissance archive.

Recommendation 18:

Routine determination of trace elements is almost entirely contracted-out to commercial laboratories already. Stringent quality control procedures are used to monitor both precision and accuracy of analyses for the National Geochemical Reconnaissance, and we are satisfied that results are consistent over the nearly 20 year history of the program. Quality control procedures have not always been as systematic for some other data sets, but steps are being taken to rectify deficiencies. With respect to contracting procedures, it should be realized that objectives listed in the report (p. 88) are reviewed with the Department of Supply and Services on a continuing basis and that elaborate evaluation criteria are established for each tender process.

Recommendation 19:

This recommendation is being implemented. For example, the Geological Survey of Canada began offering the standard reference samples of lake and stream sediments for sale through CANMET in 1990. Standards for soils and till are currently being certified and will be on the market within two years.

Recommendation 20:

The Geological Survey is seeking to increase the awareness of its geochemical activities among its client community by (i) inauguration of a biennial Minerals Colloquium, which includes a significant geochemical component, (ii) sponsorship of a series of geochemical workshops or short courses, and (iii) more active participation in national and regional meetings and Open Houses. In addition, the Survey has recently begun to publicize the availability of the National Geochemical Reconnaissance digital data set through a special brochure.

Recommendation 21:

The frequency and timeliness of published output are already important criteria for project approval and funding decisions. However, we do not accept the basis on which the recommendation was made: namely that on average GSC geochemists produce fewer articles in refereed journals than would be considered the norm for a university faculty. Firstly, for many survey projects, GSC publications of various types are more appropriate products than refereed journals and therefore any assessment of productivity should consider these media. Secondly, the Committee's compilation appears to have included individuals who were not in the research scientist category and should not be compared with university faculty. In fact, the 13 research scientists involved in exploration geochemistry had an average annual productivity of 3.75 publications, including 2.3 in refereed journals, in the period 1984-88.

Recommendation 22:

The first part of this recommendation is difficult to accept for three reasons. Firstly, it would put an unreasonable extra burden on the Supervisor of the Analytical Chemistry Laboratories. Secondly, the largest single activity in the Sample Preparation Unit is the separation of minerals for geochronology and isotopic studies. Finally, primary management responsibility for the Analytical Chemistry Laboratories and Sample Preparation Unit already resides in the same individual, namely the Head of Mineralogy and Chemistry Subdivision. With respect to development of sample preparation techniques, it is quite possible that the Analytical Methods Development unit could be given this responsibility but the priority given to these techniques would have to be weighed against other demands for method development.

Recommendation 23:

Standard reference materials are already used routinely for all methods employed in the Analytical Chemistry Laboratories and it is not clear what benefits would accrue from more extensive use. Five percent of samples run through the laboratories are blind duplicates inserted by the laboratory supervisor. In addition, laboratory clients are advised to insert their own duplicates and check samples, but this practice is not policed.

Recommendation 24:

The Geological Survey will re-examine the question of internal cost recovery for analytical services.

Recommendation 25:

As the Committee states (p.94), priority setting is the responsibility of management. The Analytical Priorities Committee in fact no longer exists. Research geologists are expected to discuss their analytical requirements with laboratory staff prior to initiating a requisition. Requisitions are screened by laboratory management to ensure that the work is feasible within a reasonable timeframe and that it will not impose an unrealistic load on the laboratory.

Recommendation 26:

The Geological Survey agrees that the maintenance of costly laboratory equipment is a matter of critical concern, and Mineralogy and Chemistry Subdivision budget does include a component for repairs. Maintenance contracts are in place for a number of instruments but in many cases it is more cost effective to "self insure".

Recommendation 27:

GSC realizes the importance of maintaining an adequate capital budget to ensure the availability of state-of-the-art analytical technology and acknowledges the precarious position it had reached in the early and mid-1980's. However, the introduction of CARP (Capital Acquisition and Replacement Plan) in 1989, as a result of negotiations with Treasury Board, allowed GSC to significantly upgrade its

capital assets. Unfortunately, the increase of capital funds came at the cost of a decrease in person-years and was not accompanied by an increase in operating funds. This latter is particularly worrying because although state-of-the-art equipment increases productivity, it also costs more to maintain.

Recommendations 28:

As a matter of principle, truly routine analyses which are commercially available are contracted-out for the most part (see also, Recommendation 18). Methods which have become "routine" within the Method Development Laboratory are being transferred to the Analytical Chemistry Laboratory. However, this is an evolutionary process since the Analytical Chemistry Laboratory will not necessarily have the personnel and equipment in place to implement a new procedure immediately.

Recommendation 29:

The Geological Survey does not agree with the Committee's conclusion that stable isotope facilities are not of sufficient priority in mineral deposits research to warrant the expense involved. The Survey considers isotopic investigations to be one of the potentially most fruitful and exciting aspects in modern mineral deposit research and is in the process of establishing a state of the art stable isotope laboratory. Moreover, stable isotope studies will play an important role in environmental geoscience. With respect to clean room facilities, although a final decision has not been made, it is quite possible that these will be necessary not only for mineral deposits research but also if the Survey becomes more involved in water analysis for both exploration and environmental geochemistry. Such facilities may be factored into a major retrofit of the 601 Booth Street building that is scheduled to take place in the next few years.

Recommendation 30 and 31:

The Geological Survey is moving rapidly to increase availability of digital data. With respect to geochemical data, for example, the entire National Geochemical Reconnaissance database is now available to clients in diskette form. The GSC network, currently being implemented, will greatly facilitate electronic communication within the Survey.

Recommendation 32:

The Survey agrees that it is important to keep abreast of developments in GIS technology. However, it should be recognized that the considerable investment in hardware, software, training and development time already devoted to the SPANS GIS by Exploration Geochemistry Subdivision means that a decision to change systems could not be taken lightly.

Recommendation 33:

The Exploration Geochemistry Subdivision is currently developing a comprehensive system with the working title "Canadian Database on Geochemistry" (CDOG). This could in principle incorporate not only the National Geochemical Reconnaissance data but other geochemical data sets.

Recommendation 34:

Considerable thought and discussion has already been given to the integration of various geoscience data sets within the GSC. A likely scenario as a first step would be the linking of the various distributed databases (geological, geophysical, geochemical) through the GSC network, and the provision of a single "porthole" through which clients could access digital data. Whether these diverse data sets should then be pre-packaged on a geographic basis is an interesting question and will be examined in more detail.

PART II

INTRODUCTION

The successful application and adaptation of geochemical exploration techniques in a wide variety of conditions, the rapid development of analytical and computer technology, and improvements in field transportation have made geochemistry one of the more effective and widely applied mineral exploration disciplines in Canada. This effectiveness is illustrated by the tabulation of mineral discoveries in Table 1, modified after Brummer, Gleeson and Hansuld.

The Geological Survey of Canada has contributed to this success directly and indirectly through research into geochemical exploration processes and their application in the wide variety of natural environments existing in Canada.

Exploration geochemical research activities in the Geological Survey of Canada began in 1949 with Dr. R.W. Boyle's studies of primary haloes around gold deposits in the Yellowknife area. These studies were followed in the 1950s by geochemical surveys of stream and spring waters, stream sediments and soils in the Yukon and the Maritime provinces. Geochemical analytical laboratories were established in Ottawa in the late 1950s.

Through the 1960s and the 1970s the exploration geochemical research and survey activities of the G.S.C. expanded significantly with investigations of a variety of media in many varied and difficult environments across the Canadian landmass. Over a 40 year period, scientists at the Geological Survey of Canada have made significant contributions to exploration geochemistry, and they have received world-wide recognition. Their findings, including data published as regional surveys, have significantly stimulated mineral exploration activity across Canada, and the developed expertise has made contributions to the natural resource development of other nations through CIDA and other foreign aid programs.

The major growth of exploration geochemical activity in the Survey took place during the 1972-1986 period when exploration geochemists were included in the Resource Geophysics and Geochemistry Division (RGG), and activities expanded to include the Uranium Reconnaissance Program and the National Geochemical Reconnaissance. Not all geochemical research at the Survey was conducted by scientists in RGG during this period. Terrain Science Division personnel commenced research on gold in glacial tills in the Kirkland Lake area in 1963, and in the early 1970s the Sedimentary Mineral Tracing Group became active with lake water and lake sediment sampling and expanded till studies. Elsewhere in the Survey, new analytical technologies and scientific advancements stimulated the increased application of geochemistry in many types of earth science research other than mineral exploration. This included the more extensive use of lithogeochemistry mainly directed toward problems of genesis of mineral deposits, as well as isotope work, organic geochemical support in oil and gas research, and other applications.

Recent Reorganization

Beginning in 1986, a series of organizational changes were instituted in the Geological Survey which affected the administration of exploration geochemistry as a scientific activity. A technically driven change in April, 1986 resulted in the disbanding of the Resource Geophysics and Geochemistry (RGG) Division during the amalgamation of the Geological Survey of Canada and the Earth Physics Branches of EMR. Exploration geochemists of the Resource Geochemistry Subdivision of RGG were grouped in the Exploration Geochemistry Subdivision of the Mineral Resources Division (MRD). At the same time, the Analytical Laboratories unit of the Resource Geochemistry Subdivision became the Analytical Methods Development unit with the Mineralogy and Chemistry Subdivision of MRD. This change was followed, one year later, by a further reorganization: the Geological Survey of Canada was elevated to Sector status within EMR and the Mineral Resource Division was included in the newly created Continental Geoscience and Mineral Resources Branch (Figs. 1 and 2).

The impact of these reorganizations has been complex, but many of the programs in existence in 1986 have continued. Major changes experienced by the Exploration Geochemical Group have included (a) changes in the management structure and in management personnel at the division and branch levels, (b) the transfer of geochemical exploration analytical activities, previously part of the Exploration Geochemical Group, into the Mineralogy and Chemistry Subdivision, and (c) the inclusion of the Mathematical Applications in Geology Section within the Exploration Geochemical Subdivision.

As a consequence of the reorganization, personnel within the Exploration Geochemical Subdivision have experienced, to different degrees, changes in working relationships,

Table 1. Deposits found by application of geochemical prospecting methods

	1938-1968	1969-1989
Appalachian Orogen	Magnet Cove Barim Corp. (Pb-Zn-Cu-Ag) Mount Pleasant (W-Mo-Sn) Murray Brook (Cu-Zn-Pb) Restigouche (Pb-Zn-Cu-Ag) Newfoundland Zinc (Zn)	East Kemptville (Sn) Woodstock (Cu) Tally Pond (Cu-Zn) Nugget Pond (Au)
Precambrian Shield	Louven East (Zn) Delbridge (Cu-Zn) Millenbach (Cu-Zn)	Corbett (Cu-Zn) Bell Creek (Au) LAC Minerals Hemlo, Zone "C" (Au) Aquarius (Au) Key Lake (U) Collins Bay, Zone "B" (U) Waddy Lake, Gisement EP (Au) Winstone Lake (Zn)
Cordilleran Orogen	Craigmont (Cu-Fe) Stikine Copper (Cu) Sam Goosly (Au-Ag-Cu) Bell Copper (Cu) Morrison (Cu-Mo) Berg (Cu-Mo) Huckleberry (Cu-Mo) O.K. (Cu-Mo) Island Copper (Cu-Mo) Husky (Ag)	Chapelle (Au-Ag) Casino Silver (Cu-Mo) Lawyers (Au-Ag) Howards Pass (Pb-Zn) Midway (Pb-Zn-Ag) Brandywine (Au) Kutcho Creek (Cu-Zn-Ag-Au) Kutcho Creek (Cu-Zn-Ag-Au) Rea Gold (Au-Ag-Cu-Pb-Zn) Mount Skukum (Au-Ag) Bear-Totem (Au-Ag) Mount Milligan (Au-Cu)

Modified after Brummer J.J. et al., 1986, "A Historical Perspective of Exploration Geochemistry in Canada - The First 30 Years", R.G. Garrett ed., *Journal of Geochemical Exploration*, Elsevier Science Publishers, Vol. 28, No. 1/3, June 1987, pp. 1-39.

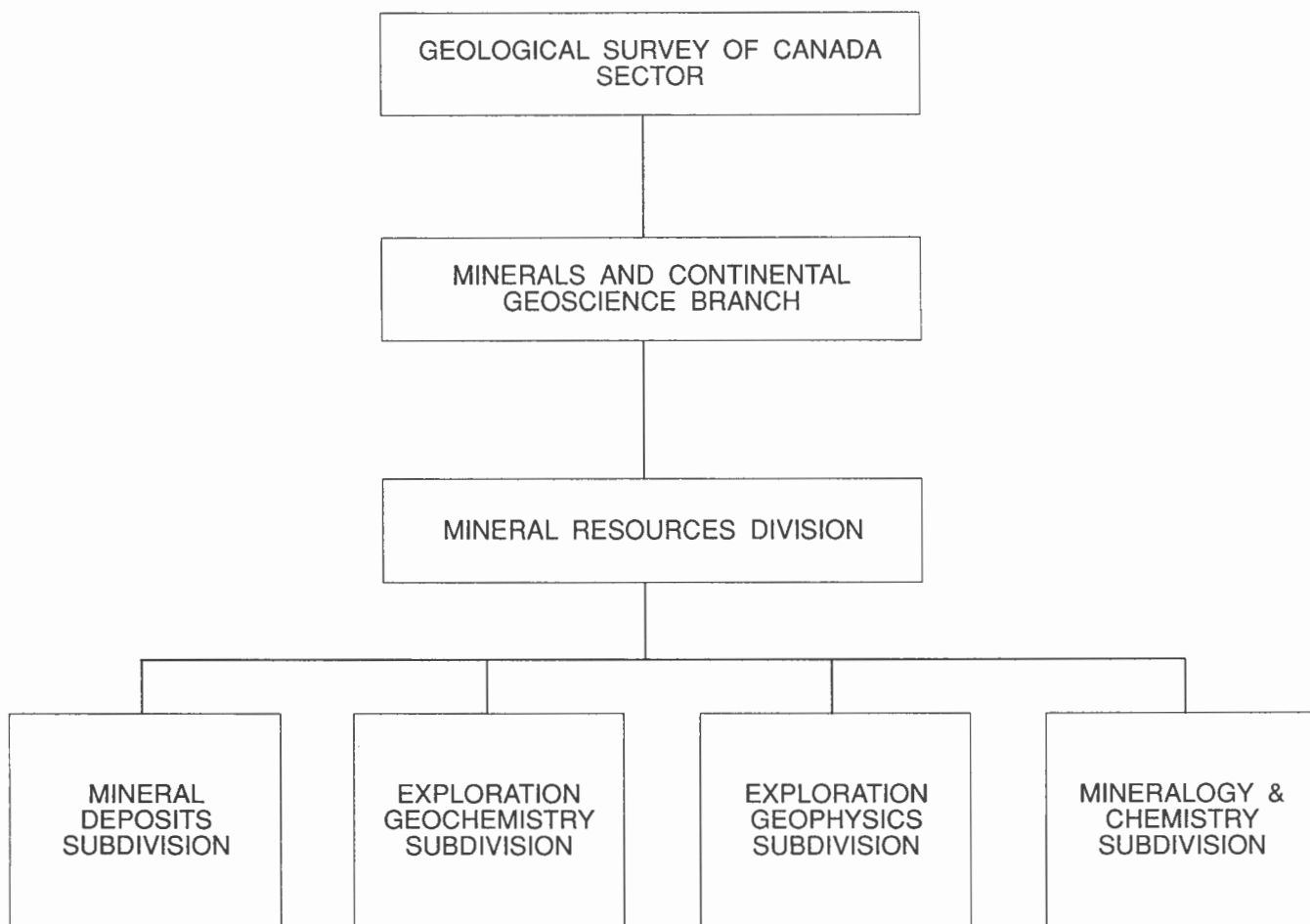


Figure 1a. Organizational chart – Mineral Resources Division.

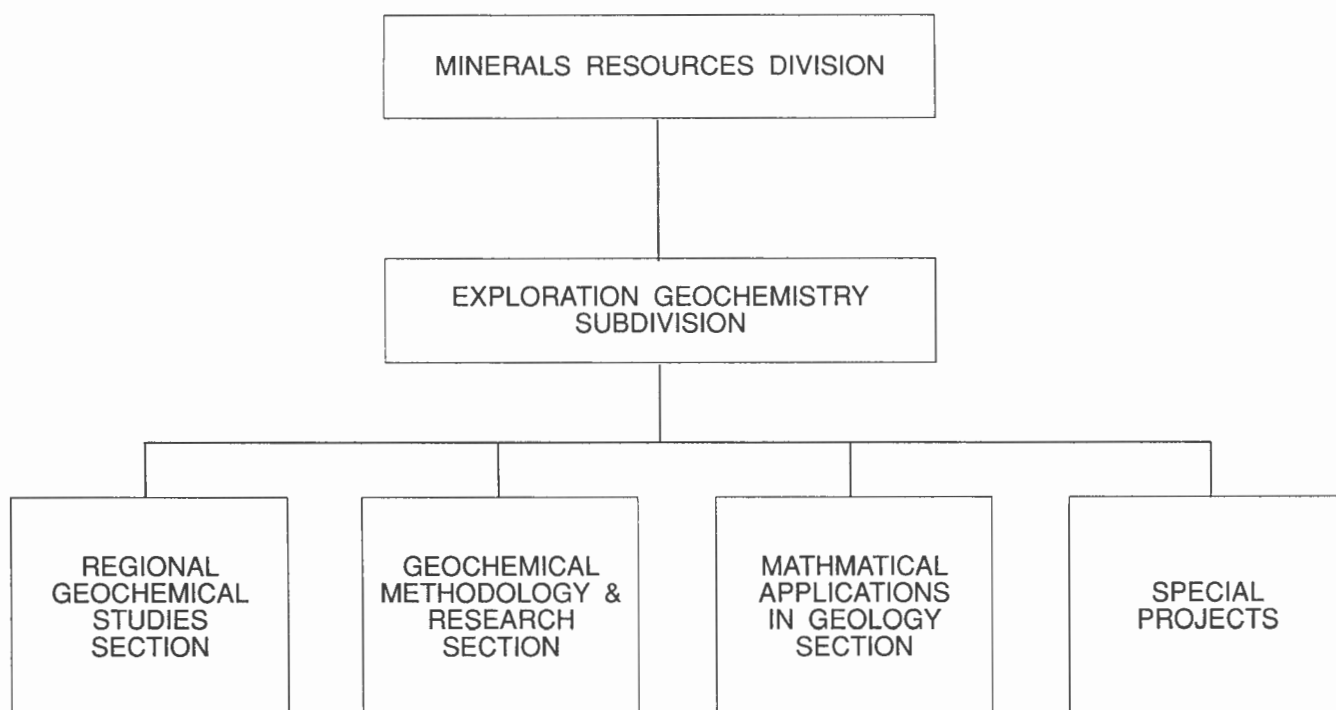


Figure 1b. Organizational chart – Exploration Geochemistry Subdivision.

disruptions of communication diminished morale and other anxieties. In 1988, the GSC management deemed the time appropriate for a Canadian Geoscience Council Advisory Committee to review the geochemical activities at the Geological Survey of Canada and formulate appropriate recommendations for the future.

The Advisory Committee and its Terms of Reference

Action on the 1985 proposal of the Naldrett Committee that an advisory committee be formed to advise on the activities of the Resource Geophysics and Geochemistry Division, has necessarily been delayed by the reorganizations that have been described. In late 1987, the Geological Survey of Canada requested the Canadian Geoscience Council to provide separate peer evaluations of both the geophysical and the geochemical activities in the GSC. A geophysical committee under the chairmanship of Dr. H.O. Siegel was first formed, and a geochemical committee of six under the chairmanship of Dr. J. Alan Coope, representing expertise in exploration geochemistry, Quaternary geology and mineral deposits geology from the academic, provincial government, and industrial sectors was formed in May, 1988 and held its first meetings in Ottawa in July, 1988.

The specific terms of reference of the Advisory Committee reviewing the Geochemistry Activities at the Geological Survey of Canada were developed as follows:

1. To determine and document the appropriateness and the current levels of geochemical research, method development and surveys at the Geological Survey of Canada.
2. To assess their impact and relevance to users in industry, university and government sectors and for Branch and Departmental responsibilities.
3. To assess the timeliness, relevance, type quality, and quantity of publications reporting on the results of geochemical research, method development and regional geochemical surveys.
4. To assess the range, adequacy, organization and quality of research equipment, support staff, analytical and computing services and contracting procedures available to support geochemical research, surveys and related activities.
5. To examine the methods and procedures used in originating, implementing, assigning priorities and managing geochemistry projects and regional surveys.

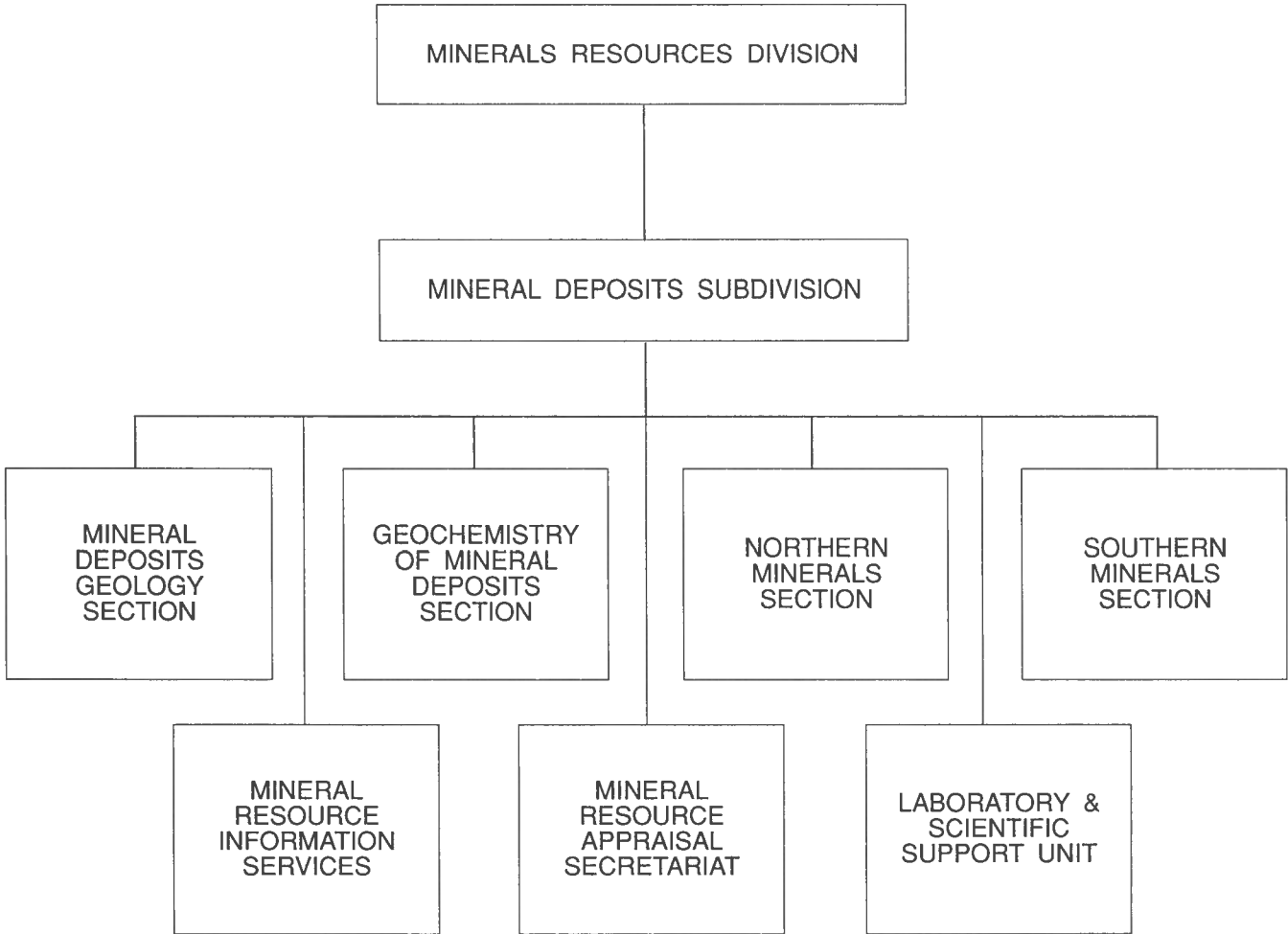


Figure 1c. Organizational chart – Mineral Deposits Subdivision.

6. To comment on the present organization structure of geochemical activities in the GSC.
7. To identify new initiatives and opportunities for geochemical research, method development and surveys.
8. To make written recommendations, as appropriate, to the Assistant Deputy Minister, Geological Survey of Canada Sector, concerning ways in which the quality and effectiveness of geochemical research surveys and reporting of results might be improved. The Canadian Geoscience Council Advisory Committee shall report its findings and appropriate recommendations in writing to the Assistant Deputy Minister, GSC. The report of the Committee shall be made public, but the mechanism and format of publication shall be determined by mutual agreement of the Assistant Deputy Minister, GSC and the Canadian Geoscience Council.
9. Unless otherwise agreed to by the Assistant Deputy Minister, GSC and the Chairman, Canadian Geoscience Council Advisory Committee, the Committee's report shall be submitted to the Geological Survey within one year of the formal commencement of the study.

Activities of the Advisory Committee

Following the directive of its mandate, the Advisory Committee addressed itself to the following activities:

1. Through interviews with GSC personnel:
 - (a) Investigated the distribution of geochemical exploration activities within the various divisions and subdivisions of the GSC
 - (b) Investigated the procedures used in the development and implementation of exploration geochemical surveys and research
 - (c) Investigated the effect of the technical and organizational changes of the GSC in 1986 and 1987
2. Through selective interviews with personnel from the Departments of the Environment and Health and Welfare, investigated their interaction with GSC geochemical personnel and the value and usefulness of GSC exploration geochemical data in the programs of these departments.

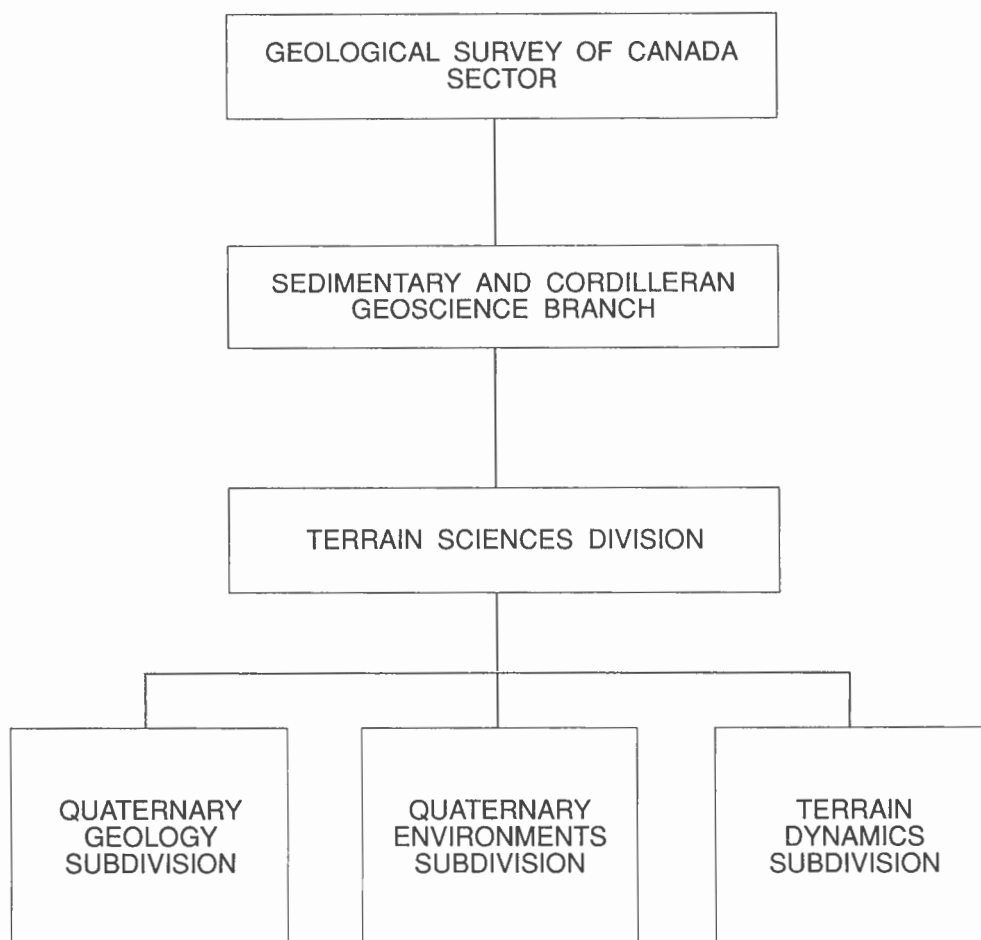


Figure 1d. Organizational chart – Terrain Sciences Division.

3. Through visits to offices of the Geological Survey of Finland, the USGS, and an additional interview with a geochemist of the British Geological Survey, compared the organization and conduct of geochemical activities relating to mineral exploration, environmental and other concerns.
4. Through the circulation of questionnaires to selected earth scientists employed in industry, provincial governments, and academia, investigated how well the GSC satisfies the needs of its various clients in these constituencies and how these constituents perceive the appropriateness and effectiveness of the geochemical activities in the GSC.

Of 163 questionnaires distributed to these constituent groups, 103 were returned, for a response of 63.2%. This high level of response reflects the concern and interest of the client communities in the geochemical activities of the GSC and has provided the Committee with valuable opinion on GSC geochemical output by clients outside the federal government.

Within the time constraints imposed by the terms of reference, these activities, plus the prompt responses of the GSC management to requests for background information and supporting data, has provided the committee with an adequate insight into fact and opinion to formulate conclusions and recommendations in response to its mandate.

The Committee finds, despite the generally favourable client response to past output and performance, internal problems of management, organization and morale are such that the exploration geochemical activities at the Geological Survey of Canada are at a critical crossroads. Difficulties and problems have been identified, and this report presents several recommendations for consideration.

THE GEOCHEMICAL PROGRAM WITHIN THE GEOLOGICAL SURVEY OF CANADA

Geochemical output originates primarily from the following sources within the Geological Survey of Canada:

1. Mineral Resources Division: (Figs. 1a, 1b, 1c)
 - (a) Exploration Geochemistry Subdivision
 - (b) Mineral Deposits Subdivision
 - (c) Mineralogy and Chemistry Subdivision
2. Terrain Sciences Division (Fig. 1d)
 - (a) Quaternary Geology Subdivision
3. Institute of Sedimentary and Petroleum Geology
 - (a) Petroleum Geology Subdivision (Organic Geochemistry)

As noted in the introductory sections to this report, the availability of improved analytical technologies and advances in scientific understanding have stimulated increased utilization of geochemical measurements in the majority of earth science disciplines practiced within the

GSC. However, since the prime focus of the Committee's mandate is to evaluate geochemical activities bearing on mineral exploration application, attention has been directed primarily to geochemical activity of the Mineral Resources and Terrain Sciences Divisions (1 and 2 above).

Objectives and Activities of Subdivisions within the Geological Survey of Canada Generating Geochemical Output

Within the Mineral Resources Division, the **Exploration Geochemistry Subdivision** conducts research on geochemical processes and on the development, application, and evaluation of geochemical exploration methods to assist the mineral exploration industry and to aid government resource assessment and geological mapping programs. It provides geochemical data relevant to environmental and health problems, land use planning and, through the Mathematical Applications in Geology Group, develops and applies mathematical and statistical methods for the integration and interpretation of geochemical and other geoscience data.

Prior to the 1986 reorganization, the predecessor to the Exploration Geochemistry Subdivision (the Resource Geochemistry Subdivision of RGG) included a laboratory section for analytical development and routine analysis. With the reorganization, this analytical group was included in the Mineralogy and Chemistry Subdivision. Currently the Exploration Geochemistry Subdivision is a major client of the Analytical Methods Development Section within this subdivision.

The **Mineralogy and Chemistry Subdivision** provides analytical and mineralogical services in support of Division and Sector research activities and develops analytical techniques to fulfill the requirements of its clients and for transfer to commercial laboratories. The subdivision is also responsible for the curation of National and Geological Survey of Canada rock, mineral and meteorite collections, and for the provision of mineralogical information, including the sale of reference rocks and mineral sets to the public.

The **Minerals Deposits Subdivision** conducts research on the mechanisms of formation of mineral deposits, interprets the relationships of mineral deposits to the geological characteristics of Canada's principal geological regions, and maintains a national information base on the nature, distribution, and geological characteristics of Canada's non-hydrocarbon mineral resources. Through the integration of results from these activities (including increasing amounts of geochemical data), guidelines and models for use by the Canadian exploration industry are developed. Input is also provided in the development of government policies related to resource management and land-use planning activities.

The Mineral Deposits Subdivision is also a major client of the Mineralogy and Chemistry Subdivision. This service includes both routine and special analytical work aimed, to an important degree, at the study of the metal distributions in

rocks, minerals, and other geological materials in mineral deposit environments and the resolution of problems of mineral deposit genesis.

The prime objectives of the **Quaternary Geology Subdivision** are to provide a Canada-wide inventory of surficial materials and landforms, to establish the stratigraphy and environmental history of Quaternary deposits, and to provide basic data on drift composition and provenance and on geological processes acting on the landmass.

Exploration Geochemistry Subdivision (Fig. 1b)

The activities of the Exploration Geochemistry Subdivision are subdivided into three broad categories:

- (i) Geochemical Methodology and Research
- (ii) Data Integration and Analysis
- (iii) Regional Geochemical Studies

The Operational Plan (Appendix A) of the Subdivision for the 1988-89 fiscal year provides some additional details and geographic distribution of the various activities. Except for salaries of the supervising geochemists and chemists and the cost of some sample re-analyses, all the expenditures incurred in the Regional Geochemical Studies (\$1.7 million in 1988-89) are financed through the MDA program. The activities included in Geochemical Methodology and Research and Data Integration and Analysis are financed through A-Base funding (\$1.6 million in 1988-89). Salaries constitute 66% of the A-Base in comparison to only 13% in the MDA programming, reflecting the salary exclusions and the higher proportional cost of contracted sampling and analytical services.

The prime objective of the **Geochemical Methodology and Research Section** is the development of geochemical methods having practical application in mineral exploration and other industries needing geochemical data. Currently most of the research is directed towards gold, silver, and the platinum group of metals. The Section includes six research scientists specializing in a variety of methods of geochemical exploration and two scientists responsible for data management and other support. Current studies include till geochemistry, heavy mineral studies, isotope studies, biogeochemistry, hydrogeochemistry, lithogeochemistry, and the application of computer-based data analysis systems.

The till geochemical program commenced in 1986 and represents a late effort by the Exploration Geochemistry Subdivision to investigate exploration methodology first applied during the EGMA program and used extensively by industry in exploration for base metals, uranium and later for gold over the past 12-15 years. The research is integrated with workers in the Quaternary Geology Subdivision and includes the study of glacial stratigraphy, the lithogeochemistry of the underlying bedrock, the geochemistry of different size fractions and the heavy mineral component of tills.

Intermittent biogeochemical studies which characterized the GSC program since the early 1960s, gave way in 1985, to the current, longer-range studies in the boreal forest regions which are now being internationally acknowledged and closely followed. The roof-top biogeochemical laboratory has been reestablished in Ottawa to supplement and complement field studies.

Activity in hydrogeochemistry has been three years of instrument/sample tool development and patent application without completion of surveys or release of data to the public.

In addition to the lithogeochemistry included in the till studies program, one subdivision geochemist is working closely with scientists in the Mineral Deposits Subdivision in investigations of gold-copper porphyry systems in the Cordillera, and isotope studies are being pursued in the investigation of the genesis of precious metal deposits in the Abitibi region and Scandinavia.

Data integration and analysis within the Exploration Geochemical Subdivision is achieved through the work of the *Mathematical Applications in Geology* Section supplemented by scientists from the Regional Geochemical and Geochemical Methodology and Research Sections who are involved with technology transfer. The five research scientists in the Mathematical Applications Section are charged with (1) the development and the application of probabilistic methods of mineral resource estimation for land use planning purposes; (ii) the development and application of new methods for the integration and interpretation of various geoscience data sets, including LANDSAT and other remotely-sensed data; (iii) the development of statistical methods for exploration geochemical and other related geoscience data; and (iv) the provision of statistical expertise and services to projects throughout the Geological Survey.

Although included in the Exploration Geochemical Subdivision, it is quite apparent that the Mathematical Applications Section serves the whole of the GSC as well as other sectors of the federal government. However, the closer administrative association as well as the obvious applicability of statistical and image analysis to the interpretation of geochemical data is contributing to the closer integration with exploration geochemistry within the Subdivision. This is clearly seen with the adaptation of the SPANS, Spatial Analysis System, and the EASIPACE, Image Analysis System, to spatial data integration studies of data from Nova Scotia, New Brunswick and Saskatchewan. In addition, new statistical techniques and the corresponding computer programs have been developed for the analysis of truncated and randomly censored data typical of multielement geochemical analytical results with detection limits.

Technology transfer investigations, primarily by personnel outside the Mathematical Applications Group, include the recently completed computer-based geochemical data system, IDEAS, the development of laser-plotting procedures for geochemical maps and expert systems applications.

The objectives of the **Regional Geochemical Studies Section** are to carry out geochemical reconnaissance surveys and related orientation/follow-up studies to: (i) provide a national geochemical database and (ii) to develop and improve the methodology and methods of interpretation and data integration. The regional survey data are used by industry in mineral exploration and by governments as a database for resource assessments. The data can be further applied to assist geological mapping in covered areas and to provide relevant information for the investigation of environmental and public health concerns.

To meet these objectives the Section undertakes the following activities:

- (a) conducts regional geochemical drainage surveys
- (b) conducts reanalysis of archived samples
- (c) conducts orientation, follow-up and interpretive studies related to the regional surveys

which are financed primarily through Mineral Development Agreements (MDA's) with the provinces.

The majority of the Section's resources are directed towards the completion of drainage surveys and releasing the results as part of the National Geochemical Reconnaissance (NGR) program. Approximately two million km² of the Canadian landmass (totalling 9.92 million km²) were covered by the NGR program to the end of 1988. Seven hundred thousand km² have been covered under the 5 year MDA program which began in 1984. Major components of these surveys are contracted-out and it is the role of the Section to provide the geochemical and organizational expertise and monitor all contracted work to ensure quality control in all phases of the surveys. Most of the surveys that have been undertaken are multielement, relatively low density (1 sample/13 km²), helicopter supported, stream and lake sediment and water surveys that are synonymous with the NGR program. In recent years a number of changes and options have been incorporated into the methodology including higher density (1 sample/2 km²) surveys in specific areas of high economic potential; high density infill surveys in previously covered areas to encourage industry follow-up; the addition of Au, Sb, W, Ba and Sn to the core analytical suite, and improvements in data management and presentation.

The following is a summary of the Section's activities during the first 5 years of the MDA program.

- Let 28 sampling contracts
- Coordinated 25 field programs
- Trained 19 collection crews
- Checked 60,000 incoming sediment and water samples
- Monitored the analysis of 98,000 samples (~2.3 million determinations)
- Produced 48 new data open files (~1010 geochemical maps)

Approximately 560,000 acres of mineral claims were staked following publication of results in 1986 and 1987, mostly by individual prospectors and junior mining companies.

Excess sample material from the NGR program has been catalogued and placed in archival storage. Approximately 180,000 samples are now stored and over a recent 4 year period over 17,000 of these samples have been retrieved for additional analysis, primarily for Au and up to 33 additional elements by neutron activation.

More specific studies are conducted to address particular problems of regional surveys. This work, which may be in the form of orientation, follow-up, interpretive, analytical or data presentation studies, is of value in the evaluation of the regional surveys and of exploration strategies. Such studies have included the evaluation of a (1) lake sediments as a medium for Au and PGE exploration, (ii) the use of various stream sediment media in New Brunswick, and (iii) ICP and INAA analytical techniques for the generation of "core" NGR data, (iv) data management and (v) data presentation techniques.

Mineralogy and Chemistry Subdivision (Fig. 1a)

The Mineralogy and Chemistry Subdivision includes the Sample Preparation and Mineral Separation Unit, the Analytical Chemistry Laboratories and the Analytical Methods Development Unit. Other responsibilities of the Subdivision include the GSC Mineralogical Laboratories, the curation of rock collections including the National Mineral and the National Meteorite Collections and the preparation and sale of rock and mineral sets and guidebooks. The total complement in the Subdivision is 47 person years distributed as follows: Mineralogical Laboratories - 10; Sample Preparation Laboratories - 5; Curation of Collections - 4; Rock and Mineral Sets - 5; Analytical Chemistry Laboratories - 15; and Analytical Methods Development - 8. In conformity with its mandate the Committee has focussed its attention on the Sample Preparation and Mineral Separation Analytical Chemistry Laboratories and the Analytical Method Development units.

As a support service facility the *Analytical Chemistry Laboratories* provides analyses for over 40 different elements to scientists in all divisions of the GSC. The most popular service is a "whole rock" (19 element) analytical package, but considerable effort is devoted to non-routine samples requiring special analytical procedures. In 1987-88 the Mineral Resources Division submitted almost 80% of the samples that were analyzed. The Analytical Laboratories are not responsible for the routine analysis of exploration geochemical samples, such as soils and sediments or lithogeochemical samples generated through the MDA programs. This work along with some routine rock analyses is largely contracted out to commercial laboratories.

The facilities and performance of the Analytical Chemistry Laboratories were criticized in the Naldrett Report (1986). However, following acquisition of a simultaneous ICP spectrometer in 1984 and an automated XRF in 1986, the

laboratory is now better equipped to meet its clients needs. More recently, the unit has been providing special analyses using the ICP-MS instrument shared with the Analytical Methods development unit. Despite a slight decline in staff over the same period, there has been a very substantial increase in the number of samples processed annually from 5205 in 1984-85 to 12,795 in 1987-88. The laboratory has established its own quality control procedure by including blanks and approximately 5% random duplication of sample materials.

In 1987 the 50th and 90th percentiles on turnaround time on requests for analysis were 90 and 166 days, respectively. The average turnaround of 90 days is lengthy, but perhaps not unreasonable for the analysis of samples with highly variable and difficult (i.e., highly mineralized) matrices. However, a significant number of requisitions take considerably longer. In many instances the main problem affecting turnaround relates to unexpected surges in the receipt of samples from Survey geologists and previously unannounced requests for specific analyses requiring special procedures.

In the 1986 reorganization most of the staff and resources of the Analytical Laboratories unit of the Resource Geochemistry Subdivision of RGG were regrouped into *Analytical Methods Development* Unit and transferred to the Mineralogy and Chemistry Subdivision. Their mandate was expanded as follows:

- Advancement in analytical methods to support GSC projects and the mineral exploration community;
- Development of methods for other matrices;
- Examination of new technology for application in geo-analysis;
- Improvements in existing technologies, and the securing of patents;
- Transfer of methods developed in-house to industry
- Evaluation of methods used in industry

The unit is well equipped with modern analytical instrumentation including a Sciex ICP Mass Spectrometer (1986), a Yvon-Jobin sequential ICP-ES and several atomic absorption spectrometers. Despite a small staff of 8, advances in analytical geochemistry are being successfully tackled on several fronts and results published. In this context, the various constituencies of GSC clients all regard analytical development by the GSC as an important activity and generally give its output a high rating for relevance. In addition to analytical development, the unit also undertakes a substantial number of "routine" determinations that have not yet been included in the repertoire of the Analytical Chemistry Laboratory.

Sample preparation, including the crushing and pulverizing of rocks for chemical analysis, is the responsibility of the *Sample Preparation and Mineral Separation Unit*. The activities of this relatively small unit (5 person-years), while under the supervision of the Head of

the Mineralogy and Chemistry Subdivision, are conducted with only very limited communication with the Analytical Chemistry and the Analytical Methods Development Units. These relationships are the subject of comment in the following discussion of the Mineralogy and Chemistry Subdivisions.

Mineral Deposits Subdivision (Fig. 1c)

Mineral deposits research is heavily dependent on geochemistry and is applied in research not only within the Geochemistry of Mineral Deposits Section but most of the other Sections within the Subdivision. Geochemical investigations – lithochemical, isotopic, fluid inclusions, etc. – are applied principally to better understand mineral deposits and their environments of formation, but with the expectation that the findings will lead to the definition of detailed geochemical exploration methodology within mineralized systems and, less directly and with less certainty, indicate more regional techniques dependent on an understanding of the geological environment.

Programs in recent years have been directed towards the investigation of gold and platinum group element mineralization in Cordilleran and Canadian Shield settings and have revealed potentially significant relationships between S and Se and PGE's and sulphur, alkaline oxides and gold in specific areas. Other applications have been made in the study of tin and tungsten deposits in the Appalachians and in the investigation of sedimentary basins along the Yukon-NWT border. Joint investigations with personnel from the Geochemical Exploration Subdivision are underway in the Sulphurets district of British Columbia and other investigations have required joint development of analytical methods with chemists in the Analytical Methods Development Unit. One such example of this integration has been the development of analytical techniques for the investigation of samples from the Seafloor Minerals Project off the coast of British Columbia.

It is quite clear from the Committee interviews that several projects within the Mineral Deposits Subdivision have benefitted, and, indeed, have been stimulated by close, integrated involvement with trained geochemists both within and outside the subdivision. Clearly, this integration should be continued and encouraged. The translation of geochemical characteristics outlined by research in mineral deposit environments into practical geochemical exploration methodology is always a significant challenge and should always be highlighted as a prominent objective by GSC management.

Terrain Sciences Division (Fig. 1d)

The application of geochemical methods in research into Quaternary geology problems dates back to the early 1960s. The history of its application in the work of the Terrain Science Division is recorded elsewhere in this report.

Prior to 1986, the main thrust of geochemical research in Terrain Science was through the Sedimentary and Mineral Tracing Group (SMTG). Following the dissolution of this Group, widely spaced till sampling, a methodology developed by SMTG, has been routinely included in mapping programs of the Quaternary Geology Subdivision financed with A-base or MDA funding.

The Quaternary Geology Subdivision has been heavily involved in MDA programs in the Maritime Provinces, Ontario, Manitoba and the N.W.T. with a 1988-89 budget commitment of \$1.35 million. These projects are located in areas having mineral potential but where drift cover is extensive. An additional \$100,000 is allocated for the Quebec Geoscience Program. These figures compare with a budget of \$2.04 million for "A" base programs.

The quality of geochemical data produced during the early years of the MDA programs suffered because of inadequate specifications for sample preparation and analysis in contracts negotiated with commercial laboratories. In more recent years procedures have been developed to remedy these problems through closer coordination and input from personal in the Exploration Geochemical Subdivision. Standard reference samples have been obtained from the Exploration Geochemical Subdivision and more interaction has developed between geochemists from this Subdivision on specific geochemical problems.

The low density till sampling technique developed by the TSD (650 samples/1:250,000 map sheet) is widely used in the MDA survey programs as a standardized procedure to supplement surficial mapping and the definition of till units and the sequence of Pleistocene events. Despite the very low density of some of the TSD sampling programs, strongly anomalous values always receive follow-up attention by private companies and the Quaternary stratigraphic information is of value to industry in the planning and the subsequent interpretation of geochemical exploration programs.

The degree of geochemical input into A-base Quaternary mapping programs is less clear to the Committee because limited geochemical expertise is available to several projects being carried out in the Eastern and North-Central regions. Approximately 13% (5 PY's) of the Quaternary Geology Subdivisions' 1987-88 A-base budget of \$1.75 million (28 PY's) was allocated to acid-rain related studies in southeastern Ontario, to mineral exploration research predominately into the geochemical behavior of gold and PGE's in tills and soils, and to clay mineralogy studies on samples from the Juan de Fuca Ridge.

DEVELOPMENT OF EXPLORATION GEOCHEMICAL ACTIVITIES IN THE EXPLORATION GEOCHEMISTRY AND QUATERNARY GEOLOGY SUBDIVISIONS

A general historical review of the exploration geochemical developments in the GSC presents an informative background to the current distribution of exploration

geochemical activities in the Mineral Resources and Terrain Sciences Divisions and serves to explain some current difficulties.

Prior to 1962, all geochemical research and development in support of mineral exploration in the Geological Survey was pursued by scientists in the Resource Geophysics and Geochemistry and its predecessor Divisions. As noted, these developments in exploration geochemistry included work with stream sediments, soils, stream and spring waters in the Yukon and the Maritime Provinces through the 1950s. The relatively poorly developed drainage patterns and extensive, transported glacial cover in regions of the Canadian Shield dictated a much slower development of exploration techniques in these regions. Geochemists in the Geological Survey commenced biogeochemical research in glaciated environments in 1962, at approximately the same time as the Terrain Science geologists began classical mineralogical and clast studies down ice of the Kirkland Lake gold camp and identified particulate gold in shallow tills. These results and those from orientation studies completed by geochemists in tills over the Louvem deposit in 1969 provided justification for the EGMA program of overburden drilling to sample tills in the thick glacial successions in the Abitibi region in 1971. This program also funded the first regional lake bottom sediment survey (36,000 km²) in the Timmins-Kirkland Lake-Rouyn- Val d'Or region in the same period.

In 1973, the Sedimentology and Mineral Tracing Section of the Terrain Sciences Division embarked on studies of metal distribution in eskers and tills, and in cooperation with Queen's University, the dispersion of metals in lake sediments and waters in glaciated regions. The Sedimentology and Mineral Tracing Group gained world-wide recognition particularly for demonstrating the benefits and the utilization of size-fraction partitioning in till sampling studies.

Near-shore lake sediment sampling was investigated by the Geological Survey in 1972 in the Northwest Territories and applied to large scale reconnaissance surveys (93,000 km² at a site density 1 per 26 km²) in the Bear-Slave region. However, profundal or centre-lake sampling, first developed and utilized in the southern Abitibi survey in 1971 and further evaluated in Newfoundland in 1972, eventually became the preferred technique for the National Geochemical Reconnaissance Program which commenced with regional surveys in Newfoundland in 1973 and in Saskatchewan in 1974.

The Federal/Provincial Uranium Reconnaissance Program (URP) was established in 1975 to provide industry with high quality reconnaissance exploration data to indicate areas having the greatest probability for the location of new uranium deposits and to provide the federal government with national systematic data to serve as a basis for uranium resource appraisal. Stream and lake sediment sampling at a density of 1 per 13 km² formed the geochemical component of this program. With strong urging and support from several provinces, these surveys continued as a revived National Geochemical Reconnaissance program after the federal government ended funding to URP in 1979.

The contrasting scientific philosophies caused by the preference for till sampling in the Sedimentology and Mineral Tracing Group and the preference for drainage sampling (lake sediment and, where applicable, stream sediment sampling) for exploration in glaciated areas by the exploration geochemists became the basis for philosophical differences and rivalry between the Terrain Science and the Resource Geophysics and Geochemistry Division in the mid-1970s. This problem was accentuated by the federal government's allocation of special funds for the Uranium Reconnaissance Program conducted by RGG.

Generally, URP was favourably received with 73% of industrial respondents to a 1977 questionnaire indicating the program to be a proper pursuit of the Federal/Provincial governments. However, there was a strong opposition (50% of the respondents) to Geological Survey of Canada follow-up on the reconnaissance data collected during the program on the grounds that this would be an unwelcome government incursion into the mineral exploration field and would place government in direct competition with industry. Although limited follow-up work was being done, the perceived emphasis on areal coverage resulted in URP being classified by some observers as a routine data gathering program without a research component. This led to philosophical arguments within the GSC that the URP undertaking was inappropriate Survey practice.

The Uranium Reconnaissance and National Geochemical Reconnaissance programs were well received in the private sector and the published information stimulated expanded mineral exploration activity. This experience, along with other factors, prompted the provincial governments (who have vested administrative control over mineral rights in their respective jurisdictions in Canada) to negotiate joint 5 year Mineral Development Agreements (MDA's) with the federal government to expand resource evaluation coverage. These MDA programs commenced in 1984, and progressively through the 1988-89 fiscal year they have become a dominant activity in several GSC Divisions. The commitment of the Exploration Geochemistry Subdivision to MDA's through the Regional Geochemical Studies Section constituted approximately 52% of the Subdivision budget of 3.3 million dollars in 1988-89.

The continually growing appreciation in industry and government (provincial and federal) of the need for a greater understanding of Quaternary stratigraphy in mineral exploration, created the opportunity for the Terrain Sciences Division to participate in the MDA programs and, in 1988-89, 41.5% of the budget of the Quaternary Geology Subdivision (\$3.48 million) was allocated to MDA work.

In keeping with their developed expertise, Quaternary Geology Subdivision's contribution to the MDA projects are concerned mainly with determining the distribution, history and provenance of glacial drift, and demonstrating the use of the geochemistry of glacial drift in mineral exploration. In its contribution, the Exploration Geochemistry Subdivision conducts geochemical drainage surveys to develop and

improve methodology and to provide a high quality, national geochemical data base to promote and support mineral exploration by the private sector.

The Committee has found that the differences in scientific philosophy between the Quaternary Geology and Exploration Geochemistry subdivisions have continued into the period of MDA programs and, with few exceptions, have resulted in somewhat negative competitive rather than positive cooperative attitudes between both scientists and administrators in the two groups. These differences have, no doubt, been heightened through the competition for the additional, available funding under the MDA program.

Clearly, it is the mandate of the Mineral Resources Division to develop concepts and technologies to aid Canadian industry in the search for new resources, and the Committee believes that it would be in the interests of all the clients of the Geological Survey of Canada if activities pertaining specifically to the development of mineral exploration concepts, technologies, and methodologies be the responsibility of the Mineral Resources Division. With respect to exploration geochemical methods, the responsibility for this should be with the Exploration Geochemistry Subdivision.

It is acknowledged that geochemical measurements and investigations in Quaternary geology studies are an important contributor to the definition of the provenance of the variety of glacial facies, and it can be confidently predicted that the contributions of chemistry in terrain mapping will increase with time. It is also acknowledged that the glacial erosion of a mineral deposit will create a distinctive and readily identifiable signature in the resulting glacial facies which will aid in the evaluation and clarification of developing ideas on the source of these facies and the processes involved in their formation. In this context, till geochemistry becomes an important accessory tool and a surrogate for mineralogy. However, the target signatures and the sampling strategies most suited to the resolution of provenance in the Quaternary succession contrast significantly, in a majority of situations, with the sampling strategies and metal associations necessary for effective mineral exploration in the same terrain. Thus, to achieve both of these objectives in the same reconnaissance program necessitates a compromise of efficiencies.

To reaffirm that exploration geochemical methodological, conceptual and technological development is the mandate of the Exploration Geochemistry Subdivision will not detract in any way from the economic importance of the study of Quaternary geology. This has been demonstrated many times and the importance of an understanding of Quaternary geology in relation to petroleum exploration, pipeline, and other commercial construction as well as its value in assisting in the interpretation of mineral exploration data and in identifying and solving natural hazard and environmental problems is strongly endorsed by the Committee.

It is, therefore, recommended that future geochemical programs of the Quaternary Geology and Exploration Geochemistry Subdivisions be critically evaluated in terms of the Divisional and Subdivisional objectives and that

personnel with developed expertise in the determination of provenance and genesis of Quaternary deposits as applied in geochemical exploration be transferred to the Exploration Geochemistry Subdivision. These personnel should be integrated into a recognized group within the Exploration Geochemistry Subdivision concerned with drift studies and the geochemistry of the surficial environment.

In presenting these recommendations pertaining to exploration geochemical activities in the Geological Survey of Canada, the Committee wishes to emphasize that, in no way, should they be interpreted as a negative evaluation of the importance or the quality of the work of the Terrain Science Division.

THE EFFECT OF CHANGES IN THE ADMINISTRATION OF THE EXPLORATION GEOCHEMISTRY SUBDIVISION AND PROPOSED SOLUTIONS TO IDENTIFIED PROBLEMS

Prior to the 1986 and 1987 reorganizations of the Geological Survey, the Director of the Resource Geophysics and Geochemistry Division (RGG) reported directly to the Director-General, the senior officer in the GSC management structure. Following reorganization, the mineral exploration-oriented subdivisions were separated from the most senior GSC officer by an additional level of administration and decision-making.

Following numerous interviews, it became apparent to the Committee that the reorganizations had a variable impact on personnel in the Exploration Geochemistry Subdivision.

The changes, particularly the 1986 technically driven change and the implied de-emphasis of applied research in mineral exploration methodology within the GSC, came unheralded and were very unsettling to some of the longer term employees of RGG. The transfer of the administrative control of the geochemical exploration laboratories into the Mineralogical and Chemical Subdivision and a reduction in the allocated financial resources compounded the disappointment and loss of identity felt by these personnel who had previously worked closely at the project level with the laboratory chemists in the development of analytical methods and had enjoyed greater financial support. In addition, and in part because of the new administrative structure, effective communication with management in the Division declined.

A management proposal to form a multidisciplinary exploration technology development subdivision within the Mineral Resources Division to include geochemists, geophysicists, and laboratory personnel, presented before the 1987 restructuring but after the 1986 reorganization, was rejected.

Two geochemists, whose research interests included detailed investigations and process studies, accepted an invitation to join the Mineral Deposits Subdivision to conduct lithogeochemical research into the genesis of mineral deposits and to study ore fluids in the offshore.

Exploration geochemists joining the Subdivision either during or immediately after the reorganizations have not been significantly affected and work effectively, commonly in close coordination with scientists in other subdivisions.

The inclusion of the Mathematical Applications in Geology Section as part of the reorganization is generally considered to be a move of convenience. While some of the work of this small but nationally and internationally well-regarded mathematical group does not relate directly to exploration geochemistry, the expertise in this group in multivariate analysis, image analysis and integration of exploration data sets is of critical importance in the development of geochemical and other earth science interpretational procedures. The effectiveness of the Mathematical Section has not been diminished by the reorganization, and the group is successfully integrating its expertise with scientists in other subdivisions through well-developed interpersonal skills.

The Analytical Laboratories unit of the Resource Geochemistry Division of RGG became re-established as the Analytical Methods Development unit within the Mineralogy and Chemistry Subdivision. These chemists now serve the whole Geological Survey Section and have less contact with senior management than previously. With some personnel, professional satisfaction and productive interaction has declined. The main work of the Section is the development of new analytical techniques to meet specific requirements of research scientists. The greater part of the R and D work is in collaboration with the Exploration Geochemistry Subdivision, and once developed, the analytical techniques are transferred to the commercial sector for routine analysis of GSC samples. Other important work includes the monitoring of routine analytical work on MDA geochemical samples performed in the private sector.

It is apparent from these summaries that the Exploration Geochemistry Subdivision in addition to losing expertise and resources has lost considerable professional momentum and morale as a result of the reorganization within the Geological Survey. The perceived de-emphasis of applied exploration research within the Geological Survey, the reluctance among longer-term scientists to accept change, the loss of communication and scientific leadership and the inability of management to develop the necessary flexibility and initiatives to be influential in the new Survey organization has led to a pronounced lack of focus and mission within the Exploration Geochemistry Subdivision.

Because geochemical methods are effective and well-established in Canadian mineral exploration the Advisory Committee strongly recommends (a) that the Geological Survey of Canada reaffirms its important role in sustaining a vigorous and active program of research and development of exploration geochemical concepts, technologies and methodologies through The Exploration Geochemistry Subdivision, and (b) in addition, the Exploration Geochemistry Subdivision takes full advantage of the opportunity and setting within the Geological Survey of Canada to revitalize the overall geochemical program within the framework of a long-term national mapping

program and through integrated involvement in the investigation of exploration problems, advance the development of exploration science and technology in support of the mineral industry. The situation presents an exciting challenge for innovative personnel management and scientific leadership.

In addition, it is clear that within the Subdivision (and, more generally, within the Mineral Resources Division), there is (a) a dangerously low level of technical support reflected in the imbalance between the number of research scientists and the number of junior scientists and technical assistants and (b), a perceived ceiling on advancement due to existing limitations on the number of senior research scientists. In concert with the above recommendations, the Committee urges management to address these personnel issues by providing proper recognition and assurance and additional means of technical support.

ENVIRONMENTAL GEOCHEMISTRY

A common theme among the numerous presentations to the Committee has been the recommendation that the GSC redirect some of its resources into the fields of environmental earth science. It is now much more widely appreciated that the geoscience and particularly the geochemical database, contains a wealth of information fundamental to the understanding of the environment. This view is shared by the Committee.

The Department of Energy, Mines and Resources has been concerned with environmental issues for many years and, in 1973, established an Office of Environmental Affairs to coordinate its efforts with other federal and provincial agencies and the mineral industry.

Procedures for pollution prevention during the development and exploration of mineral resources have been incorporated into waste-management programs. Research has been carried out into alternative, potentially less polluting energy sources, and also on improved technologies for processing and extracting metals, both leading to more efficient uses of resources. In addition, guidelines were developed for environmental protection.

It is anticipated that in the foreseeable future, EMR will intensify its involvement in these activities and in the implementation of a national "sustainable development" program.

Traditionally, within EMR, the Geological Survey of Canada has not had a mandate to pursue environmental studies and, to this time, has had little involvement with environmental issues despite the fact that a considerable amount of relevant information is routinely collected during GSC programs and added to the geoscience data base.

However, in May 1988, the Minister of Energy Mines and Resources reaffirmed EMR's commitment to the environment and this commitment has become embodied in the GSC Sector's strategic planning prepared in December 1988. The plan recognizes an environmental geology program focussing on national and local problems as a desirable new initiative to be implemented in the 1989-90

fiscal year. The favoured approach to these environmental issues would be through multi-disciplinary and problem oriented programs.

In addition, a recent report discussing future directions of the Geological Survey of Canada (Lindseth et al., 1989) supports this involvement. The Canadian Geoscience Council Review Committee cites the increasingly evident interdependence of geological processes and natural and induced hazards, including the pollution of ocean and groundwaters, in support of its recommended creation of a Health and Environmental Division within the GSC.

At the same time, the Terrain Science Division has proposed future research to meet the objectives of the "International Geosphere-Biosphere Program: A Study of Global Change" directed by the Royal Society of Canada. However, this new research thrust, although requiring a conscious evaluation of environmental matters will not entail substantial changes in the TSD work programs.

It is with this background that the GSC geochemical contribution to environmental programs has to be examined and evaluated.

There is a near-unanimous consensus among research scientists and management that GSC input into the study of environmental problems is desirable. This is a reflection of the current global awareness and the need for basic geochemical baseline data to identify environmental problems and gauge environmental change.

The critical understanding of complex geochemical processes operative in terrestrial environments can only be contributed by geochemists through the study of regional geochemical data from a variety of naturally occurring media. However, there is no consensus on the level or form of geochemical involvement. Suggestions range from a modest increase in the measurement of chemical parameters on samples collected in ongoing programs, to active research programs in applied environmental geochemistry. The scale of recommended activities vary from intensive site studies to extensive, low density geochemical atlas coverages. All these kinds of activity, when pursued by other national geological surveys, particularly in Finland and Great Britain, have proven to be useful in environmental and epidemiological studies.

If the GSC does involve itself in environmental research, GSC scientists state that integrated process-oriented programs could be developed which would involve the geochemical group in (for example) "... a study of transport processes in glaciated environments (to) include the primary dispersion step by glacial action, the weathering of dispersed minerals, the transport of the weathered products by water or by gravity, the role of biota in this transport process, the role of higher vegetation, the importance of the organic cycle..." Such activities would fit well into a Health and Environmental Division within the GSC as proposed by the Lindseth report.

In response to the questionnaire distributed by this committee, respondents from universities and governments have indicated a clear interest in the GSC pursuing

environmental studies. A majority of industry and laboratory respondents also support this activity even though all four constituencies consider the field to be of only moderate relevance and importance compared with the GSC's traditional mandates. (Table 17, Figs 8,9)

The present level of collaboration between the GSC and other environmentally oriented federal agencies appears to be punctual, ad hoc, and based on personal contact. There is no formal liaison with the Department of the Environment, or with Forestry except for the ad hoc Acid Rain and Maple Dieback programs. Yet, the representatives of DOE interviewed by the Committee stated they would welcome collaborative programs with the GSC since DOE lacks scientists with earth science expertise. The Department of the Environment's primary concern is with ground and surface waters, and regularly attempts correlation of their data with published bedrock and surficial geological data as a surrogate for geochemical data on the terrestrial environment. Enquiry has revealed that the current sampling and analytical strategies used for routine regional geochemical surveys by the GSC would not be readily useable by environmental scientists, partly (1) because of their need for higher density surveys, partly (2) because they require data on elements not always included in mineral exploration programs (e.g., Al, Se and Hg), partly (3) because their interest is in "readily available metals" rather than the quantities identified following more rigorous chemical extraction, and partly, (4) because some of the standardized environmental analytical procedures specified by regulation are not the preferred techniques for mineral exploration surveys. GSC management should also be aware that the geographical areas of interest for DOE are more commonly urban areas and peripheral regions which may be locations of some industrial mineral installations but not economically attractive for metallic mineral discovery and development.

Scientists in the Health Protection Branch of the Department of Health and Welfare whose prime field of responsibility is domestic well-waters, are familiar with the GSC geochemical programs. Particularly, they are interested in overburden geochemistry data and their relationship to groundwater quality. Again, there is no formal liaison but there is a desire and a need for greater interaction and increased communication with geochemists within the Geological Survey although it can be anticipated that specific needs and requirements of Health and Welfare will vary from those of the geochemical mineral exploration survey in ways analogous to the DOE needs already described.

A move, within the GSC, towards a proactive role in environmental geochemistry will require (a) the employment of scientific personnel experienced in groundwater hydrology and hydrogeochemistry – areas of expertise and responsibility that were withdrawn from the GSC and transferred to DOE many years ago – and (b) the acquisition of additional field equipment and laboratory facilities to provide pertinent samples and analyses of relevance in environmental studies. More seriously, however, it is predicted that the necessary reallocation of financial and scientific resources within the GSC will inevitably lead to a dilution of expertise, energy and funds directed towards the

traditional and important mineral applications of geochemistry. Not only will this de-emphasis affect the design and content of the geochemical exploration field programs but will predictably influence and probably overwhelm the present analytical development programs.

Consequently, because the geographic areas of interest and the sampling and analytical requirements for environmental surveys in many instances, will conflict with existing survey programs and procedures, the Committee does not recommend that the GSC should become proactive in environmentally-related geochemical activities since this will divert considerable resources from the established and important missions of providing pertinent information for use in mineral exploration and resource assessment.

While being firm in its recommendations regarding a proactive role by the GSC in detailed environmental surveys, the Advisory Committee, based on its observations of worldwide geochemical research, acknowledges that properly planned, regional exploration geochemical surveys of lake sediments, till and other media can provide valuable baseline data relating to mineral resources, surficial geology and the environment as illustrated by the following two examples:

- (i) GSC scientists, in a study of the geochemical and compositional characteristics of glacial deposits over Precambrian crystalline rocks from Ottawa to Georgian Bay, have revealed the compositional links between bedrock, glacial drift and modern ecosystems represented by glacial lakes demonstrating that the chemical characteristics of lakes and their probable sensitivity to acid rain are predictable from a study of glacial and bedrock geology. The authors emphasize that the anthropogenic contribution of trace elements through acid rain (or any other cause) cannot be evaluated without reference to the same, local, entirely natural, geochemical variations which, in turn, commonly and frequently reflect mineralization potential.
- (ii) Other countries, particularly Norway, Sweden and Finland, the United Kingdom and West Germany have collectively or individually conducted regional sampling programs involving a variety of media at sample densities varying from 1 sample/km² through 1 sample/300km². The results of these surveys have been published as *geochemical atlases* portraying natural patterns of distribution of a variety of elements. Although the merits and the usefulness of these regional data bases have been debated several times, they are now widely regarded as bold, innovative and extremely rewarding enterprises. Not only have the programs been significant in terms of geology and mineral deposit distribution, they have stimulated technical development and generated economic benefits through technology transfer. Furthermore, the atlas-type data are also now regarded to be of inestimable value to many other disciplines particularly as data bases for geochemical, epidemiological and other environmental research, agriculture and forestry.

It is therefore recommended that the GSC initiate a working group of GSC, DOE, Health and Welfare and other appropriate personnel from government and the private sector which would (a) be appraised of the extent and the purpose of the current geochemical data base generated through GSC programs (b) define the value of this existing geochemical data base to environmentally oriented scientific groups, and (c) examine how the existing exploration geochemical sampling and analytical protocols can be supplemented to provide useful environmentally-related data without compromising in any way the quality and quantity of output and the resources needed to sustain and continually improve the GSC's contribution to the mineral exploration industry through geochemical mapping and research.

The National Geochemical Reconnaissance (NGR) program, conducted at sample densities ranging from 1/2 km² to 1/13.5 km², obviously provides data of environmental significance in addition to its primary purpose of expanding the geological and mineral resource databases. To date, the NGR, which commenced in 1975, has covered approximately 20% of Canada's 9,976,000 km² area. Even fulfilling the original intent of surveying only those areas of probable and possible mineral potential, it is estimated, that at the funding levels so far provided, the intended coverage would take the Geological Survey an additional 40-50 years.

Based on the Scandinavian experience, the Committee recommends to the proposed working group that a two-tiered approach to the geochemical mapping of Canada (described in more detail in the manuscript by Dr. Davenport, included as Appendix (B)) be established to include, in addition to the ongoing NGR program, an ultra-low density, multi-media, country-wide survey (1 sample set / 300-500 km²). As Dr. Davenport predicts, the ultra-low density surveys would (a) provide a relatively rapid, multifaceted overview of landscape geochemistry to address more fundamental geological, mineral resource and general environmental questions, (b) create the geochemical framework to which the more detailed (NGR) survey data could be related and, at the same time, (c) provide the basic regional chemical database for follow-up applied environmental studies requiring sampling and analytical procedures not having a direct mineral resource assessment application.

SURVEY OF OPINION ON GEOCHEMICAL EXPLORATION ACTIVITIES OF THE GEOLOGICAL SURVEY OF CANADA

In order to gather reliable information to meet its terms of reference, the Committee conducted a survey to determine how well the geochemical group at the GSC satisfies the needs of its various client constituencies and how these constituencies perceive the activities and performance of the GSC scientists.

A questionnaire was sent to a selected group of knowledgeable individuals, experienced in the science of geochemistry, employed (a) in the exploration and mining industry, (b) as consultants to the exploration industry,

(c) in the Universities, (d) by Provincial governments, and (e) by commercial laboratories offering geochemical analytical services.

The questionnaire, a copy of which is included in Appendix C, was divided into four sections. (1) The first section (Part A) requested information on the respondent's name and affiliation. Responses to this section were held strictly confidential to the Committee. (2) The second section (Part B) was aimed at eliciting some background information on the respondents with regard to their own use and interest in a range of geochemical activities. (3) The third part of the questionnaire (Part C) sought a measure of the awareness of respondents of the activities and output of the various geochemical groups at the GSC and a determination of how well this work serves the client's needs. (4) The fourth part of the questionnaire (Part D) asked for opinions on (i) the various facets of geochemistry which the groups perceived to be appropriate activities for the GSC and their relevance to their own work and needs, (ii) what alternative sources of geochemical information were available or should be available, and (iii) a difficult question for most respondents, an assessment of the performance of the various geochemically oriented groups in the GSC.

In addition, Parts E, F and G directed individually to university, government and laboratory respondents asked questions specifically directed to areas of interaction with the GSC e.g., joint regional funding and analytical contracting. No polling of the environment constituency was undertaken as the GSC's current involvement in this field is minimal. Likewise no questionnaires were sent to oil industry users of geochemical data.

A total of 163 questionnaires were distributed and 103 were returned for a response of 63.2% (Table 2). Although the absolute number of respondents in the government, university and laboratory groups is small, (Table 2), it should be kept in mind that they represent a high proportion of the geochemically-active population in these constituencies in Canada. The relatively low level of response from laboratories arises because although there are many laboratories doing production geochemical work, few offer the full range of services obtainable from nationally represented laboratories.

Table 2. Response to questionnaire

	OUT	IN	%	
<u>Exploration Industry</u>				
Large producers	32	28	87	71%
Small Producers	16	10	62	
Exploration Companies	21	15	71	
Consulting Companies	15	7	46	
Universities	15	10	66	66%
Governments	21	18	85	85%
Laboratories	43	15	34	34%
	163	103	63.2	

The very extensive amount of information provided by the questionnaire has, of necessity, been condensed and simplified for the purpose of this report.

Several of the questions included in the geochemical exploration questionnaire, particularly those relating to output, are similar to those included in the questionnaire designed for the earlier CGC report "An Examination of the Output of the Geological Survey of Canada" published as GSC Paper 82-6 Part 1. (Coope et al., 1983). Although cross references to this Paper are made in this section, GSC management is urged to make its own comparison of the results from the two surveys and the conclusions and recommendations of the two advisory committees.

Table 3. Geographic area of interest of respondents

	<u>Industry</u> n=60 %	<u>University</u> n=10 %	<u>Government</u> n=18 %	<u>Laboratory</u> n=15 %
Western Cordillera	67	50	39	80
W. Sediment Basin	10	0	50	60
Arctic Islands	5	20	33	47
Precambrian Shield	77	60	78	80
Eastern Lowlands	11	0	28	47
Appalachians	31	30	61	53
Canadian Offshore	0	0	5	40
Outside Canada	42	60	0	67

Table 4. Purpose of geochemical activity

	<u>Industry</u> n=60 %	<u>University</u> n=10 %	<u>Government</u> n=18 %	<u>Laboratory</u> n=15 %
Mineral Discovery	100	70	67	60
Method Development	18	70	50	47
Environmental Studies	11	20	38	37
Terrain Science Studies	5	0	34	14
Mineral Deposits Research	38	80	72	37
Geol. Mapping/Research	28	20	55	37

In the following commentary, an individual's lack of response to part of the questionnaire has been interpreted as an expression of no opinion.

It is believed that all significant features of the relationship between GSC geochemical activities and the industry, government and academic people who use the output from those activities have been captured by the questionnaire, and the high level of response to the questionnaire survey reflects the concern and interest of the client communities in the geochemical activities of the GSC.

Profile of the GSC's Geochemical Clientele (Questions B-3, B-7)

Replies to this part of the questionnaire were received from clients in all four main constituencies spread across the country. The concentration of respondents' activities mainly in the Shield, Cordilleran and Appalachian areas is a reflection of demography, responsibility and mineral exploration activity (Table 3).

The principal purpose of the geochemical activities of all the groups polled was stated to be the discovery of new mineral deposits (Table 4). This is followed by mineral deposits research, weighted heavily by respondents from universities and governments. In addition, government agencies directed a significant amount of their geochemical effort to geological mapping and the development of new geochemical methods. Method development also accounted for a large part of the geochemical activities of universities and, not surprisingly, laboratories. Among the respondents, only government groups are actively using geochemical techniques in Terrain Science studies to any degree.

Only moderate effort is being devoted to the application of geochemistry to environmental studies and acid rain was mentioned specifically by only one government respondent.

Table 5. Interest and use of geochemistry by GSC clientele

	<u>Industry</u> n=60 %		<u>University</u> n=10 %		<u>Government</u> n=18 %		<u>Laboratory</u> n=15 %	
	Interest	Use	Interest	Use	Interest	Use	Interest	Use
Regional Stream Sampling	11	67	60	10	38	38	7	60
Regional Lake Sampling	23	48	50	20	22	38	13	53
Soil Sampling	8	89	30	50	11	50	7	66
Whole Rock Sampling	13	75	20	70	0	67	0	80
Trace Elements in Rocks	7	89	20	80	0	50	0	75
Hydrogeochemistry	13	11	20	30	0	38	20	46
Gas Geochemistry	13	5	30	0	22	11	0	7
Biogeochemistry	28	18	50	20	34	28	13	53
Heavy Mineral Surveys	13	67	40	30	11	38	0	53
Drift (including Till) Samples	20	55	50	20	5	55	0	66
Stable Isotopes	20	7	10	20	5	22	0	7
Fluid Inclusions	25	15	30	10	5	11	0	7
Organic Geochemistry	8	5	10	10	28	0	0	13
Envirogeochemistry	11	8	0	30	34	5	7	40

This is understandable because the GSC's principal client groups at the present time do not include a significant group whose interest is environmental studies. The environment constituency is currently largely unaware of the GSC's geochemical activities and data banks. This can be expected to change as communication between groups such as Health and Welfare, Department of Environment, etc., and the GSC increases.

It can be concluded that an appropriate client group was targeted and responded to the questionnaire.

Spectrum of Interest and Use of Geochemical Information (Questions B-4, B-5, B-6)

In the following tabulation, (Table 5), interest and use of various applications of geochemistry by the respondents are reported as a percentage of replies received. Lithogeochemistry is characterized by strong interest and high utilization for both major and trace elements, for all four client groups. It is an observation of the Committee that the GSC lacks any substantial effort in this domain except as it relates to ore deposit modelling.

Similar high levels of activity were reported by industry and laboratory clientele for regional sampling using both stream and lake samples, soil sampling, glacial drift sampling and heavy mineral sampling. This reflects the close symbiosis of the exploration community and the commercial laboratories.

Biogeochemistry and hydrogeochemistry form a modest area of activity for most of the client groups and constitutes an important source of samples for the laboratories. Except for the laboratory group, more respondents expressed a greater level of interest in biogeochemistry than actually use the technique.

Other geochemical applications have significantly lower levels of interest and use amongst the client community including gas and organic geochemistry, stable isotopes and fluid inclusion studies. Interest in stable isotopes and fluid inclusion studies well exceeds current usage among industry users

This distribution of activities by industry respondents was paralleled by responses to a later question (D-2) regarding the relevance of these various categories of work. This supports the credibility of the response. Most industry respondents use between 3 and 7 different techniques in the course of their exploration work. Few use less than three or more than eight techniques. This indicates a widespread and selective usage of what might be called standard media such as soil, stream

sediments, rocks and heavy minerals but an ignorance of or a reluctance to use other sample media requiring more sophisticated collection, analysis or interpretation.

All the universities and seven out of ten government agencies operate geochemical laboratories compared to only one out of five of the companies represented by the industry respondents. Professional geochemists are employed by just about half the government agencies compared to only 20% for industry and university groups and only 10% for laboratories (Table 6). In all cases these professionals actually collect only a minor number of samples themselves but are responsible for the work of the geologists and trained temporary employees who collect the majority of geochemical samples. Contractors gather over half the samples collected by government groups, a reflection of the current high level of Federal-Provincial regional geochemical work (MDA programs).

Communication and Utilization of GSC Geochemical Output

The geochemical activities of the diverse group of GSC staff are communicated to the user public principally through the medium of papers and maps in both GSC publications and outside journals. Informal and verbal communication is also important in making the client communities aware of the wide scope of geochemical investigations carried out by the GSC. The principal sources of geochemical information were listed in the questionnaire and respondents were asked if they were aware of this variety of sources of GSC geochemical information.

There is a significant lack of awareness of the GSC's geochemical activities within the client community (Table 7).

Whilst only 9% of industry respondents were unaware of the extent of geochemical activities at the GSC a significantly larger proportion of the other clients lacked this knowledge, reaching 80% for laboratories. Ignorance of the type of work carried out by the geochemically active sub-divisions was much higher for all respondent groups reaching 80% and 93% for universities and laboratories.

The organic geochemistry work being done at the Institute of Sedimentary and Petroleum Geology in Calgary is virtually unknown to the respondents to the committee's questionnaire. This laboratory serves GSC petroleum geology activity and representatives of the oil industry were not polled.

One respondent acknowledged that filling in the questionnaire had made him "considerably more aware of the things the GSC is doing". Another lamented that he was

Table 6. Sample collection personnel

	Industry n=60 %	University n=10 %	Government n=18 %	Laboratory n=15 %
Geochemists	23	20	44	10
Geologists	92	30	37	20
Full-Time Trainees	46	20	68	25
Part-Time Trainees	73	20	62	25
Contractors	40	10	52	20

Table 7. Awareness of GSC geochemical activity

	Industry n=60 %	University n=10 %	Government n=18 %	Laboratory n=15 %
Unaware of extent	9	30	16	80
Unaware of type of work	30	80	28	93
Non-receipt of circular	30	70	44	66

Table 8. Medium of geochemical output most commonly used

	Industry n=60 %	University n=10 %	Government n=18 %	Laboratory n=15 %
Print	64	70	61	33
Fiche	6	0	0	0
Tape	2	0	11	0
Disc	7	0	16	0

Table 9. Most often used sources of GSC geochemical data

	Industry n=60 %	University n=10 %	Government n=18 %	Laboratory n=15* %
<u>Library</u>				
Company Library	58	--	5	13
University Library	10	90	11	6
Government Library	27	10	72	27
Public Library	2	0	0	0
Personal Library	17	60	22	6
* high percentage of non-response				

Table 10. Personal communication within GSC geochemical staff

	Industry n=60		University n=10		Government n=18		Laboratory n=15	
	Infreq.	Often	Infreq.	Often	Infreq.	Often	Infreq.	Often
Field	46	7	40	20	44	5	13	0
GSC Office	56	7	50	0	55	6	6	27
Workshops, etc.	54	25	30	50	40	19	34	34
Telephone	56	10	60	20	72	23	40	27
Mail	34	3	50	10	55	22	40	0

"unfamiliar with the GSC staff who conduct geochemical studies, their specific function or the investigations they are responsible for."

Surprisingly, the GSC's Monthly Information circular is received by very few of the responding groups; even in the industry group this information is not received by one in five respondents whether from large or small producers, exploration companies or consultants (Table 7). This is a significant group of people in the exploration industry who are not reminded by this means of the ongoing reporting by the GSC staff. A number of respondents commented on a perceived lack of awareness of GSC geochemical activities and urged a better public relations effort. This may represent a large number of individuals since the circulars which go to companies are seen by many people.

To this general lack of awareness of the GSC's geochemical activities can be attributed the rather high percentage of respondents who declined to answer some of the committee's questions, further evidence of the credibility of the positive responses.

It is clear that the medium by which geochemical output is distributed to the public has an influence on the intensity of its utilization. Printed output is far and away the most often used medium, reflecting tradition and convenience (Table 8). Information on microfiche or computer tapes is hardly used at all. In the case of tapes this is probably related to the unavailability of tape-reading hardware to the average client or a general unawareness of the availability of geochemical

Table 11. Frequency of use of geochemical output

Group/Output	At Least Monthly %	At Least Yearly %	Less than Yearly %	Never %	No Opinion %
Industry n=60					
Formal publications	26	59	11	2	2
Open Files	21	63	8	5	3
Outside journals	13	34	36	13	3
Unpublished Output	2	43	31	21	3
University n=10					
Formal publications	10	60	30	0	0
Open Files	0	40	60	0	0
Outside journals	30	60	10	0	0
Unpublished Output	0	20	40	0	10
Government n=18					
Formal publications	28	50	22	0	0
Open Files	11	50	33	6	0
Outside journals	11	50	28	11	0
Unpublished Output	6	38	34	22	0
Laboratory n=15*					
Formal publications	20	40	13	7	20
Open Files	13	20	27	13	27
Outside journals	13	53	7	0	26
Unpublished Output	7	20	20	20	33
* High level of non-response					

data in this format. Fiches have been distributed with publications, particularly open files, for some years. The low utilization of fiches may reflect a general lack of use of this technology in the user community, although it has the significant advantage of being able to deliver graphic representation of data and is conveniently portable. There is an increasing utilization of computer discs following the introduction of this type of data transfer by the GSC in 1987.

As Coope found in his survey of GSC output in 1982, the principal source of GSC information used by the groups polled was the library maintained by their employer or their personal library (Table 9). Another source used by a significant minority of exploration people was the library usually found in the GSC's regional offices. This source is of particular value to small companies and individuals who cannot afford to buy all the GSC publications they need.

"The best access to GSC data and more importantly non-published data, opinions, ideas, etc., is to go to Ottawa and chat to the relevant guy(s), ladies, in the divided maze," was the advice of one respondent.

Personal communication between the client community and the GSC's geochemical staff through the various contact opportunities is infrequent (Table 10). It is only at workshops and conferences that a notable proportion of the GSC's customers make contact with the GSC geochemical staff. It may be argued that the current level of personal contact is adequate and realistic but at least one industry respondent felt that contact in the field could be improved with mutual benefit.

The lack of a GSC office in Quebec was said to be one reason for lack of communication in that province. This particular point is currently being addressed by the

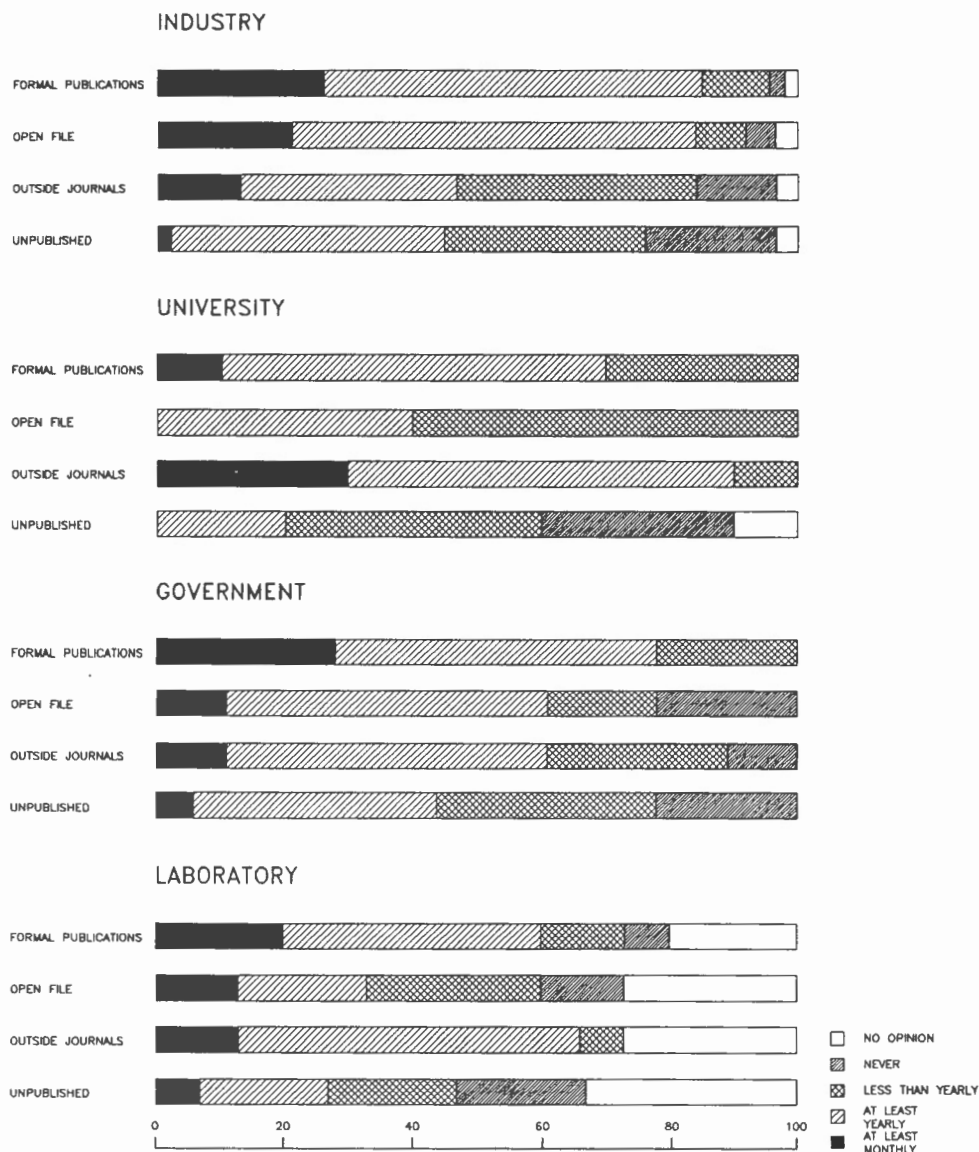


Figure 2. Frequency of use of geochemical output.

establishment of an office in that Province. Another respondent asked why there is no GSC geochemist in Vancouver. This suggests that users of geochemical techniques would appreciate the closer liaison with their colleagues in the GSC which would be achieved by staffing regional offices with a geochemist. "The GSC should publicize more that they are open and hospitable and look forward to people asking questions and looking for expertise."

The published geochemical output of the various sub-divisions of the GSC takes many forms ranging from formal Memoirs, Papers and Bulletins and through Open File Reports which are designed to bring new and current information quickly to the user community. GSC staff members also contribute papers on their geochemical work to international journals of high standing. In addition to these more formal channels of communication a considerable amount of information is disseminated through participation in symposia and workshops and other meetings both in Canada and overseas. The committee sought to assess the frequency with which the various types of geochemical information is used by their clients, its timeliness, usefulness, relevance and quality. The four categories of information referred to above were used: formal publications, open files, outside journals and unpublished output.

Frequency of Use (Question C-3)

GSC geochemical data in the form of Open Files, outside journals or Formal Publications are used by a high proportion of respondents at least once a year (Table 11, Fig. 2). Formal publications and open files are used at least monthly by 10-30% of the industry, government and laboratory sectors

whilst universities make at least monthly use of information appearing in outside journals. Unpublished information is less frequently used than the other sources of information.

Timeliness and Reliability/Scientific Quality (Question C-3)

A substantial proportion of respondents from all the groups polled declined to express an opinion on the timeliness and reliability/scientific quality of GSC geochemical output (Tables 12 and 13; Figs. 3 and 4). Of those who did express an opinion, it is clear that the geochemical work of the GSC is extremely highly regarded by all the client groups, and the majority in most cases, the timeliness of geochemical output was rated satisfactory or very satisfactory.

Significant comments include: "The quality of GSC geochemical data is beyond reproach, as always. The turnaround time could be better" and "The quality of GSC publications is uniformly high but the quantity of formal publications (where we learn of research advances) is unacceptably low" and "With the exception of some prolific individuals the majority of geochemists conduct interesting and relevant studies which, if published, are produced at least several years after the study was performed."

Satisfaction of Client Needs (Question C-4)

When asked how well GSC geochemical data meets their needs all four groups responded favourably with fewer than 20% finding the output in all formats less than acceptable (Table 14; Fig. 5). It should be noted that one third of laboratory respondents declined to comment on this question. Industry and government groups were particularly satisfied with the GSC's Open File output which reflects support for

Table 12. Timeliness of GSC geochemical output

Group/Output	Very Satisfied %	Satisfied %	Unsatisfied %	Very Unsatisfied %	No Opinion/ No Response %
Industry n=60					
Formal Publications	5	50	20	7	18
Open Files	15	62	8	0	15
Outside Journals	5	44	5	0	46
Unpublished	10	43	3	0	44
University n=10					
Formal Publications	20	70	10	0	10
Open Files	30	50	10	0	10
Outside Journals	10	50	0	10	30
Unpublished	10	20	0	0	70
Government n=18					
Formal Publications	11	56	11	0	22
Open Files	28	50	5	0	17
Outside Journals	17	50	5	0	28
Unpublished	11	39	5	0	45
Laboratory n=15					
Formal Publications	7	27	13	0	53
Open Files	0	33	7	0	60
Outside Journals	7	20	13	7	53
Unpublished	7	27	0	0	66

the regional geochemical reconnaissance surveys. The GSC work published in outside journals was, by comparison, less satisfactory in filling the needs of the client groups. This echoes concerns expressed in answers to previous questions. Overall, the responses indicate that the client groups feel their needs are well served by the GSC's geochemical output.

making a judgement on this attribute of GSC geochemistry. Of those who did express an opinion, the universities proportionally had the most positive view of GSC productivity. A significant proportion of the industry group, indicated that they were only partially satisfied with the GSC's productivity.

Productivity Based on GSC Geochemical Output (Question C-5)

With the exception of the university group, this question on geochemical productivity resulted in a relatively high level of no opinion responses even from the important industry constituency (Table 15, Fig. 6). This probably reflects the honest difficulty the members of the user public have in

Use and Application (Question C-3)

The questionnaire reveals that the principal use of all forms of GSC geochemical output is as a source of data (Table 16, Fig. 7). The exploration companies and universities also use the output in formal publications, and open files to generate exploration ideas. Laboratories find the most useful information on analytical techniques mainly in outside journals and formal publications and unpublished sources. GSC geochemical data is used to a lesser extent to develop

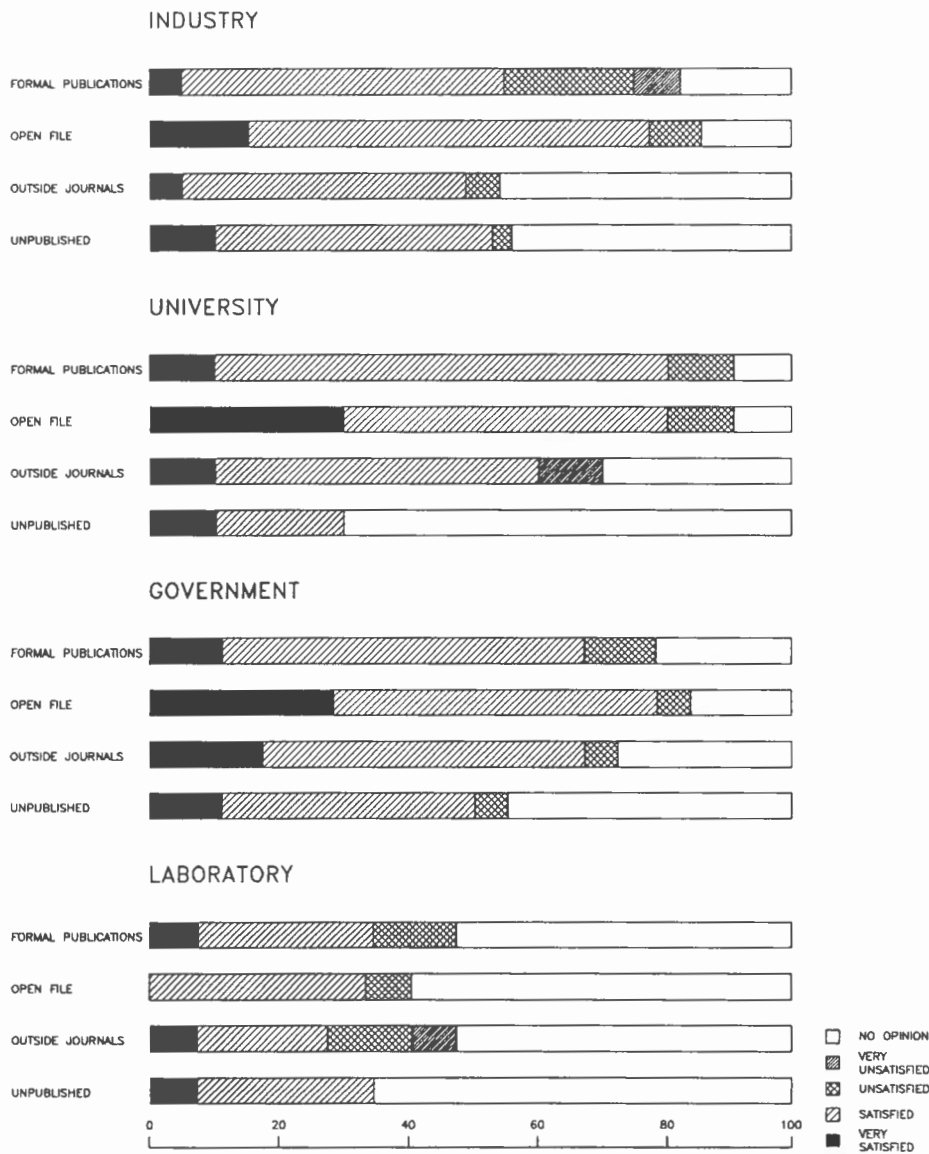


Figure 3. Timeliness of GSC geochemical output.

field methodology and interpretation techniques. The following comment on the difficulty of some respondents in assimilating numerical data sets and developing their field methods and interpretations. "The usefulness of an open file would be considerably enhanced if the geochemist responsible for its publication could devote some time to evaluating and commenting on the data rather than merely presenting it in tabular form."

The final section of the general part of the questionnaire (Section D) solicited opinions from the user public on the appropriateness, relevance to their needs and performance of the GSC's geochemical activities. A listing of activities in two broad categories, regional surveys and applied geochemical research was given for respondent's comments.

Geochemical Activities Appropriate to the GSC (Question D-1)

The Canadian university community believes that the GSC should be active in all geochemical regional survey and research fields identified in the questionnaire (Table 17; Fig. 8). Industry and government groups are equally supportive of a high level of activity but are more discriminating in their emphasis. The current high profile GSC activities are most strongly supported, i.e. regional surveys using stream and lake sediments, and drift sampling. Regional surveys utilizing heavy mineral sampling and water sampling are less well supported.

In the realm of applied research, the GSC's efforts in mineral deposits geochemistry is strongly endorsed together with strong support for applied lithogeochemical research. Within the industry and government groups it is considered highly appropriate that the GSC carryout applied research

into the geochemistry of the sample media most commonly used in regional surveys with the intent of improving methodology and interpretation procedures. This is in sharp contrast with questionnaire responses a decade ago when the user public was surveyed on the Uranium Reconnaissance program (Weir et al., 1979).

Biogeochemistry is also considered an appropriate topic for research and, indeed, the GSC is currently one of the leaders in this field. There is a high level of support for analytical method development activities and a very strong endorsement of work on data management and interpretation techniques. A lower but still significant level of activity is considered necessary by all groups in gas and hydrogeochemistry as well as the other research activities of organic geochemistry, fluid inclusion and isotope studies and environmental geochemistry. The least favored activities relate to non-exploration aspects of geochemistry as exemplified by the following comment. "All areas of geochemistry listed are generally important and well done by the GSC but are not of equal relevance. The focus should be on exploration geochemistry, especially those aspects which assist industry in exploring more effectively and efficiently." All the responding groups expressed support for the GSC's involvement in environmental studies, but not as a priority.

Responses from the laboratory community were unfortunately marred by a high level of no comment. Those responding supported, in large measure, the position of the industry and government groups.

The strong endorsement of regional survey related activities at the GSC indicates broad support for the National Geochemical Reconnaissance projects being carried out as a joint venture between the Provincial and Federal

Table 13. Reliability/scientific quality of geochemical output

Group/Output	Very satisfied %	Satisfied %	Unsatisfied %	Very Unsatisfied %	No Opinion/ No Response %
Industry n=60					
Formal Publications	31	56	2	0	11
Open Files	8	74	3	2	13
Outside Journals	11	57	2	0	30
Unpublished	5	59	0	0	36
University n=10					
Formal Publications	30	70	0	0	0
Open Files	30	70	0	0	0
Outside Journals	30	70	0	0	0
Unpublished	20	30	0	0	50
Government n=18					
Formal Publications	33	50	0	0	17
Open Files	28	61	0	0	11
Outside Journals	28	44	0	0	28
Unpublished	12	44	0	0	44
Laboratory n=15					
Formal Publications	13	47	0	0	40
Open Files	6	47	0	0	47
Outside Journals	20	33	0	0	47
Unpublished	7	27	0	0	66

governments. The Provincial Surveys and Departments of Mines are seen as the logical and most likely alternative sources for geochemical survey data whilst research into geochemical exploration techniques should be supplemented by work in universities. Opinions vary, however, -- "Where possible, the GSC should leave routine surveys to be done by Provincial agencies. I see the GSC role as providing national leadership in research derived at discovering and refining geochemical exploration methods." Others consider that more development, methodology, and analytical techniques as well as research into exploration geochemistry/mineral deposits in universities would ensure an ongoing supply of highly

trained professionals capable of assuming exploration related activities and at the same time redirect funding from the GSC to universities."

Other comments, in response to the topics raised by the section of the questionnaire, relate to the overall scope of GSC geochemical activity and its relationship with other estates.

"... (the GSC) can't do everything for everybody - so what niche have they carved out of the Canadian experience and become world leaders?"

"... the GSC geochemical unit should be devoting the vast majority of its time to providing a fundamental understanding of the process(es) affecting the ultimate interpretation of geochemical data."

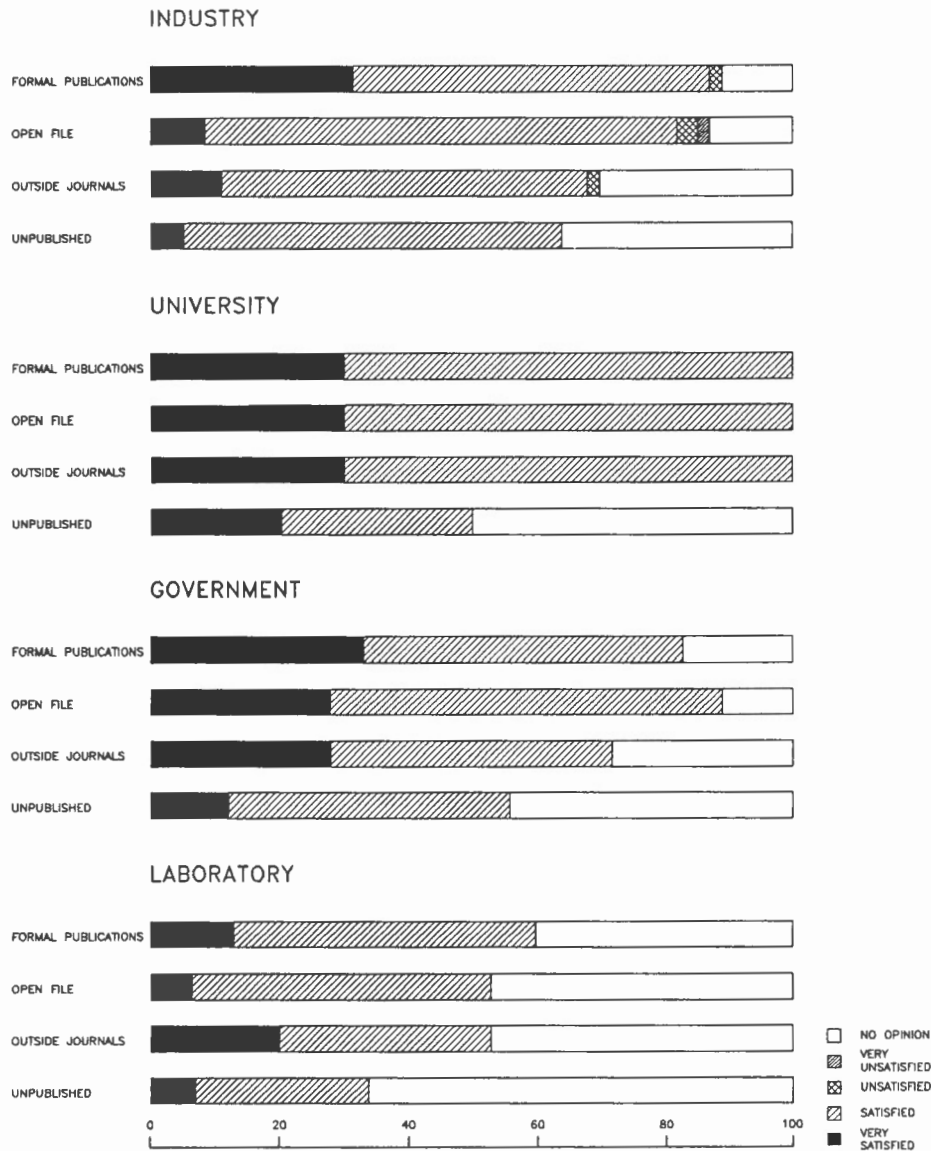


Figure 4. Reliability/scientific quality of geochemical output.

The involvement of the GSC in the production of regional geochemical data is strongly endorsed but Provincial governments are seen as alternative agencies for this activity. A change in the relative involvement of Federal and Provincial agencies in regional geochemical mapping may make more resources available for much needed research into the interpretation and evaluation of these data.

Relevance and Importance of GSC Geochemical Activity (Question D-2)

The university group considered all identified activities relevant and important to their own work (Table 17; Fig 9). Regional surveys carried out by the GSC and research on the geochemical behaviour of most common sample media including biogeochemical media are seen to be highly relevant by industry and government groups. Industry, as would be expected, finds analytical methodology of only moderate relevance to its own activities in contrast to the laboratories group for whom it is the most important GSC geochemical activity. The lesser developed and utilized geochemical research fields such as gas and organic geochemistry, fluid inclusion and stable isotope work and environment related studies are ranked important mainly by university and government constituencies.

In general terms the geochemical work of the GSC closely matches the activities of the client community. There is no strongly indicated area of deficient or inappropriate activity identified in the questionnaire response relative to the current geochemical exploration practices of the groups polled.

Assessment of GSC Geochemical Performance (Question D-3)

Most of the respondent groups and especially the laboratories had considerable difficulty in assessing the performance of the GSC in the various activities listed. This is in part because the GSC is not very active in the less common areas of exploration geochemistry.

The regional drainage survey work being carried out by the GSC is relatively well known and the results are widely disseminated. The GSC's performance in this area is widely regarded with satisfaction (Table 17; Fig 10). Whereas the university and government groups expressed a high level of satisfaction with the GSC's work in geochemistry related to mineral deposits, the industry community are considerably less well satisfied. Although fluid inclusion, isotope and other fields of research provide useful information on the genesis of several mineral deposit types, the present methods of investigation and interpretation are not readily applicable in exploration where observations are made and samples taken at remote locations from (undiscovered) orebodies. This may reflect some doubt in industry concerning the actual value of such research in regional exploration decision making. Data interpretation and analytical method research are other areas where the responding group's satisfaction was tempered.

GSC's Contribution to New Geochemical Developments (Question D-4)

The contribution of the GSC's work to new developments in exploration geochemistry is well regarded by its clients with ratings of "significant" exceeding "not significant" by a factor of almost 3 to 1 (Table 18; Fig. 11).

Table 14. Satisfaction of client needs

Group/Output	Excellent %	Well %	Acceptable %	Marginal %	Poorly %	No Opinion %
Industry n=60						
Formal Publications	8	39	43	5	3	2
Open Files	15	34	36	5	3	7
Outside Journals	0	21	44	10	11	14
Unpublished	2	28	25	11	11	23
University n=10						
Formal Publications	20	50	20	10	0	0
Open Files	0	40	40	20	0	0
Outside Journals	20	40	30	10	0	0
Unpublished	20	20	0	10	30	20
Government n=18						
Formal Publications	12	44	44	0	0	
Open Files	28	38	16	12	6	0
Outside Journals	6	44	38	0	0	12
Unpublished	0	32	24	11	11	22
Laboratory n=15						
Formal Publications	0	13	40	7	7	33
Open Files	0	20	27	13	7	33
Outside Journals	7	13	40	7	0	33
Unpublished	7	27	27	6	7	46

Perception of the GSC's Exploration Geochemical Research (Question D-5)

The GSC's clients perceive its geochemical research activities as "largely" to "somewhat applied" and driven, in part, by practical exploration needs and, in part, by scientific curiosity. Some weakness in fundamentals is identified but the universities group has identified a good balance between fundamental and applied studies.

The university, government and laboratory communities were asked for additional information relevant to their dealings with the geochemically active groups at the GSC. (Parts E, F and G of Appendix C)

Nine out of ten universities responding conduct undergraduate geochemistry courses and seven out of ten have graduate courses. This is not reflected in the availability of trained exploration geochemists and may illustrate

confusion in the respondent's minds as to the nature of the exploration geochemical field compared to the more classical geochemical study of rocks and mineral deposits.

EMR research agreements and DSS contracts supports a low level of geochemical research at the universities. None of the universities consider this support essential to their programs although three out of the ten respondents rated it as an important component. The greatest perceived benefits extended to universities and university students by the GSC are help with literature search, job opportunities, field logistics and as co-supervisors of research projects. The level of GSC support for exploration geochemistry research is considered satisfactory by the majority of universities.

The most significant relationship between the commercial laboratory community and the GSC centres on the extensive contracting out of analytical services and provision for the

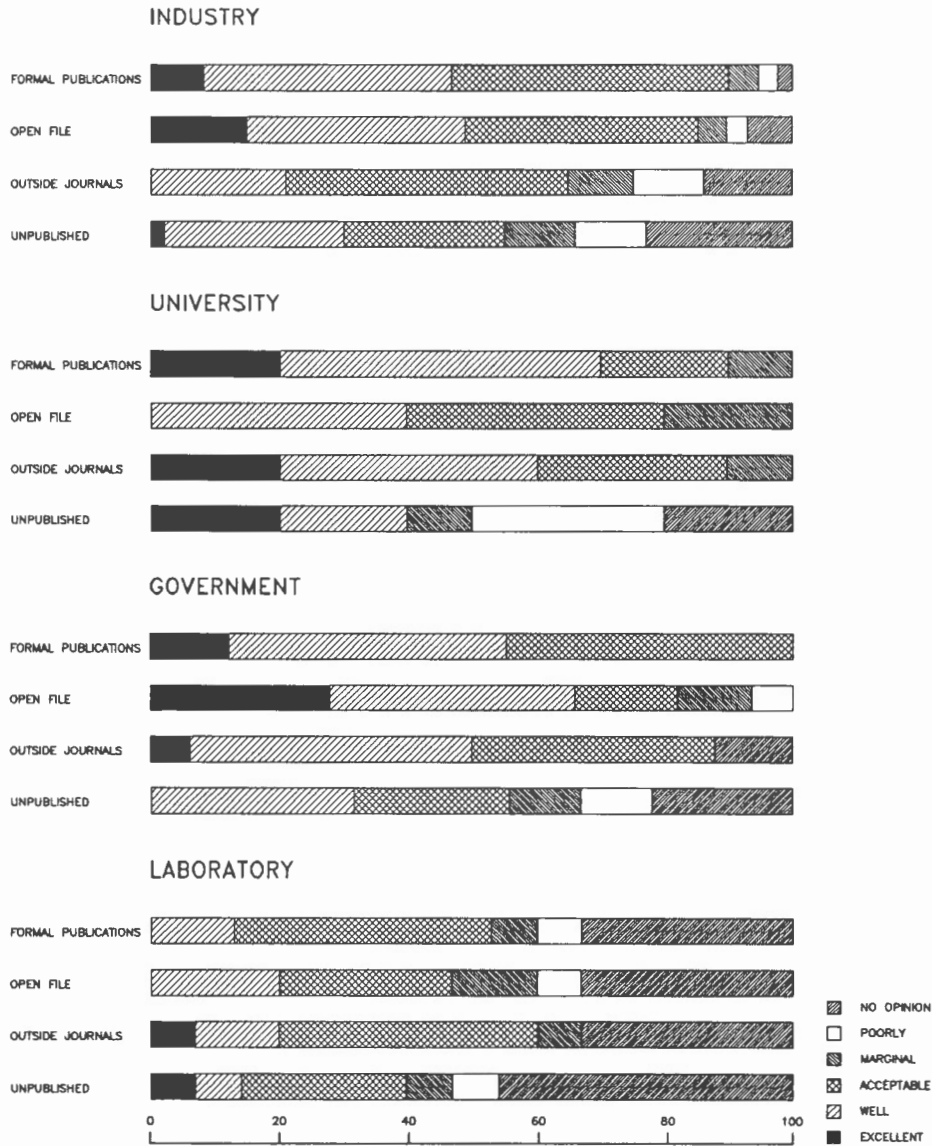


Figure 5. Satisfaction of client needs.

development of analytical techniques. This matter, which is discussed elsewhere in this report is an area of dissension which requires investigation and action.

The laboratory group do not believe that analytical method development activity by the GSC's scientists has contributed to raising the general standard of geochemical analysis in Canada. Although one third of the respondents felt they had benefitted significantly from the GSC's method development, the respondents indicate the GSC is not the source to which laboratories turn in seeking help with analytical problems. Such developments are achieved either in house (67%) or adapted from methods used in other disciplines (53%). This response from the commercial laboratories came as a surprise to the Committee. A review of the literature indicates that GSC scientists have made several significant contributions to both the development of new analytical methods and also the better understanding of established analytical procedures. The lack of impact possibly reflects uneven diffusion of information. Laboratories can normally acquire such technological information through sample enquiry and request and a basic problem may be knowledge of availability.

Part F of the questionnaire was sent to provincial and territorial government earth science agencies. Only one province (P.E.I.) did not respond.

All except one provincial survey indicated that at least one geochemist was employed, with three provinces employing three (Question F.1). Neither territorial agency has a staff geochemist. Geochemists in provincial agencies are more abundant than geophysicists (19 to 11) although both are far outnumbered by geologists (233). These relative proportions

cannot be interpreted too rigorously, as the replies from some agencies represented only a part of their total geoscience complement.

It can be concluded that the provinces, collectively, have a considerable geochemical capability, but individually none comes close to matching the resources of the GSC in number and diversity of geochemists.

Based on data provided by the provincial and territorial surveys (Question F2) The types and estimated costs of regional geochemical surveys conducted during the 1983-1988 period by government agencies is summarized in Table 20. Not all provinces provided complete information but the figures are considered to indicate the level and effort by agency and survey type and complement the government responses to questions B-4, D-1, D-2 and D-3.

In the five-year period 1983-1988, at least \$21 million was reportedly spent by the federal government and the provinces on regional geochemical surveys in Canada. Some GSC costs expenditures including some A-base and other costs, are not included in this total because detailed data was not available to the provincial agencies and so the data in Table 20 are not totally complete. The questionnaire replies show that almost half (48%) was spent by the GSC directly, 39% by the provinces directly and 14% in jointly funded programs. Much of this work was carried out through Mineral Development Agreements (MDAs). The most widely used sample media employed in government surveys are glacial till, stream sediment and lake sediment, each accounting for more than 20% of the total expenditure on regional surveys. Lithogeochemistry and radiometric surveys each account for about 10% of the total expenditures, whereas other survey media (ground water, vegetation, gas) are rarely used.

Table 15. Perceived productivity based on geochemical output

Group/Output	Very satisfactory %	Satisfactory %	Less than Satisfactory %	Unsatisfactory %	No Opinion %
Industry n=60					
Formal Publications	5	41	16	7	31
Open Files	7	48	7	5	33
Outside Journals	0	39	13	2	44
Unpublished	0	34	8	3	54
University n=10					
Formal Publications	20	40	20	10	10
Open Files	40	20	20	0	20
Outside Journals	20	60	20	0	0
Unpublished	20	10	10	0	60
Government n=18					
Formal Publications	5	55	17	0	23
Open Files	11	39	17	5	28
Outside Journals	17	55	5	0	23
Unpublished	11	23	5	0	61
Laboratory n=15					
Formal Publications	0	27	13	0	60
Open Files	7	33	7	0	53
Outside Journals	0	40	0	7	53
Unpublished	7	20	7	0	66

Lake sediment, till and radiometric surveys were dominated by GSC expenditures. Provincial and territorial expenditures predominated for stream sediment surveys, and the investment in lithogeochemical surveys were evenly divided.

Most provinces and territories (6 of 11) favour jointly executed regional geochemical surveys, (Question F.3) although a significant minority (4) favour provincial delivery. Only one province considered that the GSC should have the primary responsibility for conducting regional geochemical surveys.

Two-thirds of the provinces and territories indicated that there is a significant degree of cooperation with geochemists at the GSC in implementing regional geochemical surveys (Table 21). There is much less collaboration in other research oriented activities but a majority of provinces/territories are working with the GSC on data integration techniques, method

development for regional surveys, analytical techniques and the application of statistical methods.

DISCUSSION OF GSC GEOCHEMICAL EXPLORATION ACTIVITIES

Research and Methodology

Questionnaire responses indicate that the users of geochemical exploration data are reasonably satisfied with the GSC output. It is apparent that the major geochemical exploration activities are relevant and appropriate, the product is well regarded and frequently meets users' needs. Some improvements can be made, however, especially with respect to public awareness, productivity and the use of computer technology in the marketing of the GSC product.

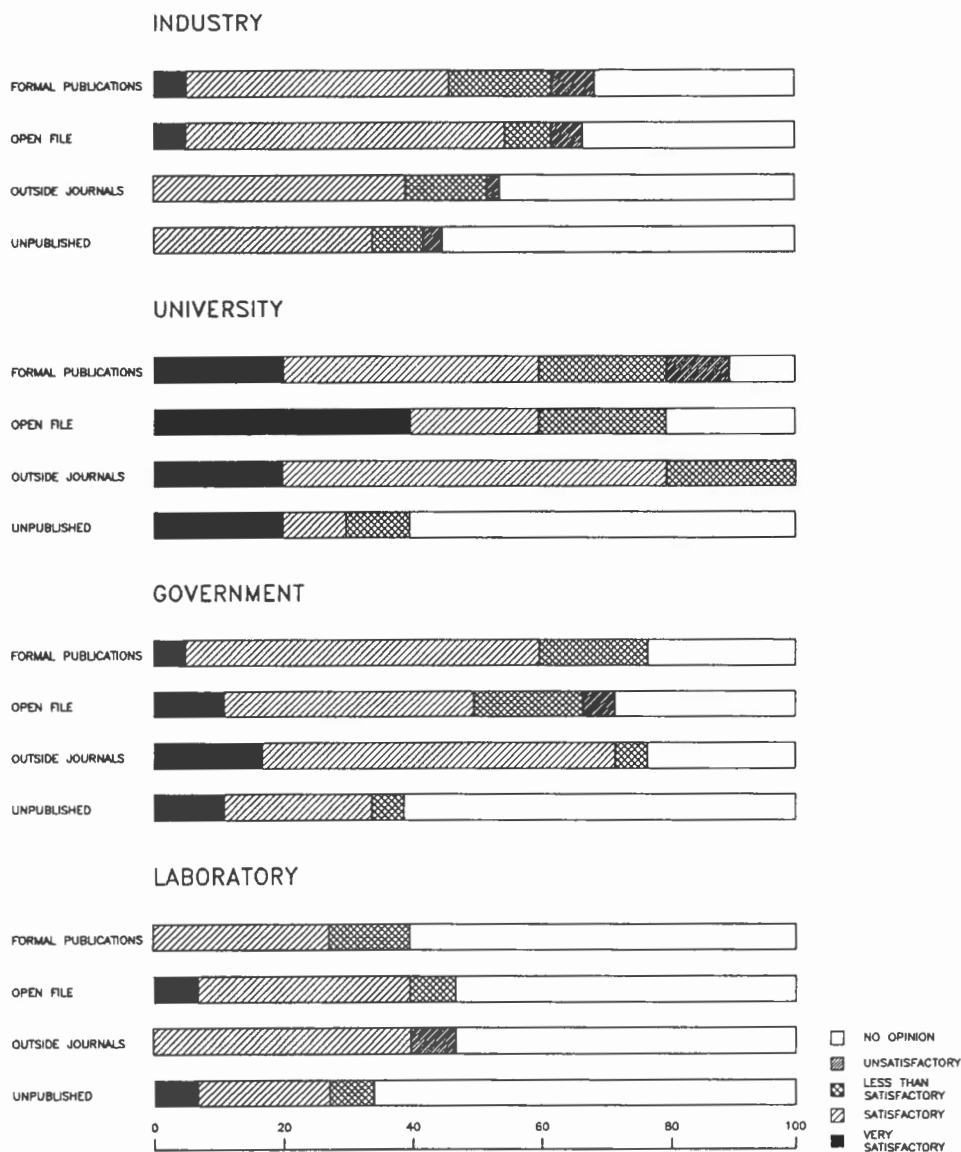


Figure 6. Productivity based on GSC geochemical output.

While acknowledging the response of the user community, the Committee believes that the overall geochemical exploration effort of the Geological Survey of Canada can be significantly increased by improved integration of personnel and resources through management, organizational and attitudinal changes within the relevant Divisions and Subdivisions of the Survey.

The nature and the diversity of the Canadian landscape requires that exploration geochemical research programs in biogeochemistry, hydrogeochemistry and the behaviour of elements in glacial sediments be prominent activities of the Geological Survey of Canada. Levels of activity in biogeochemistry and the surficial geochemistry in glaciated regions should be continued at present levels. Reporting of G.S.C. studies in hydrogeochemistry in recent years has been extremely meager and the Survey is urged to rectify this situation so allowing the user-public an opportunity to judge the nature, relevance and quality of this research.

There is a notable low-level of activity in lithogeochemistry. "Rock-chip" sampling is a currently favored technique in exploration for precious metal deposits but much of this work is carried out unsystematically. Detailed studies of the characteristics and distribution of metals in rocks based on well planned geochemical orientation surveys are needed to improve both the general understanding and the general quality of lithogeochemical exploration surveys in the private sector. The Geological Survey should be addressing this opportunity and this need more systematically through careful studies in mineral districts where samples can be obtained from drill cores and underground workings in addition to outcrops. Private sector work indicates important potential for lithogeochemistry in volcanogenic and other mineral environments.

Gas geochemistry research, which used to be a field of expertise of the Survey as little as 10 years ago, is in abeyance. As illustrated by work in Scandinavia, the USA, Japan and elsewhere, gas geochemistry shows great promise for the subtle but distinctive detection of mineralization buried beneath barren and/or transported cover. Electrogeochemical methods have been developed in the Soviet Union, China and elsewhere and tested in several areas of Europe, Asia and the USA. These techniques claim success in prospecting through thicknesses of hundreds of meters of transported cover but have not yet been evaluated by the Geological Survey in Canada. Bearing in mind the nature of the Canadian surficial environment, these omissions are clearly an area of Geological Survey neglect.

The present study, as well as previous advisory committee reports, clearly reveals that the GSC's user public looks to the Survey for practical and balanced evaluations of new or developing ideas and techniques whilst fulfilling its commitment to research and mapping the geological landscape. In view of the constrained resources available this is the most significant task of the GSC's management. It requires active and determined management of projects and resources rather than passive direction of studies initiated by scientists often for their own intellectual satisfaction. Furthermore, the GSC should beware of diverting an inappropriate amount of scarce resources into areas of fundamental research with only long term potential application to the timely development of Canada's mineral resources. Such research should be done in universities with GSC support and supervisory involvement. In this way the GSC can take immediate advantage of the research findings and apply them to their programs and at the same time convey and consult on new research approaches that can be pursued by the universities.

Table 16. Use and application of GSC geochemical data

Group/Output	Source of Data %	Field Methods %	Analytical Techniques %	Interpretation Techniques %	Ideas %	Exploration Training %
Industry n=60						
Formal Publications	83	24	5	59	64	11
Open Files	83	24	5	29	56	3
Outside Journals	55	17	11	37	55	4
Unpublished	65	25	13	31	54	13
University n=10						
Formal Publications	60	20	0	20	60	10
Open Files	60	10	10	0	20	0
Outside Journals	60	20	10	30	40	10
Unpublished	20	10	0	20	30	10
Government n=18						
Formal Publications	77	22	22	16	28	0
Open Files	94	16	16	0	6	0
Outside Journals	44	22	22	33	22	0
Unpublished	44	16	16	0	6	0
Laboratory n=15						
Formal Publications	40	6	46	13	26	6
Open Files	46	6	13	0	6	0
Outside Journals	13	20	53	20	33	6
Unpublished	6	26	46	20	13	0

PROJECT GENERATION

There is considerable variety in the way Geological Survey projects are defined and given priority. Geochemical prospecting activities are significantly influenced by the initiatives and the interest of individual geoscientists and the present Committee urges a management environment that still encourages initiatives from below but maintains a firm direction to the overall thrust of geochemical research.

In the same spirit as recommendations by previous advisory committees (Weir et al., 1979; Coope et al., 1983), it is emphasized that the integration of the various geoscientific disciplines within the Geological Survey often results in greater communication through interdisciplinary debate and discussion among participating scientists leading

to greater professional stimulation and greater productivity. In order to encourage this kind of interaction and also exercise some overall direction, it is recommended that GSC management be prepared to fund carefully conceived interdisciplinary research programs and invite Survey geoscientists, including exploration geochemists, to participate in this research through joint-collaborative proposals that would compete for the funds allocated for the program. Scientists either authoring unsuccessful proposals or not disposed to interdisciplinary programs would have to share the remaining, maybe limited, funding within subdivisional budgets.

Without duplicating comment already set out in the discussion of responses to the questionnaire, the survey did identify significant observations on the part of some clients

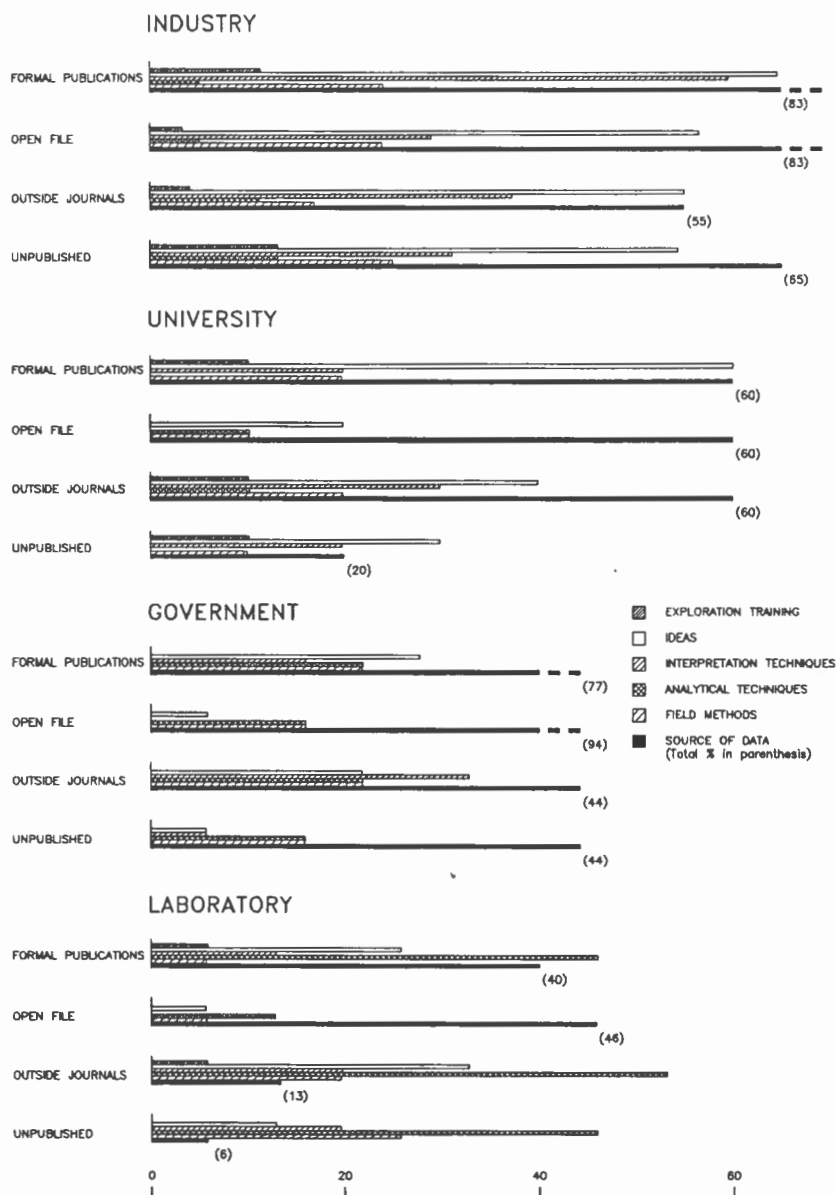


Figure 7. Use and application of GSC geochemical data.

with respect to public awareness, interaction with the public, attendance at meetings, certain types of publications and the distribution of data in digital form.

TRAINING IN EXPLORATION GEOCHEMISTRY

The comment, "the usefulness of an open file would be considerably enhanced if the geochemist responsible for its publication could devote some time to evaluating and commenting on the data rather than merely presenting it in a tabular form" probably is not entirely a reflection of irritation on being faced with an apparent inconvenience but a legitimate request for interpretational help.

Similar interest by geologists in the Survey's exploration data from lithogeochemical surveys in British Columbia has been noted and the Committee considers this to reflect the general lack of instruction in exploration geochemical methods contained in undergraduate economic geology courses taught in Canadian universities. Despite the urging of industry for universities to improve and broaden instruction in the application of geochemistry in mineral exploration, the majority of these institutes provide little or no opportunity to study this subject at

either the undergraduate or graduate level. As a result there is a critical shortage of both professional exploration geochemists and geologists knowledgeable about exploration geochemistry. The geochemists within the Geological Survey of Canada represent the major concentration of this expertise in Canada and could assist in filling this near vacuum by promoting university participation in its projects and significantly increasing the very limited support now given through the EMR Research Agreement Program. (In 1989-1990 less than 1.5% of the Research Agreement Program funding of \$1.39 million was allocated to exploration geochemical projects.)

In its own programs the GSC should place greater emphasis on its formal and informal output on the selection of the optimum methods of sampling and analysis based on orientation surveys and other pilot studies carried out in advance or as part of the GSC projects. In addition, the Exploration Geochemistry Subdivision should consider the preparation of a catalog of orientation case histories using different media which would be available to industry and the universities and be updated from time to time.

Questionnaire responses indicate that only minor use is made of GSC geochemical data for training in exploration techniques. The GSC should seize this opportunity to expand

Table 17. Appropriate geochemical activities for the GSC

	Industry			University			Government			Laboratory		
	A	R	P	A	R	P	A	R	P	A	R	P
<u>Regional Sampling Survey</u>												
Stream Sediments	84	77	65	80	80	80	84	82	61	59	66	**
Lake Sediments	80	78	69	90	80	80	84	88	56	66	66	**
Glacial Drift (including Till)	80	75	49	80	80	80	78	82	67	53	59	**
Heavy Minerals	74	69	38	80	70	50	61	53	38	59	58	**
Water	34	76	20*	100	80	50	61	59	44	59	52	**
<u>Applied Research</u>												
Mineral Deposits	94	86	47	100	80	70	78	69	61	60	52	**
Stream Sediment Sampling	85	79	52	80	70	60	83	76	61	60	59	**
Lake Sediment Sampling	79	82	49	90	70	70	83	83	56	66	46	**
Soil Sampling	87	85	41	90	70	60	83	76	55	59	59	**
Drift (including Till)	80	78	49	70	70	60	83	76	67	52	52	**
Hydrogeochemistry	58	46	20*	90	80	30	78	64	38	66	53	**
Biogeochemistry	70	68	29	80	80	60	83	76	56	66	53	**
Lithogeochemistry	88	86	40	80	70	70	83	70	39	66	66	**
Heavy Mineral Sampling	74	77	40	70	60	40	83	53	33	66	60	**
Gas Geochemistry	53	36	8*	70	80	10*	67	53	28	60	39	**
Analytical Techniques	69	54	39	90	80	50	90	70	50	80	72	**
Data Handling/Interpretation	87	70	41	80	70	40	84	70	50	66	59	**
<u>Other Research</u>												
Organic Geochemistry	51	34	7*	70	60	20*	66	24	17*	32	33	**
Fluid Including Geochemistry	56	49	13*	80	60	20	62	35	22*	33	39	**
Stable Isotope Geochemistry	57	49	18*	70	60	30	62	35	22*	46	32	**
Envirogeochemistry	58	49	8*	80	50	30	78	41	17*	53	40	**
Non Exploration Geochemistry	23	20	2*	50	40	40	38	24	11*	46	32	**
* approximately 33% nonresponse ** more than 60% nonresponse CODE : A - Active or very active (Activity) R - Important or very important (Relevance) P - Satisfactory or very satisfactory (Performance)												

programs and initiatives for the dissemination and presentation of data that can readily be used as case history and instructional material for training in geochemical methodology.

NATIONAL GEOCHEMICAL RECONNAISSANCE

The questionnaire responses record a strong endorsement of regional survey related activities of the Geological Survey and a broad support for the National Geochemical Reconnaissance financed, most recently, under the federal-provincial Mineral Development Agreements (MDA's). These programs have successfully stimulated and focussed private mineral exploration activity in Canada.

Because of the developed linkage between NGR surveys and MDA financing, the continuity of the programs is dependent on political decisions bearing on the renewal of funding commitments. Many of the agreements will not be renewed for fiscal 1989-90 and, unless alternative funding sources are arranged, field programs and analytical contracts will be terminated. Such terminations will be viewed by many of the Geological Surveys clients as negative developments partly because of the curtailment of the exploration and business opportunities and partly because the withdrawal of the GSC from country-wide regional programs may threaten the existing national standards that are responsible for the present high quality regional geochemical database.

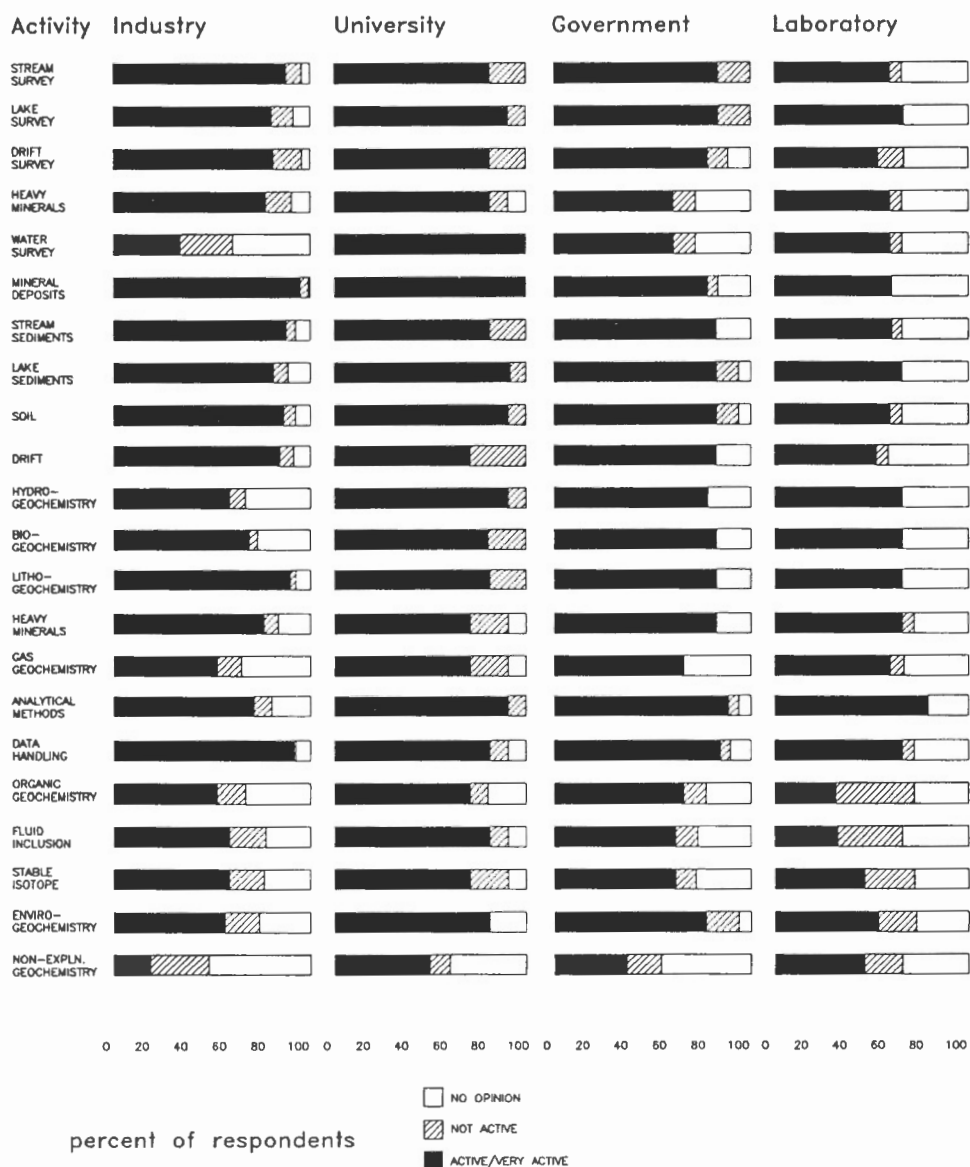


Figure 8. Appropriate geochemical activities for the GSC.

One of the most prominent criticisms of the NGR program from several quarters is the low-level of follow-up interpretation of data and the limited evaluation of geochemical processes responsible for the outlined dispersion patterns. This represents a distinct change of attitude on the part of many in industry, who originally voiced strong objections to any GSC follow-up or other detailed geochemical investigations that might be perceived as prospecting.

Although the Committee strongly supports the continuation of the NGR programs, it strongly recommends that additional A-base funding be made available to investigate those aspects of the NGR database that will lead to a better understanding of geochemical processes in the surficial environments and the development of better

methodologies for more effective mineral exploration and regional surveying. Such background research is necessary for the NGR program to reach its full potential.

ARCHIVING OF SAMPLES

MDA funding has enabled the GSC to provide for archiving of geochemical drainage and water sample materials from across the country. The reanalysis program on selected archived materials has allowed the GSC to expand its analytical database to conform with changes in demand for mineral commodities and respond to the needs of its customers both inside and outside the natural resource industries. Predictably, data of environmental significance

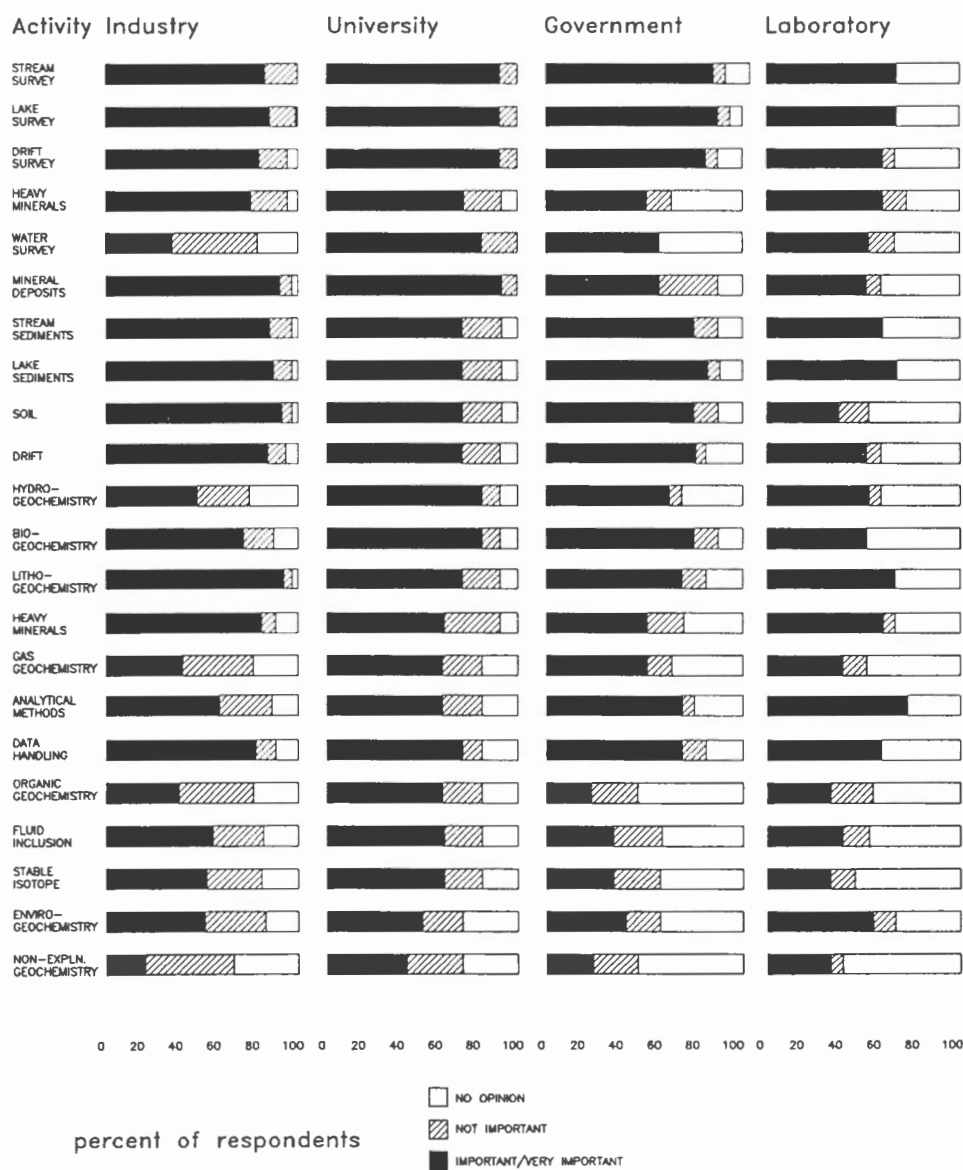


Figure 9. Relevance and importance of GSC geochemical activity.

can be gained from these samples and the Committee recommends that the geochemical archives be supported and maintained as a valuable national resource.

CONTRACTING OUT

Routine determination of trace element contents of soils, sediments, drift, etc. in support of exploration geochemical activities by the Mineral Resources and Terrain Sciences Divisions and MDA regional surveys is almost entirely contracted out. This practice should continue. For regional programmes, it is **essential** to ensure long term consistency and reliability of the resulting database through requiring samples to be prepared and analyzed by specified methods and by maintaining a rigorous programme of quality control. In the Mineral Resources Division one person is responsible

for coordinating contracting-out and monitoring quality control. In the past, coordination of contracting-out and maintenance of quality control appears to have been less effective in Terrain Sciences.

Comment received from commercial geochemical analytical laboratories through the Committee questionnaire expressed considerable dissatisfaction with the DSS contracting out procedures for geochemical analysis. The Committee appreciates that not all laboratories will be successful in the competitive tendering process but GSC-DSS should review contracting out procedures to ensure they achieve: (i) high technical standards and competence, (ii) acceptable turnaround time, (iii) reasonably low costs, and (iv) equal opportunity to participate provided the foregoing criteria are met.

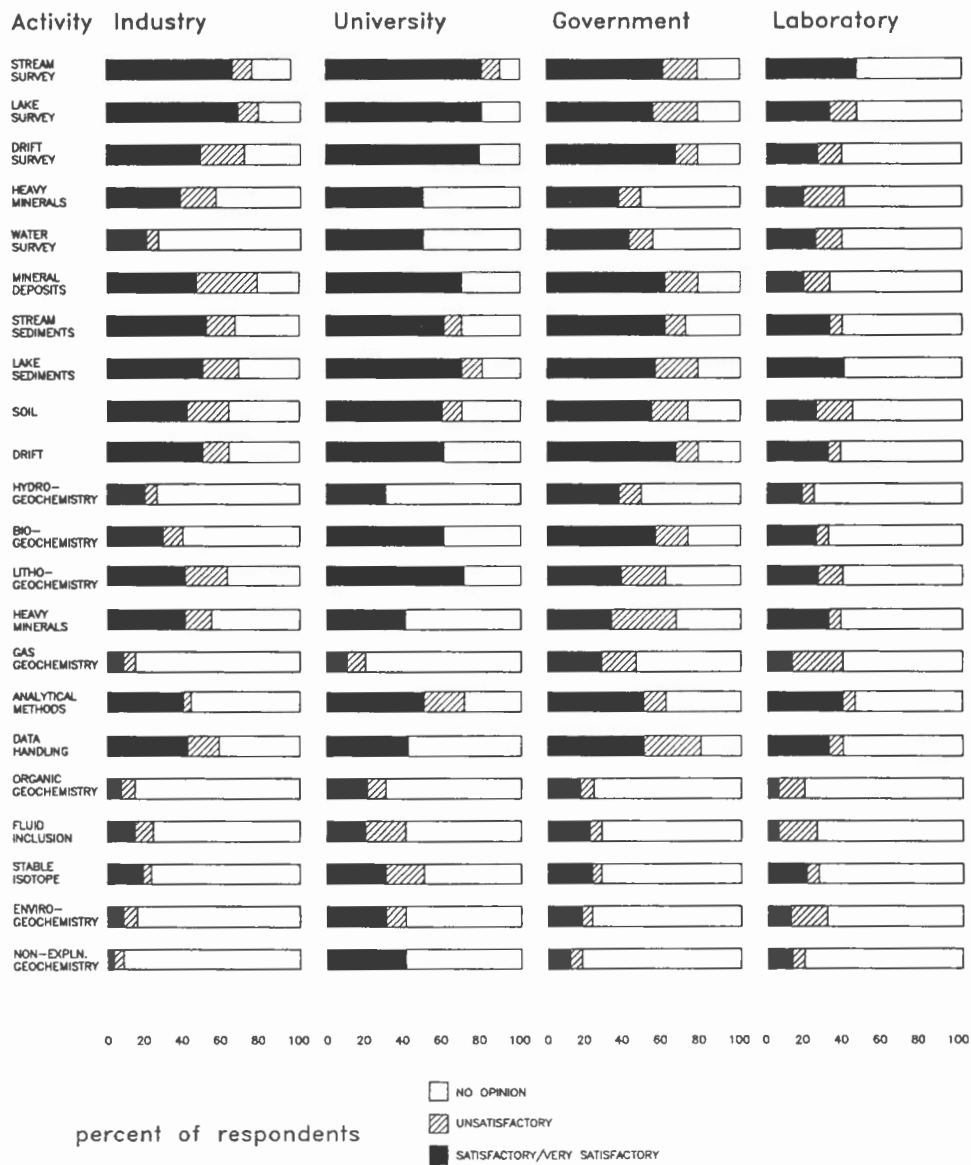


Figure 10. Assessment of GSC geochemical performance.

STANDARD REFERENCE SAMPLES

For some years, the Geological Survey has been preparing a series of twelve standard reference samples for use in geochemical analysis quality control. In the questionnaire response, a majority (80%) of private sector laboratories stated that the GSC should increase the availability of these materials to standardize commercial operations. While recognizing that certification of reference materials is a lengthy process, and that the 12 standards are intended for use in the NGR program, the GSC should make every effort to expedite their release and make them available to the

Canadian analytical community. Expansion of the program to include other media, "difficult" matrices and a greater number of elements should be actively considered.

DISSEMINATION OF INFORMATION

Surprisingly few people in industry (approximately 20%) regularly read the GSC's Information Circular. A review of the Circular mailing list may reveal some opportunities for expanding the dissemination of this information. An annual subscription offer to include the Circular, Current Research volumes, the Volume of Abstracts, the Cumulative Index and

Table 18. GSC's contribution to new geochemical developments

	Industry n=60 %	University n=10 %	Government n=18 %	Laboratory n=15 %
Very Significant	15	0	11	0
Significant	41	70	50	60
Not Very Significant	22	30	0	20
Insignificant	0	0	17	0
No Opinion	22	0	21	20

Table 19. Perception of GSC's geochemical exploration research

	Industry n=60 %	University n=10 %	Government n=18 %	Laboratory n=15 %
Largely Applied	8	40	17	0
Somewhat Applied	51	10	28	47
Weak on Fundamentals	11	30	17	20
Too Much Fundamentals	8	0	0	0
Good Balance	25	50	17	0
Exploration Driven	23	30	22	20
Scientific Curiosity Driven	20	0	28	27
No Opinion	23	0	22	27

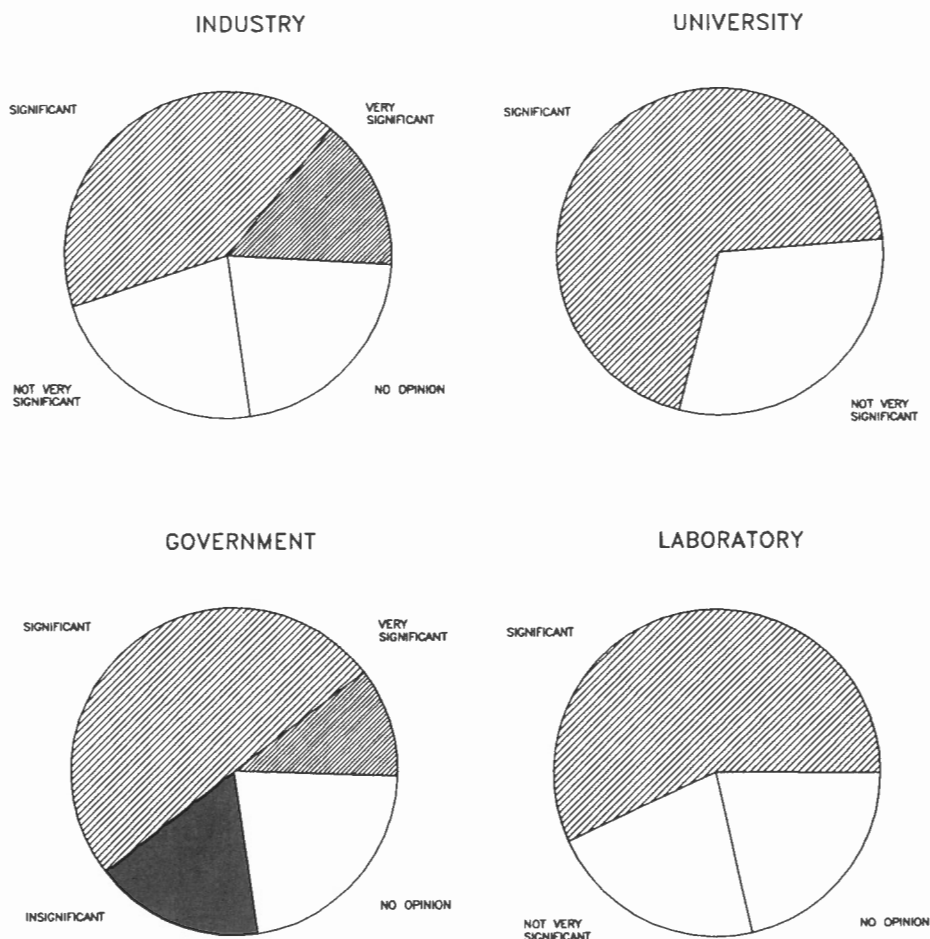


Figure 11. GSC's contribution to new geochemical developments.

the GSC Yearly Index was suggested by an earlier committee (Coope, 1982) and a response to the geochemical questionnaire suggested a regular newsletter that would inform the client community of field project locations and other activities to encourage more contact between private sector geologists and GSC staff. Another suggestion was the compilation of an annual summary of geochemical exploration publications and current research by topic. It was also noted that many GSC publications have blank end pages which could be used for advertising other GSC publications on related topics or areas.

It is recommended that management at the GSC should continue to examine the effectiveness of their public relations activities and seek cost-effective ways to make the public at large, and the mineral industry in particular, more aware of GSC geochemical activities.

It is clear that printed output is the preferred medium for the receipt of geochemical output. Considering the numerical nature of much of the geochemical information it is surprising that microfiche and computer tapes are not more widely used. In an age when virtually all geochemical data users have access to computers, the Committee recommends that the

GSC should terminate the use of fiches and tapes for distributing geochemical output and expand the use of computer discs. The growth in the use of computer discs for information dissemination will be paralleled by a similar expansion of disc usage as a publication medium. Whilst print will remain the most useful form of output for memoirs, reports and maps for some years it can be envisaged that all data will be increasingly stored and transferred electronically. The GSC is lagging behind in using this technology and considerably more effort should be made to bridge this technological gap. There is a danger in moving to electronic data transfer that this will favor the organizations which are computer literate at the expense of the individual for whom acquisition of the requisite computer facilities still represents a large investment. "A better, user friendly, interactive computer base would be welcome" and indeed the GSC is working slowly towards this Nirvana. The very high cost of installing and maintaining a "live" data base for public use should also signal caution in the way that electronic data transfer is implemented. The GSC should move expeditiously and deliberately but carefully into distribution of its geochemical data by electronic media.

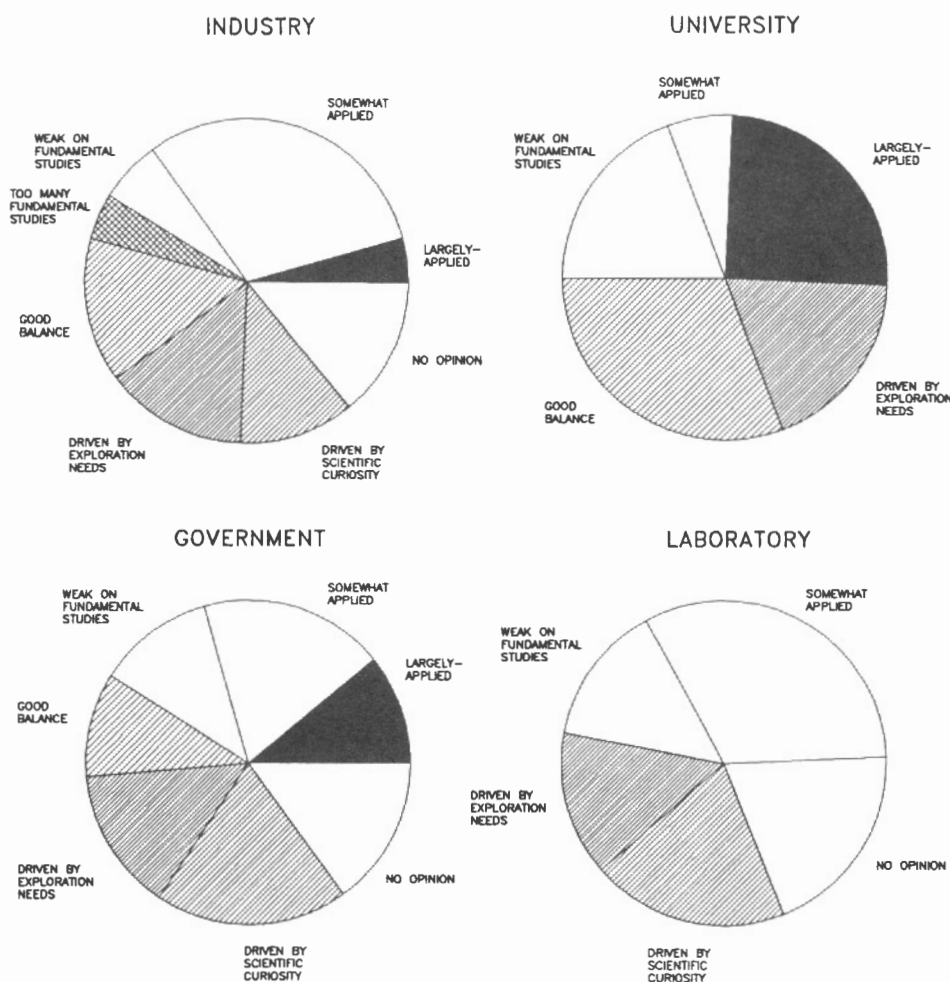


Figure 12. Perception of GSC's exploration geochemical research.

The data gathered on personal communication with the GSC geochemical staff (Table 10) reveals that the most frequent interaction occurs at workshops and conferences. This underlines the great value and effectiveness of the GSC participation in these meetings despite the acknowledged difficulties in obtaining the necessary leave and travel funds. The GSC should continue to encourage presentation of its geochemical output at regional meetings focussed either by topic or area. This would also present increased opportunities for subsequent personal contacts in the field.

The timeliness of the publication of GSC work in general was the subject of some criticism in the past (Coope, 1982) and it is still a prominent complaint even if by a minority. It is apparent that detailed descriptions and interpretations of geochemical data included in the formal output and outside journals is a need of an important segment of the exploration public. Since the scientific reputation of organizations like the GSC is judged on the basis of such publications, this matter still deserves the attention of GSC management.

Table 20. Question F-2. Type and cost by agency of regional geochemical surveys (1983-1988)

Survey type	Agency	Expenditures \$ x 10 ³			(% of Total)	
		Minimum	Maximum		Total	
Stream Sediment (fine fraction)	Prov./Territory	0	1,500	(7.1%)	2,839	(11.3)
	GSC	0	700	(3.3)	1,350	(6.4)
	Joint	0	443	(2.1)	643	(3.0)
					<u>4,382</u>	<u>(20.7)</u>
Stream Sediments (HMC)	Prov./Territory	0	225	(1.1)	225	(1.1)
	GSC	0	0	(0)	0	(0)
	Joint	0	843	(4.0)	843	(4.0)
					<u>1,068</u>	<u>(5.1)</u>
Lake Sediment	Prov./Territory	0	1,600	(7.6)	1,720	(8.1)
	GSC	0	1,169	(5.5)	2,854	(13.5)
	Joint	0	200	(0.9)	225	(1.1)
					<u>4,799</u>	<u>(22.7)</u>
Glacial Till (fine fraction)	Prov./Territory	0	700	(3.3)	1,274	(6.0)
	GSC	0	1,856	(8.8)	3,001	(14.2)
	Joint	0	491	(2.3)	691	(3.3)
					<u>4,966</u>	<u>(23.5)</u>
Glacial Till (HMC)	Prov./Territory	0	600	(2.8)	850	(4.0)
	GSC	0	0	(0)	0	(0)
	Joint	0	0	(0)	0	(0)
					<u>850</u>	<u>(4.0)</u>
Biogeochemistry	Prov./Territory	0	240	(1.)	250	(1.2)
	GSC	0	0	(0)	0	(0)
	Joint	0	35	(0.1)	35	(0.2)
					<u>285</u>	<u>(1.4)</u>
Ground Water	Prov./Territory	0	500	(2.4)	500	(2.4)
	GSC	0	0	(0)	0	(0)
	Joint	0	10	(0.1)	10	(0.1)
					<u>510</u>	<u>(2.5)</u>
Gas Geochemistry	Prov./Territory	0			0	
	GSC	0			0	
	Joint	0			0	
					<u>0</u>	
Lithogeochemistry	Prov./Territory	0	800	(3.8)	944	(4.5)
	GSC	0	1,100	(5.2)	1,100	(5.2)
	Joint	0	500	(2.4)	500	(2.4)
					<u>2,544</u>	<u>(12.1)</u>
Radiometric	Prov./Territory	0	0	(0)	0	(0)
	GSC	0	700	(3.3)	1,763	(8.3)
	Joint	0	0	(0)	0	(0)
					<u>0</u>	<u>(0)</u>
Total costs	Prov./Territory				8152	(38.5)
	GSC				10,068	(95.3)
	Joint				2,947	(100)

Scrutiny by peer review and publication in refereed journals is an accepted yardstick of scientific credibility and productivity. It is also recognized to be an important factor in career advancement within the GSC.

Table 22 summarizes output in refereed journals over a five year period ending in 1988. It is apparent that there are wide disparities in productivity among individuals and that while several GSC scientists have enviable records of productivity, the productivity of others is less than satisfactory. As a result, average output is less than two papers per year - significantly lower than the level expected in the University community.

The committee regards this as a serious problem and recommends that strong evidence of productivity, based on frequency and timeliness of published output, become an important criterion for funding research by GSC scientists. The Committee also urges that GSC management reconsider the recommendation in Coope et al. (1983) that innovative formal publications introducing new concepts and ideas be subject to external review.

MINERALOGY AND CHEMISTRY SUBDIVISION

In its evaluation of mineral deposits research at the Geological Survey of Canada, the Naldrett Committee, (Naldrett et al., 1986), examined the predecessor Mineralogy, Chemical and Applied Chemical Laboratories, the predecessor to the Mineralogy and Chemistry Subdivision. Some of the recommendations of the Naldrett Committee have been instituted since the publication of the report and the present Committee has chosen to reinforce other recommendations not yet acted upon.

Table 21. Question F-4. Degree of cooperation between GSC geochemical and their provincial/territorial counterparts, in both regional surveys and methods research and development

	Close Cooperation	Some Cooperation	Little or no Cooperation	Activity of no interest
Conducting regional geochemical surveys for minerals	4	4	3	1
Research into regional survey techniques	1	3	5	3
Research into the interpretation of regional surveys	1	2	6	3
Research into methods of data integration and interpretation	1	4	6	1
Research into geochemical dispersion processes	1	2	6	3
Research into geochemistry of ore deposits	0	2	7	3
Research into the geochemistry of hydrocarbons	0	0	5	7
Biogeochemical research	2	1	5	4
Analytical techniques	1	3	6	2
Application of statistics to geochemical data	1	3	7	1
Use of image analysis for geochemical data géochimiques	1	2	5	3
12 responses				

The Subdivision performs reasonably well given the present structure and management controls. However, it is considered that greater administrative and operational coordination among the units and the various clients within the Geological Survey will significantly improve quality control, efficiency and productivity in several areas.

It was a general observation of the Committee, that communication between personnel employed in the Analytical chemistry, Analytical Methods Development and the Sample and Mineral Preparation units is disappointingly limited. Considering the common scientific interests of these personnel, this lack of communication cannot be attributed entirely to differing responsibilities but can be traced to

Table 22. Numbers of papers published in refereed journals for the five years ending in 1988

Section/Unit	N	Range	Average
<u>Exploration Geochemistry Subdivision</u>			
Mathematical Application	5	4 - 11	1.9
Geochemical Methodology & Special Projects	6	0 - 11	1.2
<u>Mineral Deposits Subdivision</u>	9	2 - 15	1.2
<u>Mineralogy and Chemistry Subdivision</u>			
Analytical Methods Development	2	7 - 14	2.1
<u>Terrain Sciences Division</u>			
Individuals involved in exploration geochemistry method development	4	1 - 8	0.9
Overall	26	0 - 15	1.4

N = Number of individuals considered.
R = Range in total number of publications by individuals over the last five years.
Average = Average number of publications per person-year.

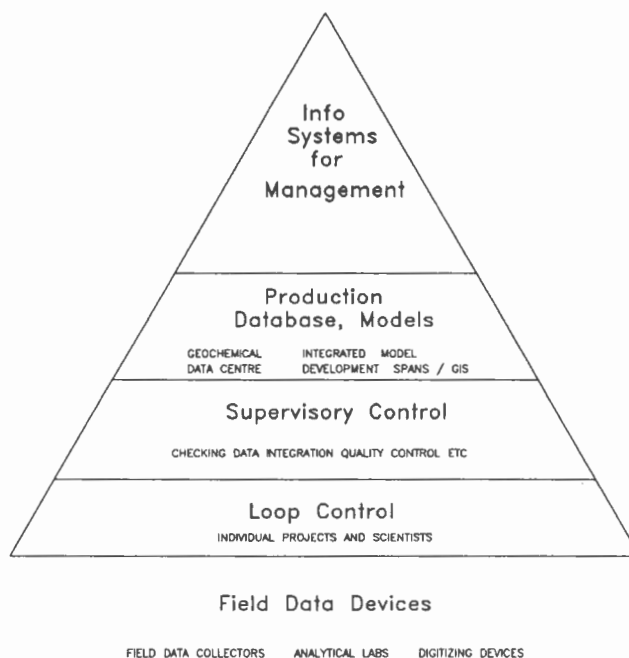


Figure 13. Recommended information integration for geochemistry at the GSC.

organizational difficulties affecting quality control and efficiency and individual differences which should be focus of management attention.

Reference has already been made to the relative isolation of the Sample Preparation and Mineral Preparation Unit within the Subdivision. It is a fundamental understanding with respect to the analysis of geological materials that the most appropriate standards of quality control in sample preparation can only be determined with a knowledge of the nature of the sample, the required analysis and the type(s) of analytical procedures to be used. Inadequate controls at this stage can destroy the integrity of the sample and it is recommended that the Analytical Chemistry Laboratories be given responsibility for sample preparation preceding chemical analysis and that the Analytical Methods Development unit also extend its responsibilities to the development of new and improved sample preparation techniques for specific exploration analytical problems.

Quality controls would be improved by supplementing the established Analytical Chemistry Laboratories procedures with the wider utilization of standard reference samples and the inclusion of field duplicates chosen and inserted by the GSC geologists and geochemists. The laboratory staff would welcome such a program to maintain the high quality of the Laboratories' output.

The problems of turnaround in the Analytical Chemistry Unit can be attributed in part to surges in the receipt of samples and unannounced requests for specific services. The existing Analytical Priorities Committee with membership from all GSC Divisions, should introduce measures to alleviate these problems by requiring GSC scientists to observe reasonable planning procedures to coordinate with laboratory scheduling. In addition, the Advisory Committee endorses the Naldrett Committee's recommendation 4.3.2.2.3 that a realistic costing of internal analytical work be instituted with costs to be charged against the budgets of individual projects. Such a procedure would encourage the closer liaison between the project scientist and the laboratory and make the scientists more accountable and more aware of the laboratory procedures.

The prioritizing of requests for analytical development as a function of management within the Division should also be more fully addressed. Few geologists, in any organization, seem to have any idea of the effort and time required for analytical development, and to avoid unrealistic expectations on the part of research geologists and allow adequate time for analytical development, an internal analytical liaison committee should evaluate the probable commitment required to take any particular development to a successful conclusion. Careful consideration should be given to establishing internal cost recovery and charging a proportion of analytical development costs to the projects involved.

Traditionally, the Analytical Chemical Laboratories get long service from their equipment but this is not always without loss of production through maintenance problems. It is essential that operating budgets include a realistic

component to cover maintenance costs and, whenever possible and appropriate, practical maintenance contracts should be established with instrument manufacturers.

To ensure high standards of analytical quality and further increase its productivity the GSC must make full use of advances in analytical technology and other R & D developments achieved within the Subdivision or elsewhere and maintain a state-of-the-art analytical laboratory. Inadequate funding in the early 1980s resulted in a serious deterioration in these standards: a realistic capital cost budget is necessary to avoid such a recurrence.

Similarly, if the Analytical Methods Development Unit is to maintain its present position in applied analytical geochemistry development in Canada it will be necessary for the GSC to meet the capital costs of increasingly sophisticated instrumentation. The Committee believes it to be important that the GSC makes this commitment, and as recommended in the discussion of the Analytical Chemistry Laboratories, a realistic capital equipment budget should be provided for Analytical Methods Development. The generally dilapidated condition of laboratory facilities was alluded to during several interviews. The Committee emphasizes that proper maintenance and repair and the timely replacement of old or obsolete equipment is necessary to ensure effective laboratory performance.

With the transfer of the Analytical Development unit into the Mineralogy and Chemistry Subdivision from Resource Geophysics and Geochemistry there was inevitable concern (internally and externally) over loss of contact with exploration geochemistry and maintaining the relevance of future analytical developments to mineral exploration. The committee observed that the greater part of the R and D work done by the unit is in collaboration with the Exploration Geochemistry subdivision and communication linkages continue. It is the committee's opinion that analytical methods development in exploration geochemistry is an important output of the GSC that should be maintained at about its present level.

Currently, the Analytical Methods Development Unit often undertakes "routine" analyses utilizing analytical methods developed in house but not yet included in the repertoire of the Analytical Chemistry Laboratories. While recognizing that there will be a "hand-over" phase following new developments the committee recommends that "routine" work within the Analytical Methods Development Unit be minimized by transferring newly developed or established procedures to the Analytical Chemistry Laboratories or commercial laboratories more promptly.

A number of scientists within the subdivision presented arguments to the Committee in support of the establishment of clean room facilities and an isotope laboratory at the Geological Survey. While the Committee agrees that such facilities are necessary for the determination of metals present in natural waters at low ppt concentrations, it is not convinced that **process oriented** geochemical studies requiring this type of analysis are of sufficient priority in mineral deposits research at the GSC to warrant the expense involved in retrofitting old laboratory facilities. The limited number of

analyses should be contracted out to organizations within government or the private sector that already have suitable facilities and methodologies in place. The Committee takes a similar stand with respect to the proposed isotope laboratory and urges GSC scientists needing sensitive water analyses and isotope determinations to establish close coordination and make the necessary arrangements with appropriate well established and well regarded laboratories capable of providing prompt and accurate results on GSC sample materials.

COMPUTERS AND DATABASES

Among the many types of information collected by the GSC, geochemical data is one of the most readily quantifiable. Thus for many years, the GSC geochemical data has been stored in numeric form in computers.

The revolution in computer capability and capacity that has taken place in recent years has outpaced its utilization in most applications. It is the Committee's observation that geochemists within the GSC should be taking fuller advantage of the computer revolution to facilitate communication within the survey and in the service of its user clients.

The Church committee in its report on "Mapping the Landscape" (GSC Paper 87-25) explained that "geological data possess several characteristics that are difficult to reconcile with contemporary computer data banks."

- (i) Certain data are point-parametric; that is, the observation is summarized by a single number or code at a discrete point in geographical space (e.g., a geochemical assay; topographic gradient).
- (ii) Data may be chorological; that is, a (supposedly) homogenous unit is identified which has finite spatial extent (landform or terrain units, outcrop pattern of a formation).
- (iii) Data may be stratigraphic; that is, a string of information representing variation with depth below the surface is recorded at a point in space.
- (iv) Data may be linearly distributed; that is, there is continuous variation in some geographical direction(s).
- (v) Data may be fully distributed geographically.

Although much classic geochemical data is point-parametric and thus relatively easy to store in a computer database (i.e., a geochemical analysis at a particular point in space), there is an increasing emphasis and need to tie this information to stratigraphic data (e.g., analytical results on till horizons in a single overburden drill hole) and to fully distributed data such as geological maps.

Present Situation

At the time of the Committee's visits to Ottawa, computer use by the various GSC groups involved with geochemical exploration was as follows:

1. **Mineral Deposits Subdivision** - ad hoc geochemical data management. No established procedures for centralization of results for broader distribution and use. Geochemical analyses treated as private research data.
2. **Exploration Geochemistry Subdivision - Geochemical Methodology and Research Section.** Although computer facilities are used intermittently by most researchers in this section, they are used actively by five scientists. Generally, data is delivered to a PC by keyboard entry of field notes. Locations are added by digitized entry and the laboratory results by modem. These data are then stored in the R-base System 5 database, (later replaced by R-base for DOS), as a series of separate data packages of up to 2000 samples each with 15 descriptive and 35 analytical variables. Databases generally have the same structure although there are ad hoc variations. All applications packages resided in mainframe computers (CYBER and VAX) but more recently a VAX-based Oracle database has been installed to be fed by R-base local users.

The development of the IDEAS computer-based geochemical data system for technology transfer is one of the key projects of the Section. The system has functionality in terms of large data package interactive graphics not available on PC software packages. The operation of IDEAS is relatively complex and lacks the versatility of some inexpensive PC-based software programs. Although a PC-based version of IDEAS is being considered by the USGS, it is apparent that the system is at a disadvantage due to the rapid developments in microcomputer technology, and will need strong support from a software company to gain widespread use in industry.

3. **Exploration Geochemistry Subdivision - Regional Geochemical Studies Section.** In 1988 when this review was made, this Section, which produces by far the greater volume of geochemical data from its regional programs, was plagued by marginal computer support and the confusing disadvantages of the three unrelated and overlapping CYBER, VAX and PC computer systems. The CYBER contained 90% of the National Geochemical Reconnaissance data and the VAX all the NGR data through 1988 as hundreds of separate ASCII files of descriptive, location and analytical information and each with no database structure. Plans called for the loading of the NGR data into ORACLE database software to be stored in the VAX, and R-base is now being used as a cheaper alternative for use with the PC's. By early 1990 the system was largely PC based. One, more integrated, plan calls for uploading data from the PC to the VAX ORACLE database with provision for downloading for access to applications software or for client phone-in enquiries. The enquiries database would allow for search using menus leading to the production of the required file for downloading to a remote computer. However, implementation of such a system is less critical than providing a single centre where all

geochemical data can be obtained along the lines of or included with the currently operating Geophysical data centre. NGR digital data has been available on magnetic tape since the 1970s and on floppy disk for the past three years. However, it is not always clear from where it can be ordered.

The full array of data incorporating that from terrain sciences, the methodology section and the regional geochemistry section is not all available from one source or in consistent formats.

4. **Exploration Geochemistry Subdivision, Mathematical Applications in Geology Section.** The responsibilities of this Section relate to the Geological Survey Sector as a whole with only a partial application to geochemical exploration. The Section has made significant contributions in statistical treatment and image processing of certain data sets and has been successful in integrating its services with scientists in other disciplines. The SPANS/GIS system is a valuable application, adaptable to spatial data, being advanced by the Section. It has been applied with success to several geochemical data sets generated by the Exploration Geochemistry Subdivision and has proven to be a positive stimulant to the added utilization and improved interpretation of regional geochemical data. SPAN's selection of the QUADTREE system to minimize the size of data sets tends to prohibit desirable rapid interaction with the data set in some applications and will limit the effectiveness of SPANS in the manipulation of very large data sets in the future. As a consequence, the timely evaluation of other GIS systems is an essential requisite to enable the effective presentation and interpretation of GSC geochemical data and at the same time facilitating the utilization of GIS systems analysis by GSC clients.

Discussion

GSC data, and particularly geochemical data, are an important resource, and are of greatest value when they are readily available, in a digitized form, for general use. Restrictions to the flow of this information beyond the need to ensure its quality and integrity are detrimental to total effectiveness. The establishment of a computer system to facilitate this utilization is a necessary investment in any geochemical program.

From the Committee's findings and observations, it is apparent that the GSC lacks a coherent strategy for input, quality control, storage and output of geochemical data. At the present time, much of the data collected, including analyses performed, are not readily available. A procedure is needed whereby data collected during research and surveys is passed through to more general databases which are accessible to other researchers and, importantly, to the Survey's clients. Open file data should be available to clients in digital form within two years of collection. At present large sets of geochemical data collected several years ago, at considerable taxpayer expense, are not electronically available.

A pyramidal computer system structure with centralized storage and information integration capability as illustrated diagrammatically in Fig. 13 is recommended. The pyramid portrays data management stages as information moves "upwards" into a centralized data bank. Establishment of such a structure will ensure data quality and longevity and the data bank will be widely available both within the GSC and to the Survey's clients. Major management difficulties likely to be encountered in the implementation such a system involves the acceptance by scientists of (a) a flexible but standardized data recording procedure and, (b) the ready availability of research and survey data through publicly accessible databanks. These principles are generally acceptable to exploration geochemists and standardized procedures of geochemical data acquisition and merging are commonly practiced. The predictable rapid development of rugged and reliable hand-held computers, now becoming available, and the establishment of portable navigational and positioning devices with an accuracy of a few meters will encourage their general use with geographic data at the sample site.

Automated procedures are likely to be less readily accepted by researchers in other disciplines. However, their needs can be accommodated by the development of a flexible geographic and descriptive data recording system.

The increased use of geographic information systems will necessitate the integration of geoscientific database systems. Immediate planning should be instituted to accommodate the ready collection of geophysical, geological, geochemical and other earth science data as part of geographic data packages plus the provision of floppy or compact disc distribution procedures to satisfy the needs of clients. Demand and technical advances will determine the feasibility of establishing a "live" database for electronic transmission to registered clients. In the interest of efficient data management, this proposal should probably be considered as part of a more encompassing evaluation of computer data management within the GSC. Such an evaluation necessarily must be progressive and senior management must recognize the critical importance and inevitability of efficient and effective computer data management and counter the retarding force of the status quo.

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APPENDIX A

OPERATIONAL PLAN OF THE EXPLORATION GEOCHEMISTRY SUBDIVISION 1988-1989

1. GEOCHEMICAL RESEARCH AND METHODOLOGY

1.1 Precious Metals - Continue

- .1 Lithostratigraphic, lithogeochemical, clay/till geochemical studies for Au and PGE in:
 - (a) Ontario
 - (b) Quebec
 - (c) British Columbia
 - (d) Northwest Territories
- .2 Regional lithogeochemical studies of Au-porphyry copper systems and alteration zones in British Columbia (Mitchell-Sulphurets)
- .3 Investigation of relationship of Archean Au mineralization to oxidized felsic intrusions in the Abitibi belt and deep ductile shear zone, Bamble belt, Norway

1.2 Biogeochemistry - Continue investigations of:

- .1 Biogeochemical behaviour of precious metals and seasonal variations in plant tissues in:
 - (a) Saskatchewan (Star Lake)
 - (b) British Columbia (Quesnel, Hedley)
- .2 Sugar maple sap chemistry and applications to die-back phenomenon in Quebec (Eastern Townships)

1.3 Groundwater

- .1 Complete testing of reverse circulation groundwater sampling systems and obtain patents
- .2 Continue:
 - (a) testing multilevel piezometer system
 - (b) investigation of groundwater geochemical processes in environments adjacent to lakes

2. DATA INTEGRATION AND ANALYSIS

2.1 Geomathematics/Geostatistics

- .1 Continue investigating:
 - (a) applications of advanced mathematics/statistics to data interpretation and integration for resource evaluation and software development
 - (b) computer modeling of fluid flow and solute transport for enhanced oil recovery and hazardous waste disposal problems

2.2 Data Integration - Continue:

- .1 Development of SPANS-PCI system for geoscience data integration and study of spatial inter-relations
- .2 Ground studies to verify identification of vegetation stress and alteration zones from remotely sensed data in:
 - (a) Northwest Territories (Ferguson and Yathkyed Lakes)
 - (b) Northern New Brunswick (Elmtree)
 - (c) Quebec (Schefferville)
 - (d) Ontario (Mazinaw Lake)
- .3 Laboratory studies to determine effects of metal uptake on plant stress

2.3 Technology Transfer

- .1 Complete computer-based geochemical data system (IDEAS) for technology transfer
- .2 Continue Optronics Laser Plotter software development for production of geochemical maps
- .3 Initiate studies of expert systems applications in exploration geochemistry

3. REGIONAL GEOCHEMICAL STUDIES

3.1 Regional Surveys

- .1 Conduct regional geochemical lake/stream surveys in:
 - (a) New Brunswick
 - (b) Ontario
 - (c) British Columbia
 - (d) Yukon
- .2 Reanalyze archived Labrador samples
- .3 Publish results of 1987 regional surveys (estimated 18 Open Files, 475 maps)
- .4 Continue compilation and interpretation of heavy mineral data in:
 - (a) Eastern Townships
 - (b) Lower St. Lawrence areas, Quebec
- .5 Initiate follow-up investigations of tungsten, base metal, rare earth, PGE and barite-rich anomalous zones in above areas
- .6 Provide technical assistance for the CIDA Jamaica survey program

3.2 Method Development - Continue development or modification of exploration techniques for national reconnaissance surveys with regard to:

- (a) Au/PGE
- (b) instrumental neutron activation analysis
- (c) pathfinder elements
- (d) high density surveys

3.3 Quality Control - Continue:

- .1 Evaluation of International Reference Standards and analytical data

APPENDIX B

GEOCHEMICAL ATLAS OF CANADA (a suggestion for a country-wide approach)

SUMMARY

A two-tiered approach to the geochemical mapping of Canada is suggested: an ultra-low density, multi-media, country-wide survey; and much higher density, NGR-type regional surveys in areas of significant mineral potential. The ultra-low density survey would map the geochemical background across the country by sampling representative profiles of the landscape prism with one sample set per 300-500 km². This type of sampling would provide comprehensive data on the chemical nature of the country's landscape, and should be completed in a short (5 year) period to provide a temporal baseline relative to which future environmental changes can be monitored. The results would also map continental-scale geochemical features over an area of unprecedented size, and allow a comparison over this broad area of geochemical response in the various media (vegetation, surface water, drainage sediment, soil and till). These geochemical features would reflect both major tectonostratigraphic units, and major metallotects.

The more conventional surveys in areas of significant mineral potential would be a continuation and extension of the current NGR-type surveys, optimized to be useful to the mineral exploration sector. Surveys would typically involve the collection of a single sample medium, the choice of which would depend on local geological and physiographic conditions. Sample density would be in the range 1 site per 2-13 km², dependent on local geological conditions. These surveys would be carried out in consultation and cooperation with provincial and territorial agencies, but the GSC would ensure that methods used could be related to the framework of country-wide, low density geochemical mapping which would permit an analysis spatial geochemical variations over a very wide range of scales.

This two-tiered approach would be a logical development of the current NGR program, taking into account work in Europe on national geochemical surveys. The more detailed surveys, with their emphasis on mineral resource appraisal, would continue to be optimized for this purpose against the background of local conditions of physiography, target commodities and state of the overall geoscience information base. The multi-media, ultra-low density surveys would provide a geochemical framework to which the more detailed survey data could be related, and would provide a relatively rapid, multi-faceted overview of landscape geochemistry to address more fundamental geological and general environmental questions, questions that will not be addressed comprehensively by the more detailed regional surveys for mineral resource appraisal. This separation of survey objectives, scales and design should avoid the compromises that often make a multi-purpose survey of limited use to anyone. It is recognized that the ultra-low-density survey would require significant new funding, and considerable

multi-disciplinary expertise to implement. The GSC has the expertise in its geoscientists, and as the environment is of paramount concern to Canadians, it might be opportune to seek this scale of new funding. This initiative could form a focus for greater collaboration between geochemists and geoscientists in related fields at the GSC, and help to maintain the worldwide reputation of applied geochemistry at the GSC.

INTRODUCTION

National geochemical atlases are becoming available for an increasing number of countries, and with their availability an awareness is growing of their usefulness to both geologists and scientists from other disciplines concerned with the geochemistry of the biosphere. Their main uses are for mineral exploration, in making regional geological and metallogenic syntheses, and for the measurement of the geochemical background in our environment. Various sample media have been employed, the choice being influenced by landscape, primary survey objective, and commonly, the experiences of the individual groups of geochemists involved in each national survey. The density of sample sites has also varied considerably from country to country, and also within some countries. Sample densities range from 1 site per 1-2 km² to as low as 1 site per 25-30 km². In many cases the adoption of a low sample density seems to have been predicated on economics - a function of the resources available and the area to be covered. The sample density strongly influences the potential uses of survey data; for mineral exploration in particular, the higher the sample density the more the direct impact on mineral exploration. Despite the variety of designs, it is encouraging to note that, where sampling and analysis have been conducted in a systematic and carefully controlled manner, the geochemical patterns closely reflect known geology and they usually suggest new, hitherto cryptic features. Furthermore the patterns show both regions of man-made pollution and areas naturally enriched in toxic elements that may be of environmental concern.

Canada's National Geochemical Reconnaissance Program (NGR), which commenced in 1975 has covered about 20% of the country's 9,976,000 km² area or 23% if the Arctic Islands are excluded. It was not the intention to entirely cover the whole country with NGR-type surveys, a task that would require another 40-50 years to complete at the funding level so far provided, but to focus on areas of probable or possible mineral potential. The surveys typically involve the collection of both sediment and water samples (lake or stream depending on physiography), and the overall program was conceived primarily to provide regional mineral assessments for uranium and base metals, and to stimulate and focus mineral exploration. More recently, survey parameters have been modified (mainly by the incorporation of recently

developed analytical techniques) to provide data relevant to exploration for a much greater range of commodities, including gold. Overall, the program is achieving its main objective of stimulating and focusing private sector exploration, and in addition the data are finding application in environmental studies (e.g., acid rain, mercury levels in fish).

Although the N.G.R. was initiated at about the same time as several other national geochemical surveys, complete coverage of Canada by this program may never be achieved, whereas those of many other (smaller) countries in the northern hemisphere are either complete or nearly so. Perhaps now is a time to review the NGR: its objectives, its design and the level of resources committed to it as well as alternatives to provide a reconnaissance geochemical database in areas not likely to be covered by NGR surveys in the future. The current review of geochemistry at the GSC implies a time for evaluation of programs and new directions. A revitalized program of geochemical mapping would enhance the international reputation of the geochemistry group at the GSC, and could lead to Canada's taking the lead in projects such as International Geochemical Mapping (IGCP 259), an area currently dominated scientifically by the Scandinavians.

A critique of the current NGR

This program has proven successful in stimulating and focusing mineral exploration in Canada, and the GSC should make sufficient resources available to ensure that the program continues until all areas of possible economic mineral potential (based on prevailing geological models) are covered. In addition these resources should be sufficient to allow a continuing program of R and D into regional survey methods so that program specifications can be rapidly changed to meet varying requirements dictated by changing commodity needs, and the changes in the geochemical landscape as the survey crosses physiographic provinces. Some aspects of the program deserve comment.

Objective. The program was designed initially for uranium resource appraisal, and design features such as the typical sample site density of 1 per 13 km² were chosen with this in mind. With the change in demand for mineral commodities - precious metals, and more recently base metals - this density is too wide to provide more than a broad-brush appraisal of the mineral resources of a terrain. In recent surveys this problem has been addressed by changing such survey parameters as sample density and element suite. In a program extending over many years, the focus will change, requiring a continuous R and D program to guide modifications to meet these changing objectives. The level of support for this R and D, both in terms of personnel and funding level, has been barely adequate, and appears to be diminishing while the pace of change is accelerating.

Rate of coverage. Considering Canada's size, complete coverage by NGR-type surveys remains a distant prospect at the present rate of progress. Even those areas which are currently considered to have possible economic mineral potential are very extensive, and will require significant

resources to map geochemically at a sample density useful to the mineral exploration industry. Furthermore, the rate of coverage has been quite variable due to large variations in program funding. This variation creates problems in survey implementation, since during lean years the regional survey group is cut back, so that the group has difficulty responding when funding is expanded, often with little warning. The regional surveys group should prepare a long range plan that would identify those areas of Canada remaining to be covered by NGR-type surveys and the approximate cost, a suggested ideal rate of coverage, and the size of the core of geochemists and technicians required to implement these surveys. This core within the regional surveys group should be funded entirely by the GSC on a long term basis, not from short term program funds. The rate of coverage should be sufficient to ensure that sample collection of the areas of mineral potential is completed by the end of the century.

Survey Design

Drainage sediment (fine fraction) and water have been used effectively worldwide in reconnaissance geochemical surveys for mineral exploration, and they are entirely appropriate as the main sample media for the NGR. Other media such as ground water and the heavy mineral fraction of stream sediment have been included in specific NGR surveys, and till geochemistry, lithogeochemistry and biogeochemistry have been used in particular areas, although these results have not been included under the NGR umbrella.

Given that encouraging and focusing mineral exploration remain the principal objective of the NGR, it is desirable to continue using drainage sediment and water as the 'standard' media, unless they are demonstrably ineffective in a particular area, in which case another approach would have to be used. The design of multi-element geochemical surveys such as the NGR is always a compromise, and in a national program standardization is an important factor in survey design together with cost and effectiveness.

The data from NGR surveys give a great deal of information relevant not only to mineral exploration, but also to metallogenic studies, geological mapping and environmental concerns. The NGR surveys may not provide optimum data for all of these end uses, but they do provide useful information for all. Drainage geochemistry is particularly relevant in measuring the geochemical background as a basic input for environmental studies. By measuring the abundances of as many elements as technically and economically feasible, the NGR data can be made more relevant to more users.

The suite of elements determined on drainage samples has grown from about a dozen elements in early surveys (Zn, Cu, Pb, Ni, Co, Ag, As, Mo, U, Mn and Fe, together with LOI), to include additional elements such as F, V, Sb, Sn, W, Cd and Hg. This suite is relevant to uranium and base metal exploration, as well as to gold exploration to a degree. It includes several elements that are toxic at low levels to many organisms and hence of environmental concern (e.g., As, Cd, Cu, Hg, Sb and Pb). More recently, Au determinations have been made by a fire assay, neutron activation technique, and

most recently by direct neutron activation. This last method provides, in addition to Au, useful data for a further 17 elements (Ba, Br, Ce, Cr, Cs, Eu, Hf, Ia, Lu, Na, Rb, Sc, Sm, Ta, Tb, Th and Yb). The method has a great advantage in being non-destructive, thus preserving valuable sample material for archiving.

Recent analytical developments such as NAA and ICP-ES that provide low cost, high quality, multi-element analyses make a rationalization of analytical techniques in NGR surveys necessary. Such a rationalization could lead to an expanded element suite at the same or lower cost per sample, while at the same time consuming less sample material. The well designed system for monitoring analytical quality and control that has been in place throughout the NGR should ensure that any changes in the geochemical data due to changing methods can be measured and compensated for. Further research is required to develop analytical methods to be even more cost-effective, and also to determine adequately and economically those elements for which practical techniques are not yet available, e.g., for the platinum group metals.

The water samples are currently routinely analysed only for U, F and pH. With new analytical techniques such as ICP-MS and ICP-ES, this suite could and should be greatly expanded to include major elements and a range of trace elements. Some modification of sample collection might be required to include field filtration, but the resulting data would be useful for both mineral exploration and environmental purposes.

The Future of the NGR

The basic design of the NGR is sound, and the method of implementation whereby design and data verification and compilation are done by GSC staff, while sample collection, preparation and analysis are contracted to the private sector, is cost effective. It is most important that the GSC retain control over survey design and quality control. There is a misconception by some that once specifications are finalized, a program such as the NGR can be run by technicians. To respond appropriately to the challenges of geochemical mapping in the different physiographic terrains of Canada, to meet the changing demands of the users of survey data, and to ensure that survey technology is up to date, it is essential that a group of geochemists and technicians is supported to carry out the necessary research and development to ensure continuing survey effectiveness, appropriateness and efficiency. Currently, on-going support for the regional surveys group is inadequate.

Inevitably, technological change can make the results of early surveys somewhat obsolete. The practice of archiving NGR material after the completion of analyses has been amply justified by the strong industry response to recent results from the reanalysis of the material by NAA for gold and associated elements. The GSC must undertake to maintain these archives permanently. The reanalysis of these archived samples to make the element suite compatible with newly collected samples should be a priority.

There are also data from reconnaissance geochemical surveys that are not included as contributions to the NGR coverage. Some of these surveys were done by the GSC and involve media other than drainage sediment: till and vegetation principally. Other surveys were carried out by agencies other than the GSC, and many involve drainage sediment. The most extensive of these were carried by the Quebec Ministry of Energy and Resources. The data from surveys using media other than drainage samples should be evaluated to determine whether they should be included as part of the NGR coverage, or whether the results reflect geochemical features significantly different from the 'standard' NGR sample media. For drainage sediment data collected by agencies outside the GSC, every attempt should be made to incorporate the results. Sampling methods should be compared, as well as analytical methods. If samples from these surveys have been archived, consideration should be given to reanalysis of the remaining material using NGR methods, or at the very least reanalysis of the reference materials used to monitor accuracy and batch to batch precision. Where neither archived material nor control reference sample material are available, a limited resampling program using NGR methods might be required to allow reconciliation and levelling of non-GSC survey data to NGR standards. The maintenance of NGR standards is important to ensure that users, in particular the mineral exploration industry, can have the same confidence in data from the same sample medium from adjacent provinces. At the same time, where data from a well designed and implemented survey exist, it makes no sense to duplicate the survey. The GSC should initiate discussions with the agencies concerned, especially the Quebec Ministry of Energy and Resources to address this issue.

Finally, the value, in both practical exploration and scientific terms, of the NGR should be emphasized more strongly. An overall plan with estimated costs and a proposed timetable should be prepared, to cover both areas to be sampled and areas where further analyses are required. This plan should be promoted and funding solicited from within the GSC, from regional development programs, from the provinces, and possibly from industry.

Ultra-low density survey

Rationale. Because of Canada's huge size, small population and the very limited development of surface transportation routes, country-wide geochemical mapping within a limited period (say five years) could only be achieved by very low density sampling. Work in Scandinavia by Bjorklund has shown that densities as low as one composite sample per 300 km² reveal coherent, interpretable geochemical patterns (e.g., the geochemical atlas of Finland). This work was based on analysis of composite samples of the fine fraction of till (62 microns); similar results were reported nearly 20 years ago by Armour-Brown and Nichol based on stream sediment data at a density of 1 site per 200 km² in Zambia. Geochemical maps of Norway (over 324,000 km²) based on 690 overbank stream sediment samples also produce coherent, interpretable patterns as shown by Ottesen and Bolviken. One type of feature that these low density surveys appear capable of

defining are extensive metallogenetic belts such as the Canadian Copper Belt, the Raahe-Ladoga main ore belt of Finland, and the mineral districts within the Dalradian metamorphic province of Scotland. As well as defining these metallogenetic provinces spatially, where appropriate elements are determined, the reconnaissance geochemical data provide a unique perspective on ore genesis on a regional scale.

A density on the order of 1 site per 300-500 km², while being dictated for Canada by economics, would be expected to provide unique geochemical patterns relevant to regional geological correlation and metallogenetic studies. It could potentially provide a comprehensive review of element levels and other spatial variations across the spectra of geological regimes, physiographic provinces and ecosystems of Canada. This environmental perspective alone would be a significant contribution to long term environmental studies into the next millennium, and one that will not be made by other government agencies.

Design. The survey should seek to sample a cross-section of the geochemical landscape of each site (the landscape prism will vary from region to region). Key sample media would be drainage sediment (lake or stream), surface water (lake or stream), and glacial till (preferably lodgement till). Ancillary media would include vegetation samples (possibly both overstory and understory) and soil samples (humus and B horizon). The selection of sample sites within each regional grid cell would be very important and would require the expertise of specialists in drainage geochemistry, Quaternary geology and till geochemistry and biogeochemistry. For many parts of Canada there is sufficient information to allow sampling schemes to be finalized, but elsewhere orientation surveys might be required.

Each set of sites would yield a suite of material for analysis:

- 1) Drainage sediment -lake sediment, or
stream sediment, fine fraction
stream sediment, heavy mineral fraction
stream sediment, organic material
- 2) Surface water - lake water, or
stream water
- 3) Till -fine fraction
heavy mineral concentrate
- 4) Vegetation -overstory
understory
- 5) Soil -humus
B-horizon

To be interpretable, a comprehensive description of the landscape around the set of sites would be required, with particular emphasis given to the nature of the overburden.

Each medium should be analysed for a broad range of elements (as discussed above for the present NGR samples). This would yield sets of overlapping data for each medium, with element patterns in different media reflecting different aspects of the geochemistry of the earth's surface. Heavy mineral concentrates, and whole till samples would emphasize primary geological features. Lake sediment would emphasize trace element patterns related to bedrock alteration and metallogenesis. The hydrogeochemical data would map leachable metal, available for biological uptake. The vegetation data would indicate actual levels of uptake by the flora.

To provide the maximum amount of useful information from the widely spaced sample sites, a statistically sound sampling design must be employed to allow a thorough analysis of variance at all levels of the survey. Sampling must be consistent and analytical quality must be as good as economically feasible, and both must be carefully monitored and measured. A GIS such as SPANS will be essential to handle, display and analyse quantitatively the very many layers of data that will result from such a large, multi-layered survey.

Post survey studies

Two kinds can be envisaged: higher density studies to better define spatial features in the data and to characterize the geochemical processes causing the patterns to aid interpretation, and repeated sampling at a few selected site sets to provide a measure of temporal variation in the data (both seasonal and year to year). Many of these studies might be carried out under university research agreements by graduate students.

Funding

This type of survey would not likely receive funding from Mineral Development Agreements as its economic returns are too long term. The survey would constitute a new initiative to be completed by a project team within a specified time period (i.e., 5 years), and should be funded mainly as a new program.

CONCLUSION

Regional geochemical surveys of the type carried out under the National Geochemical Reconnaissance program are contributing significantly to more efficient and effective mineral exploration in Canada. These surveys provide a unique type of information about the nature and location of mineralization in the country, and are widely supported by the majority of mineral exploration companies, and by most provincial governments. The GSC should continue and expand somewhat its funding of the regional surveys section so that this group has sufficient resources to both continue the survey work, and carry out method development through orientation studies and post-survey follow up. In addition the GSC should develop a plan with provincial and territorial agencies to delineate the areas to be covered by NGR surveys,

and to outline the cost and time required to complete coverage of the total area. An adequate and more stable source or sources of funding should then be sought for the work.

Provincial and territorial surveys have differing views on their degree of involvement in NGR type surveys. Some wish to carry out the surveys themselves, others are happy to have the GSC perform the work, and most see some form of shared delivery as optimum. All provinces and territories wish to have some control over where within their jurisdiction the surveys are done, but most, if not all, are prepared to contribute to the survey costs. Many provincial government geochemists would like to see a National Geochemical Survey committee set up with representatives from the GSC and provincial and territorial surveys. This committee should meet regularly (at least once a year) and the NGR would be a major item for discussion. Most provinces consider NGR methods and standards to be satisfactory, and recognize that the GSC has by far the largest group of exploration geochemists in Canada. They therefore regard the GSC as a

centre of expertise in this field, although some provincial surveys can also contribute significantly to the development and improvement of geochemical survey methodology. The interchange of ideas would be greatly facilitated by round-table discussions between all government geochemists.

In addition to the continuation of NGR-type surveys, a country-wide multi-media, ultra-low density survey is proposed. This would form a framework to which the more detailed, single medium, and areally restricted NGR surveys would be related. Such a survey would seek to establish the geochemical background of Canada in a representative cross-section of the landscape prism in a relatively short period of time (5 years). This broad, country-wide survey would appear to fit within the mandate of the Federal Government alone. It should be regarded as a program to complement the NGR surveys, not to replace them or to compete with them for funding.

APPENDIX C

QUESTIONNAIRE

CANADIAN GEOSCIENCE COUNCIL

ADVISORY COMMITTEE REVIEW
OF GEOCHEMICAL ACTIVITIES
AT THE
GEOLOGICAL SURVEY OF CANADA

QUESTIONNAIRE

September 1988

COMPLETION INSTRUCTIONS

1. All recipients are asked to complete Parts A, B, C, and D.
2. Recipients at universities are asked to complete additional Part E.
3. Recipients in government agencies are asked to complete additional Part F.
4. Recipients representing analytical service laboratories are asked to complete additional Part G.

(Note - Additional Parts E, F, G forwarded only to the appropriate recipients).

PART A

Respondent No. ____

Your response to Part A of this questionnaire is optional. However, the Committee would appreciate the provision of the following background information which will be held strictly confidential to the Committee and only used for follow-up or clarification purposes by members of the Committee.

Name

Title/Position

Organization

Address

Telephone

Thank you for your cooperation. When completed, please return the questionnaire to:

Dr. I.L. Elliott
Cominco Exploration
700 - 409 Granville Street
Vancouver, BC V6C 1T2

PART B

Geochemistry is carried out by a very diverse community in Canada. This section will provide the Committee with background to your responses in terms of your use of geochemistry and resources and the geographic distribution of your activities.

B-1. In answering this questionnaire -

- | | Yes |
|---|-------|
| (a) Do you represent yourself? | _____ |
| (b) Do you represent your organization? | _____ |

B-2. Is your organization (Check one or more). -

- | | |
|--|-------|
| (a) A producing mining or petroleum company? | _____ |
| (b) An exploration company? | _____ |
| (c) A university/educational institution? | _____ |
| (d) A federal government agency? | _____ |
| (e) A provincial government agency? | _____ |
| (f) An analytical service laboratory? | _____ |
| (g) A consulting or service agency | |
| (i) in exploration? | _____ |
| (ii) in environmental matters? | _____ |
| (iii) in hydrogeology? | _____ |
| (h) Other (please specify)..... | |

B-3. What is your geographic area of interest? (Check one or more).

- | | |
|-------------------------------|-------|
| (a) Western Cordillera | _____ |
| (b) Western Sedimentary Basin | _____ |
| (c) Arctic Islands | _____ |
| (d) Precambrian Shield | _____ |
| (e) Eastern Lowlands | _____ |
| (f) Appalachian Region | _____ |
| (g) Canadian Offshore | _____ |
| (h) Outside of Canada | _____ |

B-4. Indicate your interest and use of various applications of geochemistry by checking one or more of the following:

- | | <u>Interest</u> | <u>Use</u> |
|---|-----------------|------------|
| (a) Regional Stream Sediment Sampling | _____ | _____ |
| (b) Regional Lake Sediment Sampling | _____ | _____ |
| (c) Soil Sampling | _____ | _____ |
| (d) Whole Rock Analyses (Major Elements) | _____ | _____ |
| (e) Trace Elements in Rock | _____ | _____ |
| (f) Hydrogeochemistry | _____ | _____ |
| (g) Gas Sampling | _____ | _____ |
| (h) Biogeochemistry | _____ | _____ |
| (i) Heavy Mineral Surveys | _____ | _____ |
| (j) Glacial Drift (including till) sampling | _____ | _____ |
| (k) Stable Isotopes | _____ | _____ |
| (l) Fluid Inclusion Geochemistry | _____ | _____ |
| (m) Organic Geochemistry | _____ | _____ |
| (n) Environmentally-related Geochemistry | _____ | _____ |
| (o) Other (Please specify) | | |

B-5. Does your organization operate a geochemical laboratory

- | | Yes | No |
|---|-------|-------|
| (a) For analysis of samples collected by employees or consultants/contractors to your organization? | _____ | _____ |
| (b) As a commercial enterprise? | _____ | _____ |

B-6. What percentage (approximate) of the geochemical samples collected by your organization are

- | | Approx. % |
|---|-----------|
| (a) collected by professional geochemists? | _____ |
| (b) collected by professional geologists? | _____ |
| (c) collected by other trained full-time employees? | _____ |
| (d) collected by part-time or casual employees? | _____ |
| (e) collected by contractors or consultants? | _____ |

B-7. What is the purpose of your geochemical activity? (Check one or more).

- | | |
|--|-------|
| (a) discovery of new mineral resources | _____ |
| (b) development of new geochemical exploration methods | _____ |
| (c) environmental studies/investigations | _____ |
| (d) terrain science studies | _____ |
| (e) mineral deposits research | _____ |
| (f) geological mapping/research | _____ |
| (g) Other (please specify) | _____ |

PART C

This section is designed to: (a) gain a measure of your awareness and use of GSC formal and informal geochemical output, and to: (b) gauge how well your needs are served by this GSC output.

Geochemical output originates from several sources in the GSC as follows:

1. Mineral Resources Division -
 - (a) Exploration Geochemistry Subdivision
 - (b) Mineral Deposits Subdivision
 - (c) Mineralogy and Chemistry Subdivision
2. Terrain Sciences Division -
 - (a) Quaternary Geology Subdivision
 - (b) Quaternary Environments Subdivision
3. Institute of Sedimentary and Petroleum Geology -
 - (a) Petroleum Geology Subdivision (Organic Geochemistry)

Please answer the following questions:

	Yes	In Part	No
C-1.			
(a) Were you aware of this dissemination of geochemical activity within the GSC?	_____	_____	_____
(b) Are you aware of the type of geochemical work carried out in each subdivision?	_____	_____	_____
C-2. Do you receive the Monthly Information Circular of the GSC?	_____		_____

The output of the GSC can be classified as follows:

- Published Output
- (a) Formal GSC Publications:
Memoirs, Papers, Bulletins, Econ. Geol. Reports and 'A' series (colored) maps. Current Research publications.
 - (b) Open Files: includes some 'G' series maps (Aeromagnetic, radiometric, Geochemical Maps); Preliminary Maps; Unedited text reports; Contracted reports by non-GSC personnel; Geochemical data from MDA programs; Selected software.
 - (c) Publications in Outside Journals.

Unpublished Output Geoscientific information distributed to government, university, industry and public at large through lectures; memoranda; participation in workshops; symposia and committees; as advisors to other countries and Canadian federal and provincial government departments; and at informal meetings and discussions.

C-3. Please indicate your use and your evaluation of the timeliness and reliability/scientific quality of GSC geochemical output by circling the appropriate numbers in the following tabulation. Please use the following classifications:

Frequency of Use

1. at least monthly
2. at least yearly
3. less than yearly
4. never

Your Use and Application

1. source of data
2. field methodology
3. analytical techniques
4. interpretation techniques
5. exploration ideas
6. exploration training

Timeliness

1. very satisfactory
2. satisfactory
3. unsatisfactory
4. very unsatisfactory
5. don't know/no opinion

Reliability/Scientific Quality

1. very reliable
2. reliable
3. unreliable
4. very unreliable
5. don't know/no opinion

	Frequency of Use	Your Use and Application	Timeliness	Scientific Quality/ Reliability
Formal Publications	1 2 3 4	1 2 3 4 5 6	1 2 3 4 5	1 2 3 4 5
Open Files	1 2 3 4	1 2 3 4 5 6	1 2 3 4 5	1 2 3 4 5
Outside Journals	1 2 3 4	1 2 3 4 5 6	1 2 3 4 5	1 2 3 4 5
Unpublished Output	1 2 3 4	1 2 3 4 5 6	1 2 3 4 5	1 2 3 4 5

C-4. How well do these different forms of GSC geochemical output meet your needs? Please circle the appropriate number.

1. Excellently
2. Well
3. Acceptably
4. Marginally
5. Poorly

- | | |
|--------------------------|-----------|
| (a) Formal Publications | 1 2 3 4 5 |
| (b) Open Files | 1 2 3 4 5 |
| (c) Outside Publications | 1 2 3 4 5 |
| (d) Unpublished Output | 1 2 3 4 5 |

C-5. On the basis of the existing GSC geochemical output, how do you rate productivity in the following categories? Please circle the appropriate number in the following classification.

1. Very Satisfactory
2. Satisfactory
3. Less than Satisfactory
4. Unsatisfactory
5. No Opinion

(a) GSC Formal Publications (internally refereed)	1	2	3	4	5
(b) Outside Publications (externally refereed)	1	2	3	4	5
(c) Open File Publications	1	2	3	4	5
(d) Unpublished Output	1	2	3	4	5

C-6. In what form do you use GSC geochemical output?

	Never	Infrequently	Often
(a) Printed Output	_____	_____	_____
(b) Microfiche	_____	_____	_____
(c) Computer Tapes	_____	_____	_____
(d) Computer Disc	_____	_____	_____

C-7. What is your source of published GSC geochemical output?

	Never	Infrequently	Often
(a) Company Library	_____	_____	_____
(b) University Library	_____	_____	_____
(c) Government Library	_____	_____	_____
(d) Public Library	_____	_____	_____
(e) Personal Library	_____	_____	_____

C-8. How often do you communicate with GSC personnel on geochemical matters?

	Never	Infrequently	Often
(a) In the field	_____	_____	_____
(b) In the GSC offices	_____	_____	_____
(c) At workshops, conferences	_____	_____	_____
(d) By telephone	_____	_____	_____
(e) By mail	_____	_____	_____

Note The Committee welcomes any additional comments relevant to questions C-1 through C-8.

PART D

This section solicits your opinion on (i) the appropriateness of the GSC's involvement in various geochemical activities, (ii) how relevant these activities are to your needs and (iii) how you rate the performance of the GSC's geochemically oriented subdivisions.

D-1. Please indicate how active the GSC should be in the following areas of geochemical activity by circling the appropriate numbers according to the following classifications:

1. Very active 2. Active 3. Not active 4. No opinion

Under the subheading Other Agencies, please indicate any other agencies, organizations or institutions which, in your opinion should have a major role in performing the itemized geochemical activities.

(a) Regional surveys in both the GSC core program and externally funded programs such as MDA's (Mineral Development Agreements) using:

		Other Agencies
(i) Stream Sediment Sampling	1 2 3 4	_____
(ii) Lake Sediment Sampling	1 2 3 4	_____
(iii) Glacial Drift (including till) sampling	1 2 3 4	_____
(iv) Heavy Mineral Sampling	1 2 3 4	_____
(v) Hydrogeochemistry	1 2 3 4	_____

(b) Applied research aimed at improved methods for the execution and interpretation of regional and follow-up geochemical surveys:

		Other Agencies
(i) Geochemical characterization of mineral deposits	1 2 3 4	_____
Field techniques using:		
(ii) Stream sediment sampling	1 2 3 4	_____
(iii) Lake sediment sampling	1 2 3 4	_____
(iv) Soil sampling	1 2 3 4	_____
(v) Glacial Drift (including till) sampling	1 2 3 4	_____
(vi) Hydrogeochemistry	1 2 3 4	_____
(vii) Biogeochemistry	1 2 3 4	_____
(viii) Lithogeochemistry	1 2 3 4	_____
(ix) Heavy mineral sampling	1 2 3 4	_____
(x) Gas geochemistry	1 2 3 4	_____
(xi) Analytical techniques	1 2 3 4	_____
(xii) Data handling/interpretation techniques	1 2 3 4	_____
Other (Please specify)		

(c) Other areas of geochemical research:

		Other Agencies
(i) Organic geochemistry	1 2 3 4	_____
(ii) Fluid Inclusion geochemistry	1 2 3 4	_____
(iii) Stable Isotope geochemistry	1 2 3 4	_____
(iv) Environmental geochemistry	1 2 3 4	_____

- (v) Geochemical studies not concerned specifically with exploration e.g. agrogeochemistry, urban geochemistry 1 2 3 4 _____
 Other (Please specify)

D-2. How relevant and important to you is GSC geochemical output in the following areas? Circle the appropriate number according to the following rating:

1. Very important 2. Important 3. Somewhat important
 4. Not important 5. No opinion

Indicate, under Other Agencies, where (if anywhere) you could get comparable information if it was not available from the GSC.

(a) Regional surveys in both the GSC core program and externally funded programs such as MDA’s (Mineral Development Agreements) using:

- | | | |
|---|-----------|----------------|
| | | Other Agencies |
| (i) Stream Sediment Sampling | 1 2 3 4 5 | _____ |
| (ii) Lake Sediment Sampling | 1 2 3 4 5 | _____ |
| (iii) Glacial Drift (including till) sampling | 1 2 3 4 5 | _____ |
| (iv) Heavy Mineral Sampling | 1 2 3 4 5 | _____ |
| (v) Hydrogeochemistry | 1 2 3 4 5 | _____ |

(b) Applied research aimed at improved methods for the execution and interpretation of regional and follow-up geochemical surveys:

- | | | |
|--|-----------|----------------|
| | | Other Agencies |
| (i) Geochemical characterization of mineral deposits | 1 2 3 4 5 | _____ |
| Field techniques using: | | |
| (ii) Stream sediment sampling | 1 2 3 4 5 | _____ |
| (iii) Lake sediment sampling | 1 2 3 4 5 | _____ |
| (iv) Soil sampling | 1 2 3 4 5 | _____ |
| (v) Glacial Drift (including till) sampling | 1 2 3 4 5 | _____ |
| (vi) Hydrogeochemistry | 1 2 3 4 5 | _____ |
| (vii) Biogeochemistry | 1 2 3 4 5 | _____ |
| (viii) Lithogeochemistry | 1 2 3 4 5 | _____ |
| (ix) Heavy mineral sampling | 1 2 3 4 5 | _____ |
| (x) Gas geochemistry | 1 2 3 4 5 | _____ |
| (xi) Analytical techniques | 1 2 3 4 5 | _____ |
| (xii) Data handling/interpretation techniques | 1 2 3 4 5 | _____ |
| Other (Please specify) | | |

(c) Other areas of geochemical research:

- | | | |
|-----------------------------------|-----------|----------------|
| | | Other Agencies |
| (i) Organic geochemistry | 1 2 3 4 5 | _____ |
| (ii) Fluid Inclusion geochemistry | 1 2 3 4 5 | _____ |

- | | | |
|---|-----------|-------|
| (iii) Stable Isotope geochemistry | 1 2 3 4 5 | _____ |
| (iv) Environmental geochemistry | 1 2 3 4 5 | _____ |
| (v) Geochemical studies not concerned specifically
with exploration e.g. agrogeochemistry, urban
geochemistry | 1 2 3 4 5 | _____ |
| Other (Please specify) | | |

D-3. How do you rate the performance at the GSC for the following? Circle the appropriate number according to the following rating:

- | | | |
|------------------------|-----------------|-------------------|
| 1. Very satisfactory | 2. Satisfactory | 3. Unsatisfactory |
| 4. Very unsatisfactory | 5. No opinion | |

(a) Regional surveys in both the GSC core program and externally funded programs such as MDA's (Mineral Development Agreements) using:

- | | |
|---|-----------|
| (i) Stream Sediment Sampling | 1 2 3 4 5 |
| (ii) Lake Sediment Sampling | 1 2 3 4 5 |
| (iii) Glacial Drift (including till) sampling | 1 2 3 4 5 |
| (iv) Heavy Mineral Sampling | 1 2 3 4 5 |
| (v) Hydrogeochemistry | 1 2 3 4 5 |

(b) Applied research aimed at improved methods for the execution and interpretation of regional and follow-up geochemical surveys:

- | | |
|--|-----------|
| (i) Geochemical characterization of mineral deposits | 1 2 3 4 5 |
| Field techniques using: | |
| (ii) Stream sediment sampling | 1 2 3 4 5 |
| (iii) Lake sediment sampling | 1 2 3 4 5 |
| (iv) Soil sampling | 1 2 3 4 5 |
| (v) Glacial Drift (including till) sampling | 1 2 3 4 5 |
| (vi) Hydrogeochemistry | 1 2 3 4 5 |
| (vii) Biogeochemistry? | 1 2 3 4 5 |
| (viii) Lithogeochemistry | 1 2 3 4 5 |
| (ix) Heavy mineral sampling? | 1 2 3 4 5 |
| (x) Gas geochemistry | 1 2 3 4 5 |
| (xi) Analytical techniques | 1 2 3 4 5 |
| (xii) Data handling/interpretation techniques | 1 2 3 4 5 |
| Other (Please specify) | |

(c) Other areas of geochemical research:

- | | |
|--|-----------|
| (i) Organic geochemistry | 1 2 3 4 5 |
| (ii) Fluid Inclusion geochemistry | 1 2 3 4 5 |
| (iii) Stable Isotope geochemistry | 1 2 3 4 5 |
| (iv) Environmental geochemistry | 1 2 3 4 5 |
| (v) Geochemical studies not concerned specifically with
exploration e.g. agrogeochemistry, urban geochemistry | 1 2 3 4 5 |
| Other (Please specify) | |

D-4. With regard to new developments in exploration geochemistry over the past two decades, do you consider the output of the GSC to be: (check one)

Yes

- (a) Very significant? _____
- (b) Significant? _____
- (c) Not very significant? _____
- (d) Insignificant? _____
- (e) No opinion _____

D-5. Do you perceive exploration geochemical research conducted by the GSC to be: (check one or more)

Yes

- (a) Largely applied? _____
- (b) Somewhat applied? _____
- (c) Weak on fundamental studies? _____
- (d) Too many fundamental studies? _____
- (e) Good balance of fundamental/applied? _____
- (f) Driven by practical exploration needs? _____
- (g) Driven by scientific curiosity? _____
- (h) No opinion _____

Note The Committee welcomes any additional comments relevant to Questions D-1 through D-5.

ADDITIONAL QUESTIONS FOR UNIVERSITY RESPONDENTS

PART E

E-1. Does your department offer classes in exploration geochemistry?

	Yes	No
(a) At the undergraduate level	_____	_____
(b) At the graduate level	_____	_____

E-2. Does your department have graduate students involved in exploration geochemical research?

Yes	No
_____	_____

E-3. Has any of your research in exploration geochemistry been funded by the GSC through:

	Yes	No
(a) EMR Research Agreements?	_____	_____
(b) DSS Contracts?	_____	_____
(c) Other (Please specify)		

E-4. If you have been awarded either EMR Research Agreements or DSS Contracts please answer the following:

(a) Please indicate the frequency of funding: (check one)

(i) At least once every three years	_____
(ii) At least once every five years	_____
(iii) Less often than (ii)	_____

(b) Compared to your overall research budget would you consider the funding you have received from the GSC to be: (check one)

(i) A minor component?	_____
(ii) An important component?	_____
(iii) An essential component?	_____

E-5. Have your research projects benefited from any of the following from the GSC?

- (a) Research-related employment of student _____
- (b) Help with field logistics _____
- (c) Help with sample analysis _____
- (d) Help with literature search _____
- (e) Co-supervision of graduate students _____
- Other (Please specify)

E-6. Do you think GSC support for the exploration geochemistry research by universities is: (check one)

- (a) Very satisfactory? _____
- (b) Satisfactory? _____
- (c) Unsatisfactory? _____
- (d) Very unsatisfactory? _____

Note The Committee welcomes any additional comments relevant to questions E-1 through E-6.

PART F

Please complete this section if you represent and/or are employed by a provincial government agency or equivalent territorial agency.

F-1. Indicate the number of geochemists, geologists and geophysicists in your organization

- (a) Geochemists _____
- (b) Geologists _____
- (c) Geophysicists _____

F-2. Please provide an estimate of the total expenditures in your province or territory by government agencies on REGIONAL SURVEYS (i.e. surveys covering at least 1000 km²) for the five fiscal years from 1983/84 to 1987/88, under the following categories by sample medium and agency delivering program:

	Provincial/ Territorial Delivery	GSC Delivery	Jointly Funded & Delivered
(a) Stream sediment and/or water	_____	_____	_____
(b) Lake sediment and/or water	_____	_____	_____
(c) Glacial drift (including till)	_____	_____	_____
(d) Heavy mineral concentrates (till)	_____	_____	_____
(e) Heavy mineral concentrates (stream sed)	_____	_____	_____
(f) Biogeochemistry	_____	_____	_____
(g) Groundwater geochemistry	_____	_____	_____
(h) Gas geochemistry	_____	_____	_____
(i) Lithogeochemistry	_____	_____	_____
(j) Airborne radiometric surveys	_____	_____	_____
(k) Other (Please specify)	_____	_____	_____

F-3. Do you think the delivery of regional geochemical surveys should be the primary responsibility of (check one)

- (1) your agency? _____
- (2) the GSC? _____
- (3) equally shared? _____

F-4. Please rate the degree of joint cooperation and research on geochemical projects between geoscientists of your agency and those of the GSC in the following categories. Circle the appropriate number according to the following ratings?

- | | | | | |
|---|---|---|---|---|
| (a) conducting regional geochemical surveys for minerals | 1 | 2 | 3 | 4 |
| (b) research into improving techniques for regional surveys | 1 | 2 | 3 | 4 |
| (c) research into the interpretation of regional surveys | 1 | 2 | 3 | 4 |
| (d) research into methods of integration and interpretation of geochemical and other geoscientific data | 1 | 2 | 3 | 4 |
| (e) research into geochemical dispersion processes | 1 | 2 | 3 | 4 |
| (f) research into the geochemistry of ore deposits | 1 | 2 | 3 | 4 |
| (g) research in geochemical surveys for hydrocarbons | 1 | 2 | 3 | 4 |
| (h) biogeochemical research | 1 | 2 | 3 | 4 |
| (i) techniques of geochemical analysis | 1 | 2 | 3 | 4 |
| (j) application of statistical analysis to geochemical data | 1 | 2 | 3 | 4 |
| (k) the use of image analysis techniques for geochemical data | 1 | 2 | 3 | 4 |
| (l) other (please specify) | | | | |

[illegible]

ADDITIONAL QUESTIONS FOR
GEOCHEMICAL LABORATORY RESPONDENTS

PART G

G-1. Do you consider that the development of analytical methods by the GSC has raised the general standards of geochemical analysis by Canadian laboratories? (check one)

- | | |
|------------------------|-------|
| (a) Very significantly | _____ |
| (b) Significantly | _____ |
| (c) Slightly | _____ |
| (d) Not at all | _____ |
| (e) No opinion | _____ |

G-2. Has your organization benefited directly from the use of analytical methods developed by the GSC?

- | | |
|------------------------|-------|
| (a) Very significantly | _____ |
| (b) Significantly | _____ |
| (c) Slightly | _____ |
| (d) Not at all | _____ |
| (e) No opinion | _____ |

G-3. When you encounter analytical problems do you find assistance from GSC personnel: (check one)

- | | |
|------------------------------|-------|
| | Yes |
| (a) Very helpful? | _____ |
| (b) Helpful? | _____ |
| (c) Marginally helpful? | _____ |
| (d) Not helpful? | _____ |
| (e) Assistance not requested | _____ |

G-4. If analytical methods were not developed at the GSC would you have to: (check one or two)

- | | |
|--|-------|
| (a) Do more in-house development? | _____ |
| (b) Rely on other organizations or agencies? | _____ |

G-5. If your answer to G-4 (b) was positive which organizations or agencies?

G-6. Are the Certified Reference Materials distributed by EMR used in your laboratory?
Yes ____ No ____

G-7. Would you like to see the availability of Certified Reference Materials:

- (a) Greatly increased? ____
- (b) Slightly increased? ____
- (c) Remain at present level? ____

G-8. Would you approve of the GSC directing or assisting laboratories obtain access to other government initiatives, such as The Western Diversification Fund, to fund research and development on analytical methods for exploration geochemistry?

- (a) Very strongly approve ____
- (b) Strongly approve ____
- (c) Weakly approve ____
- (d) Not approve ____

G-9. Is your organization generally satisfied with GSC/DSS selection criteria and procedures for contracting out analysis of regional geochemical samples to service laboratories?

- (a) Very satisfied ____
- (b) Satisfied ____
- (c) Dissatisfied ____
- (d) Very dissatisfied ____
- (e) No opinion ____

Note The Committee welcomes any additional comments relevant to questions G-1 through G-9.
