GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES, OTTAWA

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THE GEOSCIENCES IN CANADA — 1974

A STATUS REPORT PREPARED BY THE CANADIAN GEOSCIENCE COUNCIL

Edited by

E.R.W. NEALE
A.C. CLAGUE
H.R. WYNNE-EDWARDS

1975

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

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ABSTRACT

The public is aware as never before of the importance of domestic supplies of energy and mineral resources and of the major exploration expenditure and effort necessary to secure them, as well as the need for careful management of the environment. Yet domestic expenditures in this sector are declining drastically. By any kind of logic, a major increase in the priorities assigned to the geosciences for development and expenditure should be taking place. Instead quite the reverse is happening, even though in the last year or two the university enrollment in geological sciences has at last approached the general level of demand and the geoscientists in govenment, industry, and university are organized into societies and associations and well served by publications, newsletters, and meetings. Research activity is quite high, but not yet at the critical level where a significant section of the geoscience community is able to devote its whole effort to frontier research and consequently to major innovations and breakthroughs that lead to real scientific and technical progress. Opportunities for more concentrated effort are needed.

RESUME

Le public est plus que jamais conscient de l'importance de l'approvisionnement du pays en ressources énergétiques et minérales, des efforts exigés pour les obtenir, des coûts élevés de l'exploration et de la nécessité d'une gestion prudente de l'environnement. Malgré cela, les investissements au Canada dans ce secteur diminuent considérablement. En toute logique, on devrait assister à un important accroissement des priorités pour un développement des sciences de la Terre et une augmentation des dépenses dans ce domaine. Au contraire, on constate l'inverse, même si depuis un an ou deux le total des inscriptions universitaires en sciences de la Terre approche du niveau général de la demande et que les géoscientifiques du gouvernement, de l'industrie et des universités sont organisés en sociétés et en associations et bien documentés par des publications, des communiqués et des réunions scientifiques. Les recherches augmentent mais n'ont pas encore atteint le niveau critique où un pourcentage important de scientifiques Canadiens peut se consacrer entièrement à la recherche d'avant-garde, génératrice de grandes innovations et de découvertes vers un réel progrès scientifique et technique. Il nous faut trouver les occasions de pousser plus à fond nos recherches.

PART 1

CANADIAN GEOSCIENCE IN 1974 — ANALYSIS AND RECOMMENDATIONS

Every aspect of our present and future prosperity depends directly on the supply of mineral and energy resources, and hence on the geosciences. No other group of disciplines will be so vitally important in the 25 years remaining in this century.

INTRODUCTION

In 1968 the Blais Report identified 5844 solid earth scientists in Canada: there has probably been a large increase since then. The twelve groups adhering to the Canadian Geoscience Council report an aggregate membership of 9300, but some individuals belong to more than one society. With few exceptions, the geoscience community is well served by its associations which have grown greatly in strength, activity, and stature in the past decade. At present, like all scientific and technical societies in Canada, they are struggling to find the resources for permanent headquarters and to support scientific publications and newsletters, but the meetings and other activities listed in the summary table attest to health and vigor.

The earth science community is divided among industry, government, and the universities. Both the mining and petroleum industries have interests across Canada, but the mining companies are concentrated in Toronto, Vancouver, and Montreal, and the petroleum companies in Calgary and Edmonton. In the Federal Government, the Department of Energy, Mines and Resources and the Department of the Environment employ many earth scientists, and the Department of Indian and Northern Affairs, the Department of National Defence, and the National Research Council rather fewer. Each of the provinces has a natural resource department with professional personnel. There are 30 universities offering at least the B.Sc. degree in the Geological Sciences or Geophysics and collectively they annually graduate about 1000 at Bachelors, 220 at Masters, and 90 at Doctorate levels.

The broad scope of this report, the uneven pattern of reporting, and the extensive editing involved to reduce material to an acceptable total length, will possibly make it seem shallow to some and unduly exhaustive to others. Nevertheless, it does provide a unique overview of the geosciences in Canada in 1974, with their quite evident strengths, imbalances, and weaknesses, and it indicates important gaps in organization that need to be filled.

The report describes many bright spots in the Canadian geoscience scene: Canada is a world leader in geophysical instrumentation and prospecting methods; it has pioneered in seismic studies of deep mantle inhomogeneities; it has produced internationally renowned geological and geophysical maps; it is far advanced in data storage and retrieval and the production of coloured geological maps by autocartography; studies of the Appalachian and Cordilleran mountain belts and their contained mineral deposits have attracted wide attention; the stratigraphy of the Devonian and Triassic systems has been unravelled and important contributions made to world understanding of these rocks.

However, there are many weaknesses to be rectified, such as: the lack of innovation in our isotopic age programs which is inconsistent with the magnitude of Canadian Precambrian Shield problems; the shortage of manpower at all levels in geodesy; the urgent need for financing of university seismological research; the growing obsolescence of the country's marine science fleet and the need for marine geoscientists to communicate more frequently with colleagues at home and abroad; the need to participate much more vigorously in international offshore drilling programs and to become more aware of the implications of deep-sea mineral exploitation; the lack of a national centre of applied geomathematics; and the need for a national system of recording economic mineral data in postgraduate theses--the single most important source of geological data on mineral deposits.

We hope this report will provide those outside the geosciences with an accessible summary of the state of the subject in Canada, and members of the geoscience community with new insights. Certainly the experience gained from the first attempt at this pattern of reporting will be valuable, and we would urge those who are critical of this first edition of the Canadian Geoscience Council Report to take an active part in the preparation of subsequent reports.

RESEARCH AND DEVELOPMENT

Previously both the Department of Energy, Mines and Resources (EMR) and the National Research Council of Canada supported discipline-oriented committees and subcommittees such as the National Advisory Committee on Research in the Geological Sciences of EMR and the Associate Committee for Geodesy and Geophysics of the National Research Council. These served effectively as a means of communication among scientists when the groups were small and the government research sector was proportionately very large. Canadian science has now reached maturity and such activities are now more properly being assumed by non-governmental organizations.

Specialized scientific groups must communicate well and meet regularly. Numerous successful societies and divisions of societies have only this objective. Among the disciplines of the geosciences, research geophysics perhaps offers the best organizational model, a tightly knit group with its own bulletin, meeting, and sub-committee structure that has recently been transferred almost intact from under the aegis of the National Research Council which started it and funded it to the new Canadian Geophysical Union affiliated both to the Canadian Association of Physicists and the Geological Association of Canada. The disciplines not yet well served by any national society or group are coal geology, paleontology (and palynology), the marine geosciences, mathematical geosciences, and experimental petrology. Several other disciplinary groups such as environmental geology, volcanology, structural geology, and engineering geology have only just been organized.

We recommend to the geoscience associations that they seek means of organizing specialized discipline groups, in particular those that would serve the interests of coal geologists, paleontologists, palynologists, marine geoscientists, mathematical geoscientists, and experimental, metamorphic, and igneous petrologists.

To preserve the specialized objectives of scientific associations intact, umbrella organizations like the Canadian Geoscience Council have become necessary to deal with matters of interdisciplinary communication and broad policy. Unfortunately, the present transfer of responsibility for communications in and among related disciplines from government to nongovernmental organizations has left the geosciences without a direct influence within the Federal Government. Until the voice from the Canadian Geoscience Council and other associations grows stronger and until effective communications are established by the Ministry of State for Science and Technology or others, we feel this is far from satisfactory, particularly in view of the needed increase in priority for the geoscience sector which we believe to be a critical necessity for Canada.

We recommend that the Department of Energy, Mines and Resources continue to support and foster geoscience research and development as far as is possible within its policies, and that it continue to make representation as to the critical importance of the geosciences to Canada at all the levels of the Federal Government.

We further recommend that the Department of Energy, Mines and Resources continue to sponsor and itself undertake long-range planning for the national geoscience needs of the future, and that it support the steps necessary to fulfill these needs.

The large associations have education committees fostering the development of earth science curricula and public information in the public and secondary schools. The Canadian Geoscience Council is trying to provide adequate communication among these groups through its own education committee, and is currently moving from the planning stage of evaluating the need, the demand, and the state of activity in earth science education in Canada to the sponsoring of regional workshops. In many provinces the number of students in high school receiving identifiable and adequately rounded earth science education is increasing rapidly.

The western world has become acutely conscious of the fragility of the human environment and near critical shortages of some energy and mineral resources. Even without economic growth, the demand for resources and for satisfactory levels of environmental conservation, effective waste disposal, and pollution control will be formidable by the end of this century. Before the year 2000, we face a massive shift from petroleum, which currently supplies 80 per cent of Canada's total energy needs, to other sources of fuel, and in the interim a need to develop non-conventional and frontier petroleum reserves such as the Athabasca Tar Sands and Arctic Oil and Gas. Our current oil and gas reserves have been well documented but our mineral reserves are much less well-known. Steps to remedy this are already being taken, but as the exploration geoscientists have noted, there should be some alarm from the observation that our present mineral production outstrips the discovery rate by five to ten times. In the face of these developments the maintenance of our prosperity will depend directly on the use we make of the geosciences. No other group of disciplines will be so vitally important in the 25 years remaining in this century.

The rest of this report shows clearly that geoscience activities are being vigorously undertaken in every part of the nation, that most of the disciplines are organized, that most of the research scientists are able to communicate with each other quite effectively, and that there are very few gaps across the whole spectrum of possible activity. The Canadian contribution to Cordilleran and Appalachian studies has been significant, particularly in the construction of plate tectonic models and interpretations. Marine geology and geophysics have advanced considerably, especially through the co-operative efforts of government and university scientists and through participation in the JOIDES program. Environmental geology has gained stature and personnel, as has the geotechnical aspect of that subject.

Yet in spite of this and other energy, excitement, and action, there is lamentably little real excellence above the level of single individuals. As many of the reviews in this folio attest, Canadian geoscience is strong in data collection and data analysis, yet weak in providing new conceptual models, new syntheses, and major developments. The probable explanation is that there are still far too few people responsible for far too much territory and a consequent preoccupation with the non-innovative research necessary to furnish the minimum inventory. The problem is summarized well in the report on glacier science which finds that from 1970 to 1973 Canada published 17 per cent of the research articles and notes in the principal English language glaciological journal, compared with 4 per cent from Australia, 15 per cent from the United Kingdom, and 49 per cent from the United States. "Breakdown by agency shows that in Australia almost all glaciological research is carried out by government; Canada comes next with approximately 60 per cent government and 40 per cent university research; in the United States the percentages are 24 per cent government, 73 per cent university, and 3 per cent other; while the United Kingdom has 9 per cent government, 87 per cent university, and 4 per cent other ... considering the degree of activity, it is surprising that none of the major developments in glacier science has occurred in Canada; indeed most of them occurred in the United Kingdom, a country without glaciers ... The theoretical side of glacier science is not highly advanced in Canada ... It is particularly unfortunate that the largest glacier science group (within the Department of the Environment) ... is to a great extent committed to non-innovative programs." There are other illustrations. In the article on Geochronology we find "in terms of published results a large proportion of the significant age determinations have been measured in the United States. This practice, however beneficial to the practice of Canadian geology does not contribute directly to the education of Canadian students, does not allow for a maximum of interaction between field geologists and geochronologists, and does not provide a system by which vital geochronological data can be obtained in the future ... Most applied geochronology in Canada is equipment limited; viable groups that combine their diverse talents are scarce; and groups with equipment, diverse talents, and field oriented programs are virtually non-existent ... The Geological Survey of Canada is the only group that has consistently operated at a fairly high level of funding and production with capabilities for all types of methods ... Both in manpower and instruments they have lagged behind the U.S. Geological Survey (or even Switzerland for that matter)... Canada at present is not the home of many leading names in the field. It has not been possible in a small organization to be both productive of dates for the geologists and innovative at the idea and technique level. Service has taken precedence to science..."

The message is plain. We have failed to develop research groups of viable size and concentration so that our facilities and personnel are spread too thinly across this large country to realize their full potential. To rectify this, we can do one of two things: expand the expenditures and increase the professional population, or specialize intensely in a few fields to achieve real excellence. Unfortunately, it is difficult to see which of the geoscience disciplines listed in this report could be done without in Canada because this is a nation that depends heavily on the development of its natural resources and frontier areas for which the geosciences are indispensable. A major increase in the priority assigned to the earth sciences for development and for expenditure is the only answer.

Unfortunately there are numerous signs that just the reverse is happening in legislation and in the level of government funding. As the article on grants-in-aid points out, earth science support from the National Research Council accounts for only 8 per cent of the total, a proportion that has not changed in a period when enrollment in geoscience programs in Canadian universities has more than doubled, and in which we have become aware of the urgent steps necessary to preserve our mineral- and energy-based economy and our increasingly fragile environment. Furthermore, there has been a very significant real decline in the funds available through National Research Council for scientific research in general.

The formation of the National Research Council of Canada arose from national need in wartime to develop research capabilities in chemistry and physics. Wisely and farsightedly the Council has tended the growth of these and the other sciences ever since, and has gained world respect for the way it has done so. There is still a pressing national need for science but the present crisis is not national defence or the waging of war, but the multifaceted one of resource development, conservation, and management. These problems transcend science alone but geology and geophysics and the attendant mineral technology are the critical scientific components. Food production, energy supply, communications, and urbanization all depend directly on mineral production.

We recommend that the Federal Government, through the Ministry of State for Science and Technology, the National Research Council, and other agencies, re-examine its operating grant budget priorities in the light of the national need for mineral resources and environmental studies with a view to increasing both the support for basic research and its application, and the representation in decision-making from the geosciences.

We further recommend that the Federal Government, as a matter of national priority and need, renew efforts to foster the establishment of basic research centres in some aspects of the geosciences on a scale permitting of innovation and excellence.

The report on grants-in-aid also shows significant expenditures for geoscience research within the Departments of Energy, Mines and Resources and Environment in particular, but very small fractions of these are made available to contracts and research agreements with industry and universities. Nevertheless, these fractions are becoming an increasingly important proportion of the total funds available for basic geoscience research outside of government. Inevitably, as the essay on Glacier Science points out, these agencies "exert a strong control over research through 'research contracts' awarded to scientists for programs consistent with the aims of these federal agencies. Although there is little evidence that worthy programs inconsistent with these aims have been thwarted, the structure makes the quality and nature of all Canadian geoscience highly dependent on the quality and the nature of government science. This is a source of apprehension both to university and industrial scientists who have little influence on federal programs. The problem could be avoided by insuring that there is a broad and diverse input to government research priorities."

We recommend that the Department of Energy, Mines and Resources achieve a higher proportion of its research and development objectives through contracts and agreements for geoscientific research by industry and university personnel in order to help raise Canadian research capability to the level of excellence, and to contribute to university and post-university training of Canadian geoscientists.

We further recommend that the Department of the Environment also achieve a higher proportion of its research and development objectives through contract and agreement for geoscientific research by industry and university personnel.

The tasks facing government agencies involve the use of many disciplines, so that basic decisions as to priorities must take place before the need for a particular scientific input can be identified. At that point, however, we consider it vital that effective communication with the appropriate public scientific sector be established so that the intellectual resources and research capacity of industry and university can be fully utilized in the decision-making process. Failure to so communicate can only result in industry and the universities becoming the passive recipients and instruments of de facto government policy, and in accusations that the government has become the master rather than the servant of society. The need for participation in policy making is variable and short-term so that no permanent advisory panel representative of any discipline or group of disciplines can serve effectively. More flexible means must be found.

We recommend that the Canadian Geoscience Council prepare a roster of advisors who could be available at short notice to represent viewpoints and special knowledge from the industrial and university sectors of geoscience so as to assist government in the definition and attainment of its objectives and so as to provide a service to the non-governmental geoscience community by communicating and interpreting governmental actions and decisions.

We also recommend that the Department of Energy, Mines and Resources request these advisors through the Canadian Geoscience Council whenever practicable and desirable, and that a mutually satisfactory system of communication be established that will ensure participation by industrial and university geoscientists in the conception, development, and evaluation of government research priorities involving the geosciences, not just in their execution.

APPLIED GEOSCIENCE AND EXPLORATION

A despondent mood has recently enveloped the applied geoscience sector, the mineral exploration, petroleum exploration, and applied geophysics fields, wherein Canada has developed an outstanding international reputation. Mining geophysical instrumentation may be the only part of the electronics industry in which Canada, with 75 per cent of the business, dominates the world market. It is regrettable that we do not make full use of this capability at home, for in 1974 half of Canadian geophysical exploration for minerals was conducted abroad and domestic mineral exploration is declining sharply. The rate of discovery of Canadian mineral deposits is only a small fraction of the present production rate. Petroleum geophysical exploration is down even more drastically, the indication being that 120 seismic crews were operating in 1967 and only 45 in the current exploration year.

The geological side of mineral and petroleum exploration is in similar disarray, the expenditure on mineral exploration in some provinces being so drastically curtailed in 1974 that much expertise and experience is being lost to Canada, perhaps permanently, and with it much valuable documentation in private company files. It is alarming that "the single most important public source of geological data on Canadian mineral deposits is in university theses," mostly unpublished.

We recommend to the Canada Institute for Scientific and Technological Information that steps be taken immediately to collect bibliographic and basic synoptic data (e.g., keywords) on university theses, especially those relating to mineral and hydrocarbon deposits.

Petroleum geological exploration and development is also being greatly affected. Canada apparently largely lacks the expertise in petrophysics applicable to secondary and tertiary recovery from conventional petroleum reserves, and offers little training in the organic geochemistry and clay mineralogy that have become essential exploration tools. Similarly, the level of fundamental research and training in some aspects of paleontology is judged deficient. Coal, the important alternative fossil energy source, is not a subject of major emphasis in any university geology department, and the first Geological Conference on Western Canadian Coal dates from only 1972. These are serious charges. We face oil and gas shortages in a year or two and some mineral shortages will follow soon thereafter in the absence of further discoveries.

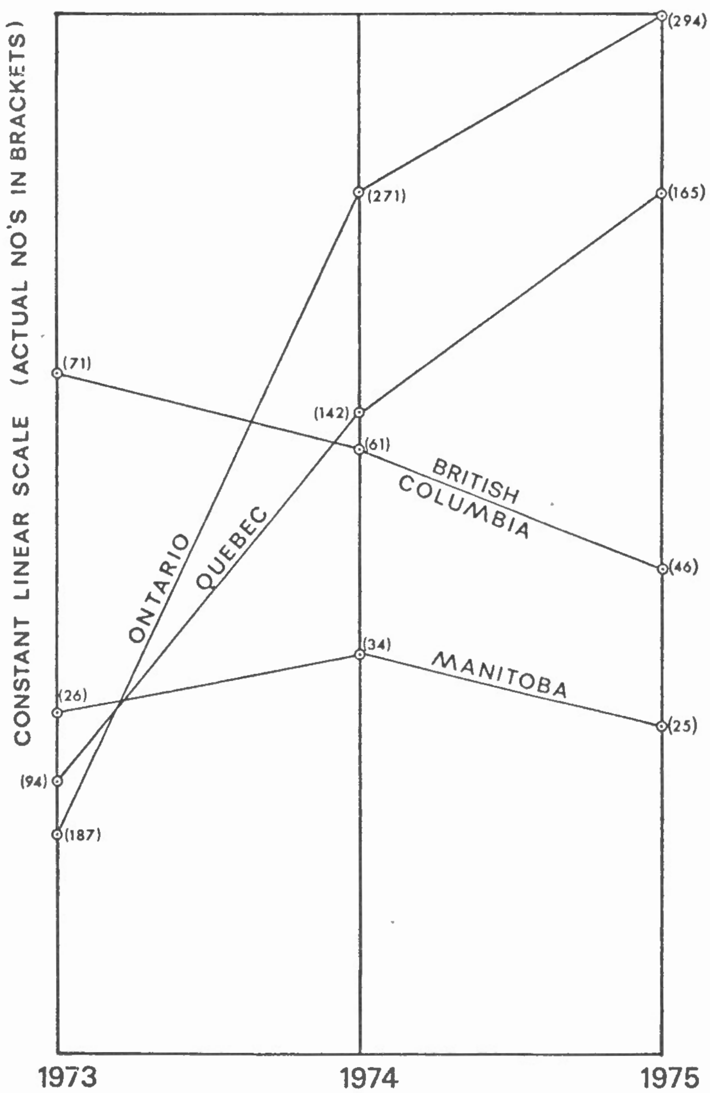
We recommend to Canadian universities that they co-operatively examine the major gaps in geoscience excellence in Canada, for example, those in paleontology, coal geology, petrophysics, and organic geochemistry, with a veiw to establishing viable programs at one or more centres.

There are already indications that the hiring of new graduates in the Canadian mineral and petroleum exploration industry will be greatly curtailed in the coming year. The lead time necessary to find and develop new supplies does not allow for any slackening of effort. The decline in mineral and petroleum exploration is accompanied by adverse publicity for the geoscience profession, so that there is a concomitant and readily understandable decline in the enrollment of students and hence in the future supply of geologists, geological engineers, and geophysicists, at a time when it has only just grown to the point where the domestic supply can meet the domestic demand. Figure 1, for example, shows that the patterns of enrollment in British Columbia and Manitoba as of early 1974 were sharply declining in the face of provincial royalty legislation, whereas enrollments in Ontario and Quebec, provinces with more expansive mineral policies, were increasing very sharply. We can expect similar but more widespread reactions from the new federal resource taxation policies, and from the current federal-provincial debates over jurisdiction.

We offer no comment on the political aspects of new legislation, but we do point out that one regrettable side-effect is the catastrophic decline of a viable mineral and petroleum exploration capability at a time when the nation needs it very badly. Efforts to preserve this expertise and experience must be made, either by restoring industrial incentives for exploration, or by some alternative form of government sponsorship. Failure to do so must be regarded as equivalent to jettisoning the lifeboats from a sinking ship.

We recommend that a view of the anticipated loss of Canadian self sufficiency of hydrocarbon supply in the next decade combined with the declining mineral discovery rate and the time lag of 5 to 15 years between discovery and commencement of production, the Federal and provincial governments and industry take the necessary action to: (a) stimulate exploration to offset this alarming drop in discovery rate, (b) ensure that scientists with the skills to find new resources are not lost or redeployed from the Canadian scene, and (c) encourage a level of enrollment and a quality of research at the universities to supply the geoscientists so vitally needed in the remaining years of this century.

NEW MINERAL EXPLORATION
MANPOWER FOR DIFFERENT PROVINCES



SOURCE: Survey of B. Sc. Graduates in Mineral Sciences and Engineering, Canadian Institute of Mining and Metallurgy Bulletin, March 1974, p. 99-102. (Number of graduates in brackets.)

FIGURE 1

Natural resources, especially mineral and energy resources, are the most critical factors in any consideration of the future of man on Earth. In addition to finding more such resources through exploration, we must husband them well and manage them farsightedly. The need to forecast and assess reserves and resources accurately is inescapable. Accurate resource assessment and evaluation is a part of applied geoscience, for geological reasoning is the key to prediction and estimation of non-renewable resources. Geoscientists must develop this aspect of their work so as to exert an influence on economic theory, and mineral resource managers and administrators should either be geoscientists or at least have adequate knowledge of their physical environment. The universities must consult with government and industry in order to introduce new undergraduate and/or graduate programs which will produce both geoscientists equipped to manage and evaluate economic problems and managers and economists with adequate natural science backgrounds. Much of our future will be in their hands.

We recommend to Canadian universities that, in consultation with government and industry, they modify their curricula to meet the rapidly increasing need for geoscientists able to manage and assess natural resources from the standpoint of economic policy and the need for resource planners and managers who are trained in the sciences relating to natural resources.

RECOMMENDATIONS

The following recommendations arise from this report:

To Federal Government

MOSST and NRC

1. We recommend that the Federal Government, through the Ministry of State for Science and Technology, the National Research Council, and other agencies, re-examine its operating grant budget priorities in the light of the national need for mineral recources and environmental studies with a view to increasing both the support for basic research and its application, and the representation in decision-making from the geosciences.

   We further recommend that the Federal Government, as a matter of national priority and need, renew efforts to foster the establishment of basic research centres in some aspects of the geosciences on a scale permitting of innovation and excellence.

Energy, Mines and Resources

2. We recommend that the Department of Energy, Mines and Resources continue to support and foster geoscience research and development as far as is possible within its policies, and that it continue to make representation as to the critical importance of the geosciences to Canada at all the levels of the Federal Government.

   We further recommend that the Department of Energy, Mines and Resources continue to sponsor and itself undertake long-range planning for the national geoscience needs of the future, and that it support the steps necessary to fulfill these needs.

3. We also recommend that the Department of Energy, Mines and Resources request advisors through the Canadian Geoscience Council whenever practicable and desirable, and that a mutually satisfactory system of communication be established that will ensure participation by industrial and university geoscientists in the conception, development, and evaluation of government research priorities involving the geosciences, not just in their execution.

4. We recommend that the Department of Energy, Mines and Resources achieve a higher proportion of its research and development objectives through contracts and agreements for geoscientific research by industry and university personnel in order to help raise Canadian research capability to the level of excellence, and to contribute to university and post-university training of Canadian geoscientists.

Environment

5. We further recommend that the Department of the Environment also achieve a higher proportion of its research and development objectives through contract and agreement for geoscientific research by industry and university personnel.

To Federal and Provincial Governments and to Industry

6. We recommend that in view of the anticipated loss of Canadian self sufficiency of hydrocarbon supply in the next decade combined with the declining mineral discovery rate and the time lag of 5 to 15 years between discovery and commencement of production, the Federal and provincial governments and industry take the necessary action to: (a) stimulate exploration to offset this alarming drop in discovery rate, (b) ensure that scientists with the skills to find new resources are not lost or redeployed from the Canadian scene, and (c) encourage a level of enrollment and a quality of research at the universities to supply the geoscientists so vitally needed in the remaining years of this century.

To Canada Institute for Scientific and Technological Information

7. We recommend to the Canada Institute for Scientific and Technological Information that steps be taken immediately to collect bibliographic and basic synoptic data (e.g., keywords) on university theses, especially those relating to mineral and hydrocarbon deposits.

To Universities

8. We recommend to Canadian universities that they co-operatively examine the major gaps in geoscience excellence in Canada, for example, those in paleontology, coal geology, petrophysics, and organic geochemistry, with a view to establishing viable programs at one or more centres.

9. We recommend to Canadian universities that, in consultation with government and industry, they modify their curricula to meet the rapidly increasing need for geoscientists able to manage and assess natural resources from the standpoint of economic policy and the need for resource planners and managers who are trained in the sciences relating to natural resources.

To Geoscience Associations

10. We recommend that the Canadian Geoscience Council prepare a roster of advisors who could be available at short notice to represent viewpoints and special knowledge from the industrial and university sectors of geoscience so as to assist government in the definition and attainment of its objectives and to provide a service to the non-governmental geoscience community by communicating and interpreting governmental actions and decisions.

11. We recommend to the geoscience associations that they seek means of organizing specialized discipline groups, in particular those that would serve the interests of coal geologists, paleontologists, palynologists, marine geoscientists, mathematical geoscientists, and experimental, metamorphic, and igneous petrologists.

Submitted by the Canadian Geoscience Council whose active membership during preparation of the report included:

Chairman	H.R. Wynne-Edwards
Past-Chairman	R.O. Lindseth
Vice-Chairman	R.L. Slavin
Secretary-Treasurer	A.R. Graham
Recording Secretary	E.C. Appleyard
Executive Member	G.C. Topp

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Canadian Geophysical Union — K. Whitham, D.I. Gough

Canadian Geotechnical Society — W.J. Eden

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Canadian Rock Mechanics Group — R.A. Price, M.S. King

Canadian Society of Exploration Geophysicists — W.N. Rabey, P.J. Savage

Canadian Society of Petroleum Geologists — R.L. Slavin, G.D. Grant

Canadian Society of Soil Science — G.C. Topp

Canadian Well Logging Society — G.N. Wright

Geological Association of Canada — W.W. Hutchison, M.J. Keen

Mineralogical Association of Canada — A.R. Graham

PART 2

REPORTS ON THE DISCIPLINES OF THE GEOSCIENCES

INTRODUCTION AND ACKNOWLEDGMENTS

A contract was drawn up in early 1974, following two meetings with senior officers of the Department of Energy, Mines and Resources whereby the Canadian Geoscience Council would co-ordinate preparation of a report assessing the state of organization and activity of the various geoscience disciplines and containing recommendations for their future development.

An editorial committee was appointed at the May 18th meeting of Council which was charged with the responsibility of obtaining submissions from the member societies and submitting a draft for the approval of Council in November 1974. Three members of the committee were named editors.

The Council asked each of its member societies to provide a review and evaluation of the past year in each of the various disciplines covered in their activities. In many cases two or more societies were asked to report on a single discipline. By the very nature of their membership and goals, some societies were asked to report on many more disciplines than others. Guidelines were given to each society regarding some of the essential features to be covered in their reports such as current status of research, important achievements of the past year, recommendations of the future, and the relationships of the disciplines to national needs.

This first attempt of the geoscience societies to report on the state of the science is bound to be imperfect. Probably the greatest single fault is the uneven coverage of the disciplines due to the fact that most societies were structurally not prepared to respond instantly to the demand for discipline reports. Some answered this demand by selecting well-qualified individuals to write reports and to submit them through two referees. Unfortunately unrealistic deadlines deterred several scientists from taking on the task, leaving gaps in our coverage, and many of those that did felt that time precluded a refereeing process. In contrast, one association which has a tradition of discipline-oriented sections was able to turn over the report-writing function to the chairmen of these sections and their colleagues and to handle the assignment with comparative ease and dispatch.

Where there were two or more reports on a single discipline they have been melded into a single report. This necessitated heavy-handed editing. Even more drastic editing was required by Council's November decision that the first edited draft must be cut by half to satisfy publishing requirements. The result is that although a few individual contributions still remain almost intact, others have been changed beyond recognition. We hope, however, that the spirit of the individual assessments and recommendations has been retained in the reports that follow.

We are grateful to the Department of Earth Sciences, University of Waterloo for use of their facilities in the initial collection of contributions for this report. We also thank the Department of Geological Sciences, University of British Columbia for making available editorial offices and secretarial assistance. Our greatest debt of course, and it is a debt shared by the entire geoscience community, is to the contributors listed below who responded to their societies' calls for these reports on the health of their disciplines.

The Editorial Committee

E.C. Appleyard	E.R.W. Neale (Chairman)
A.C. Clague	R.L. Slavin
A.R. Graham	H.R. Wynne-Edwards

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GEOCHEMISTRY

ANALYTICAL GEOCHEMISTRY

Demand has risen for broadening the sprectrum of elements determined in geochemical samples as well as increasing the rate of analysis per sample for well-established elements such as zinc, copper, and lead. Thus the analyst has been placed in the position of attempting to balance productivity against research into new methods.

The trend is toward instrumentation capable of multi-element analysis and automation. Optical emission, atomic absorption, and X-ray fluorescence are the three techniques most commonly used in Canadian laboratories, followed by neutron activation and polarography. Analysis by atomic absorption has been automated to the extent that once a sample is in solution it is carried through the determination process by the computer within preset limits of precision, the results being obtained in the form of paper tape, magnetic tape, or paper printout. Most geochemical laboratories in Canada have at least one atomic absorption unit, the basic instrument being relatively inexpensive, versatile, and sensitive. The Geological Survey of Canada has found this instrumentation excellent in field camps in the Bear/Slave territory for on-the-spot analysis of waters, soils, and sediments. This adaptability is a tremendous aid to the geologist in remote areas, however, progress is being made with far less sophisticated instrumentation; for instance, a method developed at McGill University can determine boron in rocks down to background levels with the aid of a simple ion-selective electrode. A specific area where more work is required is partial leaching to ascertain the amount of metal bound up in a certain complex rather than total metal content. Intensive study into improving the sample excitation process in emission has made the plasma source commercially available. Here detection limits of the 25 elements so far programmed are considerably improved and it appears this method will complement atomic absorption for those elements where the latter is insufficiently sensitive.

The eagerness of analysts to take part in round-robin exercises has been demonstrated by the success of the "Canadian Certification Reference Materials Project," and E.M.R. Mines Branch project establishing task forces to gather data on the different types of standard samples released. The CAN/SDI system has eased the task of keeping up with the proliferation of papers being published throughout the world in this field.

Objectives and roles need to be clearly defined. For example, the individuals in industry and university recommend that government play a greater part in developing new methods and less in routine analysis. This should come about with automation and the "contracting out" now being adopted by Government departments. Good research sections are being established in large commercial firms, mostly with American funding. A common complaint among university personnel in analytical geochemistry is that grants to support individual students or fellows are easy to obtain but those to acquire equipment are not. Another complaint is the lack of innovative teaching and research projects undertaken jointly by university geology and chemistry departments.

INORGANIC GEOCHEMISTRY

Inorganic geochemistry is being carried out at most Canadian universities, at the Geological Survey of Canada, Mines Branch, Canada Centre for Inland Waters, Bedford Institute of Oceanography, and various provincial laboratories. Currently we are extremely active in comparison, on a rough publication basis, with France, Switzerland, Britain, but only moderately active relative to the U.S.A., Japan, West Germany, and the U.S.S.R. who clearly support more geochemical work. In spite of complaints, many industrial and government geochemists have well-equipped laboratories with sophisticated, modern instruments; however, this situation will last only if efforts are made to continue adequate support.

Areas in which Canada excels include statistical interpretations, exploration geochemistry, studies of ocean floor igneous rocks, lake and stream sediments, Archean volcanic rocks, stable isotopes, geochemistry of water, rocks, and soils, and speleological carbonate. Noteworthy projects are the continuing series of imaginative oceanic igneous deep-drilling studies (Dalhousie University) in Bermuda, the Azores, and on the Atlantic floor, and the ongoing Precambrian Shield lake sediment studies (Geological Survey of Canada and Canada Centre for Inland Waters) with their overtones of exploration interest. Far too little attention has been paid to abundance studies of Canada's economically important metals in common rocks away from recognized ore deposits. Increasingly it becomes evident that many metallic ores are derived from appropriate combinations of common rock and water, yet only a few persons in Canada are studying the geochemistry of platinum, gold, silver, molybdenum, tungsten, tantalum, tin, and other metals. Another criticism is the lack of originality of many projects; too many individuals are content to tread the well-worn trails rather than to spend time looking for new ones.

The relationship of inorganic geochemistry to economic geology makes planning future lines of research in the national interest.

BIOGEOCHEMISTRY

There has been unnecessary duplication of effort. Researchers in epidemiology, agriculture, forestry, nutrition, and geology are all interested in the trace element content of vegetation and the related soil, although each for widely different reasons.

Specific suggestions for co-operation include: making available standard biogeochemical samples so different laboratories could check their results; giving results in terms of wet weight in addition to dry or ash weights, as these are the familiar terms to nutritionists; answering such questions as why Douglas Fir has an affinity for arsenic, birch for zinc, alder for copper, or hemlock for manganese which would be of interest to geologists as well as to foresters and agriculturists.

ORGANIC GEOCHEMISTRY

This discipline has been included in the discussion entitled "Mineral and Energy Geoscience." (p. 26).

EXPLORATION GEOCHEMISTRY

This discipline has been included in the discussion entitled "Mineral and Energy Geoscience." (p. 26. 28).

GEOCHRONOLOGY

Judged by international standards the level of activity in geochronology in Canada is only moderate. In terms of published results a large proportion of the significant age determinations have been measured in the United States. This practice, although beneficial to the understanding of Canadian geology, does not contribute directly to the education of Canadian students, does not allow for a maximum of interaction between field geologists and geochronologists, and does not provide a system by which vital geochronological data can be obtained in the future.

In Canada geochronometry was born outside of geology departments with physicists as midwives. The physical problems were well handled but after that a lack of continued interest in and consciousness of the geologic applications have hindered exploitation of the technique. Where geologists are dependent on related physics departments for mass spectrometer time the operation is never as productive from the geologic point of view as it might be. This is partly a reflection of where National Research Council money used to be channeled; geology wasn't on the receiving end of big equipment money.

Much of the current applied geochronology at Canadian universities is the result of a supreme effort by a few scientists operating with limited funds and a substantial teaching load. These circumstances lead to discontinuous inefficient laboratories, application of the more rapid, less costly techniques (which may be less reliable), and, in some cases, conflicting results.

There should be several well-equipped operations whose capabilities are available to visitors and who can service the modest needs of geologists of their own institution and from outside. The universities of British Columbia and Alberta are probably the closest to this capability but neither has arrived. Other labs are either by tradition more specialized--devoted to Sr isotope or Ar dating programs--or still too young to judge. Only a few seem to be operating near capacity (Dalhousie, McGill, Queen's, Carleton).

Viable groups that combine diverse talents are scarce; groups with equipment, diverse talents, and field-oriented programs are virtually non-existent. Considering the size of the Canadian Shield and its importance in the economy of the nation, this trend is difficult to understand.

The Geological Survey of Canada is the only group that has consistently operated at a fairly high level of funding and production with capabilities for all types of methods, including the zircon technique. Their operation is centralized in Ottawa and work has been concentrated on the Shield. Both in manpower and instruments they have lagged behind the U.S. Geological Survey (or even Switzerland for that matter) which is a shame for a geographically larger country where systematic bedrock mapping is a stated national goal. The U.S. Geological Survey has about 10 professionals and instruments for every one carrying the load for the Geological Survey of Canada, and three centres of activity in contrast to one. This lack of diversity is one reason that Canada, at present, has not produced or attracted many leading names in the field. It has not been possible in a small organization both to produce dates for the geologists and to innovate at the idea and technique level. Service has taken precedence to science and at times the lag of the Geological Survey of Canada behind the state of the art has been noticeable, if not embarrassing.

The lack of U-Pb isotopic dating of zircons constitutes a major shortcoming in Canadian geochronology. The technique, which can provide the most precise isotopic ages, has been recently improved, greatly reducing the sample size and time required for an analysis. Even so, only one laboratory in Canada uses this dating technique and it still uses the old method. A larger initial investment is required for this method but the overall cost, time, and effort per analysis compares favourably with other techniques The time when a large number of imprecise ages could be justified is past--support for zircon dating is needed if geochronology is to be seriously pursued.

A major change in the philosophy of funding geochronology in Canada is required. Geochronology requires the application of training based both in physics and geology and ultimately on knowledge of the behaviour of different isotopic systems under a variety of geological conditions. Because of the complexity and diversity of the subject the combined talents of several scientists together with sufficient funding are usually required. The pioneering work in lead isotope studies at the University of Toronto and in K-Ar dating at the University of Alberta are examples where the scientific output of a group exceeded perhaps the sum of the potentials of the participants. Whereas the early research concentrated mainly on the physics and chemical aspects of isotopic dating techniques, the modern trend centres on the geological aspects: which geological events recorded in the minerals and fabric of the rocks can be dated and in what way? To approach these questions a continuous interaction with a field-oriented program is essential.

GEOPHYSICS

SEISMOLOGY

The level of seismology research at Canadian universities and in government agencies is extremely active with gaps (normal mode studies, for example) mainly due to the limited number of researchers in the field.

The Federal Government's Earth Physics Branch has permanently employed only about 20 professional seismologists during the past year. Canadian universities only employ about a dozen permanent seismologists. In addition to earth science activities the Federal Government has a unit involved in seismic application research in nuclear explosion detection and identification.

Fields covered intensively include seismicity and source studies of Canadian earthquakes; time series analysis and inversion methods; loading and induced seismicity; structure of the core and mantle including array studies of mantle inhomogeneities; refraction and reflection studies of the sedimentary basins, crust, and upper mantle; theoretical seismology, particularly in the field of synthetic seismograms and inversion; marine seismology studies and seismic instrumentation; and surface waves.

Canadian seismologists were the first to obtain evidence for the degree and importance of deep mantle inhomogeneities. Observations from this study, in its infancy and relying on the deployment of large seismic arrays, have initiated discussion and new studies throughout the world.

New theoretical work on generation of seismic waves using generalized ray methods and asymptotic ray theory has also been recognized internationally. The asymptotic ray theory is of particular interest to exploration geophysicists for its application to complex two- and three-dimensional structures.

Significant advances have also been made in inversion travel time and wave slowness data using the Tau method, an extension of the Weichert-Herglotz method.

Deep crustal reflection studies are being accepted as a powerful tool for obtaining the fine structure necessary at the base of the crust to extend the plate tectonic concepts into a continental environment.

The Federal Government operates a basic seismic network with 22 standard stations and 11 regional stations. It operates a medium aperture array at Yellowknife, and has commissioned an additional telemetered array in Quebec. Seismicity associated with reservoir loading is being monitored at Mica Creek (University of British Columbia) and the Manic 5 hydrodam, Quebec (Department of Energy, Mines and Resources). Two variable aperture arrays are operated by the University of Alberta, and portable equipment for marine and/or continental studies is operated by the universities of Toronto, Western Ontario, Manitoba, Alberta, Saskatchewan, British Columbia, and Dalhousie, as well as by the Federal Government. The petroleum industry possesses massive instrumentation for marine- and land-based surveys, most of this equipment being owned and operated by the contracting companies. The need for ocean bottom seismometers is still unfulfilled.

Shallow seismic techniques have been applied by Geological Survey of Canada scientists in the study of terrestrial and marine permafrost conditions in the Canadian Arctic. Drift thickness mapping by shallow refraction methods forms an integral part of urban geology studies.

The Earth Physics Branch has been active in microearthquake research, a topic in which certain mining companies have also expressed interest. Lithospheric studies include investigations in the Okanagan and Thompson watershed of British Columbia (Geological Survey of Canada) and near Thompson, Manitoba (privately contracted). Shallow surveys have been made in the Mackenzie Valley Delta and the Sverdrup Basin. Lithospheric studies have been extended to near-Moho arrivals. The University of British Columbia has been using mine blasts in southeastern British Columbia to map structure beneath the Rocky Mountain Trench. The University of Alberta has been preparing an upper mantle model for Manitoba and Alberta from the inversion of data from Project Early Rise, Project Edzoe, Event Dialpack, and a few earthquakes. Sophisticated techniques of body wave inversion are in general use. The Geological Survey of Canada, Dalhousie University, and the University of British Columbia are all active in offshore seismic studies, usually accompanied by general geophysical surveys, many directly related to the dynamics of plate movement. Similar studies have been made in the Melville Bay and Lancaster Sound Regions of the Canadian Arctic by federal scientists. Research at Memorial University and York University have improved understanding of the planetary motions of the earth.

Major co-operative research in deep crustal sounding has only been viable through the effective co-operation of industry, university, and government, formerly co-ordinated by a sub-committee of the Associate Committee of Geodesy and Geophysics of the National Research Council of Canada. That Committee has now been disbanded and Canadian seismologists in this field have expressed concern about future planning mechanisms. Seismological groups in Canadian universities urgently require support from government on a new basis if they are to give adequate backing to the seismic exploration industry.

MAGNETOTELLURICS

Magnetotellurics studies were originally limited to the use of natural electromagnetic fields by simultaneous measurement of two components of electric field and two components of magnetic field at one or two stations. Such studies have now been extended by the use of a resistivity tensor to describe their results. They are carried out by the Earth Physics Branch, the University of Toronto, and the University of Alberta.

In recent years other methods of using electromagnetic fields have been developed to study structure in the crust and upper mantle. Geomagnetic depth sounding using line arrays of six or eight magnetometers was pioneered at the University of British Columbia, the Victoria Observatory, and the Earth Physics Branch, Ottawa.

A further extension of observational technique occurs when natural time-varying magnetic fields are recorded by 25 to 50 three-component magnetometers covering an area of the Earth's surface. Such magnetometer array studies allow a conductive structure to be mapped in the magnetic fields of currents induced by a single external magnetic disturbance event. Magnetometer array studies with large two-dimensional arrays originated at the University of Texas at Dallas and University of Alberta. This technique has been applied in Canada by the Earth Physics Branch and on three continents by the University of Alberta group.

Whichever observational method is chosen, results must be interpreted by comparison with fields calculated for conductive structures. Analytic calculations for simple structures are carried on at the University of Victoria. Numerical calculations are pursued at the University of Alberta, Memorial University of Newfoundland, and the University of Toronto. Model measurements using scaled-down structures in the laboratory are being done at the University of Victoria.

Electrical conductivity in the Earth is of interest partly because it rises rapidly when mantle minerals are partially melted and partly because high conductivity is associated with certain ores, notably sulphides, in the crust.

Canada is among the countries leading in "magnetotellurics" in this wider sense. The Second International Workshop on Electromagnetic Induction in the Earth was held in Ottawa in August 1974, a choice of venue which reflects our strong position in this field of science. The benefits and importance of electromagnetic induction studies using natural fields has yet to be realized by most geologists.

Magnetotellurics as a tool in petroleum exploration is still in a developmental stage, the few magnetotelluric surveys so far carried out by industry being of limited coverage. Two magnetotelluric exploration services have been established in Canada in the last year.

GEOMAGNETISM

Geomagnetism is understandably active in Canada, as Canada covers a significant part of the globe and has within its boundaries the north magnetic pole. In the past year, continued monitoring of the magnetic field has yielded results ranging in scope from a more precise determination of the present location and secular motion of the north magnetic dip pole to a redetermination of the magnetic compass bearings over the approaches to Quebec Harbour on Lake Superior. Extensive magnetic surveys in the Canadian Arctic have shown that the recently adopted International Geomagnetic Refernece Field has serious errors in its secular variation terms and will have to be modified.

There has been continued production of aeromagnetic maps which are a basic tool both for mineral exploration and geological mapping. Magnetic coverage is being extended off the east coast over the continental shelf in the Natural Resources series of maps. These will be of vital importance in the search for resources over the continental shelf.

The bulk of geomagnetic activity in the petroleum industry has been off the east coast of Canada and has been confined mostly to the use of magnetometers and magnetic gradiometers, the use of the latter still being very turbulence-sensitive. Main advances have been in the use of computers to analyze data and prepare contoured maps.

Research in rock magnetism and paleomagnetism is carried out in an adequate number of university and government laboratories. Information from rock magnetism studies is necessary for interpretation of both the small scale aeromagnetic anomalies of direct economic importance and the larger scale anomalies over the continental and oceanic structural areas. Paleomagnetism, through its ability to orient a site relative to ancient pole positions is the main technique for describing past motions of the lithospheric plates.

Much of the paleomagnetic effort, particularly in the Grenville province is aimed at determining whether plate motions of the sort going on now also took place when the Precambrian Shield was being formed. The growing awareness of links between ore formation and hydrothermal activity at both rifting and subducting zones, and the possibility of locating the past whereabouts of such processes is emerging as a potential guide to efficient mineral exploration. This fundamental and time-consuming research which cannot be expected to yield immediate results requires continuing government support.

The Earth Physics Branch, the Geological Survey of Canada, the universities of Manitoba and Toronto and others are studying both short and long wave anomalies in the magnetic field in their investigations of crustal evolution.

Efforts should be made to co-ordinate magnetic surveys sponsored by both the public and private domain.

GRAVITY STUDIES

Although the level of Canadian activity last year remained high, coverage was uneven. The Earth Physics Branch (EPB) and Bedford Institute of Oceanography (BIO) between them were responsible for carrying out most of an extensive program of gravity mapping, new data acquisition, and interpretation, much of it from offshore eastern Canada and the Arctic. Most of the work by BIO involved surface gravity profiling during joint hydrographic/geophysical surveys close to the continental margin, including a 25,000 line-kilometre coverage northeast of Newfoundland in 1973.

The new data from government projects have been valuable in defining geological structure, notably in regions of high potential for petroleum. For example, model studies by BIO scientists have shown the transition zone from continental to oceanic crust off Nova Scotia and Newfoundland to be narrow. In another combined geophysical study, BIO discovered a marked offset in the edge anomaly off central Labrador that might signify an offshore continuation of the Grenville Front. In the Arctic, EPB conducted gravity studies across the continental margin and Beaufort Sea, and of the subsidence history of the Sverdrup Basin; the results so far suggest a northeasterly seaward extension of that basin. The Nova Scotia Research Foundation extended their regional and commercial gravity surveys to northern parts of the province in a search for oil, gas, and salt; preliminary underwater gravity results suggest the presence of salt structures in George Bay and thick sediments under Bras d'Or Lake.

Probably the year's major achievements were in mapping. EPB produced three maps of Canada: the third edition of the Bouguer anomaly map (published), the first gravitationally determined geoid map, and a free-air anomaly map, all based on the new international gravity standards (1967, 1971). The Canadian Hydrographic Service published 45 maps of $2^{o} \times 1^{o}$ areas at 1: 250 000 scale, based on hydrographic/geophysical surveys off eastern Canada by the Bedford Institute; a multi-geophysical survey at 40-mile spacing over the whole Labrador Sea is underway.

The Earth Physics Branch carried out comprehensive tests of the new La Coste and Romberg microgravity meter, showing that a 1 microgal level of significance now seems achievable over a grid of a few square kilometres; this can open up hitherto inaccessible research fields in crustal motion, groundwater studies, geo-engineering and secular gravity variations. In the field of dynamic gravimetry, EPB continued testing a three-axis inertial platform intended as a step toward developing an aerogravity system in fixed-wing aircraft. This is important since gravity surveys using helicopters, although technically successful, have proved excessively expensive. Airborne surveys accurate to 5 mgal or so would be useful in geodesy and reconnaissance, but once accuracy can be improved to 1 mgal the application to detail surveys and in oil exploration will be formidable. Other EPB projects included gravity studies of presumed meteorite craters such as Mistastin Lake, Labrador; tidal observations by gravity meter; and combined analyses of gravity and magnetic fields using the classical Poisson's relation. Since such analyses under favourable conditions enable one to infer directly the magnetic remanence of submerged bodies, they may have an important application to paleomagnetism.

In contrast to the Federal Government involvement, gravity work by other Canadian institutions has been only moderate. Except for Nova Scotia Research Council provincial research centres are not conducting significant gravitational research or exploration. University departments generally lack the resources needed for ambitious projects, but have a potentially important role to play, especially by supplementing regional surveys with detailed studies and by instrumentation design. Detailed gravity studies were carried out by the University of New Brunswick over a Carboniferous contact zone in southern New Brunswick, and by Memorial University of Newfoundland in the region of an early Paleozoic consuming plate margin of Notre Dame Bay. University of British Columbia undertook gravity model studies over economic copper deposits in that province. Tilt and strain tides are being observed by UNB jointly with EPB to examine the loading of the Bay of Fundy tide. York University is conducting tidal research with some new instrumentation.

Finally, gravity operations by the oil industry in Canada declined significantly (by 43 per cent) during 1972-3, this being the fifth consecutive annual decrease in crew-months worked. In setting this dismal development against the impressive total of Canadian activities in gravity, one is struck by a paradox; whereas many of these activities, especially offshore and onshore surveys and instrumentation, are directly relevant to oil and mineral exploration, agencies other than industry are chiefly involved. No significant gravitational research or development appears to be done in Canada by the oil companies. It is true that low priorities assigned to gravity exploration stem partly from superiority of seismic methods, however, multidisciplinary surveys are becoming increasingly important. Moreover, one of the assets of gravitational surveying is its relative speed, and once aerogravity has become accurate enough it should prove to be an important prospecting tool, both less expensive than other geophysical methods and also permits more efficient follow-up work with fewer random lines. There is also the consideration that procedures and equipment used in gravity exploration cause no environmental damage. In view of this and the importance to Canada of establishing improved exploration methods, it is recommended that high priority be given to requests for extensive government support of projects on airborne and other potentially important gravity tools. The government gravity base net in western and northern Canada should continue to be upgraded, base locations being chosen carefully to ensure a closer, better net. Such bases should be permanent, marked so they are readily recoverable at any time of year, and accurately located. If all gravity surveys were tied to this nationwide government base net, combining different sets of gravity data would be greatly facilitated. Industry, particularly the major oil companies, can only gain from such developments and should be encouraged to contribute significantly toward the costs.

GEODESY

The full spectrum of geodesy was encompassed at the conference, "Geodesy for Canada," held in January 1974. Other meetings, courses, and workshops focussed mainly on positioning and the redefinition of geodetic networks. Several Canadian geodesists were also invited to participate in International Union of Geodesy and Geophysics working groups.

Various instruments (e.g., Canadian Marconi Doppler satellite receiver, hydrostatic tiltmeter, self recording gyrotheodolite), methods (e.g., astro-gravimetric geoid computation, determination of vertical crustal movements from scattered relevellings), and systems (e.g., hydrographic positioning) have been developed recently. Development is needed in use of geodetic information in environmental management, earthquake prediction, ecology, engineering projects, and oceanography. This will require new applications and new technology (e.g., new satellite systems, lunar ranging, inertial positioning).

Routine satellite positioning and at least two co-operative satellite positioning programs were established involving several institutions and levels of government.

The Canadian geodetic networks are no longer adequate to serve positioning needs and should be redefined as soon as possible. More organizational structure funds, and a schedule for this redefinition should be set up immediately.

There is an urgent need for funds in data collection, data handling, and research. Because geodesy is a global discipline it needs national direction to ensure proper co-operation and communication with international organizations.

A national inter-institutional research team on satellite geodesy should be established to deal with orbit analysis and prediction, and investigation of new satellite systems.

Canada suffers from a shortage of manpower in geodesy on all levels and has relied heavily on imported professionals. Canadian students should be encouraged to enroll in existing university geodetic programs by groups such as professional surveying associations.

GEOTHERMAL STUDIES

A study at the University of Western Ontario has related the concentration of the heat-producing elements potassium, uranium, and thorium in the core of one of the deep holes in the centre of the Brent Crater.

Feasibility studies of heat flow measurement in shallow lakes in the Kenora area, have started at the University of Toronto.

At Dalhousie University, studies are completed of heat generation and heat flow on data from Nova Scotia boreholes and lakes. Dalhousie is also involved with geothermal measurements in special boreholes in the Azores and Bermuda, and is now working on the current deep-sea drilling experiment.

Earth Physics Branch measurements have now produced the first reliable information concerning the lower limit of permafrost and its spatial variation in Canada. Interest in permafrost is generated by exploratory drilling and the need for pipelines in the north. In co-operation with the Geological Survey, many temperature measurements have been made in shallow boreholes in the Mackenzie Valley and the Beaufort Sea.

The heat-generation program continues on several batholiths in the Cordillera. Work continues on the World Heat Flow Data Collection.

Energy problems have prompted an appraisal of geothermal energy in Canada. Measurements of heat flow and heat generation in the Cordillera have value as background information, but other techniques such as electric resistivity and magnetic deep sounding surveys need to be employed in selected areas. The Geological Survey has undertaken a thorough geochemical survey of hot spring waters.

Permafrost and geothermal energy studies are important to the economic welfare of the nation. In order to promote the development of geothermal energy resources new financial resources are needed. Research and exploration of geothermal energy should be continued by the Department of Energy, Mines and Resources; industrial agencies hopefully will undertake development and further exploration.

TECTONOPHYSICS

Much recent Canadian research has been concerned with sea-floor spreading. In the Labrador Sea and Baffin Bay it included studies of bathymetry, submarine sedimentary basins, local earthquakes, and paleomagnetism of coastal dykes. Details of a triple junction between Africa, Eurasia and North America were discussed in the literature. Deformation in New Brunswick was attributed to uplift and block faulting preceding the opening of the Atlantic; dyke formation was also related to this event. Magnetic survey results over the Canadian Arctic were tied in with continental margins, sedimentary basins and sea-floor spreading. An Erindale College scientist and colleagues related triple junctions to mantle plumes and aulacogens.

Evidence was provided for oceanic crust beneath northeastern Washington and around Vancouver Island and recent subduction beneath Vancouver Island (but not Queen Charlotte Islands) was proposed.

A University of Windsor scientist provided paleomagnetic evidence to show that the northern Interior Plateau of British Columbia has not moved relative to the continent although southern Vancouver Island has rotated.

A Geological Survey of Canada scientist suggested that the Columbia and Omineca ranges of the Rocky Mountains have been uplifted by 7 km and are autochthonous. This reduces the shortening required in the Main and Front Ranges and Foothills by 60 per cent over previous estimates. He suggested underthrusting by a Prairie plate with perhaps an easterly dipping subduction zone farther west.

There was little agreement about Precambrian plate tectonics and whether there had been one, three, or many Precambrian plates. An important paper by a Geological Survey of Canada scientist suggested that the East Arm of Great Slave Lake and Bathurst Inlet are aulacogens formed by the breakup and later reunion of provinces of the Canadian Shield.

A University of Alberta scientist and colleagues advocated reactivation of the Churchill Province about 1900 million years ago.

Papers on paleomagnetism suggested that the Grenville Province may have moved relative to the rest of the Shield but there was little agreement regarding the polar wandering path from 2600 million to 700 million years ago. One group recommended a smooth curve but most others advocated various bends.

Seismic evidence was presented for a low-velocity, mobile zone between 95 and 330 km beneath the Canadian Shield. Other studies showed the Canadian Shield to be under compressive stress producing earthquakes on unhealed Phanerozoic faults. An area of rapid uplift was noted near Lac St. Jean by a University of Alberta worker. Numerous earthquakes near La Malbaie were attributed to post-glacial yielding of the crust weakened by a large meteorite crater there.

MINERAL EXPLORATION GEOPHYSICS

This discipline has been included in the discussion entitled "Mineral and Energy Geoscience." (p. 27).

PETROLEUM EXPLORATION GEOPHYSICS

This discipline has been included in the discussion entitled "Mineral and Energy Geoscience." (p. 28).

REMOTE SENSING

This discipline has been included in the discussion entitled "Mineral and Energy Geoscience." (p. 26, 27).

GEOTECHNIQUE

SNOW AND ICE STUDIES

Sea Ice Research

The scale of interest and effort has expanded greatly in the last five years, largely because of the desire to explore for and exploit minerals (oil, natural gas, and ores) in the Arctic and other ice-infested waters. New research teams have been formed and others expanded. Good examples are the group at Memorial University working on icebergs (radar tracking, underwater form, towing methods) and the experiments of the Arctic Petroleum Operators Association. Only limited progress has been made toward understanding such vital problems as ice stress (forces exerted by ice floes on each other), size, shape, and frequency of pressure ridges, bottom scouring (by icebergs, ice islands, and ridges), ice forces on large objects (ships, piers, and drilling rigs), and the forecasting of ice movement.

Geological Survey of Canada studies on coastal and nearshore processes in the Arctic Islands channels include the significance of floating ice as it affects beach processes and nearshore sedimentation and bottom modification related to the engineering aspects of potential pipelines.

Since sea ice research is expensive, it has led to international co-operation such as the North Water Project, a joint Canadian-U.S.-Swiss study of why a major portion of northern Baffin Bay is nearly ice-free all year. On a larger scale is AIDJEX (Arctic Ice Dynamics Joint Experiment), a major study of ice dynamics and thermodynamics in the Beaufort Sea. It should provide many of the needed answers about ice stress, ice movement and the relations between air, ice, and sea in the Arctic.

Lake and River Ice

Lake and river ice studies are being carried out by Department of the Environment, National Research Council, Alberta Research Council, St. Lawrence Seaway Authority, Ontario Hydro, Hydro Québec, Memorial University, Université Laval, University of Manitoba, University of Alberta, H.G. Acres Ltd., and Foundation Company of Canada Ltd. These investigations have focused on three problem areas: (a) ice formation and the influence of ice on hydroelectric power stations, (b) winter navigation, particularly in the St. Lawrence Seaway System, and (c) ice effects on shore structures. Studies of mechanical properties of ice and ice management (i.e., control dams) have been emphasized. Future economic gains can probably be derived by increased emphasis on studies of ice management methods (e.g., ice jam control) and on the forecasting of ice conditions. Studies of the hydraulic impact of ice cover are now receiving increased attention, particularly at the Canada Centre for Inland Waters. Little attention has been given to the ecological effects of an ice cover on an underlying water body.

Ground Ice

Energy, Mines and Resources, National Research Council, McGill University, University of Alberta, and University of British Columbia have conducted studies of ground ice. Some of these studies, particularly in the Mackenzie Delta area, have earned Canadian scientists a high international reputation. Studies have been carried out by the Geological Survey of Canada on the growth and degradation of ground ice bodies, including pingos, on the recognition of ground ice bodies by remote sensing, and on the effects of surface disturbance on ground ice.

Atmospheric Ice

The results of studies on hail processes and hail suppression operations in Alberta have attracted international interest. Future research should give more attention to ice fog conditions and associated air quality conditions. Research is carried out by Environment Canada, McGill University, and University of Toronto.

Properties of Ice

Studies done at the Department of the Environment National Research Council, McGill University, and University of Toronto have been mostly basic research. The emphasis has been on mechanical properties and on high pressure phases and thermodynamic properties. Recent efforts have paid more attention to electrical properties valuable for developing new electromagnetic remote sensing devices. The chemical properties of ice and its physical characteristics should be further investigated as a possible means of artificially weakening or strengthening ice covers. *In situ* non-destructive testing devices should be developed. Studies of small ice samples in laboratories have prevailed and the sample-size effect should be examined so the data can be applied to field conditions.

Task force groups of the Associate Committee on Geotechnical Research are actively studying ice pressures against structures, bearing pressure of ice, formation and movement of ice, and snow engineering (snow clearing, snow drifting).

Snow Hydrology

Studies of heat exchange and snow melt rates at experimental plots have concentrated on the Cordillera and on the Prairies. Satellite imagery and other remotely sensed data open new fields of research on distribution of snow cover. Further studies of meltwater movement through the snowpack-soil system are needed as opposed to some traditional studies which put an impermeable layer at the base of the snowpack. The chemistry of snow meltwater should be further investigated. Studies in snow hydrology are being done by Environment Canada, National Research Council, B. C. Hydro, University of New Brunswick, Université du Québec, University of Saskatchewan, and University of British Columbia.

AVALANCHE STUDIES

Avalanche studies by Environment Canada and National Research Council have concentrated on the Rogers Pass area. The research effort and the operational avalanche protection system there ranks among the best of its kind in the world. The lack of qualified staff and financial support has severely restricted the attention given to other areas.

PERMAFROST

Permafrost studies involve several university workers, engineers with the National Research Council Division of Building Research, and the Permafrost Subcommittee of the Associate Committee of Geotechnical Research. These studies have earned Canada a worldwide reputation.

Evidence of former permafrost in areas far from present permafrost is growing, and such features are probably more widespread than formerly supposed. Palynological study of late-glacial vegetation has yielded results consistent with this conclusion.

Permafrost studies include the identification of geothermal properties of frozen soils and the development of drilling techniques in permafrost soils. Shallow seismic work is carried out by the Geological Survey of Canada in order to detect the top and bottom of the permafrost layer.

There has been an increasing number of papers and conferences on permafrost. Highlights include the 26th and 27th Canadian Geotechnical Conferences; the volume North American Contribution to Second International Conference on Permafrost; and the Glossary of Permafrost Terminology and Permafrost Engineering Manual (in prep.).

The growing emphasis on northern development will require increased teaching of the geotechnical aspects of permafrost.

MUSKEG

Muskeg, or organic terrain, is a prominent Canadian landscape feature. Although very few workers are currently engaged in its study some outstanding work has been done in muskeg classification as a result of engineering problems. The Associate Committee on Geotechnical Research has and will continue to promote muskeg studies. Canadian geotechnical engineers are regarded as world leaders in this field. To maintain this leadership, training and complementary research must be strengthened at the university level. Papers from the 15th Muskeg Research Conference (May 1973) may be published as a Handbook on Muskeg and Northern Environment to be a companion volume to the Muskeg Engineering Handbook (1969).

SLOPE PROCESSES

Isolated studies of slope processes are underway by several workers; Canada has had some notable and destructive landslides and slope stability problems are widespread. Economic and general public pressure is maintaining a modest level of activity in slope studies. Because of practical problems, shoreline erosion has been a focus of applied research around the Great Lakes, recently heightened by accelerated erosion associated with high water levels.

The Geological Survey of Canada has undertaken studies on slope stability in the areas of mountain coal mining relative to the properties required to revegetate coal spoil piles. In addition, the Geological Survey of Canada has undertaken investigations of landslide problems in the marine clays of the Ottawa-St. Lawrence basin and of natural slope stability in the Mackenzie Valley region.

SOIL MECHANICS

Soil mechanics is one of the major concerns of the Canadian Geotechnical Society; many articles in the Canadian Geotechnical Journal and more than half the program of the 26th Annual Canadian Geotechnical Conference were devoted to this topic.

Canada's size and cold climate creates special requirements in soil mechanics. Geotechnical engineers in Canada are one of the most active groups in the world. Soil mechanics studies at present have a reasonable level of support from government, industry, and universities.

ROCK MECHANICS

Research in rock mechanics has been conducted at the different stations of the Mines Branch Mining Research Centre (Ottawa, Calgary, Elliot Lake, Quebec) and in university departments of mining, mineral, civil, and geological engineering, and geology. The universities include Alberta, British Columbia, Ecole Polytechnique, Laval, McGill, McMaster, New Brunswick, Quebec (Chicoutimi), Saskatchewan, Sherbrooke, and Western Ontario. Some others were engaged in research projects in co-operation with the Mines Branch and with universities. A number of public utilities, organizations and civil engineering firms were also active (Hydro Québec, B.C. Department of Highways). These activities have covered all aspects of rock mechanics: rock breakage (drilling, blasting, comminution) and ground stability and support (underground openings and open cuts, foundations and anchors).

A massive research project based on cost sharing was launched in April 1972 by the Department of Energy, Mines and Resources involving the design of openpit mine slopes.

Although the current year was moderately active, the volume of work was disproportionate to the size and activity of the Canadian mineral industry. At this rate we will become followers in the technology unless improvements are made along the following lines:

1. Financial support from industries and government to create rock mechanics research centres in universities, financed on a long-term basis and permitting appropriate field studies in mines and on construction sites;

2. Academic integration of rock mechanics with soil mechanics so that mining, civil, and geological engineers would have a better knowledge of both fields and be more valuable to their future employers.

ENGINEERING GEOLOGY

An Engineering Geology Division has been established within the Canadian Geotechnical Society and it may eventually become the Canadian Section of the International Association of Engineering Geology. One session of the 26th Canadian Geotechnical Conference was devoted solely to engineering geology. The National Conference on Urban Engineering Terrain Problems, held in Montreal in 1973, included several papers on engineering geology and a review paper on urban geology. Engineering geology input is increasingly required for construction on permafrost (e.g. the Mackenzie Corridor) and for investigations of sand and gravel resources near large urban centres. There is a continuing need for highly trained manpower in this field.

ENVIRONMENTAL GEOLOGY

Environmental geology is that branch of geology concerned with geological processes likely to take place in the future in a time reference significant to human society. The published literature is not a reliable guide to activities in this field as a large part of the work is undertaken by government agencies and, at an increasing rate, by major companies, who do not publish.

Activities in environmental geology include the preparation of regional reports and maps; investigation of subsurface pollution both after the fact and in site evaluation for future waste disposal on the ground or in the subsurface; analyses of terrain and engineering properties of surface materials to evaluate environmental impact of planned engineering works; examination of recent sediments and water quality, particularly on the Great Lakes, to evaluate proposals for improvement and to monitor changes; study of erosional and sedimentary processes to determine the influence of hydrologic structures and assess shoreline erosion; and geochemical studies of surface waters and groundwaters to determine the influence of pollutants that have been introduced or may be introduced into the system.

The rapid development of interest in matters relating to the physical environment has resulted in a strong demand for geologists either trained in this field or with interest in it. A geologist with an extensive educational background in a variety of fields such as geochemistry, isotope hydrology, hydrogeology, engineering geology, and sedimentary processes in addition to a sound background in geology, physics, chemistry, and biology, is best equipped to cope with the variety of problems encountered in environmental geology. Most universities offer an environmental geology course for undergraduates but this sort of course cannot be regarded as appropriate training for the field. It merely introduces the student to the typical problems.

The Federal Department of the Environment, Hydrologic Sciences Division, has a group of geologists employed mostly in hydrogeology and pollution studies. Few geologists are employed in other divisions of this Department which seriously hinders much of the work done in those divisions. The Geological Survey of Canada has a very active program in the Terrain Sciences Division, much of which can be regarded as environmental geology. The Canada Centre for Inland Waters at Burlington is concerned mainly with the Great Lakes and other inland bodies of water in Canada. Their work is almost entirely directed toward understanding the processes of the lake systems in order to promote changes that will lead to improvement. The Bedford Institute of Oceanography in Dartmouth, Nova Scotia devotes a portion of its total effort to studying seawater chemistry and sedimentary processes for the same purpose. The calibre of publications of these agencies and their effectiveness in solving their assigned tasks should be ample proof that a geologic approach to environmental problems is sound. However, it is possible that none of the geologists working in these agencies and on these projects would regard themselves as environmental geologists.

Most of the provincial governments in Canada have now reorganized in order to provide a department or division carrying the word environment in the name. To date most of their work involves groundwater and surface water pollution from waste disposal or surface operations. These provincial departments also employ geologists working on broader aspects of environmental geology including surface mapping, shoreline processes, stream regimen, and influence of hydrologic structures.

In most cities across Canada consulting engineering firms and geology firms provide professional services in environmental geology; most of the geologists employed by these firms have a background in engineering geology, Quaternary geology, hydrogeology, or geochemistry.

HYDROGEOLOGY

Most of the hydrogeologic work done in Canada is sponsored by government agencies either at the provincial or the federal level. The interest of various agencies in groundwater has been almost solely a response to a demonstrated need for technical development. Thus, the earliest work in hydrogeology in Canada was undertaken by the Federal Government because of the obvious need for groundwater supplies in areas of the arid west.

There are approximately 150 practising hydrogeologists. The Federal Government employs groundwater geologists in the Terrain Sciences Division of the Geological Survey of Canada, and in the Hydrologic Science Division of the Inland Waters Branch, Department of the Environment. Other agencies employing groundwater geologists to serve as specialists, mostly in the role of technical support, include Prairie Farm Rehabilition Administration, Atomic Energy Control Board, and the Department of Northern and Indian Affairs. At present (1974) Newfoundland is the only province in Canada that does not have an active provincial agency for groundwater work.

The main effort of most provincial agencies is evaluation of groundwater resources for development of water supplies, provision of technical support for other provincial agencies, and offering consulting advice to the public. During the past decade the hazards of groundwater pollution have become more apparent and a significant part of the studies of these agencies is directed toward water quality.

Hydrographs of observation wells from across Canada with records of up to 10 and 15 years are now available. This allows investigation of groundwater regimes and resources that was not possible a decade ago. Regional groundwater reports have been prepared in most provinces.

Most provincial groundwater agencies have undertaken research projects sponsored in part or whole by the Federal Government under the auspices of International Hydrologic Decade of the Agricultural Research Development Act. One result has been the establishment of a hydrologic research basin or reference basin in each groundwater region of Canada.

Establishing the potential yield of aquifers remains one of the main tasks of most provincial organizations. The Theis solution remains the analytical technique most used for pump test analysis or long-term aquifer response. Electric analog models are accepted techniques for groundwater flow problems in Alberta, Saskatchewan, and Manitoba. Digital models have been used by the Hydrological Sciences Division of the Inland Waters Branch and by the Provincial agencies in Manitoba and Nova Scotia for the solution of groundwater flow problems. Most of the research on this technique is done at the universities of British Columbia, Alberta, and Waterloo. Most hydrogeologists do not use this powerful tool to its fullest extent. Borehole geophysics has produced excellent results, yet geophysical logging of boreholes is practised by only a few of the hundreds of water well drillers in Canada. The next major advance in understanding the groundwater resources of the nation will probably stem from a regulation requiring all drillholes to be electrically-logged and suitably described.

Most groundwater research suffers from a lack of understanding of the geochemical implications of the problem. Reservoirs that contain water unsuitable for municipal use are simply ignored. Only in western Canada where there is considerable information on the hydraulic heads and chemistry of water in the deep subsurface has there been any good work done on this topic. There has been interest in the thermodynamics of groundwater flow systems, in part to understand carbonate solution so that ^{14}C techniques may be applied, and in part to predict the chemical changes that will occur in contaminated systems.

During the past five years there has been marked increase in the number of groundwater consultants across the country. There are now fifteen to twenty private consulting firms. A good portion of their work is on engineering problems not directly related to water supply from the ground, but to dewatering around engineering sites, deep mines and strip mines, design of sanitary landfill sites, disposal of wastes in the subsurface, and environmental implications of engineering construction.

Graduate work to the Ph. D. level in hydrology is offered by faculty who have been specially trained in this field in at least three Canadian universities: University of Alberta, University of British Columbia, and University of Waterloo.

GLACIOLOGY

GLACIER SCIENCE

Since 1970 glacier science in Canada has been conducted by Federal Government agencies (Defence Research Board; Glaciology Division, Department of the Environment; Observatories Branch and the Polar Continental Shelf Project, Department of Energy, Mines and Resources), Canadian universities (primarily British Columbia, Calgary, McGill, Ottawa, Toronto), American universities (Colorado and Minnesota), and other organizations (American Geographical Society, Arctic Institute of North America, Scott Polar Research Institute). Emphasis has been on field studies in the Arctic Archipelago and western Canada.

The prime goal of glacier science is to elucidate the interactions between glaciers and climate leading to a greater understanding of past and future climatic changes. The complexities are such that no synthesis will be forthcoming until glaciers themselves have been systematically investigated. Thus the present mainstreams of Canadian glacier research are:

a) measurements of the physical properties of laboratory and glacier ice (elastic and creep deformation; electromagnetic and thermal properties; isotope abundances; ice fabrics),

b) glacier measurements (channel geometry; temperature and velocity fields; mass and energy balance; meteorology and climatology; surface and englacial water flow),

c) development of instruments and methods (UHF pulsed radar systems; HF radio interferometry; coring of polar ice caps) and

d) theoretical and computational analyses (simple models of glacier velocity, stress, and temperature fields; dynamic response of glaciers to variations in budget; runoff prediction).

An area of immediate practical importance concerns glaciers as a source of fresh water and hydropower, and as an agent of destruction potential (jökulhlaups, surges, and catastrophes).

As an index of Canadian glaciological activity relative to that of other English-speaking nations, research articles and notes in the principal English-language glaciological journal were surveyed for the period 1970-73. Of the 153 articles and notes, 4 per cent were from Australia, 17 per cent from Canada, 15 per cent from the United Kingdom, 49 per cent from the United States, and 16 per cent from other countries; 80 of the 153 articles and notes were related to glacier research as opposed to geotechnical studies and a breakdown of them by nations presents a very similar distribution. A breakdown by agencies shows that in Australia almost all glaciological research is carried out by government; Canada comes next with approximately 60 per cent government and 40 per cent university research; in the United States the percentages are 24 per cent government, 73 per cent university, and 3 per cent other; while the United Kingdom has 9 per cent government, 87 per cent university, and 4 per cent other. A breakdown of the 80 papers on glacier research presents a similar picture. This is consistent with national patterns in other areas of research and development. The Inland Waters Branch and the Polar Continental Shelf Project respectively account for 23 per cent and 21 per cent of the national contribution and for 20 per cent and 30 per cent to glacier science in particular.

Canadian glacier research has been both energetic and competent. Noteworthy have been the continued study of six glaciers in western Canada as part of Canada's International Hydrologic Decade program, coring of polar ice caps to obtain a record of past climate variations and predict future ones, field studies of surge-type glaciers, the design and construction of UHF pulsed radar systems and HF interferometers for glacier and lunar soundings and other applications, and an ambitious inventory of Canadian glaciers.

Considering the degree of activity, it is surprising that none of the major developments in glacier science has occurred in Canada; indeed, most of them occurred in the United Kingdom, a country without glaciers. This is probably because the theoretical side of glacier science is not highly advanced in Canada, thus the co-ordination of theoretical and experimental research is often unsatisfactory. In view of the high degree of government participation it is particularly unfortunate that the largest glacier science group (within the Department of Environment) includes very few active scientists and is to a great extent committed to non-innovative programs. A good example is the glacier inventory, an essential program in the context of resource management, but one which is unlikely to lead to scientific innovation.

Not only do federal agencies constitute the largest sector of Canadian glacier science, they exert a strong control over university research through research contracts awarded to university scientists for programs consistent with the aims of these federal agencies. Although there is little evidence that worthy programs inconsistent with these aims have been thwarted, the structure makes the quality and nature of all Canadian glacier science highly dependent on the quality and nature of government science. This is a source of apprehension both to university and industrial scientists who have little influence on federal programs. The problem could be avoided by insuring that there is broad and diverse input shaping government research priorities.

GEOMORPHOLOGY AND QUATERNARY GEOLOGY

Because much of the Canadian effort in Quaternary geology involves geomorphology, especially glacial geomorphology, this discipline and the broader field of study are merged in the following report.

Studies of glacial till have been mostly descriptive, with some supporting analytical data provided on pebble lithology, grain size, heavy mineralogy, and carbonate content. More sophisticated analytical instruments and methods rarely have been used. Basic research on glacial till in Canada is deficient in respect to currently available analytical, data processing, modelling techniques, and in studies of genesis, deposition, and structure. Preliminary paleomagnetic studies of till suggest a useful approach to conditions and timing of glacial deposition.

Studies of stratified Quaternary sediments also have been mostly descriptive. Structural analyses, experimental studies, mathematical analysis, and computer modelling have been used successfully. Some Canadian sedimentology compares well with the best in the world, but studies of lacustrine sediments, except those in the Great Lakes, have been inadequate. Excepting a few excellent individual studies, little attention has been paid to Quaternary air-fall deposits (volcanic tephra, loess, and dune sand), organic deposits (lacustrine and peat), and fossil soils (paleosols).

Economic importance in construction and engineering has promoted activity in glacial geomorphology by several government agencies. Interest has centred in the Arctic because of resource development proposals such as in the Mackenzie Valley. Canada should be a world leader in glacial and periglacial geomorphology but this has been incidental to other pursuits.

The use of glacial deposits in mineral exploration has been recognized through boulder tracing, geochemistry of glacial till, and heavy mineral studies but the full potential is not yet being realized.

Underwater studies (both lakes and seacoasts) and studies of buried landforms (paleogeomorphology) merit increased attention. The latter is of interest to stratigraphers, and petroleum and mining geologists. Buried glacial landforms can be sources of gravel or water, or the cause of engineering problems.

The major effort in applied Quaternary geology in Canada involves the mapping of surficial sediments at local (1: 50 000) and regional scales. Major regional syntheses include the Glacial Map of Canada (issued by the Geological Survey of Canada) and the studies of Quaternary geology in Saskatchewan. Mapping is proceeding too slowly to meet the needs of environmental, agricultural, forestry, exploration, urban, and engineering demands.

The application of stable isotopes as well as radioisotopes is yielding information on solution and deposition rates, paleoclimates, and weathering rates in different environments. Because of continuing improvements in, and additions to, techniques of dating past events, opportunities for studying the rates of geomorphic processes are unparalleled.

The application of principles of Quaternary geology in geochemical studies must also be strengthened because of the beneficial interactions with environmental, medical, and biological sciences (polution, health, and plant and animal nutritional problems). Consideration of soil development in the context of inorganic weathering needs more emphasis.

Most Canadian Quaternary geologists until recently received their advanced academic training outside of Canada. Our undergraduate and graduate programs are oriented strongly toward pre-Quaternary geology and are particularly deficient in courses that cover the more specialized aspects of Quaternary geology. This has led to a shortage of properly qualified Quaternary geologists and the belief that anybody with geological training can qualify as a Quaternary geologist.

Canadian geomorphology suffers from tension and competition between the U. S. -trained geologist-geomorphologist and the European- (usually British-) trained geographer-geomorphologist. Relations are improving, but the usual placement of geology departments in science faculties of universities and geography departments in arts faculties aggravates this division. Consideration should be given to the formation of interdisciplinary institutes or divisions of geomorphology at a few centres in Canada, involving interested geologists, geographers, pedologists, and civil engineers. The recent formation of an association of geomorphologists in Ontario may provide neutral ground where geographers and geologists can meet to discuss common interests and problems. The new Environmental Earth Sciences Division of the Geological Association of Canada will provide a much-needed forum and will expand communication between Quaternary geologists and related subdisciplines.

MARINE GEOSCIENCE

The Canadian government is pursuing an extension of resource management control and ownership limits to the base of the continental rise. Substantiation of these claims will require a vastly expanded geoscience data base, an inventory of the resources, and detailed offshore mapping. However, scientific interest extends beyond the management zone and includes all the provinces of the abyssal zone. Within this region the objectives are: (1) intelligent and economically advantageous development of mineral and energy resources; (2) preservation, protection, and restoration of the environment; (3) development of an effective and visible management structure; and (4) contribution to basic knowledge.

The transition zone between older continental and younger oceanic crust has stimulated an active research program, especially deep crustal seismic refraction work in which Canada is one of the leaders. The structure and tectonic history of the transition zone are recognized as the outstanding problem of offshore geology, both for understanding global tectonics and because the zone may be a future hydrocarbon province. The active projects are carried out by Geological Survey of Canada, Earth Physics Branch, Dalhousie University, University of British Columbia, and on ancient margins by Memorial University.

Canada has taken an early lead in construction of a data base and remains in the forefront with offshore multidisciplinary hydrographic-geophysical surveys. As a result of these surveys a folio of 1: 250,000 charts is in preparation. As of October 1974, 72 bathymetric, 33 magnetic, and 34 gravity (free air anomaly) charts have been issued. In addition, all the data points used in preparation of these charts have been released in digital format on magnetic tape. A number of sheets have been published covering the Nova Scotia shelf and parts of the Grand Banks. If this momentum is maintained, by the end of the century Canada will have the best-mapped continental shelf in spite of its vastness.

A part of surficial studies is evaluation of terrain sensitivity with respect to pipeline construction, pollution of beaches, dredging, and dumping. Studies in progress are of pipeline crossings in the Arctic; beach morphology and dynamics around southern Gulf of St. Lawrence; and Fraser Delta sedimentation processes.

A major contribution to the knowledge of offshore geology has been made by oil exploration, particularly stratigraphic maps based on deep drilling data. Industry resource inventory data are available to the Federal Government. The samples from offshore wells are curated by the government and are available for study by qualified scientists two years after the completion of a well. During 1974 nineteen wells or 60,000 metres of stratigraphic data on the east coast of Canada will be released. Some seismic contract companies have presented examples of the effectiveness of geophysical methods in extrapolating stratigraphy from seismic response.

The Geological Survey of Canada is compiling a biostratigraphic reference system for the east coast as part of the Basin Analysis Program. These and other studies were presented at an International Symposium in Calgary, September 1974.

Important contributions to continental reconstructions have been made by Dalhousie University through its program of deep crustal seismic measurements and more recently by a program of deep drilling on oceanic islands and the Mid-Atlantic Ridge on Deep Sea Drilling Project Leg 37 (Project JOIDES); by Geological Survey of Canada with a program of aeromagnetic flights across Baffin Bay, Labrador Sea, and Northern Atlantic Ocean; and by Bedford Institute of Oceanography with studies of Baffin Bay, Labrador Sea, and in particular a section of Mid-Atlantic Ridge near latitude 45^{o}N.

Other contributions to Canadian marine geoscience include the electromagnetic induction studies on the east and west coasts and in the Arctic; seismic anisotropy of the oceanic crust; heat flow studies in ocean basins and near mid-ocean ridges; manganese nodules in west coast fiords; undersea geological sampling by diving, submersibles, and drilling; the effect of organic constituents in sediments on the geochemical flux of metals; and the paleocology and paleoenvironment of microfossil assemblages.

The Canadian marine geoscience program is strong in scientific data collection and mapping; in basin analysis and regional geological synthesis; in petrology of deep sea crustal rocks; and in some aspects of environmental geology. The program is weak in development of conceptual models and synthesis; in coastal zone research; in study of engineering properties of sediments; and in innovative techniques and instrument development. The program also suffers from a parochial outlook and lack of worldwide views. Some specific weaknesses and recommendations follow:

1. Canadian marine geoscientists suffer from a lack of scientific exchange and interchange schemes. One of the reasons for this is that there have only been two global oceanographic expeditions originating from Canada. A partial remedy is to sponsor young scientists on the expeditions of foreign ships.

2. There is a paucity of research projects in the coastal zone. As the pressure on the environment from industrial activities increases, as recreational demands expand, and as the public becomes more conscious of the need for conservation in the littoral zone, the present gap in the Canadian program will become even more obvious.

3. The weakness of our deep-ocean geoscience is impairing our ability to play an active role in the search for and eventual exploitation of deep-sea mineral deposits. This rapidly expanding activity is dominated at present by the U. S. A., Germany, Japan, and France. Canada would experience economic dislocation if deep-sea mineral exploitation becomes an economic competitor to conventional mining.

4. The existing fleet is fast becoming obsolete. Even if a construction program were initiated tomorrow, a major research ship would not be available before 1979. New submersibles and tender ships should be included in a construction plan.

5. There is a need for the development of seismic shooting techniques in the presence of dense ice cover. Submarines are only one possible solution, and one that is fraught with a multitude of problems and dangers. It seems more logical that an evolutionary approach to the conventional operation will yield a practical, safe solution.

6. Canada should initiate a program of offshore drilling for scientific purposes in order to obtain geological samples otherwise unobtainable. This program should include shallow corehole drilling on contrinental shelves as well as participation in the International Program of Ocean Drilling.

7. There is no continuing forum in Canada which brings marine geoscientists together, although some successful formal symposia have been held. Canadian geoscience societies should create such a forum.

8. A long-term national plan in the marine geosciences is required. An inventory of outstanding problems could be the starting point for such a plan.

MATHEMATICAL GEOSCIENCE

In Canada, as in other countries, we have witnessed slight but significant increases in (1) the ability of earth scientists in general to apply mathematical methods; and (2) the emergence of individual geoscientists whose prime interest is mathematical geology. These two trends are, for example, reflected in the contents of the Canadian Journal of Earth Sciences where mathematics or statistics are used in many papers, a few of which deal with specific topics of mathematical geology. These papers usually reflect university and government research from about two years previous. That industry research which is published stresses analysis of geochemical data. Numerous analytical methods of treating certain kinds of geophysical data (e.g., magnetic, seismic, etc.) are now routine.

Geological research involving mathematical techniques has a fairly high level of activity in Canada with a broad range of application. Federal and provincial government institutions are applying these techniques along with the petroleum industry and, to a lesser extent, the mining industries. The intensity of application varies considerably; synthesis has not gained as much acceptance as analysis. This is because of complexities in application to particular problems and the development time required to establish working models. Topics emphasized in Canada are the development of multivariate analysis for the classification and comparison of economic potential of geological environments, and the use of geostatistics in exploration and ore reserve evaluation of individual mineral deposits.

Mathematical geophysicists and their research units have made a broad range of contributions, both scientific and applied. These include time series analysis, inverse theory, glacier surging theory, glacial rebound analysis, seismic array theory, seismic wave propagation, earthquake displacement fields, rotation of the earth, core oscillations, theory of earth and ocean tides, long baseline interferometric methods of measuring continental drift, relativity theory in geophysics, dynamo theory of the main magnetic field, and earthquake-nuclear test discrimination. There are approximately 30 workers in this field of whom at least 5 have attained international recognition.

Mathematical geologists have contributed to a wide range of geological problems and have been well represented in the literature. Most geomathematical techniques have been borrowed from other disciplines. However, a team at Ecole Polytechnique is recognized for its work in correspondence analysis. Perhaps the most significant Canadian achievement in geomathematics is the publication of the fundamental reference text, Geomathematics, by a scientist of the Geological Survey of Canada. Also of importance is the appearance of additional personnel versed in the French geostatistics methods, the study of regionalized variables. A small group established at Ecole Polytechnique is now supplemented by geostatisticians of the French school at the Geological Survey of Canada and the University of British Columbia. This means that other Canadian scientists will have access to the French approach to ore reserve estimation problems. Perhaps these techniques could be used for developing a needed national code for ore reserve grade and tonnage estimates.

Sound geomathematical techniques are essential in dealing with the vast quantities of earth science data now becoming routinely available to industry. Geomathematics combined with computerized files opens up an entirely new approach for mineral exploration, metallogenic studies, resource analysis, and land use studies, which is important for government decision-making. Data files resulting from geomathematical research are now available through the Canadian Centre for Geoscience Data for re-analysis as new analytical procedures become available. This service and the content of the files should be made better known and available to the interested public. An additional by-product is development of computer programs which have a general application and which should be made available on a national scale, perhaps through the Canadian Centre for Geoscience Data.

Applied aspects of mathematical geology remain disorganized in Canada primarily due to the absence of a single, recognized, co-ordinating centre such as Centre de Morphologie Mathématique associated with the Paris School of Mines. The only potential centre of this nature in Canada is the geomathematical group within the Geological Survey of Canada. This group, however, is far too small and lacks a co-ordinated, systematic approach. An effective, financially stable centre for research in applied geomathematics is required in Canada. This should be jointly funded by government and industry, and could probably be located in the apolitical environment of a university where it might be affiliated with a large centre for research in economic geology.

COMPUTER APPLICATIONS

Geophysicists, petroleum geologists, and mining geologists are relatively far advanced in their application of computer techniques compared to petrologists, Quaternary geologists, and geochemists. However, in exploration the capabilities of computers in decision making are often either underestimated or over-rated. Disappointment is bound to occur when evaluation of geological data is entrusted to computers without a proper mathematical modelling of the geological environment.

The impact of computer applications in the earth sciences possibly has been greatest of all in the field of geophysics. The object studied by mathematical geophysicists is far from ideal in its behaviour and properties and can really only be satisfactorily modelled numerically. Geophysicists, along with geochemists, can often more effectively use computers than most geologists because their data collection schemes can be designed in a more systematic manner.

The petroleum industry has been extremely active in use of the computer for processing geological data because of (a) widespread data availability due to government regulations requiring release of well data within a specified time, (b) the availability of computer facilities and trained personnel due to industry reliance on computers for processing geophysical data, and (c) the large volume of well data requiring computers for storage and manipulation. Extensive computer usage by petroleum companies has resulted in vastly increased efficiency and improved techniques in handling data on 73 000 wells, as well as contributing to discoveries of new oil and gas reserves. Computerized well data are available from the Alberta, British Columbia, and Saskatchewan governments, the Alberta Energy Resources Conservation Board, a number of commercial, digital well-log libraries, and from proprietary computer data files.

There is a continued need to upgrade the quality of data in existing systems by improved and automated editing and by updating techniques and procedures. It is obvious that wider and easier data exchange through the application of additional data standards will extend the use of existing data banks to non-industry users.

Canadian industry is expanding the use of mini-computers and mini-systems. These systems are versatile, portable, and less expensive, allowing computer technology to be extended to remote areas such as the high Arctic, and allowing Canadian firms to expand into other countries yet meet the requirements of foreign governments that data be processed within the host country.

A typical application in mining exploration is to use methods of multivariate statistical analysis for the classification of geological environments in order to select promising areas which are geologically similar to those in productive mining districts. The geostatistical technique of Kriging is used for estimating the average grade values of metals in various blocks of ore or potential ore. An important byproduct of Kriging is calculation of the precision of these estimates.

Well-designed input documents have proved to be time saving on the outcrop and have improved the quality of data collected. The criticism that input documents restrict the geologist by making it difficult to properly express contacts and age relationships has little validity in big exploration projects where rarely is there enough time to follow particular contacts. On such projects the information pertaining to contact and age relationships is best treated by including descriptive notes which may be incorporated in the data file and retrieved. Studies involving more detailed examinations must use an entirely different design.

Systems in use for data collection and retrieval have been developed by the Geological Survey of Canada, Manitoba Department of Mines, Quebec Department of Natural Resources, Ontario Department of Natural Resources, New Brunswick Department of Natural Resources, Carleton University, University of British Columbia, and University of Manitoba. In some of these projects input documents have not only replaced the traditional field notebook but have been used for laboratory data collection such as petrographic thin section study and geochemical analyses. The Geological Survey of Canada has played a leading role with over 40 projects using computer systems for field geology, mineral deposits, geochemistry, chemical analyses, urban geology, and geophysics. Many of these projects use interactive data management systems. Special programs permit retrieval of selected data with parameters specified by the user allowing rapid comparison of data on different rocks.

Since the final products of most geological investigations and research are graphic in nature many application programs have been developed to display data in their proper geographical locations. Sophisticated and versatile gridding, map posting, and contouring packages can generate maps and diagrams with parameters chosen by the geologist. The Geological Survey of Canada is the first geological survey in the world to go into full-scale production using autocartography for the production of colour geological maps. This system also provides a base for management of spatially distributed geological data and a facility to conduct cartographic analysis. Programs are available to produce subsurface cross-sections and various complex displays. These can serve as primary documents for making geological interpretations for log analysis, stratigraphic and structural studies, seismic modelling, and trend surface analysis. Many special programs, although not widely available, are in use for creating displays of data obtained from well bores, e.g., lithology, wireline log responses, geochemical and petrophysical analyses. Conversational retrieval systems have also been developed for display of geological data on remote cathode ray tube terminals.

The communication gap between geologists and the computer can be narrowed by improved education of geology students, not only in computer programming but also in mathematics and statistics. The Canadian Institute of Mining and Metallurgy Computer Applications and Process Control Committee has assisted industry in keeping abreast of computer developments by sponsoring, during the past two years, special sessions at meetings, workshops, and short courses. The Canadian Society of Exploration Geophysicists through its journal disseminates new information on computer applications to geophysics.

Government funds (the principal source) for applied research in mathematical geology have not been forthcoming and are needed for the support of technical personnel, research associates, and post-doctoral fellows. Grants earmarked for computer applications by Geological Survey of Canada were responsible for much of the early development, but have now been discontinued. Further, the Special Computing Grants of the National Research Council are cancelled as of the 1975-1976 fiscal year. Computer-based research must now compete against other research projects for operating grants.

MINERAL AND ENERGY GEOSCIENCE

MINERAL EXPLORATION GEOLOGY

The relationship of mineral deposits to volcanism and other plate tectonic phenomena played an increasingly larger role in mineral exploration and mineral deposit research in the period under review. It was the subject of two important symposia in 1974 which attracted large international participation, one in Vancouver sponsored by the Geological Association of Canada, the other in St. John's, Newfoundland sponsored by this association in co-operation with the NATO Advanced Studies Institute.

The present low level of mineral exploration in Canada is causing some concern to the mining industry as production is outstripping the discovery rate by five to ten times. Recent exploration activity was probably most intense in the northern Cordillera and Appalachian regions. In the Cordillera (particularly in the Selwyn Basin) interest in lead-zinc mineralization has been sustained by the release of several high quality four-mile geological maps by the Geological Survey of Canada and by the availability of a rapid, spray-type field test for zinc. Exploration for lead and zinc in the Carboniferous of the Appalachians was initiated by recognition of geological similarities to mineralized areas in Ireland. It has led to discovery of an important lead-zinc deposit in Gays River, Nova Scotia.

A national system for storing selected core is badly needed. This would preserve geological data for future studies and comparisons.

Pure research in mineral deposits must receive increased support to provide the data bank necessary for new or improved metallogenic concepts. Now, as never before, economic geologists are pulling together information from all fields of geology and using this information in the understanding of and search for ore deposits. They are using data from (a) detailed paleontology to trace stratigraphic correlations and facies changes related to mineralization; (b) petrochemical studies of volcanic rocks to outline those parts of a volcanic pile most likely to contain mineral deposits; (c) paleomagnetism to determine the paleolatitudes of certain strata to assess their potential for red-bed copper deposits; and (d) mineral equilibria studies to determine under what conditions nickel, for example, is most likely to occur as the extractable sulphide rather than as silicates unavailable by present technology.

The single most important public source of geological data on Canadian mineral deposits is in university theses. The perpetuation of this source of data should be safeguarded and partially organized to ensure adequate coverage of Canada's mineral deposits. Some mines have undergone several thesis studies because of exceptionally co-operative mine management or sufficiently complex geology to merit the research. On the other hand, many deposits are either not documented at all, or in insufficient detail. This causes serious gaps in our data on mineral deposits. Some means of improving communications between universities and mining companies would be desirable, possibly through a common clearing-house such as the Geological Survey of Canada or the Canadian Geoscience Council.

MINERAL EXPLORATION GEOCHEMISTRY

The breadth of geochemical application has been maintained and locally increased by mining companies utilizing geochemistry more fully in their exploration programs with the latest major advances in the glaciated areas of the Canadian Shield. However, there has been a reduction in overall activity since the peak years of 1968-1969, especially in the provinces west of Ontario due to political and legislative actions considered detrimental by many Canadian mining exploration companies.

Some of the most significant advances in geochemistry have been in remote sampling methods. Limited experimental work has been carried out on the detection of gases over orebodies using spectral correlation techniques to measure selected absorption bands.

Fairly extensive research has been carried out in sampling vapors, gases, and particulates for exploration purposes. Early work concentrated on the measurement of mercury vapor and showed certain types of mineralization to exhibit anomalous concentrations of mercury vapor in the overlying atmosphere close to the ground. However, it has not proven feasible to apply this method to airborne survey operations, since adequate detection has so far not been achieved at practical altitudes for airborne survey.

Perhaps the most promising approach to airborne detection of geochemical anomalies in Canada to date has been in sampling particulates. Investigations carried out by Barringer Research have indicated that there is continuous generation of particulate material by vegetation and that materials emitted can carry anomalous quantities of a wide range of elements when the vegetation overlies mineralization. The precise mechanisms of particulate generation are complex and still under investigation, however, empirical data has clearly indicated the potential of this technique. Flight tests across a variety of deposits in Canada and elsewhere in the world have shown that strong anomalies can be developed over ore deposits. Reproducibility is a function of meteorological conditions and research is currently underway on methods of evaluating continuously inflight the vertical mixing conditions which exist between the aircraft and the ground. Under Canadian conditions atmospheric particulate sampling (designated under the trademark AIRTRACE) is essentially a biogeochemical technique differing from conventional biogeochemistry in that the samples are composite and derived from a wide range of plant species. The material sampled is totally different in character from conventional samples. Experience must be gathered with this technique before its interpretation can be fully understood. The concept appears to have great potential since it can be employed simultaneously with all of the well-established airborne geophysical prospecting techniques.

The Geological Survey of Canada continued its studies of lake bed sampling, establishing this as a viable exploration technique. Statistical treatment of lake bed sample data has been applied to delineate mineralized areas in research studies in northwestern Ontario.

Stimulated by modern ideas of volcanogenesis, lithogeochemical techniques are being applied to exploration for massive sulphide deposits in favourable belts of the Canadian Shield and the Appalachian region contributing to a greater understanding of the environment and the genesis of these deposits. This work is being carried out by the University of New Brunswick, Queen's University, the Newfoundland Department of Mines and Energy, and other groups.

Critical studies aimed at improving the understanding of dispersion of metals in rocks are underway at the University of New Brunswick. Electrochemical experiments are currently being carried out to determine if natural self-potential currents can explain both the concentration of metals and the zoning of ore elements in massive stratiform sulphide bodies.

There is a need for improved communication between personnel in government, universities, and industry to identify the problems of exploration so that research can be directed toward them.

MINERAL EXPLORATION GEOPHYSICS

The mining geophysics industry in Canada is now predominantly an export-oriented industry, with an estimated 51 per cent of its services and 58 per cent of its instrument sales currently being foreign. Domestic activity this year appears to be down still further, though foreign activity may be increasing. The energy panic has resulted in increased airborne surveying and ground instrumentaion for uranium exploration.

The most important achievements in the mining geophysical field in the past year include (1) the recent trend toward large crystal arrays in airborne gamma-ray spectrometry, with associated digital recording and processing techniques; (2) the publication of high-sensitivity aeromagnetic maps by the Geological Survey of Canada and the development of computer-assisted interpretation techniques designed to take advantage of the higher sensitivity data; (3) the significant trend toward overseas work, particularly airborne; (4) multi-frequency airborne electromagnetic systems such as the Scintrex Tridem and the new McPhar and Barringer multi-frequency systems; (5) development of ground pulse electromagnetic systems of various types; (6) the introduction of phase-measuring IP systems by at least two manufacturers; and (7) use of data from the first remote sensing space craft, ERTS-1.

The lower level of mineral exploration activity over the past several years in North America has brought with it an increase in the development of new instrumentation by those companies which both manufacture and offer contract surveys. This is probable because research and development is one way of keeping one's staff gainfully employed. There are presently 17 companies in Canada, 10 being in the Toronto area, manufacturing about 130 different types of mining geophysical equipment. Between them these companies spend between $1. 5 and $2 million annually on the development of new airborne and ground equipment, a surprisingly high 10 per cent of the gross sales and contract services of the industry. A significant proportion of this development is government-supported through such research and development grants as the Industrial Research and Development Incentives Act (IRDIA) and Program for Advancement of Industrial Technology (PAIT) schemes of the Department of Industry, Trade and Commerce, and Industrial Research Assistance Program (IRAP) of the National Research Council of Canada. Without government support it is doubtful whether Canada could have maintained her present position as the leading manufacturer of mining geophysical equipment in the world as the mining industry itself spends little money in this area.

Canadian instrument companies alone supply about 75 per cent of all mining geophysical equipment manufactured in the world. Thus mining geophysical instrumentation is probably the only part of the electronic industry in which Canada dominates the world market, although there is increasing competition from manufacturers in Europe, Australia, and the United States.

With the primary objective of involving the mining industry in the support of research in exploration techniques (including geophysics) the Mineral Exploration Research Institute (Institut de Recherche et Exploration Minière) has been established, initially as a co-operative venture between the Ecole Polytechnique and McGill University with National Research Council support.

PETROLEUM GEOLOGY

Petroleum geology involves the application of many of the subdisciplines of geology to the search for and recovery of oil and gas. Both exploration and development geology are being actively pursued in view of the serious shortage of gas and domestically produced oil that Canada faces and the necessity to discover new fields and increase the recovery from presently known fields and from oil sand deposits.

Basin analysis studies to determine the hydrocarbon resource potential of untested areas have received much attention in recent months. These analyses involve study of the type, thickness, and distribution of sediments, the occurrence of source and reservoir rocks, the geological history of the basin, in effect, the total geology, with particular emphasis on geochemistry. Two recent publications on this subject are noteworthy: Future Petroleum Provinces of Canada, Their Geology and Potential, published by the Canadian Society of Petroleum Geologists, and An Energy Policy for Canada, published by the Department of Energy, Mines and Resources and containing geological analysis and estimates by the Geological Survey of Canada. The Canadian Society of Petroleum Geologists and the University of Alberta sponsored a one-week seminar on "Geological Principles of World Oil Occurrence" in May 1974.

Exploration activity in Canada's offshore areas and in the Mackenzie Delta has caused a marked increase in interest in clastic sedimentology by petroleum geologists. This subject, along with petrology, clay mineralogy, detailed stratigraphy, and petrophysics, will require more research in the future in connection with the development of secondary and tertiary oil recovery methods for existing reservoirs. Petroleum geology would also benefit from additional research and training at the universities in geochemistry, hydrodynamics, and micropaleontology.

There are approximately 2500 petroleum geologists in Canada. A large number of geoscientists using the most modern concepts and technology will be required to find and produce the oil and gas necessary to Canada's future. Unfortunately, because of the severe economic straits claimed by the petroleum industry, there may well be a decrease in the number of new graduates hired into the industry in 1975.

PETROLEUM EXPLORATION GEOCHEMISTRY

It is estimated that there are only about a dozen active workers with sufficient background and experience to have a comprehensive view of the theory, methods, and use of petroleum geochemistry. The petroleum industry as a whole has larger staff and budget allocations for geochemistry than universities and government combined. The oil companies also draw on the expertise of major research facilities of associated companies and service organizations in the United States and Europe. There has been a traditional reluctance to publish any developments or interpretations which could provide a competitive edge. However, there appears to be a growing tendency to realize that the industry as a whole benefits from broader distribution of results of significant studies.

The efforts of the petroleum industry are directed primarily toward solution of problems related to origin of petroleum, identification of source rocks, determination of regional maturity (organic metamorphism) levels, typing of oils and gases, and relating specific hydrocarbon accumulations to their source through chemical analyses of oils, gases, and rocks. Only the major oil companies maintain laboratories in Canada. Geochemical services are available in eastern Canada (INRS-Pétrole, Université du Québec). Other companies offer analytical services done outside Canada. There is a need for increased geochemical service capacity to support the requirements of smaller companies.

Government activity includes both routine work and research carried out in Geological Survey of Canada laboratories at Calgary and Dartmouth, the Fuels Research Centre in Ottawa, and the Research Council of Alberta. A significant achievement was the joint study by the Geological Survey of Canada and Institut Français du Pétrole to classify Alberta crude oils and correlate them to source rocks. At the Research Council of Alberta, continuing studies have been made on the geochemistry of formation waters, gases, and oils.

The universities have had a more restricted, specialized approach, related to subjects suitable for basic research. A Hydrocarbon Research Centre has been formed at the University of Alberta and an Environmental Sciences Centre (Kananaskis) at University of Calgary. Stable isotope work on petroleum gases and fluids continues at both universities and microbiological aspects are investigated at University of Alberta. Carbon and sulphur isotope studies have been made at University of Calgary, University of Alberta, and McMaster University. Work has been done at the University of Calgary on the geochemical origin of sulphur compounds in crude oils.

The current conceptual model of the origin of oil and natural gas is as a deep subsurface, temperature-controlled, abiological, chemical process, acting on lipid-rich oil and gas source rocks and humic-rich dry gas source rocks. This model determines the direction of research and the development of operational methods and interpretation criteria.

A series of important Canadian papers has appeared during the last year documenting the effects and processes of biodegradation. However, there continues to be some scepticism regarding the importance of these processes in the formation of the Athabasca Tar Sands.

There is a surprising lack of specific geochemical data for most basins. Government agencies responsible should consider including this data as part of the required geological data package in well history or other reports.

Most laboratories have developed suitable analysis methods based on their particular requirements. If industry and government groups could agree on a suitable analysis for all oils recovered in wildcat wells, data exchange for oil classification would be facilitated. Interested workers could then compare oil types and make their own interpretations of a much larger number of oils than are now available.

The use of organic geochemistry as an exploration tool should be stressed in university courses dealing with petroleum geology.

PETROLEUM EXPLORATION GEOPHYSICS

The Canadian strength has been in the development of innovative techniques in the use of geophysical instruments. In particular, adaptations of equipment and methods to suit conditions found in Canada have been very successful, the results being used in many countries of the world. Early seismic equipment used in the mid-1940's was entirely unsuited to the Canadian winter climate, and operations were not possible in temperatures much below freezing. Within a few years, special design, ingenious methods of utilization of waste heat, and improved technique allowed continuous operations to be carried out in -40^{O}F weather. Muskeg was another problem, the development of tracked transport vehicles being due in large part to the demands of the geophysical industry.

Interest in the Canadian Arctic has spawned several recent developments. One of the most interesting is the continuous tow cable in which seismic wave detectors and connecting cables are integrated into a single unit a mile long. This unit can be towed continuously over the ice and snow, stopping only to make an observation. Conventional procedures require the detectors and cables to be picked up and laid down for each observation or small number of observations.

Another Canadian development is a highly efficient, focused energy source consisting of several small impulses detonated in a closely controlled sequence and pattern.

Unfortunately such progress is not likely to continue. Due to the relatively high cost of exploration in Canada compared to the rest of the world, the seismic exploration industry has declined at a rate of about 10 per cent per year since 1967, when over 120 seismic crews were operative in Canada. The decline was greatly accelerated in 1974, when approximately half of the remaining 60 seismic crews in Canada moved into the United States.

The geophysical decline has also had a depressing effect on digital data processing, which reached a peak in Canada in 1969-1970. Foreign-owned companies now dominate the local market.

The decline in exploration activity foreshadows a serious shortage of Canadian oil production in the future. The seismic method generally precedes by five to eight years actual production of any oil discovered. So it is difficult to believe that Canada, with little more than 15 years proven conventional oil supplies, should be at a 25-year low point in exploration. It is estimated that approximately 100 seismic crews are necessary to maintain discoveries for Canada's future consumption requirements.

PETROLEUM FORMATION EVALUATION

Petrophysics

Theoretical Petrophysics

During the past year parameters related to the evaluation and producing behaviour of hydrocarbon-bearing reservoirs were investigated with the most notable results being obtained in the determination of residual hydrocarbon and the application of pulsed neutron logging techniques.

Producing fields approaching depletion require the implementation of improved secondary and possibly tertiary recovery schemes. Knowledge of residual hydrocarbon saturation obtained through radioactive tracer logging techniques or pressure coring will be required. The search for new reservoirs, chiefly within sandstones and shales, requires identification of the shale content of sandstone reservoirs from open hole logs to differentiate pay from non-pay and to better define effective hydrocarbon saturation. Prototype tools and interpretative techniques to measure *in situ* permeability have been constructed and are still being tested.

Rock Typing

Crossplotting on one graph the neutron, density, and acoustic data helps differentiate lithologies and differentiate between porous and non-porous rocks; the inclusion of gamma-ray measurements allows even finer definition of the evaporite sequences. Several methods of displaying such crossplots have been developed, including those utilizing computer manipulations and output.

The future need is for laboratory-derived matrix parameters to compare to down-hole measurements. More spectral gamma logging (i.e., that which differentiates between elemental gamma-ray sources) is needed to complete this picture.

One of the problems in interpreting well logs is caused by the irregular shape of the bore-hole. Improved communications between drilling engineers and geologists could reduce this problem.

Research is done only within integrated oil companies of U.S. origin and by the major service companies. Canadian institutions should be encouraged to initiate their own research.

Paleoenvironment and Diagenesis

The environment of deposition of the rocks may be deduced by analyzing the shape of one or more well log component curves. The self-potential log and resistivity and porosity devices basically respond to variations in pore volume and shale or clay content which are in part related to environment of deposition. Abnormal pressures in the formations can also be detected from logs.

Production Logs

Any log which yields useful information in cased holes can be used as a production log.

Tools intended primarily for measuring the performance of producing and injecting wells include: casing thickness, cement bond, neutron, gamma, pulsed neutron, thermometer, manometers, flowmeters, caliper, water-holdup meter, and radioactive-tracer survey. Pulsed neutron devices which measure artificially induced neutron population changes per unit time have become popular recently, helping to differentiate between hydrocarbon- and water-bearing formations in cased and uncased holes.

The methods of determining flow rates need refining. A better understanding and documentation of multi-phase flow behaviour is required.

The Petroleum Recovery Research Institute in Calgary should be encouraged to synthesize its results on the engineering aspects of petroleum recovery with logs run both before and after casing. A broader cross-section of the industry should be made aware of their conclusions.

Oil Sands Evaluation

Published interpretive studies are mainly confined to the Alberta Energy Resources Conservation Board's own report on the Cold Lake deposit and documents supporting mining of the Athabasca Tar Sands. These tend to emphasize the use of logs in the exploration phase. However, in the past year there has been a shift in emphasis from exploratory-type programs designed to estimate reserves to engineering-oriented programs for lease development.

Future developments will require refinements in evaluation to make possible sound decisions regarding surface mineable areas and *in situ* recovery schemes. In *in situ* recovery the monitoring of schemes will lean heavily on the tools of formation evaluation. In pilot mining schemes much core material is being obtained to evaluate bitumen recovery processes and to examine the critical and varied effects of clays in these processes.

The most pressing short-term need is for agreement between the different levels of government to provide the proper atmosphere for enterprises to undertake the vast projects with confidence. Co-operation between government and industry in both development and research is desirable and should be isolated from short-term politics.

Drill Stem Testing

By lowering instruments into a bore-hole the fluids contained within the rocks can be sampled and an estimate made of the permeability, and on occasion, the lateral extent of the reservoir. Due to improved tools and pressure interpretation techniques in the last five years, drill stem testing has become one of the most reliable methods of evaluating a well prior to completion or abandonment.

Inflatable tools are capable of testing in abnormally wide holes without resting on the bottom of the hole. They also have the capacity to test several stratigraphic horizons without having to return to the ground surface. About 40 per cent of the total testing is done in this manner.

During the past year a major integrated oil company developed a system for determining at the drilling rig floor what type of fluids are entering the tool during testing. This is an important advance.

Improvements are required in testing techniques; often too little time is allowed for testing and the information gained is not thoroughly analyzed.

Practical improvements would include the development of pressure recorders capable of withstanding severe conditions of temperature and pressure. Pressure recorders are also required which are capable of recording down-hole pressures at the drilling rig floor during testing. Further development is needed on the hydraulic systems which operate the tools, thus eliminating unnecessary misruns. Also needed are standardization of gas and fluid recovery descriptions; a gas testing manual stating orifice sizes, pressures, and methods of testing; a fluid analysis kit for field operations, and a more accurate gauge for measuring down-hole temperatures.

Continuing education is needed so that evaluators working in small companies can keep in touch with new methods.

COAL GEOLOGY

Recent concern over long-term energy supplies and requirements has greatly expanded the study of coal deposits, increasing both field exploration and examination of the depositional, diagenetic, structural, and other geological elements that determine coal genesis and type.

The only recent conference devoted solely to coal was the First Geological Conference on Western Canadian Coal (Edmonton, 1972). Important papers were presented by Canadian coal geologists at the Canadian Institute of Mining and Metallurgy Annual General Meeting (April 1974); Circum-Pacific Energy and Mineral Resources Conference (August 1974); and Saskatchewan Geological Society Symposium: "Fuels—a geological appraisal" (November 1974).

On-going mapping, stratigraphic, and structural studies by industry and government agencies provide a measure of recoverable coal reserves. Significant contributions by universities are presently made in recent genetic/dynamic approaches to deposition and diagenesis of terrigenous clastic rocks; these methods must be applied to prediction, exploration, and recovery of Canada's coal deposits. Insights to the maturation processes of coal are part of the general problem of diagenesis of organic matter; the relationships among physics, chemistry, and geologic history in organic diagenesis are receiving increased and needed study.

Although Canadian universities have recognized expertise in subdisciplines associated with coal geology, in not one of those universities is there a Chair of Coal Geology. Likewise, geoscience societies should encourage increased activity.

The fall and rise of interest in coal research is a first-order example of the folly of treating curiosity-oriented research as separate from applied research. When coal was in low demand, most coal research was viewed as curiosity-oriented. Now that coal is needed this research is regarded as mission-oriented.

INDUSTRIAL MINERALS AND AGGREGATES

The value of industrial minerals and construction materials continues to increase with the general economy of the country.

Transportation cost has tied the development of construction materials such as deposits of sand and gravel, limestone, dolomite, and various building stones to the near-urban areas. However, the conflict over land use in the near-urban areas is threatening to overturn traditional economics and is forcing producers to look farther afield.

One of the most recent achievements has been the study, sponsored by the Ontario government, entitled "Mineral Aggregate Study, Central Ontario Planning

Region." This study shows that annual per capita consumption of mineral aggregates in Ontario was six tons in the late 1940's, 15 tons in the late 1960's, and is expected to be 25 tons by the year 2000, due mainly to the automobile and demand for modern highways and extensive parking areas, the many high-rise office, hotel, and apartment complexes, and airports and other major urban redevelopment projects.

Surely the jurisdiction over all minerals should be part of a provincial mineral resource plan that balances the total needs of the entire population to the resources available.

MINERALOGY AND CRYSTALLOGRAPHY

Canadians continued to be very active in mineralogy and crystallography. In 1973 their 60 papers published represented 20 per cent of the content of four major mineralogical journals.

Outstanding results have accrued from the sulphide research program at the Federal Mines Branch. During 1973 this program resulted in the publication of four new mineral descriptions and five structure determinations, as well as the redefinition and confirmation of two incompletely characterized pallodium minerals from Sudbury. The group's work on the system Cu-Fe-S has clarified the relation of the phases and the condition of formation of copper minerals. They have also explored the composition of natural platinum metal alloys.

Also noteworthy are continuing studies by mineralogists at Ecole Polytechnique, the Royal Ontario Museum, and Carleton University on minerals from the Desourdy quarry at Mont-St-Hilaire, Quebec, which has been established as one of the classic mineral localities of the world. To date, at least 140 different minerals have been recognized at the quarry including almost 20 new or, as yet, unidentified ones. Scientists at Carleton University, have recently described the new St-Hilaire minerals hilairite and gaidonnayaite, tri- and di-hydrates of sodium zirconium silicate, and carletonite. A University of Ottawa scientist published a significant work on the kinetics of garnet crystallization.

One of the important and continuing contributions of mineralogy and crystallography to Canadian society is in application to mining and milling problems. An example of this is in the processing of some uranium ores at Elliot Lake, Ontario, where differences in grinding time and acid consumption of different ores were found to be related to differences in the uranium mineralogy, the mineral in one ore being more refractory than in the other. Detailed mineralogical studies can detect such changes in advance and allow for appropriate adjustments to milling procedures. More studies on uranium and thorium minerals and clay minerals could lead to important economic applications.

Although the activity in mineralogy and crystallography has been commendable, the number of workers and volume of research has remained about the same for the last two or three years. This situation is regrettable because the development of our mineral resources is an important part of the profile of national activity and the quality of fundamental and applied mineralogical research is far from occupying the position it should.

ISOTOPE MINERALOGY

Canadian research in isotopic mineralogy has focused on sulphur isotope effects in sulphide and sulphate systems. This work, underway for some years now at Alberta, Calgary, and McMaster universities, continued to some extent on the determination of equilibrium partitioning of S-isotopes between sulphide minerals by both experimental synthesis and field studies of natural sulphide assemblages. Also, at the universities of Manitoba and McMaster, studies of S-isotope fractionation in ore sulphides are continuing, partly for their possible usefulness in determining temperatures of ore formation. Studies of the isotopic composition of lunar troilite and the effects of shock metamorphism on it are also underway at McMaster.

The major need for further research appears to be to improve our knowledge of the dependence of inter-mineral fractionations on temperature, both for sulphides and for silicate and oxide oxygen-isotope fractionations.

PETROLOGY

IGNEOUS PETROLOGY

The new global tectonics, with all of its implications for restriction of certain magma types to specific tectonic environments, has forced a re-examination of igneous rocks however barren or metamorphosed they may be. Igneous petrologists in Canada have an excellent opportunity to make significant contributions, especially to our understanding of activity at mid-oceanic ridge crests and to early crustal evolution.

Volcanism in the western Cordillera from at least early Mesozoic to recent times has been integrated into a plate tectonics model due to the co-operative research of the Geological Survey of Canada, the British Columbia Department of Mines and Petroleum Resources, and the University of British Columbia. A number of stratigraphic and petrochemical studies, mainly on Mesozoic volcanics, are underway to reinforce the model. Detailed studies of recent and potentially active volcanoes, most notably Mount Edziza, by the Geological Survey are closing an important gap in knowledge of the circum-Pacific ring of volcanoes. They also provide sound scientific data on the hazard to the public of possible future eruptions.

Bedford Institute and Dalhousie University have furnished a wealth of data on volcanism of the Mid-Atlantic Ridge with JOIDES in "Deep Drill 1974". Investigators in a number of institutions across Canada will participate in studies of the JOIDES core. Dalhousie University is also carrying out research of the intraplate islands of Bermuda and the Azores. Geochemical studies at the University of Montreal have provided much data on volcanic rocks of oceanic islands and island arcs.

The Appalachian geosyncline has been attributed to former opening and closing of the Atlantic Ocean. Current studies at Memorial University on ophiolites and volcanic belts of Newfoundland are providing much new data relevant to this interpretation. Calc-alkaline volcanic rocks of Nova Scotia and New Brunswick which in the modern context are generated at converging plate margins, are being investigated at Dalhousie and at the universities of New Brunswick and Montreal.

Previous work in the Proterozoic Circum-Ungava geosyncline indicated that the Labrador Trough was ensialic, thus difficult to reconcile with a plate tectonics model. Calc-alkaline rocks, the hallmark of subduction zones, were apparently lacking. However, current work by the Geological Survey in the Cape Smith belt has recognized calc-alkaline rocks which warrant a re-examination of previous views. Volcanic rocks of the Proterozoic Coronation geosyncline presently being examined by the Geological Survey are dominated by enormous thicknesses of late-orogenic ignimbrites which may, by analogy, be amenable to a plate tectonics interpretation. Grenville geosynclinal volcanic rocks comprise a thick assemblage of mafic to felsic calc-alkaline rocks according to studies at Carleton University and the Geological Survey. Volcanic belts of the Baffin geosyncline on Melville Peninsula are now being examined in detail by the Geological Survey.

Archean igneous rocks are chemically analogous to those of modern island arcs but their tectonic setting and structural style are unique. Fragmentary evidence suggests they may have been deposited in part on a sialic crust and may be related to a primitive type of plate tectonics. Geochemical and stratigraphic studies of Archean igneous rocks are continuing at the University of Manitoba, the University of Toronto, the Ontario Division of Mines, the Geological Survey of Canada, the Quebec Department of Natural Resources, and other centres. Basin analyses in the Abitibi and other greenstone belts is aided by recognition of the environmental significance of facies changes in iron-formation or "exhalite" and by the identification of volcanic centres. Recent discovery of ultramafic lava flows in the Abitibi belt and of quench textures in Archean lavas from several localities may produce interesting advances in Archean petrography.

Plateau basalts, the principal igneous rocks of the stable crustal platforms, have been studied by the Geological Survey in the mid-Proterozoic provinces of Coppermine River, the Keweenawan, and Seal Lake, and in the Miocene province of central British Columbia. Kimberlite diatremes of Somerset Island, N.W.T., are being studied by scientists from Lakehead and Dalhousie universities, and kimberlite-like dykes in the Archean rocks of Labrador have been discovered by Memorial University scientists.

Work at Brock University, University of British Columbia, and elsewhere is producing evidence on likely changes in composition of volcanic rocks attending diagenesis.

Petrologic studies of anorthosites and of the basic rocks of the Muskox intrusion by officers of the Geological Survey of Canada continue to gain international recognition.

Few major petrological concepts have developed from Canadian research despite the great diversity of igneous rocks in this country and the strong economic incentives to study them in detail. One contributor suggests that this is due to lack of co-ordination and cites the dozen institutions working on Archean igneous rocks of northern Ontario without any central theme or guidelines. This person advocates regional centres of excellence and the need to compile and circulate an annual directory of igneous workers and a description of their research projects. Another states that Canadian petrologists must be encouraged to travel more frequently beyond our shores, e.g., to study new eruptions in their initial stages. All agree that the potential Canadian contribution is great in evolution of the Archean crust, orogenic igneous suites and oceanic petrology.

METAMORPHIC PETROLOGY

Metamorphic petrology encompasses field and laboratory studies, experiments on simplified rock systems, and theoretical investigations aimed at defining metamorphic reactions and evaluating intensive variables operative during metamorphism. Analytical aspects of laboratory and experimental work require facilities for whole rock and mineral analysis (x-ray fluorescence, atomic absorption, wet chemical, and particularly electron microprobe) to produce significant research results. An increasing number of Canadian institutions have most of these facilities available and functioning.

Provincial and federal government agencies and university geology departments make distinctively different contributions with little overlap.

Regional metamorphic studies

Metamorphic information (1: 1 000 000 to 1: 5 000 000) has been compiled for only a few geologic regions in Canada: The Cordillera (Geological Survey of Canada Paper 70-33), the Appalachians (Geological Association of Canada Special Paper 11), and part of the Canadian Shield in Ontario. Vast areas either lack data or its compilation and no institution is responsible for its acquisition or updating. Regional mapping (1: 250 000 to 1: 1 000 000) usually omits metamorphic data such as isograds. The few areas with such data, such as the Geological Map of part of the southeastern Canadian Cordillera (1: 750 000), have fostered many detailed metamorphic studies. A similar metamorphic map of the Canadian Shield is currently being prepared by geologists of the Geological Survey of Canada, provincial surveys, and universities, who will all be given an opportunity to present their veiws at a symposium in Ottawa.

Many greenstone belts of the Superior Province, formerly regarded as low-grade, have recently been reinterpreted as medium-grade metamorphic terranes. Other Superior Province rocks have been recognized as very low grade, characterized by the occurrence of prehnite and pumpellyite. In fact, subgreenschist facies rocks are probably more extensively exposed throughout Canada than anywhere else in the world. In many parts of the Shield, metamorphism took place at relatively low pressures, not only in the Slave Province, where the occurrence of cordierite-andalusite has been known for some time, but also in other parts, e.g., in the Rice Lake greenstone belt of Manitoba. Many sulphide deposits in greenstone belts have been metamorphosed together with the surrounding rocks. This implies that the accumulation of sulphides predates metamorphism and that sulphide deposits are not necessarily destroyed by metamorphism.

The additional costs of obtaining metamorphic data during regional mapping are negligible. Responsibility for development, compilation, and updating of Canada's metamorphic framework should be assigned within government surveys on a regional basis. Regional metamorphic studies yield fossil geotherms which are additional data in the critical assessment rather than the uncritical acceptance of various plate tectonic models. These models emphasize horizontal movements, but regional metamorphic studies provide data on vertical movements.

Detailed field and laboratory studies

Most detailed studies result from university research which involves defining and evaluating intensive variables operative during metamorphism and unravelling local metamorphic history. These studies require extensive analytical facilities and most progress has come from institutions with such equipment. Regional metamorphic studies of the Cordillera have spurred research by University of British Columbia and Queen's and Carleton Universities particularly in areas of closely spaced isograds where extreme relief allows estimation of isograd orientation. The area for research is vast and no single university has the manpower to cover sufficient terrane and produce regionally valid results in a reasonable length of time. Co-ordination of investigators within and among universities should be encouraged particularly in the Cordillera.

Textural studies in Newfoundland by Cambridge and Memorial Universities scientists have recently led to the recognition of Precambrian basement gneisses within polydeformed medium-grade cover rocks which form the east and west flanks of the Appalachian central mobile belt. Metamorphism of transported (obducted) ophiolites and their basal "aureoles" is also under study by university scientists who seek to distinguish *in situ* mantle deformation from syn- and post-emplacement phenomena.

Experimental and theoretical studies

Experimental studies by Canadian geoscientists of simplified rock systems and theoretical studies of problems in metamorphic petrology, such as tie lines in n-dimensional space, mathematical analysis of mineral assemblage data, and mass transfer of heat and materials yield universally applicable results. These studies are carried out by the federal government and several universities, for example, Queen's Carleton, and British Columbia. They improve field and laboratory studies and funding of them should not suffer at the expense of applied research.

Organization and co-operation

Canadian graduate students and geologists involved in metamorphic petrology total about 80. They lack organization even on a regional basis such as in the Cordillera, where seven Canadian universities (Alberta, British Columbia, Calgary, Carleton, McGill, Queen's and Saskatchewan) are carrying out research. Funds to allow principal investigators to meet, discuss and co-ordinate research would improve efficiency. The Mineralogical Association of Canada staged a successful symposium on subgreenschist facies metamorphism at St. John's, Newfoundland in 1974 and has expressed interest in organization and publication of further research in metamorphic petrology.

EXPERIMENTAL PETROLOGY

Universities with well-established research programs in experimental petrology include British Columbia, Manitoba, Laurentian, Western Ontario, Toronto, McMaster, Queen's, Carleton, and McGill. Government agencies include Saskatchewan Research Council and the Mines Branch and Geological Survey of the Federal Department of Energy, Mines and Resources. Most have only one or two active researchers, the largest is four, and even then they are working in separate fields. Hence, facilities are widely dispersed and not always fully used. Modern, essential equipment, e.g., high-pressure equipment for phase equilibrium work in the 5-25 kilobar range, is lacking in some laboratories.

During the past year, university emphasis has been on field studies and chemical analyses of rocks and ores to the neglect of experimental petrology. Currently most work is devoted to sulphide genesis and sulphide-silicate phase relations. Other studies involve the genesis of alkalic igneous rocks, the origin of anorthosite, the genesis of metamorphosed carbonate and pelitic rocks, element partitioning among silicates and sulphides, and experimental studies concentrating on specific mineral families, including pyroxenes, feldspars, and serpentine group minerals.

There is growing use of thermodynamic theory to extend results of experiments to more complicated natural systems. The strong chemistry background of Canadian undergraduates has resulted in Canadians being among the leaders in this field. Canadian researchers are also active in the use of computer techniques to extract thermochemical data from the results of hydrothermal experiments.

The seventh annual two-day conference on experimental petrology held at McGill University in 1974 attracted more papers than could be accommodated. Two of six invited speakers to an IUGS symposium on "Thermodynamics in Experimental Mineralogy and Petrology" are Canadians. More such special conferences are needed for experimental petrologists because they presently lack any formal organization which could provide a forum.

Closer communication between university and industry scientists is required for proper interpretation and use of experimental research.

Specific fields that require attention are (a) ore-forming processes and the petrology of associated rocks; (b) high-pressure studies in petrology and ore deposits, particularly Ni-Cu sulphide and chromite deposits.

PALEONTOLOGY

INVERTEBRATE PALEONTOLOGY

Canada's paleontological research has, on the whole, strongly focused its attention on biostratigraphic correlation problems. Several of Canada's paleontologists have achieved worldwide fame because of their contributions to global correlation programs and have served on international committees dealing with boundary problems, e.g., the Siluro-Devonian boundary, correlations of Triassic rocks, and, more recently, revisions of the Ordovician time-scale and the Precambrian-Cambrian boundaries.

On paleoecological, theoretical, and purely morphological levels Canada's paleontological efforts have lagged. Relatively few workers have tackled paleoecological problems. Significant Precambrian sedimentological-paleobiological contributions have been carried out on the Great Slave Lake stromatolites and their Recent counterparts in Shark Bay (Australia) and attempts have been made to reach a satisfactory taxonomic nomenclature and explanation of both stromatolites and structures of dubious organic origin. The Paleozoic (particularly Devonian) calcareous algae have turned out to be useful environmental indicators in both the intertidal and shallow subtidal zones. Canada has no experts on the highly diverse Ordovician-Silurian calcareous algal assemblages, nor on late Paleozoic or younger forms. As these forms are critical to reef development in the Paleozoic this gap should be filled.

Several Canadian workers have established international reputations working on the Paleozoic corralline metazoans (archaeocyathids, stromatoporoids, tabulates, rugosans, and bryozoans). However, research has been lacking on the coralline animals and on the evolution and eco-structure of Paleozoic reefs.

In the past two or three years research on the shelly organisms in general has been quiescent. Biostratigraphic-taxonomic work has been the main preoccupation. Canada lacks workers on fossil gastropods and bivalves. It has had few representatives working with the international group on the paleoecology of benthic animals and the ecological structure of shelly communities. Research should be directed to animal-plant diversity in relation to time, transgressions-regressions, and plate tectonics. Few workers have devoted themselves to fossil planktonic life although there has been good research on Ordovician graptolites and on Ordovician and Devonian conodonts. Canada lacks active workers on lesser known planktonic elements, but has a relatively new focus of interest in Cenozoic micro-fossils on the eastern continental shelf off the Maritime coast.

The image of the industrial paleontologist is not inviting. Although there are employment opportunities there are few Canadian-trained applicants. This could be improved by integrated industry-university training programs, and by Canadian industry directing its research needs to Canadian universities instead of foreign institutions.

Canadian universities should offer basic paleontology courses in the early years and courses in paleoecology, evolution, and carbonate sedimentation in the upper years. At present nearly all geology departments offer paleontology only as a final year option and tend to concentrate heavily on invertebrate taxonomy and index fossils. A review of curricula would do much to revitalize the somewhat musty image of paleontology in Canada.

VERTEBRATE PALEONTOLOGY

Vertebrate paleontology tends toward comparative anatomy and evolutionary studies rather than toward biostratigraphy. The localities for vertebrate fossils in Canada are mostly in the Atlantic and Prairie Provinces, but Canadian workers do not confine themselves to materials from this country.

The study of fossil fishes is being somewhat neglected in Canada at this time. One exception is a recently completed investigation of the Eocene fishes of British Columbia carried out at the Royal Ontario Museum.

The Redpath Museum of McGill University is the Canadian centre for the study of late Paleozoic and early Mesozoic amphibians and reptiles. Following the revision of the famous Joggins material, McGill workers have recently published or are working on Pennsylvanian reptiles from Kansas and Permian reptiles from Tanzania.

Later Mesozoic marine reptiles are under study at the Royal Ontario Museum. This includes a survey of European ichthyosaurs and a preliminary examination of mosasaurs and plesiosaurs from the Cretaceous of Manitoba. At the National Museum of Natural Sciences, work continues on the Cretaceous dinosaurs of Alberta.

A recently discovered fossil bird from the Eocene of British Columbia is currently under study at the Royal Ontario Museum. Here too work continues on the Cretaceous mammals of Montana and the Paleocene and Oligocene mammals of Saskatchewan and some elements of the early Eocene mammalian fauna of Wyoming.

At the University of Alberta a monograph of Cretaceous mammals of Alberta and an account of the Paleocene mammals of southeastern Saskatchewan are in preparation. At the Provincial Museum of Alberta a monograph on the late Miocene mammals of Saskatchewan has been completed, based in part on work done at the Royal Ontario Museum. Pliocene mammals from Alberta have also been described at the Alberta Museum.

Quaternary fossil mammals of Canada and of Africa have been described by workers at Dalhousie University and the University of Toronto. Pleistocene mammals of Yukon Territory are being studied at the National Museum of Natural Sciences.

During the past year, new and attractive exhibits of Alberta dinosaurs have been opened to the public at the Royal Ontario Museum and the National Museum of Natural Sciences. Preparation of these displays has involved intensive study of dinosaurian anatomy and locomotion and of the vegetation on which the herbivorous dinosaurs fed.

PALYNOLOGY

Spores and pollen are the primary focus of palynological research. In addition at least three Quaternary workers are now employing dinoflagellates in stratigraphic and paleontological studies. Palynologists working with pre-Quaternary materials (paleopalynologists) have become increasingly involved with dinoflagellates in the Mesozoic-Tertiary and acritarchs and chitinozoans in the Paleozoic. Scolecodonts and plant cuticles rarely are studied, although they commonly occur in palynological preparations.

Petroleum exploration companies are studying degree of carbonization of palynomorphs and other organic matter in sedimentary rocks, as a tool for evaluating petroleum potential. Similar studies are being carried out at the Geological Survey of Canada and University of Quebec (Institut National de la Recherche Scientifique--INRS), Quebec City. Three palynological consulting services have recently been established, two in Calgary and one in Quebec City.

There are 48 professional palynologists in Canada: 17 with governments, 16 with universities, 11 with petroleum companies, and 4 with consulting firms.

Paleopalynologists are chiefly concerned with biostratigraphy, mainly in connection with the search for fossil fuels. Recently the trend has been toward short-term, mission-oriented activity to the neglect of basic palynological reference data.

Major objectives of Quaternary palynologists include age determinations, phytogeographic and paleoclimatic information, vegetation history, and plant taxonomy. Electron microscope studies and computerized data handling are increasingly important in their studies.

There are deficiencies in three types of basic information: inventory and reference standards from stratotype sections; descriptive and taxonomic studies; and information on fundamental questions such as palynofacies, floral migrations, and phylogeny. Measures that might correct these deficiencies include (a) establishment of centres for inventory studies; (b) encouragement of fundamental research by university-based palynologists; (c) more emphasis by government laboratories on monographic inventory and other studies to provide a framework for applied palynology within industry; (d) pursuit of a co-ordinated, detailed isotopic dating program for the Quaternary.

Communication and co-operation has been inadequate resulting in unintentional duplication of work, too little co-operation between those working on related projects, and insufficient interdisciplinary integration. This could be improved by (a) establishment of a Canadian palynological group, possibly with some international affiliations; (b) a means of distributing lengthy systematic-stratigraphic papers; (c) Canada-wide legislation to ensure public availability of data and information generated by industry; (d) promotion of a comprehensive national type and reference collection.

SEDIMENTOLOGY

Sedimentological research can be subdivided into three categories: empirical studies of modern sediments, practical research and interpretations of ancient sedimentary rocks, and research into sedimentary processes.

MODERN SEDIMENTS

Activity was slight and restricted mainly to coastline erosion and sedimentation, estuarine and marine shelf-bottom sediment studies, and river deposits, mostly of the braided-channel type.

Needed is more detailed sedimentological mapping of modern marine and lacustrine sediments including the extensive continental shelf sediments.

ANCIENT SEDIMENTS

Activity was moderate to intense. Regional studies of ancient sedimentary rocks are concentrated in oil-bearing areas of the western provinces and the Arctic, and in flat-lying strata in other parts of Canada. In contrast, there are few detailed sedimentologic interpretations in most parts of the Western Cordillera, Shield, and Appalachians where they might provide the key to understanding of the pre-tectonic history of these complex areas. Government sedimentologists should be encouraged to study these regions.

Precambrian sedimentologic studies anywhere in the world are relatively few but some very significant contributions have been made in more accessible parts of the Canadian Shield. The immediate economic importance is substantial in connection with uranium, iron, and other ores.

PROCESSES OF SEDIMENTATION AND DIAGENESIS

Fields in which significant studies are presently being made in Canada include sea ice, lacustrine sedimentation, glacial sedimentology, coastal and intertidal sedimentation, fluvial processes, and sedimentation on the continental shelf and in the deep sea. Canadian effort should concentrate in those fields in which there is direct economic application (such as lacustrine sedimentation) or geographical advantages (such as sea ice). Glacial sedimentology, the dynamics of continental shelf processes, and processes of deep water sedimentation in polar areas should have more research effort. Successful co-operation between government and universities in marine geology might serve as a model in these fields.

Studies of non-clastic sedimentation are mainly on ancient rocks. Canadian knowledge of ancient carbonate reefs and evaporites is among the best in the world. However, interpretation requires that Canadian sedimentologists study modern analogues. Co-operative research programs with tropical developing nations might provide this opportunity.

Study of compaction and diagenetic changes are chiefly at the instigation of the oil industry. The electron microprobe and scanning electron microscope have increased Canadian strength in this field. Deliberate establishment of interdisciplinary groups may remedy inadequate co-operation in environmental studies and in the prediction of sediment type and distribution.

STRATIGRAPHY

Canada's early stratigraphers were generalists; the task of mapping so vast a country demanded this. More recently there has been opportunity and economic incentive to concentrate on certain strata and to unravel their complexities.

Canadian stratigraphers have realized that study of certain sequences could effect better understanding of the systems to which they belong. For example, Devonian rocks of western Canada represent three series and seven stages of the system. At Royal Creek in northern Yukon Territory they contain alternating graptolitic and shelly faunas including some of the youngest graptolites known (Siegenian-Emsian). This sequence has assumed particular significance in recent international controversy over the position of the Siluro-Devonian boundary. Middle Devonian sequences along the Mackenzie River, Northwest Territories, less deformed, better exposed, and every bit as fossiliferous as the classical exposures in the German Eifel and Franco-Belgian Ardennes, have yielded faunas that compare closely with those of Nevada and contrast with those of the Appalachians. The Upper Devonian rocks, particularly of the southern Interior Platform and adjacent Rocky Mountains, have attained world fame for their many and varied reef complexes. The reefs have been the subject of extremely detailed sedimentological studies because of their rich oil pools. A multitude of workers have contributed to our understanding of the Devonian System in Canada and a measure of world interest in their work was provided by the encyclopedic proceedings of the International Symposium on the Devonian System, published by the Alberta Society of Petroleum Geologists.

A Triassic time-stratigraphical edifice commanding world attention has resulted chiefly from the research of a single scientist of the Geological Survey of Canada, building upon the paleontological foundation constructed by a now-deceased colleague. Using mainly faunal successions in the Cordilleran and Innuitian orogens, he has recognized 31 ammonoid zones and has grouped these into nine stages with additional substages to provide a standard for expressing the age of marine Triassic rocks in Canada. These zones have been supplemented with four from the U. S. A. to produce a unified scheme applicable to the whole continent. The Canadian model will contribute substantially to a new time-stratigraphic standard for the Triassic system.

Ammonoids have also been used by two officers of the Geological Survey to bring new order to the stratigraphy of Jurassic and Cretaceous rocks. Recent work by petroleum company geologists on the Mesozoic and Cenozoic strata of the Mackenzie Delta has done much to elucidate the stratigraphy of this unit.

Notable advances have been made in the biostratigraphy of the Paleozoic systems, particularly in the Cordilleran and Appalachian orogens. Many trilobite zones have been devised for the Cambrian in both the Atlantic and Pacific faunal realms; the Ordovician of the Arctic Islands has been set in a framework of international conodont zones; and improved zonal schemes based upon graptolites have been reconciled with surprisingly refined schemes founded upon shelly benthos. Biostratigraphic analysis using brachiopods and corals together with foraminifers, has conferred continental congruity on Carboniferous and Permian stratigraphy.

The concepts and principles used in Phanerozoic geology have been increasingly applied to the Canadian Shield, even to the metamorphosed terranes. Interest in the spatial and temporal aspects of sedimentation with consideration of facies and depositional environment is now commonplace. Precambrian fossil study has emphasized Proterozoic stromatolites and their potential in correlation and as paleocurrent indicators. Many fine contributions have been made by university and federal government scientists using techniques of paleomagnetism. A sounder stratigraphy has emerged, promising a plausible history for the basement complex.

There has been an enhanced awareness in recent years of the role of stratigraphy in the quest for economic deposits, particularly oil, gas, coal, and potash ores. It has also become the basis of exploration and development of strata-bound or strata-controlled mineral deposits.

The Canadian stratigraphic framework could now be strengthened by more detailed conventional studies; on the other hand it is now strong enough to support innovative, specialized studies aimed at improving stratigraphic understanding on a continental and global scale. The future probably will see a compromise with both kinds of studies vigorously pursued.

STRUCTURAL GEOLOGY AND TECTONICS

Canadian research in structural geology and tectonics is focused primarily on regional geologic field studies which also involve petrology, stratigraphy and sedimentation, geophysics, and metallogeny. Most of the support for this research is provided by governments; but it does involve participation by university personnel, and a major contribution from the mineral and energy exploration industries. These studies, which provide the geoscience data base for resource development planning, have produced important data and concepts on the tectonic evolution of the earth's crust, the role of plate tectonics in mountain building, and on processes of rock deformation.

During the past few years exciting new models which have emerged for the tectonic evolution of the Appalachian, Cordilleran, and Innuitian Orogenic Belts, the Coronation and Labrador geosynclines, and the geologic provinces of the Canadian Shield have been described in Geological Association of Canada's special volume Variations in Tectonic Styles in Canada and elsewhere. Some of these tectonic models have gained wide recognition on an international scale, and many may provide an important conceptual framework for exploration and resource evaluation.

Canadians have made important contributions in the field of global tectonics, particularly through detailed studies of the Mid-Atlantic Ridge and Canada's continental margins and in the development of models for the evolution of lithospheric plates and for the isostatic response of the lithosphere. Canada is well represented in the programs of the International Geodynamics Project and in the Circum-Pacific Plutonism Project of the International Geological Correlation Program.

Field studies of rock deformation are often an outgrowth of regional investigations, e.g., the greenstone belts of the Canadian Shield and in the Appalachian and Cordilleran regions; but some have been established independently to elucidate specific problems. They include detailed studies of tectonite fabrics, finite strain variations, strain history, and flow mechanisms which may lead to better understanding of processes governing deformation of the earth's crust. The Canadian effort in this field is relatively small and widely dispersed.

Experimental and theoretical investigations form a minor but growing component of structural studies. Laboratory experiments and theoretical studies of rock deformation and the rheology of the earth are underway in the universities and elsewhere but the numbers of people involved remain relatively small. Studies of this type provide an important conceptual framework for the field investigations which encompass most of the Canadian effort. They should be expanded as they can have an important influence on the education of students who will undertake much of the future field-oriented research. They also provide opportunities for a much needed increase in co-operation between structural geologists on one hand and mining and civil engineers concerned with rock mechanics, or geophysicists concerned with the rheology of the earth, fault mechanisms, and other aspects of tectonophysics, on the other hand.

A series of seminars, workshops, and field conferences organized through the Subcommittee on Structural Geology of the National Advisory Committee on Research in the Geological Sciences, played an important role in fostering research on structural geology and tectonics during the 1960's. These were discontinued with the decision in 1972 to abolish the National Advisory Committee on Research in the Geological Sciences. The formation of a Calgary-based structural geology group in the Canadian Society of Petroleum Geologists and recent moves to form a national structural geology division within the Geological Association of Canada may re-establish communication among Canadian structural geologists.

The principal future requirement from structural geology and tectonics in Canada will undoubtedly be in regional field studies that can provide the geoscience data base for resource exploration and evaluation and for engineering design. This will necessitate adequate opportunities for field-oriented training and research by university students, a supporting framework for resources, and facilities for communication among the research scientists involved.

REMOTE SENSING

Remote sensing has come to mean the scanning of the earth's surface with various types of sensors working within the range of wave bands from ultraviolet to microwave for the purposes of evaluating earth resources and monitoring the near surface environment. Under this discipline fall the use of photographic imagery, infrared sensing, and side-looking radar, data presently being obtained from aircraft and from earth orbiting satellites.

In July 1972, NASA launched its first remote sensing spacecraft, ERTS-1, fitted with a multi-spectral scanner operating in four spectral bands: green/blue, red, and two in the near infrared. This scanner obtains four simultaneous images 100 x 100 nautical miles, transmitting them to earth in digital code on a frequency of 2.2 gigahertz. Each image is composed of 3500 scan lines over the format of the picture yielding a ground resolution of about 300 feet. Canada has a special agreement with NASA whereby ERTS-1 data for Canada are received at Prince Alberta, Saskatchewan and processed, reproduced, and distributed from Ottawa to about 1000 users in Canada. The data are used for studies in forestry, agriculture, hydrology, geology, limnology, oceanography, cartography, geography, atmospheric sciences, ice reconnaissance, and glaciology. Specialized working groups covering all these areas of specialty have been organized in Canada, their chairmen making up the Canadian Advisory Committee on Remote Sensing which reports to the Interagency Committee on Remote Sensing. The Canada Centre for Remote Sensing, a new branch of Energy, Mines and Resources, is the operating agency which serves these committees.

Geological studies both within and outside Canada are making use of the satellite photography; the broad geological picture is more readily identified from satellite imagery. The most practical use of this technique has been the study of time varying phenomena such as Arctic ice conditions and northern snow cover, and the monitoring of weather and surface conditions in areas where exploration and development programs are being carried out. The availability of the excellent quality colour photography from the Sky Lab missions with its far superior resolution compared to the ERTS imagery has allowed Canadian geoscientists to study the regional geology of remote areas in countries other than Canada. Satellite imagery will play an integral part in northern exploration programs such as the Arctic Islands mining studies now in progress.

Many new sensors are being tested and evaluated in an airborne remote sensing program operated by the Canada Centre for Remote Sensing. An airborne hydrography project is under development using colour photography in conjunction with an inertial navigation platform which can measure the deviation from the vertical to within 30 seconds of arc. This will allow the use of standard photogrammetric plotting machines for contouring bottom photography in the absence of ground control points. The University of Toronto Institute of Aerospace under contract to Canada Centre for Remote Sensing has produced a laser fluorosensor which is intended for use from an aircraft to detect and identify oil on the surface of water under day- or night-time conditions. It is intended to use this same sensor in the LIDAR mode to measure the depth of water for bathymetric surveys. Infrared line scanners are used on all aircraft of the Canada Centre for Remote Sensing for purposes ranging from limnological studies to forest inventory. A special spectrophotometer designed at York University is being used to measure water colour as an index of chlorophyll content for limnological studies.

PART 3

GEOSCIENCE FUNDING AND SOCIETY ACTIVITIES

FEDERAL GRANTS-IN-AID TO RESEARCH

INTRODUCTION

University research constitutes a major aspect of Canadian geoscience activities in terms of scientific and professional training, major syntheses relating to the solid Earth, and the general advancement of knowledge in a broad spectrum of geoscientific domains. The so-called Solid-Earth Science Study (Blais *et al.*, 1971)[1] still remains the major work of reference in this regard. The general validity and timeliness of its recommendations remain unchallenged. Furthermore, no other country in the world has undertaken a study of such magnitude in the geosciences.

Within that general framework, it is now opportune to examine in broad terms what has happened to geoscience university research in recent years, particularly from the point of view of student enrollment and federal government funding of this research. For a more general discussion of geoscience education in Canada, the reader is referred to a recent paper (Sabourin and Blais, 1974)[2].

GEOSCIENCE STUDENT ENROLLMENT

In spite of a major slowdown in Canadian mining exploration activity since 1969, worsened through recent announcements of more stringent government fiscal regulations, there has been an increase in geoscience student enrollment since 1968, as shown by the number of graduates of recent years (Table 1).

As recently as 1968, Canadian universities were producing less than 55 per cent of the manpower required by the Canadian mineral industry, not to mention the new demands of urban and regional development, education, and foreign service.

It appears that enrollment in most geoscience disciplines has now reached a plateau resulting in approximately 1000 bachelor, 220 master and 90 doctoral graduates each year (Table 1). The present numbers of geology graduates are probably adequate to fulfill short-term needs, including enrollment in graduate schools and new career opportunities. In geophysics, however, the situation remains somewhat static despite the fact that Canadian geophysical competence is much needed in our country and abroad. The very small number of doctoral graduates in geophysics is alarming because of the growing sophistication of geophysical instruments and methods, and the growing need for highly trained manpower in fundamental studies of physics of the earth.

NATIONAL RESEARCH COUNCIL'S REGULAR SUPPORT OF UNIVERSITY RESEARCH IN THE EARTH SCIENCES

The following statistics illustrate the critical state in which Canadian universities find themselves with respect to NRC's grants-in-aid to research in the earth sciences. Although financial support is clearly insufficient in other fields of natural sciences, largely because of inflation (Fig. 2), it is clearly worse in

NRC's EXPENDITURES ON
SCHOLARSHIPS AND GRANTS-IN-AID OF RESEARCH

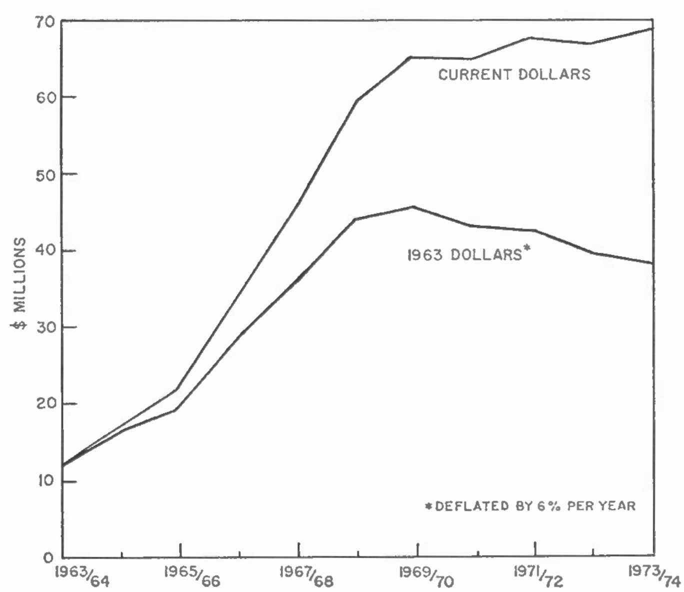

FIGURE 2

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[1]Blais, R.A. *et al.*
1971: Earth sciences serving the nation; Science Council of Canada, Special Study No. 13, Information Canada No. 55-21-1/13, Ottawa, 363 p.

[2]Sabourin, R.J.E. and Blais, R.A.
1974: Forward planning in the relations between education and the Canadian mineral industry; Can. Inst. Min. Met. Directory, June, p. 65-70.

TABLE 1 — Number of Canadian University Graduates in Mineral Industry Fields, 1967-76
(Source: CIM Bulletin) From: CIM Directory, June, 1974, p.68.

Field	1967	1968	1969	1970	1971	1972	1973	1974[2]	1975[2]	1976[2]
BACHELOR DEGREES										
Geology[1]	167	218	234	287	384	510	540	671	663	644
Geophysics	18	29	27	34	38	55	45	50	44	45
Metallurgy	102	91	85	82	98	135	127	114	103	113
Mining	38	42	49	57	76	100	129	132	116	110
Petroleum Eng.	10	13	22	41	61	43	65	47	61	61
Sub-total	335	393	417	501	657	843	906	1014	987	973
MASTER'S DEGREES										
Geology[1]	75	64	93	89	117	107	111	138	119	131
Geophysics	14	11	29	14	24	19	33	17	20	21
Metallurgy	41	32	46	44	61	51	47	38	42	45
Mining	25	31	26	24	30	27	23	24	20	26
Petroleum Eng.	3	5	4	3	1	—	12	6	5	7
Sub-total	158	143	198	174	233	204	226	223	206	230
DOCTORAL DEGREES										
Geology[1]	29	33	33	32	34	41	49	51	47	56
Geophysics	5	6	17	10	8	9	15	9	8	10
Metallurgy	25	20	19	17	40	28	27	20	21	17
Mining	1	3	5	5	3	7	4	5	5	5
Petroleum Eng.	—	—	—	—	—	2	7	2	1	2
Sub-total	60	62	74	64	85	87	102	87	82	90
TOTAL	553	598	689	739	975	1134	1234	1324	1275	1293

[1] Including geochemistry.
[2] University estimates corrected by —5.6% for B.Sc., —28.8% for M.Sc. and —42.5% for Ph.D., based on 1968-73 statistics of estimates vs actual figures.

the earth sciences where there has been a major increase in student enrollment at the B. Sc. level in recent years, with the result that graduate students are now twice as numerous in the earth sciences as they were four years ago when Treasury Board imposed cutbacks in NRC's real-dollar budget (Fig. 2). Even in the current year, NRC's expenditures for all universities and in all fields of natural sciences is 30 per cent less than the annual research budget (excluding development) of the Philips Research Laboratories!

With regard to earth sciences proper, the situation has not materially improved in recent years, as shown by the detailed statistics given in Table 2.

It should be noted that included in the earth sciences are numerous researchers of civil engineering involved in soil mechanics research, as well as a relatively small number of physical geographers and people of other disciplines, e. g., mathematicians studying ocean wave spectra. It should also be noted that during these five years, there is a net increase of only 25 in the total number of grantees whereas the total annual number of geology and geophysics graduates has increased from 433 to 936 during the period 1969-74!

Furthermore, the earth sciences have received an average of 7. 23 per cent of NRC's university budget during these five years, compared to an average of 32. 36 per cent for physics and chemistry alone, and 23. 34 per cent for all fields of engineering.

NATIONAL RESEARCH COUNCIL'S NEGOTIATED DEVELOPMENT GRANTS IN THE EARTH SCIENCES

It will have been noted under "Other Programs" near the bottom of Table 2 that earth sciences have received a rapidly increasing share of this particular budget, from 1. 00 per cent in 1969-70 to 6. 25 per cent in 1973-74. This is largely du to earth science departments now availing themselves of the financial resources provided by NRC's program of Negotiated Development Grants: indeed, the share of NDG's going to earth sciences during the past five years has increased from 0 to about 10 per cent of the annual budget allocated to this particular program ($4 137 000 in 1973-74).

This is a very healthy development and a sign of maturity of earth sciences in Canada. Table 3 gives an up-to-date list of all Negotiated Development Grants awarded to earth sciences since the inception of the NDG program in 1966. To date these amount to a total authorized expenditure of $2 990 000. It can be seen that the pace is accelerating and that earth sciences are increasingly competitive compared to other natural sciences in Canada. Furthermore, the success ratio of earth science requests is one of the highest of all disciplines supported by NRC, a fact that speaks well for Canadian earth sciences.

TABLE 2

National Research Council's scholarships and grants-in-aid to university research in the earth sciences, 1969-74

Description of Programs		1969-70	1970-71	1971-72	1972-73	1973-74
Individual Operating Grants:						
- Amounts ($ millions)		2,975	2,951	3,229	3,354	3,469
- % Total Amounts		8.85	8.38	8.75	8.88	8.53
- Number of Grantees		426	434	459	480	451
- % Total Grantees		9.62	9.44	9.48	9.83	9.06
- Number of Applicants		457	486	495	512	507
- % Total Applicants		9.34	9.24	8.94	9.23	9.02
Computing Grants ($'000)		322	249	158	105	--
Equipment Grants ($'000)		384	497	274	167	218
Major Equipment Grants ($'000)		110	214	--	212	404
Fellowships--Travel ($'000)		--	--	21	15	21
Fellowships--E. W. R. Steacie ($'000)		--	--	--	--	--
Fellowships-Senior Research ($'000)		20	--	--	--	--
Travel Grants ($'000)		24	--	--	--	--
General Research Grants ($'000)		223	247	267	270	273
	TOTAL	4,058	4,158	3,949	4,123	4,385
	Shares %	8.61	8.94	8.35	8.79	8.92
Postgraduate Scholarships ($'000)		322	337	371	344	387
Postdoctoral Fellowships ($'000)		25	22	18	30	48
	TOTAL	347	359	389	374	435
	Shares %	3.67	3.87	4.27	4.52	5.28
Other Programs	TOTAL	86	162	216	357	706
	Shares %	1.00	1.77	1.92	3.10	6.25
	GRAND TOTAL	4,491	4,679	4,554	4,854	5,526
	Shares %	6.89	7.21	6.73	7.28	8.04

OTHER FEDERAL GOVERNMENT GRANTS

An estimate is given in Table 4 of the various other federal government grants to university research in the earth sciences, including physical geography. Understandably, most of this much-needed addition of support comes from the Department of Energy, Mines and Resources, although in all cases these grants (research agreements) are miniscule compared to the total R & D budget of these departments and agencies.

CONCLUSION

University student enrollment in the geosciences has increased most appreciably since 1968, with the result that Canadian universities are now able to meet national manpower requirements in most fields of earth sciences. In fact there may even be a temporary surplus if the drastic cuts in hiring take place which are forecast by the petroleum industry.

However, federal support of university research in the earth sciences has been diminishing rather drastically in real-dollar terms during the last four years, in spite of a spectacular increase in geoscience student enrollment which had been long overdue. Considering also the need to up-date much of the research equipment, to equip new laboratories, to test new scientific discoveries, to develop major syntheses of importance to national mineral and energy procurement and the best use of our land, this financial setback has now reached a critical level.

R.A. Blais

SCITEC--A SOCIETY OF SOCIETIES

The geoscience societies through the Canadian Geoscience Council have played a modest but gradually increasing role in the activities of the Association of the Scientific Engineering and Technological Community of Canada (SCITEC) during the past year.

TABLE 3

Negotiated Development Grants awarded by the National Research Council in the earth sciences

Grantee/University	Title	Term	
1. Dr. J.A. Jacobs Univ. of Alberta	Earth and Planetary Physics	1970-75	$745,000
2. Dr. R.A. Blais Poly/McGill	Mineral Exploration Research	1972-75	$200,000[1]
3. Dr. H.G. Thode McMaster Univ.	Isotopic and Nuclear Studies in the Earth Sciences	1972-76	$254,000
4. Dr. H.D.B. Wilson Univ. of Manitoba	Precambrian Studies	1972-77	$555,000
5. Dr. D.F. Aumento Dalhousie University	Study of Material from a Deep Hole in the Atlantic	1973-76	$336,000[2]
6. Dr. D.W. Strangway Univ. of Toronto	The Continental Crust and its Mineral Deposits	1974-79	$900,000

[1]One of the conditions of this grant was the two universities concerned were to obtain matching funds from industry.

[2]Including a sum of $100,000 allocated to Canadian researchers collaborating with the Dalhousie team.

TABLE 4

Geoscience research grants and research agreements awarded to Canadian universities by the Department of Energy, Mines and Resources (EMR), the Department of the Environment (ENV), and the Department of National Defence (DND) in 1973-74.

Description	EMR	ENV	DND	Total Fed. Govt.
Intramural R & D ($ millions)	37.1	87.3	42.1	417.1
Extramuaral R & D ($ millions)	4.3	9.1	15.1	321.9
TOTAL R & D	41.4	96.4	57.2	739.0
University Research Grants ($ millions)	0.7	3.6	3.0	131.5
% Grants Relative to Intramural R & D	1.9	4.1	7.1	31.5
Earth Science University Grants:				
Geology ($'000)	319	41	35	N/A
Geophysics ($'000)	36	11	22	N/A
Physical Geography ($'000)	37	183	24	N/A
TOTAL	392	235	81	N/A
% Earth Science Grants/TOTAL grants	56.0	6.5	2.7	N/A
Number of Earth Science Grants	63	28	14	N/A
% No. of E.S. Grants/TOTAL No. of grants	55.3	11.4	3.6	N/A

The early hearings of the Lamontagne Committee (the Senate Special Committee on Science Policy) showed that societies representing the various segments and disciplines of the scientific community were uninformed of each others' views and aspirations. The senatorial committee pointed out that it was naive of Canada's scientists to entrust to government the entire task of comparing and integrating these various and differing views. SCITEC grew out of this awareness of the need for an interdisciplinary forum where scientists could meet to discuss matters of national concern. Its progress has been slow, for genuine communication between the scientific and technological groups can only come with time and patience.

Some societies, including most geoscience societies, were originally deterred from participation by the possibility of disproportionately strong representation of individual scientists in SCITEC Council. A 1974 revision of the by-laws makes SCITEC more truly a society of societies although there still remains some Council representation for members-at-large.

The Senate Committee's suggestion that SCITEC should be the spokesman for societies on policy for science and technology has also caused adverse reaction from many societies according to a recent statement by Senator Lamontagne. This despite published statements by the President of SCITEC that this organization was not designed to interfere with the autonomy of member societies and their ability to deal directly with government.

Although beset by problems in its formative years, SCITEC has successes to its credit. It has established a small office and secretariat in Ottawa supported by contracts, grants, and society dues. Over 50 societies are now members in their own right or through umbrella organizations. The concept of a House of Science and Technology originated with and was brought to its present stage of development by a SCITEC committee. It has organized interdisciplinary forums on topics of widespread concern where, despite heated debate, a surprising amount of consensus has emerged.

The Canadian Geoscience Council adhered formally to SCITEC in May 1973. Attitudes toward SCITEC goals naturally differ among the member societies but there was general agreement that geoscience views should be heard in SCITEC and that the geosciences should co-operate with other scientific societies in support of SCITEC as a forum for discussion and public debate on major national issues such as science policy and environmental concerns. The outcome of this decision is that geoscientists are now active on several committees and working groups and are possibly better represented numerically than any other discipline group on SCITEC's council.

There is a need for communication and co-operation between the various science and engineering groups which, on a different level, is just as real and pressing as it was between the individual geoscience societies. SCITEC is attempting to fulfill this need and deserves the continued participation and support of the geoscience community.

HOST--AN ANSWER TO GEOSCIENCE HOUSING?

Most geoscience societies operate from headquarters donated without long-term commitment by universities, government departments, or industry. They also lack salaried staff except possibly at the clerical level. Such societies are seriously interested in occupying quarters within a House of Science and Technology (HOST) in Ottawa. In contrast, those geoscience societies which are financially viable, have permanent rented headquarters and salaried staff, or which have a regionally restricted membership understandably have less present interest in such a headquarters.

The concept of HOST originated with SCITEC. The basic ideas were to relieve scientific societies from their preoccupation with financial problems by: reducing administrative costs through sharing of modern business facilities; economies of scale in procurement of equipment and supplies; and direct government subsidies to supplement society dues for the establishment and maintenance of full-time directors, secretarial staff, and physical plant. Another obvious benefit would be the primary contacts and the exchange of ideas with other occupants of the House of Science.

Justification of some initial subsidies lies in the relatively small size of most Canadian national scientific societies in relation to the size of the country. The expenses of travel and communication place many of them at a serious disadvantage compared to societies in other countries. The situation is comparable to that which prevailed in Australia where the Clunies Ross House, established initially through fund raising by a private foundation, has now provided the societies with headquarters and co-operative services without infringing on their autonomy.

A feasibility study of the HOST concept was commissioned by the Ministry of State for Science and Technology (MOSST) and a favourable report was produced in 1972. A seminar on the subject in Ottawa, November 1973, attracted 80 delegates from 46 societies, including representatives of several constituent societies of the Canadian Geoscience Council. A working group established by MOSST, including appointees from many interested societies met in August 1974 and produced a firm proposal describing eligibility, organizational form, nature of services, and details of financing. It asks for initial federal government aid to rent suitable space. Once achieving operational status it would mount its own full scale program to raise funds for a permanent building. At the time of writing MOSST had given no reply to the working group's proposal.

The HOST concept has been supported in principle by the Canadian Geoscience Council. Firm commitments will soon be required of its interested constituent societies.

COMMITTEE OF CANADIAN UNIVERSITY DEPARTMENTS OF EARTH SCIENCE

The chairmen from 27 Canadian university earth science departments met in May at St. John's, Newfoundland to identify problems of national concern to the university community.

An ad hoc committee was formed to study the need for a permanent council and to establish priorities. Committee members are L. Ferguson, Mount Allison University; J. Béland, University of Montreal; D.W. Strangway, University of Toronto; R. St. J. Lambert, University of Alberta; and W.M. Tupper, Carleton University (Chairman).

The committee met again in August and October. These meetings concentrated on National Research Council and other support of research and methods and procedures of awarding grants, funding to attend international meetings, representation on international committees, the desirability of national earth science field camps, e.g., one each in the Cordillera, the Shield, and the Appalachians, the availability of summer stipends for university research, and the need for more statistical information. Future discussions will concern E.S.C.P. courses, research agreements, hiring of students by the Geological Survey of Canada, and the effects of research grants on tenure and promotion.

CANADIAN GEOSCIENCE COUNCIL 1974 ANNUAL REPORT

REPORT OF THE CHAIRMAN

The Canadian Geoscience Council is now well known to MOSST, SCITEC, and the Science Council. It is one of the leading umbrella councils in the natural sciences in terms of the level of co-operation and effectiveness achieved. With few exceptions, the member associations have provided representatives prepared to become directly involved in the work of the Council, and there has been a high degree of continuity in membership of the Council from one meeting to the next. Many member organizations have confirmed that they are content to have the Council act as the senior negotiating body for the earth sciences with respect to government policy and scientific representation both nationally and internationally.

The responsibility for monitoring and fostering the good health of the sciences in Canada no longer rests with the government but with non-governmental associations. The Canadian Geoscience Council has exhibited a gratifying level of leadership in this direction in the preparation of this report under contract from the Department of Energy, Mines and Resources. In addition the Council has completed an important phase of evaluating the present level of effort and ability in secondary school earth science education and the planning of efforts to provide communication, materials, and ideas that will help it develop. The second phase, to begin in 1975, will be the sponsoring of regional earth science teachers' workshops modelled on a successful one held at the University of British Columbia in May 1974.

While in no way seeking to muzzle the opinions of member societies or of individuals within those societies, the Canadian Geoscience Council for the first time in May 1974 made a public statement on behalf of the geoscience community in response to its adoption of a modified report by the Canadian Society of Petroleum Geologists on oil reserves. The conclusions we expressed were not unanimously endorsed by the society representatives but that we were permitted to express the majority view is a sign of the maturity of this organization.

This year also marks the beginning of definite activities sponsored by the Canadian Geoscience Council. The workshop on foreign aid in St. John's, Newfoundland in May was an outstanding success and has led to the formation of an organization known as AGID (Association of Geoscientists for International Development) concerned with providing grass-roots representation from both donor and recipient countries as to the application and use of foreign aid programs. Much good may stem from these simple beginnings.

This new type of responsibility makes it imperative that the Council seek a structure that will provide continuity and a working operational body, while retaining a high level of senior executive representation from the member associations on the Council itself. In this way the important work begun can be efficiently continued and the stature and influence of the Council will rapidly grow.

H.R. Wynne-Edwards
Chairman
November 8, 1974

REPORT OF THE SECRETARY-TREASURER

History of Formation — 1970 to 1972

The Canadian Geoscience Council grew out of a Science Council of Canada report, Earth Sciences Serving the Nation, published in 1971, which recommended formation of a council of earth science societies which would "examine areas of co-ordination and co-operation, and formulate long-range plans." Two meetings of an *ad hoc* formative committee representing a number of earth science groups took place in 1970 and 1971. Further exploratory meetings on 21 December 1971 and 6 February 1972 set up the present council with R.A. Blais as first chairman and authorized preparation of the present Constitution and By-laws. The Constitution and By-laws were adopted, with minor revisions, at the third meeting of the council on 9 April 1972 in Ottawa. Six member groups voted and six more groups have since joined as shown in the table of data on member societies (Table 7). Each group with more than 1000 members is assigned one extra vote. The chairman votes only to break ties.

TABLE 5

EXECUTIVE COMMITTEES OF C.G.C., 1972-1975

	1972	1973
Chairman	Blais, R.A. (CGC)	Lindseth, R.O. (CSEG)
Vice-Chairman	McLaren, D.J. (ASPG)	Neale, E.R.W. (GAC)
Secretary-Treasurer	Graham, A.R. (MAC)	Graham, A.R. (MAC)
Executive Member	Lindseth, R.O. (CSEG)	McLaren, D.J. (ASPG)
Recording Secretary	Appleyard, E.C. (CGC)	Appleyard, E.C. (CGC)

	1974	1975-elect
Chairman	Wynne-Edwards, H.R. (GAC)	Slavin, R.L. (CSPG)
Vice-Chairman	Slavin, R.L. (CSPG)	Neale, E.R.W. (GAC)
Secretary-Treasurer	Graham, A.R. (MAC)	Eden, W. (CGS)
Executive Member	Topp, G.C. (CSSS)	Gough, D.I. (CGU)
Recording Secretary	Appleyard, E.C. (CGC)	Appleyard, E.C. (CGC)

TABLE 6

LIST OF MEMBER SOCIETIES

Association of Exploration Geochemists, Canadian Section (1972)
Canadian Exploration Geophysical Society (1973)
Canadian Geophysical Union (1972)
Canadian Geotechnical Society (1972)
Canadian Institute of Mining and Metallurgy (1973)
Canadian Rock Mechanics Group (1973)
Canadian Society of Exploration Geophysicists (1972)
Canadian Society of Petroleum Geologists (1972)
Canadian Society of Soil Science (1972)
Canadian Well Logging Society (1974)
Geological Association of Canada (1972)
Mineralogical Association of Canada (1972)

The purpose of the Council as stated in the Constitution is "to foster close relations among earth science learned societies and professional associations in Canada and to take concerted action for promoting the sciences related to the earth and the use thereof, in the best interest of both the members of the constituent organizations and the Canadian nation as a whole."

Achievements — 1972-73

1. Contracted for, and reported on, a feasibility study for a Canadian textbook on geoscience for junior high schools on behalf of the Department of Energy, Mines and Resources in 1972. The study recommended that priority be given to short monographs on geoscience subjects prepared with guidance from pedagogues and geoscientists in each province. An Education Committee was formed to work with and co-ordinate similar committees of member societies.

2. Joined SCITEC and participated in some of the co-operative activities of this organization.

3. Sent a representative to the "Man and Resources Workshop" sponsored by the Environment and Resource Ministers in 1972 and 1973.

4. Established a Canadian Geoscience Calendar of events in the geosciences to assist co-ordination of meetings, symposia, and other activities.

5. Prepared and submitted a brief on Volumes I and II of the Lamontagne Report on Canadian Science Policy.

6. Prepared position papers on the eight main objectives of the Council, each with a recommendation for action.

7. Established a committee to negotiate with government departments for broader representation from all geoscience groups on national committees concerned with earth sciences.

8. Initiated talks with both the Royal Society of Canada and SCITEC on communication between scientific and engineering societies and government.

9. Began negotiations with the Department of Energy, Mines and Resources on support of the Council by unconditional grant.

Achievements — 1974

1. The Education Committee was authorized to organize regional workshops across Canada under the sponsorship of the Council. These will involve high school science teachers and representatives of various provincial education and resource ministries.

2. Received a $4500 contract from the Department of Energy, Mines and Resources to prepare an Annual Report on Geoscience in Canada.

3. Participated in a revision of SCITEC's by-laws and also in its forum on science policy.

4. Shared sponsorship of an International Workshop on Geoscience Aid for Developing Countries held in St. John's, Newfoundland in May 1974. The Association of Geoscientists for International Development grew out of this workshop.

5. Appointed a representative to the Organizing Committee for an Interdisciplinary Symposium on Glacial Till.

6. Accepted sponsorship of a Mineral Exploration Technology Symposium to be held in 1977.

7. Discussed and released to the media a statement on present knowledge of recoverable oil and gas reserves in Canada, based on modifications of a brief by the Canadian Society of Petroleum Geologists.

8. Negotiated an interim agreement with the Department of Energy, Mines and Resources whereby this Council will be asked to supply it with advice concerning advisory committees involving the geosciences. The Department agreed that an unconditional grant of $5000 per year would be assigned to the general cost of operation of the Canadian Geoscience Council in 1975-1976.

It is concluded that the Canadian Geoscience Council has served the interest of its individual members well and a good start has been made toward the objectives outlined in its constitution.

A. R. Graham
Secretary-Treasurer
November 8, 1974

TABLE 7

DATA ON MEMBER SOCIETIES

Pages 48 to 51

Society and Membership	Objectives	Meetings, Activities, and Committees (attendance in parentheses)	Publications
ASSOCIATION OF EXPLORATION GEOCHEMISTS *c/o Dr. I. Elliot (President)* *Falconbridge Nickel Mines Ltd.* *1314 West 71st Avenue* *Vancouver, British Columbia V6P 3B2* Active membership in Canada approx. 165 Student members in Canada 18 Corporate members in Canada 20 World-wide membership 520	To represent persons specializing in the field of exploration geochemistry; to advance geochemistry as it relates to exploration.	--5th International Geochemical Exploration Symposium, Vancouver, 1-4 April 1974 (552 delegates from over 30 countries) --Annual General Meeting, Vancouver (150) --Five Council Meetings (5-12) COMMITTEES: Admission Committee, New Membership Committee	Journal of Geochemical Exploration quarterly Newsletter 3 or 4 per year to members only
CANADIAN EXPLORATION GEOPHYSICAL SOCIETY (KEGS) *c/o Mr. E.O. Anderson* *Cominco Limited* *Suite 1700--120 Adelaide St. W.* *Toronto, Ontario M5H 1T1* Active members in Canada 125 Members outside Canada 8 Student members 12 Associate members 5 Total 150 (Total is probably 75% of the geoscientists who would find membership beneficial)	To promote the science of geophysics especially as it is applied to the exploration for minerals other than oil; to foster the common scientific interests of geophysicists; to maintain a high professional standing among its members; and to promote fellowship and cooperation among persons interested in these problems.	--Eight meetings are held on the second Tuesday of each month from October to May. All are business/technical meetings (avg. 85).	
CANADIAN GEOPHYSICAL UNION *c/o Dr. D.I. Gough (Secretary)* *Department of Physics* *University of Alberta* *Edmonton, Alberta T6G 2E1* Active membership in Canada 200	To advance the science of geophysics and to promote a better understanding thereof throughout Canada.	--Inaugural Symposium, Ottawa, 22 February 1974 (100) --Symposia on Global Geodynamics, Geophysical Surveys in Canada, Geophysics of Continental Margins, and General Geophysics, 10-13 June 1974, St. John's (50) --Annual Business Meeting, 10 June 1974, St. John's (25). SUBDIVISIONS: Gravity, Seismology, and Physics of the Earth's Interior; Exploration Geophysics; Geomagnetism; Geochronology and Stable Isotope Studies. Studies are underway on formation of subdivisions on Geodesy and on Mathematical Geophysics.	
CANADIAN GEOTECHNICAL SOCIETY *c/o Dr. D.L. Townsend (Secretary)* *2050 Mansfield Street* *Montreal, Quebec* Members of C.G.S. only 139 Eng. Inst. of Canada members 404 Total 543 (C.G.S.-E.I.C. members are usually engineers by training. C.G.S.-only members may include those holding membership in another learned society or having a university degree or its equivalent.	To stimulate activities and cooperation among engineers and other professionals for the advancement of knowledge in the geotechnical field in Canada. This includes the study of the properties of soil, rock, muskeg, snow and ice, the influence of environmental factors on such properties and the application of this knowledge in practice.	--Annual Canadian Geotechnical Conference Toronto, 18-19 October 1973, included Annual Business Meeting and presentation of annual awards (300). --C.G.S. arranges the program for one session of the Annual Congress of the Engineering Institute of Canada. --Board of Directors met three times. --Local sections meet approximately nine times per year for technical sessions. DIVISION: Engineering Geology Division is being formed.	Canadian Geotechnical Journal published by National Research Council is part of membership fees.
CANADIAN INSTITUTE OF MINING AND METALLURGY *c/o E.G. Topp (Executive Director)* *#906--1117 Ste. Catherine St. West* *Montreal, Quebec H3B 1J3* Total CIM membership 9098 In Geology Division 2386	(of Geology Division) To stimulate and advance the application of geology, geophysics, and geochemistry in the exploration for, and development and exploitation of, mineral resources by arranging technical discourses, lectures, and discussions; by publication of technical papers; by sponsoring field excursions; and by the promotion and encouragement of research and education in the earth sciences.	--76th Annual General Meeting, Montreal, 21-25 April 1974 (2500) --Field Meeting, Geology Division, Sturgeon Lake Ontario, 21-22 September 1973 (46) --26th Canadian Conference on Coal, (co-sponsored by Coal Division, CIM) Calgary, 10-13 September 1974 --10th Commonwealth Mining and Metallurgical Congress, Canada, 2-28 September 1974 --Annual Western Meeting, Winnipeg, 24-26 October 1974 --Numerous Branch and Division meetings. COMMITTEES: (Geology Division) Publications, Newsletter, University Visiting Lecturers, Technical Program, Barlow Memorial Medal, Mineral Resource Research, Student Essays, Geophysics, Geochemistry, Distinguished Lecturers, Program Policy, G.A.C.-S.E.G. Liaison, Education, Nominating.	The Canadian Mining and Metallurgical Bulletin (CIM Bulletin)--monthly The Journal of Canadian Petroleum Technology--quarterly The Canadian Metallurgical Quarterly--quarterly The CIM Directory--yearly Special Volumes--13 to date

Awards	Briefs and Position Papers	Association with other Organizations Canadian and [Non-Canadian]	Other Information
Constitution provides for Honorary Members	--A.E.G. has taken the position of defining the qualifications of the professional Exploration Geochemist and is distributing this information to membership. This definition will be used in future presentations to licensing bodies in an attempt to establish an equitable and satisfactory standard of professionalism in exploration geochemistry on a world-wide basis.	Canadian Geoscience Council [Organized 4th International Geochemical Symposium with Institution of Mining and Metallurgy, London, England, 1972]	Before A.E.G. formally came into being active geochemists, now members of A.E.G., helped organize several meetings: 1st International Geochemical Symposium with Geological Survey of Canada, 1966; 2nd International Geochemical Symposium with U.S. Geological Survey and Colorado School of Mines, 1968; 3rd International Geochemical Symposium with Canadian Institute of Mining and Metallurgy and Society of Economic Geologists, 1970. --Four of the five presidents to date and half the council members to date have been Canadian-based exploration geochemists. The activities of these Canadian members have done much to establish Canada as one of the countries foremost in the exploration geochemistry field.
--Don Salt Memorial Scholarship is awarded to the most promising third and fourth year students in geology or geophysics at the University of Toronto. Selection is based on academic standing, possible future interest in mining exploration, and financial need.	--Brief to Ontario Ministry of Natural Resources Mines Act Revision Committee regarding recommendations to the Ontario Mining Act.	Canadian Geoscience Council [Became associated with the Society of Exploration Geophysicists in 1973]	KEGS was formed 8 June 1953 by a small nucleus of mining exploration geophysicists in Toronto. Members probably represent, by their employment, 90% of the mining industry in Canada. Approximately 1/4 of the members reside outside Toronto representing B.C., Alberta, Manitoba, and Quebec.
		Joint Division of the Geological Association of Canada and the Canadian Association of Physicists. Canadian Geoscience Council	
--R.F. Legget Award to an individual for significant achievements to Canada in the field of geotechnical engineering; not given every year. --Society Prize awarded annually for the best paper published in the Canadian Geotechnical Journal.	--A brief was prepared on C.G.S.'s response to Volume III of the Senate Committee Report on Science Policy in Canada for the Canadian Geoscience Council's committee to consider the Senate Report.	Canadian Geoscience Council Constituent society of E.I.C. Close links with the Associate Committee for Geotechnical Research Local C.G.S. sections may be associated with regional activities [Participates in affairs of the International Society for Soil Mechanics and Foundation Engineering] [Formal association with International Association of Engineering Geology is being considered]	Membership probably includes 90% of those engineers practicing geotechnical or foundation engineering. Engineering geologists are expected to join in greater numbers with the formation of the Engineering Geology Division. --Twelve local sections of C.G.S. are supported by rebate of fees from headquarters.
CIM awards pertaining to Geology Division: Distinguished Lecturer Award, Barlow Memorial Medal Prize, Student Essay Awards and the President's Gold Medal		Canadian Geoscience Council Canadian Standards Association [World Mining Congress] [Council of Commonwealth Mining and Metallurgical Institutions] [A.I.M.E. Council of Economics]	The Geology Division is an integral part of CIM which is a technical society covering the entire range of mining and mineral processing technology.

SOCIETY AND MEMBERSHIP	OBJECTIVES	MEETINGS, ACTIVITIES, AND COMMITTEES (attendance in parentheses)	PUBLICATIONS
CANADIAN ROCK MECHANICS GROUP (Canadian Chapter of the International Society of Rock Mechanics) *c/o Dr. W.M. Gray (Secretary)* *Mining Research Center* *Mines Branch* *555 Booth Street* *Ottawa, Ontario K1A 0G1* Individual members 132 Supporting members 8 Total 140	To develop the subject of rock mechanics, to establish liaison with interested organizations in other countries, and to advise the government on the support of research.	--Council meeting, 29-30 May 1974 (15) --Technical Seminar and Symposium, 13-15 December 1973 (198) SUBCOMMITTEES: Foundations, Subsidence, Rock Mechanics Exploration, Rock Breakage, Mine Fill, Geomechanics, Rock Mechanics Instrumentation, Slope Stability, Symposium Organizing, Award Panel.	
CANADIAN SOCIETY OF EXPLORATION GEOPHYSICISTS *c/o Mr. Frank Halpenny (Secretary)* *P.O. Box 117* *Calgary, Alberta T2P 2G9* Active membership 1162 (with honorary and corporate members in addition)	To promote the science of geophysics especially as it applies to exploration in the fields of petroleum, mining, and groundwater, and to promote fellowship and cooperation among those persons and organizations interested in geophysical problems.	--One general meeting per year --One executive and one technical meeting per month --One national convention per year COMMITTEES: Best Paper, Future Directions, Honors and Awards, Journal, Journal Business Manager, Membership, Newsletter, Professional Affairs, Government Relations, Statistics, Publicity, University Liaison, Convention, Continuing Education.	Technical Journal--published at least annually Monthly Newsletter
CANADIAN SOCIETY OF PETROLEUM GEOLOGISTS *c/o Mr. R.E. Deere (Secretary)* *612 Lougheed Building* *Calgary, Alberta T2P 1M7* Active members in Canada 1824 Active members--foreign 86 Associate members 35 Student members 74 Honorary members 19 Total 2038 Corporate members--80	To advance the science of geology, especially as it relates to fossil fuels; to promote the technology of exploration for these resources; to foster scientific research; to disseminate relevant information; to inspire and maintain a high standard of professional conduct.	--Annual Meeting (300) --Technical Meetings, 19 luncheon meetings (avg. 350) --Technical Symposia, two, one co-hosted with Geological Association of Canada and Mineralogical Association of Canada (747 and 558) COMMITTEES: Membership, Technical Program, Medal of Merit, Link Award, Geological Research, Stratigraphic Nomenclature, Discipline, Printing. Approximately 40 special committees administer business, social, and technical functions as well as liaison with other organizations.	Bulletin of Canadian Petroleum Geology--quarterly Reservoir--monthly newsletter Symposia and Memoirs on special subjects. Field trip guide books.
CANADIAN SOCIETY OF SOIL SCIENCE *c/o Mr. D.L. Massey (Secretary)* *P.O. Box 2004* *Kemptville, Ontario* Total membership 380 Active in Canada 340 Honorary 13 (approximately 50% of those eligible in Canada are members)	To foster all branches of soil science; to provide a forum to enable soil scientists to make known their views on matters pertaining to soil.	--Annual Business Meeting, 22 August 1973 (80-110) --three Technical Sessions, 20-21 August 1973 --two Council Meetings, 20 and 22 August 1973 COMMITTEES: Journals, Awards, International Activities, Rules	
CANADIAN WELL LOGGING SOCIETY *c/o Secretary* *P.O. Box 6962, Postal Station D* *Calgary, Alberta T2P 2G2* Active members 212 Honorary members 5 Corporate members 18 (about 5-10% eligible are members, most from the Calgary area)	To further the science of formation evaluation by providing regular meetings with discussion of related subjects and encouraging research and study.	--nine Luncheon Meetings (avg. 104) --Annual Meeting in Feburary (81) --nine Executive Meetings --Fifth Formation Evaluation Symposium, to be held in Calgary, May 1975 COMMITTEES: Membership, Publication Sales, C.W.L.S. Journal Editor and Business Manager, Nominating, Award, 1975 Formation Evaluation Symposium Organizing.	The CWLS Journal--annually CWLS symposium transactions--published occasionally, next--1975 Formation Water Resistivity Catalog--published occasionally, revision in 1975
GEOLOGICAL ASSOCIATION OF CANADA *c/o Dr. C.R. Barnes (Secretary)* *Department of Earth Sciences* *University of Waterloo* *Waterloo, Ontario N2L 3G1* Fellows 1568 Associates 427 Honorary members 10 Total 2005 Corporate members 87	To advance the science of geology and closely related fields of study and to promote a better understanding thereof throughout Canada.	--Annual Meeting, May 1973, Saskatoon (670) --Annual Meeting, May 1974, St. John's (705) --Council and Executive meetings --Sections and Divisions meet independently COMMITTEES: Finance, Program, Projects, Membership, Editorial, Public Information, Professional Status, Status of Women, Education, Logan Medal, Past Presidents' Medal	Geolog--newsletter published bimonthly except summer Geoscience Canada--quarterly Special Papers--twelve so far in series Canadian Journal of Earth Sciences--published by National Research Council and included in G.A.C. membership fees.
MINERALOGICAL ASSOCIATION OF CANADA *c/o Dr. F.J. Wicks (Secretary)* *Department of Mineralogy* *Royal Ontario Museum* *100 Queen's Park* *Toronto, Ontario M5S 2C6* Total membership 1432 Active in Canada 300 Student members 94 Corporate members 588 Sustaining members 34	To advance the knowledge of crystallography, geochemistry, mineralogy, petrology, and their allied sciences	--Executive Meetings, May and January 1974 --Technical Meeting, May 1973 --Business Meeting, May 1973 COMMITTEES: Membership, Nominating, Finance, By-Laws Revision	Canadian Mineralogist--quarterly

Awards	Briefs and Position Papers	Association with other Organizations CANADIAN and [Non-CANADIAN]	Other Information
Annual competition for best Canadian paper on rock mechanics within the last three years		Canadian Geoscience Council [International Society of Rock Mechanics]	Administered by the Associate Committee on Rock Mechanics, this group undertakes the coordination of research activities and the development of lines of communication between interested organizations and individuals in Canada.
--Best Paper Award --Student Scholarships	Annual reports to National Research Council Associate Committee on Geodesy and Geophysics. Briefs to the Alberta government concerning incentives for geophysical exploration 1973-1974.	Canadian Geoscience Council [Society of Exploration Geophysicists]	
--Medal of Merit, annual for best published paper related to geology of sedimentary areas of Canada --Link Award, annual for best oral presentation of geological paper to the society by one of its members. --Research and Graduate Student Awards for postgraduate theses of merit. --Undergraduate Award, a certificate awarded to one undergraduate from each of the 34 degree-granting institutions in Canada for outstanding competence in petroleum geology or related fields.	Responses to Volumes II and III of Senate Special Committee on Science Policy. Energy brief prepared at request of Energy Studies Director, Science Council of Canada and presented to SCITEC and House of Commons Standing Committee on National Resources and Public Works (May 10, 1973)	Canadian Geoscience Council Edmonton Geological Society Saskatchewan Geological Society Association of Professional Engineers, Geologists and Geophysicists of Alberta [American Association of Petroleum Geologists] [World Petroleum Congress]	
--Fellowship Award, Fellow of the Canadian Society of Soil Science --C.S.S.S. has input into various Agricultural Institute of Canada awards, Royal Bank Award, and Ministry of State for Science and Technology award in Agriculture and Technology		Agricultural Institute of Canada--affiliated, joint meetings and office services Canadian Geoscience Council SCITEC Canadian Society of Agronomy [International Soil Science Society (1978 I.S.S.S. Congress to be hosted by C.S.S.S.)] [North East Section, American Society of Agronomy]	The international Congress on Land Waste Management, organized by C.S.S.S., was held in Ottawa, 1-3 October 1973. Proceedings are available from National Research Council, Ottawa
--Award currently being planned for best paper in formation evaluation. First presentation expected in 1976.		Canadian Geoscience Council Annually a joint luncheon meeting is held with the Petroleum Society of CIM [Society of Professional Well Log Analysts--U.S.A.]	
--Logan Medal, annual for outstanding contributions to the earth sciences --Past Presidents' Medal, annual for a single outstanding achievement in the earth sciences --two awards given annually for the best earth science exhibits at National Science Fair.	A brief was prepared for Canadian Geoscience Council presenting G.A.C. opinion on the Senate Committee Report on Science Policy in Canada	Canadian Geoscience Council SCITEC Joint annual meetings with Mineralogical Association of Canada and biennially with the Canadian Geophysical Union. The C.S.P.G. co-sponsored the Canadian Arctic Symposium and special volume at the 1973 Annual Meeting [Annual Meetings are frequently organized with other organizations, e.g., 1975--the North Central Section of Geological Society of America; 1977--the Society of Economic Geologists; and 1978 the G.S.A.] [Two representatives are appointed to the American Commission on Stratigraphic Nomenclature]	Divisions of G.A.C.: Environmental Earth Sciences, Geophysics (Canadian Geophysical Union), Volcanology. Regional Sections of G.A.C. exist in Edmonton, Newfoundland, Winnipeg, and Vancouver (Cordilleran).
--Hawley Award, presented once every three years to the author(s) of the paper judged best during the period in the Canadian Mineralogist.		Canadian Geoscience Council Joint meetings with Geological Association of Canada [International Mineralogical Association] [Joint Committee on Powder Diffraction Standards] [Joint meetings with the Mineralogical Society of America]	It is interesting to note that of ordinary membership, 46% is in Canada, 39% in the U.S., and 15% in other countries.