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Science Council of Canada

April 1970
Report No.7

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Earth Sciences Serving the Nation– Recommendations

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"It does seem to me strange, to use the mildest word, that people whose destiny it is to live, even for a few short years, on the planet which we call the earth, and who do not at all intend to live on it as hermits . . . shall in general be so careless about the constitution of this same planet, and of the laws and facts on which depend, not merely their comfort and their wealth, but their health and their very lives, and the health and the lives of their children and descendants."

Charles Kingsley (1877)

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The Right Hon. Pierre Elliott Trudeau,
P.C., M.P.,
Prime Minister of Canada,
House of Commons,
Ottawa 4, Ontario.

Dear Mr. Prime Minister,
In accordance with sections eleven and thirteen of the Science Council Act, I take pleasure in forwarding to you the views and recommendations of the Council as they concern policies for the development of the earth sciences, in the form of a report entitled "Science Council Report No. 7–Earth Sciences Serving the Nation–Recommendations."

Yours sincerely,

O. M. Solandt,
Chairman,
Science Council of Canada.

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Introduction

Canada has an increasing need for the earth sciences. They are continuing to make important contributions to the Canadian economy and to many other facets of our national and international activities. If we nourish them wisely, their benefits will continue to be realized in the years ahead.

Canada has a well-established reputation in earth science. Names of pioneer geologists such as Logan, Dawson, Tyrrell and Coleman are still internationally renowned. Canadian earth scientists of today have built well on these foundations. The recommendations in this report are designed to assist still further the progress of these sciences in Canada.

Contributions from earth sciences are of paramount importance in the *mineral industry*[1] and have been well known for many years–long before Confederation. Today the industry's need for application of the science is greater than ever before and is expanding rapidly. The application of geotechnical knowledge is of vital importance in the *construction industry*. This has been a development of the last two decades. Agriculture, forestry, hydrology and programs of assistance to developing countries all make good use of earth sciences.

Earth scientists, by their presence and activities, have played and will continue to play a significant part in the development of the Far North, thus helping to assert Canadian sovereignty. In various phases of planning regional and urban development, and in environmental studies, earth science makes an essential contribution. Canadians, with more leisure time, will find that the cultural and recreational values of earth sciences contribute to the attainment of a more complete and satisfying life.

In this report the Science Council uses the term *earth sciences* to include geology, geophysics, geochemistry, soil science, physical geography and geotechnique. Those parts of earth science that relate to the atmosphere and hydrosphere, and to snow and ice, have not been included. They warrant special studies. Earth science activities in the mineral industry are largely related to exploration and, as a result, scant reference is made to the development and extraction activities of the mineral industry in this report.

In 1968, the Science Council commissioned a Special Study of the solid-earth sciences in Canada. The resulting report is in press[2], and its highlights and conclusions are included as Appendix C of this report. The Science Council regards this Special Study as an important contribution that reflects credit on its authors and on those in industry, the universities, government agencies, and the professions who co-operated so fully in its preparation. The study supplies much statistical information not heretofore available, as well as pertinent compilations from public documents. It has been used as a basis for the drafting of this report by a special committee of the Science Council, whose membership is given in Appendix A.

In this report, the Science Council will deal only with conclusions of a non-financial nature, with a view to recommending action that would lead to their implementation. The Science Council expects to deal more explicitly with conclusions concerning the proper level of earth science funding in a forthcoming series of overviews related to primary and secondary industries, and basic research.

On the basis of its review of the Study Group's report and other information, the Science Council is convinced that accelerated progress in the earth sciences is vital to the continuing development of the nation.

[1]The mineral industry includes the petroleum and natural gas industry and the mining industry (metallic and non-metallic products and structural materials).

[2]Blais, R. A., C. H. Smith, J. E. Blanchard, J. T. Cawley, D. R. Derry, Y. O. Fortier, G. G. L. Henderson, J. R. Mackay, J. S. Scott, H. O. Seigel, R. B. Toombs, H. D. B. Wilson. Earth sciences serving the nation. Science Council of Canada Special Study.

Toward National Goals

The Science Council has suggested six national goals that would serve as a framework for development of a sound national science policy.[1] These goals were based on the premise that the value to society of any scientific enterprise is determined by the social, cultural and economic aspirations of that society. *The Science Council recognizes that the earth sciences play a vital part in the attainment of several national goals.*

The contributions of earth sciences to *national prosperity* go far beyond their important contributions to the mineral industry itself. Nevertheless, the mineral industry is a keystone to the maintenance of national prosperity. The exploration for and development of mineral deposits provides special benefit by establishing highly productive industries in the less developed areas of Canada. Though other professionals–mining engineers, metallurgists, economists–play major roles in the actual production of mineral products, the activities of earth scientists are heavily concentrated in the exploration phase of the mineral industry and in related government services. Exploration activities are, in truth, the lifeblood of the mineral industry.

An important element in the attainment of national prosperity is a *high rate of economic growth.* Whether or not one accepts this as a desirable long-term goal, with consequent accelerating depletion of limited natural resources and allied difficulties in maintaining a desirable natural environment, acceptance of it as at least a short-term goal is a practical necessity. The value of production by the mineral industry nearly doubled to $4.7 billion from 1960 to 1968. The rate of growth of the industry in recent years has been steady and has exceeded that of manufacturing and of total Canadian industrial production. World consumption of mineral products is expected to double in about 15 years. Canada should seek to maintain a strong international competitive position in mineral production so that it can participate adequately in this expected growth in world demand. Without the discovery and development of new mineral resources by earth scientists, such growth would be impossible.

[1]Science Council of Canada. Towards a national science policy for Canada. Report No. 4, October 1968, Section 3. Queen's Printer, Ottawa.

A second important element in the goal of national prosperity is a *favourable balance of payments.* About two thirds of the Canadian mineral production is exported, and up to two thirds of these exports go to the United States, thereby reducing Canada's overall trade deficit with that country. In the past, the mineral industry has been able to make a major contribution to the balance of payments through its increased capacity to export and to meet import competition. For instance, in the primary sector in 1964 it had a favourable balance of $777 million; by 1968 this had grown to $1 345 million. Continued strengthening of the industry's international position will enable it to maintain this important role.

In *education,* earth science has been an integral part of university life, and therefore of science in Canada, for well over one hundred years. Many Canadian earth scientists and earth science departments have established international reputations of high standing. The flow of foreign students to Canadian earth science departments, now and in the past, attests to this and certainly contributes to *international understanding.* A national deficiency in education that should be remedied, however, is the paucity of adequate instruction in earth science in our secondary schools.

The fact that field studies of the geology of Canada can best be carried on during summer months has given *summer employment* to many thousands of students through the years. These opportunities, which could be expanded, have given and will continue to give to young Canadians a picture of their country that can inspire them in their citizenship.

The great majority of Canadians have scarcely a rudimentary knowledge of the earth on which they live. The fast-growing concern with our physical environment and the general curiosity about nature's phenomena all contribute to the relevance of earth sciences in *personal development.* Earth scientists should increase their contribution to "public information" in this regard. Fortunately, public interest in the sciences as a cultural and recreational pursuit (with some contribution to the national economy) has begun to increase in recent years. This is indicated, for example, by the rapid growth of "rockhound" activities in Canada.

Modern travel is giving more Canadians the chance to see in a leisurely manner parts of their country far removed from cities. All this is to the good, but it is clear to the Science Council that much more must be done to give to most Canadians an appreciation of the importance of the earth sciences in their daily living–not only as affecting the basic economy of their country or in explaining the beauties of Canadian scenery, but also as influencing in so many ways the environment in which they live, the planning and building of the cities in which they live and work, and the conservation of resources–water above all–that are so vital to national well-being.

Earth Science Instruction in Secondary Schools

Canada's wealth has come chiefly from products of the soil and from products of the crust of the earth beneath the soil. As a consequence, the educational system provided for young Canadians might be expected to give special emphasis to earth science. The reverse is true. Our secondary schools provide no adequate treatment of earth sciences.

This deficiency in our secondary school education does harm in several ways. Students who do not proceed to university are deprived of a base on which to build recreational and cultural interests that could give them much pleasure and satisfaction. They lack the ability to appreciate fully their physical environment and to enjoy, through knowledge, the spectacular variety of the Canadian terrain. They are not properly equipped to think, or if need be to vote, on matters that affect some of our most important enterprises. Students who do enter university do so without a complete view of the whole spectrum of higher education in science. Their ability to plan their future properly is weakened.

Some progress toward rectifying the situation has been made recently. The 1969 Conference of Provincial Ministers of Mines considered briefs from three Canadian earth science societies and adopted resolutions favouring the introduction of earth science courses in the secondary schools, and the formation of provincial committees to study "methods that will qualify more teachers to a high level of competence for the teaching of an Earth Science course in Canadian high schools."[1]

The second resolution is in response to evidence presented to the Conference that too few secondary school teachers are properly qualified to teach earth sciences and that better regulations are needed in this regard. Courses taught by incompetent teachers can be worse than no course at all at this level of education. The success of any course will also be governed by the text provided for it. Unfortunately, no satisfactory text exists for Canadian use. The preparation of a suitable text and its acceptance by provincial departments of education is a prime necessity for the teaching of earth sciences and for the training of teachers.

The Science Council believes that science curricula in secondary schools should be changed from the current, traditional, disciplinary approach (chemistry, physics, biology, etc.) to a more unified treatment. The study of earth sciences would be an important component in a unified science course.

1. The Science Council recommends:

a) that provincial departments of education encourage the introduction of more earth science into the science programs of secondary schools,

b) that these departments support the training of teachers to provide them with an adequate knowledge of earth sciences.
(Chapter II, Section 3)[2]

[1]Twenty-sixth Annual Conference of Provincial Ministers of Mines. Proceedings. Ontario Department of Mines, Toronto, 1969.

[2]This and subsequent similar references refer to pertinent chapters and sections in the Special Study on earth sciences, where supporting information will be found.

National Co-ordination of Earth Science Research

A continuing theme throughout the reports of the Science Council has been the need to promote the better use and application of science in areas of economic or social importance and, simultaneously, to ensure the health and vitality of the many disciplines of science itself. These two functions are highly important, and are separable.

The Science Council has referred in general to the organized attempts to use science and technology for social or economic ends as "missions". To obtain a national view of how best to use science in these missions, the Council has proposed that appropriate committees be established, made up of representatives of all involved sectors of the economy (industry, universities, federal and provincial governments), and all appropriate disciplines. Since for many missions the major responsibility lies with a single federal minister, and since the largest single activity or source of funding for the mission area is frequently in that minister's department, the Science Council has supported the establishment of "National Advisory Committees" to the appropriate ministers.

It should be understood that these National Advisory Committees must be concerned with reaching the goal(s) of the mission rather than with welfare of disciplines of science per se. It should also be understood that "mission-oriented" research is not synonymous with "applied" research. It does not exclude "pure" or "basic" research; the pursuit of a mission may, especially in the early stages, require a great deal of "basic" research. The criterion of "mission-orientation" is not one of degree of "appliedness" but one of relevance to the long-term objectives of the particular mission.

The second important consideration–that of the health of specific disciplines within science–is and should be of major concern to the scientific and technical societies of the nation. Through meetings, publications and other activities, the societies do play a vital part in nourishing the disciplines, but for various reasons, including inadequate funding, they have been unable to meet fully the needs of the nation in this regard. The Science Council is convinced that steps should be taken to hasten the day when the Canadian societies will assume a more prominent role in plotting the courses of their disciplines, as societies do in some nations.

Underlying the health of science is the state of the funding it receives. The role of the National Research Council should be that of supporting the sciences as sciences, in their broadest sense, in Canada through its Grant Selection Committees, acting with the benefit of industry as well as university membership.

A National Advisory Committee on Mineral Resources Research

Mineral resources make an important contribution to our national economy, and the increased application of scientific methods to mineral exploration offers the possibility of even greater economic rewards. *The Science Council recognizes that the exploration for and development of mineral resources involves more than the usual industrial risks.* Successful mineral resources research may complement tax incentives in helping to reduce the risk element. The need for research increases each year as it becomes more difficult and more costly to find new mineral resources. Existing reserves in the mining industry stem largely from deposits that were discovered through recognizable surface indications–either actual ore or related alterations. To a lesser extent they stem from discoveries based on geological reasoning supported by geophysical techniques. Most of the techniques penetrate only a few hundred feet beneath the surface, yet we know that many deposits are hidden under thousands of feet of barren rock.

Geological reasoning needs to be sharpened by research on the origin, age, tectonic history, alteration and migration of mineral deposits. Geophysical techniques need research toward increased depth penetration, distinctions between worthless and valuable anomalies, new or better airborne techniques, and better identification of, for example, low-grade, disseminated, sulphide deposits. This branch of the science is still in its infancy and new research may be expected to yield handsome returns toward lowering the risk and cost of mineral exploration.

The Study Group's report shows that the petroleum and mining companies and consulting firms spent $41.5 million on earth science research and development in 1968, over half of which involved the interpretation of earth science data. Most of the products of this research are of a proprietary

nature and are not available for public use. In addition, the major part of the research and development was performed outside of Canada. The Federal Government spent $4 million on equivalent activities, and the 10 provincial departments of resources spent somewhat less than $3 million in total. In the universities, the level of mineral resources research is much lower and is reflected further in the low proportion of graduates interested in employment in the mineral industry.

Mineral resources research involves many segments of the scientific community–the mining and petroleum and drilling industries, geophysical and geological consultants and contractors, universities, federal and provincial government agencies, and the research councils. It is multidisciplinary in nature, requiring the expertise of specialists in geology, geophysics and geochemistry as well as mathematicians, physicists, chemists, economists, and many others. Mineral resources research offers potential solutions to many Canadian problems, especially those related to the development of the North and the support of underdeveloped areas. Findings of the Study Group indicate a low level of research activity relative to the economic importance of mineral resources, and insufficient co-ordination among the various performers of mineral resources research.

2. The Science Council recommends that a National Advisory Committee on Mineral Resources Research be appointed to advise the Minister of Energy, Mines and Resources on the co-ordination of a national program of mineral resources research.

The general goals of the Committee should include:

a) Lowering the risk element in the search for mineral resources by increasing the efficiency and effectiveness of mineral exploration;

b) Promoting application of the most efficient methods in mining and extractive metallurgy;

c) Developing and promoting research into the application of wise mineral policies.

The Committee should have adequate funds to stimulate the growth of mineral resources research through cost-sharing research programs. It is envisaged that the Committee would establish three separate committees on

a) Mineral exploration research;

b) Mineral production, beneficiation, extraction and processing research;

c) Mineral policy research.

The proposal for a subcommittee on mineral policy research is a new and important one in view of the almost negligible emphasis given to this field in Canadian universities, and the growing problems of resource conservation, production and marketing. Appendix B presents further suggestions regarding the organization of the Committee.

Some conclusions of the Study Group that clearly fall within the terms of reference and implementation authority of the newly proposed National Advisory Committee on Mineral Resources Research are listed below.

a) Centres for special studies in mineral exploration (Chapter IV, Section 5);

b) Research and development in drilling technology and drill-hole instrumentation (Chapter IV, Section 5);

c) Industrial research fellowships in the earth sciences (Chapter IV, Section 3);

d) Research on the usefulness of various exploration methods (Chapter IV, Section 3);

e) Co-operation by industry in a comprehensive study of the Canadian Shield (Chapter II, Section 3).

3. The Science Council recommends that the proposed National Advisory Committee on Mineral Resources Research review the Study Group's report in full, and take the necessary steps to implement the appropriate conclusions and hence increase the effectiveness of mineral resource exploration and production in Canada.

The Role of Earth Sciences in Environmental Problems

The foregoing section provides for strengthening the essential part that earth sciences play in the mineral industry of this country–a part that is well recognized. It is clear to the Science Council that the earth sciences must come to play an equally important, although different, role in relation to the physical development of this country. Although this trend has already begun, it is still not sufficiently recognized. In the Federal Government, interest in environmental earth sciences is spread thinly over a number of departments.

The increasingly competitive use of the land, whether for mining, agriculture, fores-

try, hydroelectric development, industrial and urban development, or recreation and nature conservation, necessitates judicious use of natural resources and demands proper regard for preserving the quality of the natural environment. The present public and political concern in North America about pollution of water and air, destruction of wilderness areas, urban sprawl, and other factors contributing to deterioration in the quality of man's environment is a symptom of the acute need for much greater attention to the management of our natural environment and resources. Canadians not only face the challenge of achieving effectively the accelerated growth of urban centres that will take place in the next few years, but are also responsible for the development and management of one of the largest virgin wilderness areas remaining in the world. *A concerted attack on these challenges and problems, although encircled by social, economic and legal factors, must be based on objective, factual, scientific information concerning land or terrain–information which is the essence of the solid-earth sciences.*

Knowledge of the nature and behaviour of the land, which is essential to effective land use planning and management of land resources, is based upon solid-earth science information concerning relief and landforms, surface and near-surface bedrock, unconsolidated earth materials, soils in the pedological sense, as well as water both in and on the ground. Facets of geology, physical geography, soil science and soil engineering are all involved.

In particular, Canada is currently facing a critical need for land use planning in the permafrost and muskeg areas of the Arctic. The rapidly increasing rate of petroleum exploration is forcing the implementation of political and technical decisions without an adequate background of scientific knowledge and experience. The numbers of scientists engaged in this field are woefully inadequate. At the federal level, only five persons are engaged in permafrost research, a phenomenon covering over half of the country. *The Science Council endorses the conclusions of the Study Group that increased emphasis must be given to northern terrain studies.*

Greatly increased activity in all branches of environmental earth sciences is necessary immediately, including appropriate attention to the social aspects of planning, especially as they relate to the protection of our environment. The work already done must be rapidly expanded upon firm scientific foundations, and aided by all that research can contribute. *Accordingly, as Canada moves to investigate and solve the problems of the environment, care must be taken to ensure that the environmental earth sciences are developed to play their proper role. (Chapter VI)*

Earth Science Support for the Construction Industry

Geotechnique is the term used to describe the more detailed studies of both soil and rock in relation to construction activities. Geotechnique starts with geological background but extends into the actual design and construction of foundations and all types of "earthworks". It therefore covers some aspects of engineering geology, rock mechanics, soil mechanics, and hydrogeology. It is obvious that it is a vital part of the practice of civil engineering, since every building and every structure is founded upon the ground. Soil mechanics involves the further development of geotechnical principles that have accumulated through the experience of practitioners in design and construction. The science was first officially recognized in 1936, and has made great strides in recent years. Canadian workers have made significant contributions to its advance.

The Study Group estimated (Chapter V) that the total national expenditure on geotechnical research and development was only $3.6 million in 1968. Nearly two thirds of the research and development was performed in the universities, and the rest was divided about equally between consulting firms and the Federal Government. In view of the vital importance of geotechnical expertise to the efficiency and safety of construction projects, the present small amount of research and development performed by industry, and the expected rapid growth of the industry, research and development should be increased. The Study Group has suggested a national research and development expenditure of the order of $15 million per annum by 1985. It also concludes that the industry and related engineering groups should be encouraged, through tax incentive programs, to participate in geotechnical research and development.

The Department of Public Works serves the main construction needs of the Federal Government itself, excluding those met by the Departments of National Defence and Transport. The Central Mortgage and Housing Corporation (CMHC) is responsible for all federal interests in housing. The research needs of these agencies, particularly of CMHC, are met by the Division of Building Research of the National Research Council as a part of its general research service to the construction industry as a whole. In addition, a number of Associate Committees of NRC perform the important co-ordinating function for different facets of construction, e.g. paint research and geotechnical research.

It is therefore appropriate that at this time, and certainly until such time as construction as a whole achieves formal recognition within the Federal Government, *the Associate Committee on Geotechnical Research of the National Research Council continue to co-ordinate and support geotechnical activities in Canada.*

The general organization of this Associate Committee could well be reoriented along the lines proposed for the National Advisory Committee on Mineral Resources Research. In the view of the Science Council, this similarity of arrangement would serve to emphasize the parallelism of the two committees. The major difference is that in the mineral industry the earth sciences are applied mainly in the search for new mineral wealth, whereas in the construction industry their application is to provide essential information so that planning and construction can be safely and economically carried out.

The Future Role of the Scientific and Technical Societies

There are at least 17 large earth science groups in Canada–societies, associations or divisions of larger organizations (Chapter II, Section 8). They have grown to meet disciplinary or regional needs and are an essential part of the communications network. They also serve by maintaining, at the "grass roots" level, links between industry, universities and government agencies. But formal liaison between them is practically nonexistent. Furthermore, earth science groups that are not incorporated in larger organizations that have other interests in addition to earth science (for example, The Royal Society of Canada, the Canadian Institute of Mining and Metallurgy, The Engineering Institute of Canada) lack permanent, paid secretariats. No single body exists that can speak officially for Canadian earth scientists: the 1969 National Science and Engineering Conference noted the need to add representatives of earth science and some other branches of science to its proposed enlarged steering committee. Better co-ordination would allow the societies to pool some resources, speak on policy matters with a stronger voice, provide improved services to their members and increased benefits to the nation. It should also assist the societies to play a greater role in bringing to the public a better appreciation of the economic and cultural values of earth science.

Mention has been made (page 18) that Canadian scientific societies should assume a more prominent role in plotting the course of their various disciplines. Elsewhere in this report the Science Council has recommended the establishment of mission-oriented advisory committees to assist in the attainment of currently recognizable national objectives. These new committees will assume some but not all of the duties of existing national advisory or associate committees. Several of the existing committees are structured along disciplinary lines, for example the Associate Committee on Geodesy and Geophysics, and the National Advisory Committee on Research in the Geological Sciences. A prime objective of committees so structured is to survey and guide wisely the many specialties or disciplines of earth science. At present these committees are convened and funded by either the National Research Council or the Department of Energy, Mines and Resources.

4. The Science Council urges the leaders of the societies to formulate plans whereby the earth science community can assume an appropriate share of the disciplinary obligations of existing national committees and to discuss their plans with the National Research Council and the Department of Energy, Mines and Resources with a view to adequate funding of this new society activity.

In addition, the Science Council recommends that the earth science societies develop closer bonds with a view to establishing a national secretariat.

A strong national earth science secretariat might serve the nation in additional ways. In the following section of this report, the problem of obtaining an adequate inventory of scientific and technical manpower is discussed briefly and mention is made of a forthcoming general recommendation by the Science Council. Earth scientists in Canada should be prepared to assist in obtaining an adequate inventory if called upon to do so.

During the period in which the roles of many committees will be under review, it will be important to ensure that only those committees with valid objectives continue to operate. The Science Council would hope that the net effect of such a review would be to reduce the total number of committees in operation at any one time.

Areas for Action by Various Sectors

The Federal Government

The Federal Government plays a major role in the funding, conduct and co-ordination of earth science activities in Canada. The Study Group's report describes this role in detail (Chapter II) and suggests means for improvement as well as increased spending on earth science activities by the Federal Government. The Science Council agrees with the intent of the Study Group's conclusions and wishes to draw the attention of the Government to the specific conclusions of a non-financial nature which require early attention. In its forthcoming overview of science in the primary industries, the Council will discuss the financial recommendations in more detail.

a) Technical Assistance to Developing Countries

The Science Council is a strong supporter of Canada's foreign aid program and believes that the scientific community has an important role to play in attainment of the goals set by the aid program. It is in this context that it was particularly impressed with the Study Group's report on technical assistance (Chapter VIII) and commends it to the Canadian International Development Agency (CIDA) for review and implementation. The essential theme of the Study Group's report is that:

a) Canada's aid program will continue to enlarge;

b) the earth sciences are playing an important part in the program and their role should increase still further;

c) in order to increase their role, certain management decisions relating to planning and operations should be made by CIDA. The Science Council considers the conclusions of the Study Group to be reasonable and worthy of implementation. The essential lines for action lie with CIDA as the agency responsible for Canada's aid program, and with the Department of Energy, Mines and Resources as the earth science arm of the Federal Government. The latter Department might well establish an Overseas Branch of earth scientists specializing in external aid. Certainly, the lines of communication between the two federal agencies require improvement.

5. The Science Council recommends that the Canadian International Development Agency review the Study Group's report with a view to increasing the effective use of earth sciences in its program of aid to developing countries. (Chapter VIII)

b) Definitions of Scientific Activities

The conduct of earth science activities differs from the conduct of other physical science activities in that since the field is where the problems are, extensive field surveys are required to provide the necessary data for research studies. The present definition of "research" used by the Dominion Bureau of Statistics implies that field activities are excluded from the research expenditures reported by industry, and hence introduces a bias in the reporting of scientific statistics for science policy purposes.

6. The Science Council recommends that the Dominion Bureau of Statistics clarify its definitions of scientific activities, especially in relation to those earth science activities (geological, geophysical, geochemical, etc.) performed in the field. Field activities that advance scientific knowledge should be categorized as research. (Chapter I)

c) Co-ordination of Federal Earth Science Activities

The multiple applications of the earth sciences to governmental functions have led to their funding and use in 11 federal departments or agencies, as well as their widespread application throughout the Department of Energy, Mines and Resources. Such diversification naturally leads to problems in communication and to the possible ineffective use of the earth science capabilities that presently exist in the Federal Government. It also bewilders the public when attempting to obtain information and transact business with the Government. The Study Group has described a number of problem areas relating to communication and co-ordination at the federal level. It is apparent, for example, that federal earth science activities could be better co-ordinated through an interdepartmental committee on earth sciences (Chapter II, Section 5). Federal departments concerned with northern and regional development could make better use of earth science research and services centralized in the Department of Energy, Mines and Resources. That Department could increase the internal co-ordination and effectiveness of its scientific services to the mineral industry, possibly through a regrouping of its mineral resource

activities in a single sector of the Department.

7. The Science Council recommends that the Department of Energy, Mines and Resources review in detail the observations on federal earth science activities presented in the Study Group's report, with a view to increasing the internal efficiency of its operations. (Chapter II)

d) Scientific Services

The Council's first report on a national science policy referred only briefly to scientific services such as geological surveying and meteorological services, and indicated that:

"...because of Canada's great size, the peculiarities of her geography, and the importance of natural resource development to her economy, these scientific services are more important to Canada than they are to many other nations."[1]

The report of the Study Group describes the current status of systematic geological, geophysical, topographic and hydrographic surveying of Canada and suggests that the present rates of progress are inadequate to meet both the needs of increasing mineral exploration by industry and the formulation of effective economic, planning, developmental and legal policies by the Government. *A country must base its planning on knowledge rather than on visions.*

The Science Council recognizes that there are major problems to be resolved in the collection and processing of earth science data from industry, which is the major performer of data collection activities. The provincial government departments play a large and important role in this activity. It is, therefore, neither possible nor desirable that national goals for the rate of acceleration of these scientific services be established at this time. As a basis for the better definition of national targets, there is a need to:

a) summarize the current levels of knowledge and rate of progress;

b) review the present standards;

c) assess the future implications of resource satellites;

b) define future requirements;

e) develop co-ordinated programs for reaching acceptable targets, including proposals for funding on a cost-sharing basis.

8. The Science Council recommends that the Department of Energy, Mines and Resources convene a series of national planning conferences involving representatives from earth science data collection agencies in the federal and provincial governments, industry and universities, to define future requirements and develop co-ordinated plans. (Chapter VII)

e) Manpower Inventory

The Study Group's report (Chapter II, Section 2) indicates the problems encountered in obtaining adequate data on earth science manpower. Although the Dominion Bureau of Statistics, the Department of Manpower and Immigration, the National Research Council, the Association of Universities and Colleges of Canada, the Canadian Institute of Mining and Metallurgy, and others, collect partial manpower information, the gaps, overlaps and differences in format reduce their potential usefulness in relation to the time spent by the reporting agencies or individuals. This situation is common to all fields of science in Canada and is a weakness in the formulation of a national science policy, in the development of manpower training policies by universities and other educational institutions, in immigration policy, and in recruiting, salary negotiations, and career planning. There is an obvious need for better data on scientific and technical manpower, and steps must be initiated to obtain them. The Science Council recognizes this problem and plans to make a general recommendation on it in the near future.

The Provincial Governments

a) Co-ordination of Earth Science Activities

The multiple responsibilities of provincial governments for mineral resources, for education, for municipal governments and for urban development require that they play a key role in the development and implementation of science policies. Earth science activities in provincial governments are performed principally in departments of mines, or of natural resources, but in some provinces they are pursued as well in departments of highways, agriculture or forestry, or by provincial utilities. When one includes the earth science capabilities in provincial

[1]Science Council of Canada. Towards a national science policy. Report No. 4, 1968. Queen's Printer, Ottawa.

research councils, universities, and local mineral or construction industries, the potential for major regional earth science programs is considerable.

In national committees the question frequently arises as to *who* represents the regional earth science policy–one of the provincial departmental representatives, a member of the research council, or a member of a university staff. The problems of planning and communication described by the Study Group as existing between federal government departments exist equally at the provincial level. Hence, the Science Council considers that provincial earth science committees could serve a useful function in some provinces. They could have terms of reference similar to those proposed by the Study Group for a federal interdepartmental committee, but should include within their framework the related university, research council, industrial groups and representatives from regional laboratories funded by the Federal Government. Since departments of mines have the greatest concentration of earth science activity and expertise in most provinces, their provincial ministers occur as logical initiators of provincial action in this regard.

9. The Science Council recommends that provincial governments consider the formation of earth science co-ordinating committees. (Chapter II)

b) Environmental Earth Sciences

A number of provincial mines or natural resources departments have developed to meet the immediate governmental functions relative to the mineral industry (legislation, collection of revenue, inspection, safety, provision of data, etc.). These were the most important functions existing at the time of formation of the departments. The increasing importance of environmental earth sciences related to urban planning and development, highway and other forms of engineering construction, groundwater, etc. has been recognized and supported in only a few instances. Because environmental earth sciences relate so largely to municipal and urban problems, there is a responsibility to review the existing provincial earth science programs in relation to the demands of urban growth.

10. The Science Council recommends that provincial governments review the emphasis and scale of their earth science programs in relation to growing requirements to apply the earth sciences to urban problems as distinct from the needs of the mineral industry. (Chapters V, VI)

c) Computerized Earth Science Data

The concept of a co-ordinated nationwide system of earth science data storage and retrieval was accepted by the provincial ministers of mines at an annual meeting in Toronto in September 1969. Since provincial governments are the recipients of considerable earth science data under their mineral regulations, successful implementation of the system depends on an adequate level of funding and support by the governments concerned. This statement applies equally to the Federal Government's administration of federal lands. It is important that the provincial and federal systems develop common standards, compatible with the Canadian System for Geoscience Data and systems developed for the Scientific and Technical Information Board. (The Scientific and Technical Information Board is being established by the National Research Council, following recommendations made in Science Council Report No. 6, *A Policy for Scientific and Technical Information Dissemination.*)

11. The Science Council recommends that provincial and federal governments develop and implement plans to computerize their existing and future earth science data at the earliest possible date, preferably no later than within the next two years. (Chapter IV, Section 5)

d) Core Storage Libraries

The report of the Study Group outlines the reasons for considering that the preservation of hard-rock drill cores, similar to the existing practice for petroleum cores and cuttings, will benefit the conduct of earth science research, the search for ore deposits and, ultimately, provincial revenues and regional development. The Study Group describes the current practice and presents a proposal for the development of regional core storage libraries. The principles behind the proposal have been strongly endorsed by the mining industry in replies to questionnaires circulated by the Study Group.

12. The Science Council recommends that provincial and territorial governments jointly develop and implement plans to establish hard-rock core storage libraries as an aid to

effective mineral resource development and earth science research. (Chapter IV, Section 5)

The Mineral Industry

The mineral industry is the principal employer of earth scientists and is responsible for nearly two thirds of the total national expenditure on earth science research and development. Expenditures on scientific data collection, of which about 50 per cent is for exploratory drilling, are eight times larger than research and development expenditures. Since the data collection expenditures of industry, excluding the cost of the drilling, exceed the total expenditures of all government agencies on earth science data collection, again by a factor of 8, *it is evident that the mineral industry's files of recent years contain the major proportion of the total new Canadian earth science information.*

A review of earth science publications, including many of those by government agencies, clearly demonstrates that the mineral industry does make available to the earth science community many important contributions. Nevertheless, because much of the information in company files is of a proprietary nature and therefore is not available to the scientific community at large, there is considerable duplication of effort. For various reasons, including difficulties of preparation for publication, a great deal of valuable information may remain permanently buried in company or government files, even after a lapse of time has removed its proprietary value.

The Study Group's report considers these and other features of the mineral industry (Chapter IV) and makes a number of valuable comments on the effectiveness of, and the distribution of national effort in, mineral exploration. The Science Council believes this section of the report merits particularly careful consideration by the mineral industry, universities and government agencies. The number of actual conclusions reached by the Study Group is not great. They are classified and treated below, with suitable references to discussions in the Study Group's report.

a) Scientific Information

"The computer is already bringing about a revolution in industrial processes and management . . . Its use in the storage, manipulation and retrieval of data promises better opportunity for mastering the complex problems of our society in the future."[1]

The mineral industry, and especially some of the larger corporations, are already making good use of the computer applied to scientific information. The Science Council believes that the efficient operation of a truly national system for the storage and retrieval of earth science data would be of great benefit to the nation. Because a Canadian system has been developed and widely endorsed, at home and abroad,

13. The Science Council recommends that the mineral industry co-operate increasingly with government agencies and universities in the operation of the Canadian System for Geoscience Data. (Chapter IV, Section 5)

b) Research and Development

In the mineral industry, some corporations give much more financial support to research on Canadian problems carried out in foreign research centres (especially in those of foreign parents), than to performing similar research in Canada. More serious than the adverse transfer of funds which this causes is the consequent weakening of our research base and a decrease in the production and retention within our borders of superior earth scientists. Also of major concern should be the loss and subsequent lodging in foreign centres of valuable data on which research can be based. The Study Group reached the conclusion that the Government of Canada should adopt measures, including tax exemptions, to encourage the mineral industry to do more research of this kind in Canada and ensure that the resulting data remain in the country. The Science Council is not now prepared to judge what supporting measures, if any, should be adopted, but it does believe that a good corporate citizen will act in the best interests of this nation. The mineral industry must recognize and accept its obligation to participate actively in the formulation of policies and procedures which will ensure the attainment of national goals.

14. The Science Council recommends that the mineral industries:
a) provide concerted co-operation and support

[1]Science Council of Canada. Towards a national science policy. Report No. 4, 1968. Queen's Printer, Ottawa.

for the proposed National Advisory Committee on Mineral Resources Research and for centres of mineral exploration research,
b) support policies aimed at encouraging more earth science research in Canada on Canadian problems. (Chapter IV, Section 5)

c) The Mineral Industry and the National Advisory Committee on Mineral Resources Research

In this report, the Science Council has recommended the formation and adequate funding of a National Advisory Committee to promote progress in mineral resources research. Cost-sharing research projects in industry are among the proposed objectives. Provision is made for industry to participate in the allocation and management of the Committee's funds. The principal national benefits will accrue through increased efficiency in the industry. The mineral industry should rise to the opportunity by:

a) Encouraging its professional staff to participate in the National Committee;

b) Providing data and facilities for research;

c) Providing matching funds.

The Construction Industry

Well before the end of the century the entire physical plant of Canada will have to be duplicated, but with an even greater proportion of this vast quantity of construction concentrated in urban areas in view of the persistent trend toward city living. This result can only be achieved with every possible assistance from geotechnique, because poorer sites will have to be used for the buildings. Obviously, such a development must be properly planned in all its aspects if this country is to remain a good place in which to live and work.

Although the construction industry is both large and important to Canada, it includes many relatively small firms engaged in design and building. Accordingly, the Federal Government has provided, and industry has accepted, assistance in the form of research and other activities through the Division of Building Research of the National Research Council. In practically every country of the developed world it will be found that in view of the fragmented nature of the industry, the construction industry looks to a national, publicly supported organization (similar to the Division of Building Research) for its research needs.

The construction industry, through the Canadian Construction Association, has endeavoured to establish a "Construction Industry Development Fund" as evidence of its desire to participate corporately in research and development activity, since individual firms (apart from major material manufacturers) cannot do much because of their small size.

15. The Science Council recognizes the effort of the construction industry to increase the level of its construction research and development, and in so far as it relates to geotechnical research and development, supports the idea of a Construction Industry Development Fund. When available, such a fund should be used to increase co-operative research with universities and research councils, in the interest of improved efficiency and safety as well as lowered construction costs. (Chapter V)

The Universities

Canadian universities play a key role in the education of earth science manpower as well as in the conduct of earth science research. The Study Group's report indicates clearly that the departments are not able to graduate a sufficient number of students to meet the current demand. In spite of heavy immigration of earth scientists to Canada, amounting in 1968 to more geologists than were graduated in Canada, the requirements of industry have not been fully met. Recent figures indicate that the heavy immigration continues at about the 1968 scale: 217 geologists and 116 mining engineers immigrated to Canada in the first nine months of 1969. A "brain gain" of this magnitude is undoubtedly very valuable to Canada, but continued dependence upon it for adequate support of essential earth science activities is not desirable.

The Study Group reports that fewer than one third of the graduates in geology and geophysics (1966-68) entered the mineral industry, the largest potential employer. It is known that the industry recruits foreign earth scientists. It may be that too few Canadian graduates are motivated to accept employment in industry and that too many advanced-degree programs are not relevant to the needs of industry. In addition, the current image of industry as an employer of scientists, its low reputation for providing stimulating and challenging employment,

and its isolation from urban society contribute to the problem.

16. The Science Council recommends:
a) that undergraduate education in earth science should be broadly based,
b) that in close co-operation with industry, university departments should develop programs designed to meet the needs of industry as well as those of other earth science activities. (Chapter III, Section 8)

The performance of basic research is a fundamental obligation of university departments. Without a high quality of basic research, nourished by freedom of individual choice and adequate funds for promising researchers and those of established competence, earth science–like other disciplines–will stagnate. But productivity in basic research, whether it be in the form of positive or negative results, requires human attributes of a special kind, hard to define, that are not a common possession. Indiscriminate support of pure research can lead to waste of funds and eventual disenchantment of fund-granting agencies, both public and private.

It should be clearly understood that mission orientation by no means implies the absence of basic research. In this understanding, and with the proviso that encouragement of applied research does not imply the discouragement of basic research,

17. The Science Council recommends that universities encourage increased research in the earth sciences related to national programs. (Chapter III, Section 9)

Solitudes in earth sciences are not restricted to universities nor, in universities, to earth science activities. To some degree they are essential to the specialization that is so necessary today. Nevertheless, they do make communication and co-ordination more difficult, and can lead to duplication of effort or to a misguided approach to problems better suited to a multidisciplinary attack. This is true in regard to undergraduate education as well as to research. The Study Group has discussed this problem in detail in its report and several of its conclusions bear on it.

In closely adjoining universities, such as exist today in Eastern Canada more than in the West, there should be ample opportunity for economies and for reducing these solitudes by development of co-ordinated, interuniversity programs in teaching and in research.

Teaching and research in science and engineering related to geotechnical activities pose some special problems in co-ordination. The Study Group encountered in some universities an almost complete lack of intercourse on these activities or their application to national development. Co-operative effort by civil engineers, geologists and geographers, for example, is highly desirable in many problems of urban development and in research and development related thereto. Engineering geology, rock mechanics, muskeg and permafrost studies and hydrogeology often merit comparable co-operation.

18. The Science Council recommends increased co-ordination of university earth science groups involving geology, geophysics, geochemistry, geotechnique, physical geology and soil science. (Chapter III, Section 8)

Earlier in this report the establishment of centres for special studies in mineral exploration is placed within the terms of reference of the proposed National Advisory Committee on Mineral Resources Research. The Study Group has devoted a long section to discussion of centres for special studies in several other fields of earth science, and concludes that Canada should vigorously promote their growth. Such centres, if established, preferably should be located on or close to a university campus, whether or not they were an integral part of a university. The development of advanced programs in universities, referred to by the Study Group, would probably have a bearing on their establishment, or stem in part from them.

19. The Science Council recommends the establishment of centres for special studies in earth science research. (Chapter III, Section 1)

Appendices

Appendix A

The Earth Science Committee of the Science Council of Canada

Chairman
Dr. W. H. Gauvin*
Chemical Engineer, Research Manager of the Noranda Research Centre, Pointe Claire.

Members
Dr. R. E. Folinsbee
Geologist, Professor in the Department of Geology, University of Alberta, Edmonton.
Mr. R. Geren
Consulting Geologist, Oromocto.
Dr. H. C. Gunning
Consulting Geological Engineer, Vancouver.
Dr. J. M. Harrison*
Geologist, Assistant Deputy Minister (Geosciences), Department of Energy, Mines and Resources, Ottawa.
Dr. R. F. Legget
Geological Engineer, formerly Director of the Division of Building Research, National Research Council of Canada, Ottawa.
Dr. D. H. MacDonald
Civil Engineer, Director, Acres Limited, Niagara Falls.
Dr. G. C. Monture
Geologist and Mineral Economist, Special Consultant, Resources Engineering of Canada Limited, Ottawa.
Dr. J. T. Wilson
Geophysicist, Principal of Erindale College, University of Toronto, Toronto.
Mr. H. F. Zurbrigg
Geologist, Vice-President (Exploration),The International Nickel Company of Canada, Limited, Toronto.
The Committee is grateful for the expert assistance provided by its Project Officer, Dr. C. H. Smith, Chief, Crustal Geology Division, Geological Survey of Canada, Ottawa.

*Members of the Science Council of Canada.

Appendix B

Some Suggestions regarding Operation of the proposed National Advisory Committee on Mineral Resources Research

The following principles should be applied:

a) The terms of reference of the proposed National Advisory Committee should require it:

1. To provide continuing advice to the Minister of Energy, Mines and Resources on research needs and priorities in mineral resources research in all sectors of the economy, and on the application of science to mineral resources management and use;

2. To assist in the co-ordination of mineral resources research;

3. To review and make recommendations on applications for grants from the Department of Energy, Mines and Resources in aid of mineral resources research.

b) The membership of the Committee should be established as follows:

1. Members should represent all sectors of the economy, federal and provincial public services, universities and industry. No sector should dominate the Committee;

2. The membership of the Committee should reflect as far as possible the wide range of disciplines that contribute to mineral resources research;

3. The senior representative of the Department of Energy, Mines and Resources on the Committee should be appointed convenor of the Committee;

4. The chairman of the Committee need not be a federal public servant; he should be elected to the position by the members of the Committee;

5. The chairman should be elected for a term of three years, once renewable. Members should also be appointed to the Committee for three-year terms, once renewable;

6. The Department of Energy, Mines and Resources should provide the secretariat and a non-voting secretary.

c) The funds of concern to the National Advisory Committee on Mineral Resources Research should form a separate and identifiable item within the budget of the Department of Energy, Mines and Resources, and the responsibility for advising the Minister on the distribution of these funds should rest solely with the Committee and its appropriate subcommittees.

Appendix C

Highlights and Major Conclusions of the Report of the Solid-Earth Sciences Study Group

Solid-earth sciences serve Canada in numerous ways and provide essential services in major growth areas of the Canadian economy.

This study relates to the solid part of the earth and includes geology, geophysics, geochemistry, physical geography, hydrogeology, soil science, and several related disciplines. It embraces research and development, scientific data collection, and scientific information activities related to these disciplines.

Here, for the first time, is a detailed account of solid-earth science activities in the mineral and construction industries, federal and provincial government agencies, and research councils and universities.

The study describes the present patterns, and proposes major improvements for earth science activities during the next decade. The most important findings and conclusions are:

The importance of earth sciences in our national life extends far beyond the development of mineral resources, although this activity remains the most important for the 6 000 earth science professionals practising in Canada. Earth sciences contribute to other important objectives including regional and northern development, improved building and engineering construction, urban planning, development of water resources, management of renewable resources such as agricultural soils and forests, multiple land use, and pollution control.

In 1968, the total earth science expenditures in Canada were:

Research	$ 30 million
Development	6 million
Data interpretation	30 million
Data collection	217 million
Exploratory drilling	172 million
Scientific information	13 million
	$ 468 million

Excluding expenditures by industry on exploratory drilling, the financial participation of the various sectors in these activities is: industry, 80 per cent; federal government, 12 per cent; provincial governments, 6 per cent; and universities, 2 per cent.

Notwithstanding the importance of earth science activities in Canada's development, the great majority of Canadians have scarcely a rudimentary knowledge of the earth on which they live. The fast-growing interest in our physical environment, the mounting pressures concerning landscape preservation and anti-pollution, the need for improved urban planning, and the importance of natural resource development in Canada highlight the relevance of earth sciences for Canadians.

Students in our secondary schools should be given the opportunity to learn the principles of science through discovery of the physical world in which they live–the atmosphere, the lakes and rivers, the oceans, the mountains, the rocks, the minerals–so that science can be seen to be *relevant* and *useful*. We thus submit

Provincial departments of education should encourage and promote the teaching of earth science in secondary schools.

For several years there has been a shortage of earth science professionals in Canada. Of the positions available in 1968 for earth scientists, only 35 per cent were filled by the output of Canadian universities; scientists from abroad filled a large part of the Canadian need. Of graduate students now in geology, geophysics and physical geography, over 40 per cent are non-Canadians. Universities must face the challenge of increasing the number of graduates while simultaneously fostering research training.

In spite of the present major rejuvenating process in geology, comparable to that experienced by physics in the 1890s, and the important contributions of geology and geophysics to Canada's economic and regional development, many earth science departments in Canadian universities are inadequately housed. We conclude

Government and university administrators should take steps to improve earth science facilities in the universities.

Centres for special studies (centres of excellence) in earth sciences should be developed in some universities with the support of government and industry. These centres should focus on important national scientific problems, with special emphasis on studies of earth features which are uniquely or best developed in Canada. We conclude

The following fields are exceptionally suited for special Canadian studies (in alphabetical order): Cordilleran studies, marine sciences, mineral exploration research, northern terrain research, Precambrian studies, and Quaternary studies. Because of earth features best developed in Canada, geomagnetism, geotectonics, glaciology (including snow and ice), meteorite crater studies and mineral deposits geology are well suited for Canadian research.

Canadian earth scientists are not exempt from "solitudes". A major objective of policy in earth sciences should be better co-ordination of their activities and establishment of better communications among geoscientists in industry, government and universities. Earth science activities should be considered as an area for federal-provincial co-operation and co-ordination and should avoid constraints arising from matters of jurisdiction. In conjunction with several conclusions appearing in this report on the subject of co-ordination, we submit

The major advisory functions on the orientation, and to some extent the funding, of earth science research in Canada should be distributed as follows:

a) National Advisory Committees (such as the National Advisory Committee on Mineral Resources Research recommended herein), multidisciplinary in nature, representative of all major sectors and funded by the federal government, to advise governments and industry related to research in major national missions;

b) Research Committees formed by scientific and professional societies, to achieve co-ordination among specific earth science disciplines, to provide advice on future research, and to perform related functions; and

c) Committees of the National Research Council to provide grants-in-aid for university research.

The mineral industry is by far the largest performer of earth science activities in Canada and the largest employer of earth scientists. The sustained growth of this industry is essential to Canada's economic and social development. To this end, mineral exploration should be vigorously pursued and encouraged. Research into new methods and instrumentation for increasing the efficiency of mineral exploration warrants particular encouragement in industry, government agencies and universities. Thus, we conclude

The Canadian Government should adopt measures to encourage the mineral industry to carry out, or support, more "in-Canada"

earth science research. Industry should co-operate fully with government agencies and universities in the establishment of the Canadian Geoscience Data Institute, the establishment of central core storage libraries, the conduct of research in mineral exploration and drilling technology, and the provision of research fellowships associated with industrial sabbatical leaves. Universities should, before 1975, double their present level of research in economic geology and triple it in exploration geochemistry and geophysics.

Earth science research should be actively pursued in areas of major concern related to building and engineering construction, urban planning, multiple land use, management of renewable resources, control of pollution, and geochemical aspects of nutrition and health. Consequently, we submit

Geotechnical research and development by the construction industry and the engineering profession should be encouraged through tax incentives. Better co-ordination is needed among the various governments, including municipal authorities, to ensure an adequate earth science input in urban and regional planning.

Scientific investigation and mapping of surficial deposits and landforms should be accelerated to meet the rapidly growing needs of better land use and ensure the proper development of renewable resources. Education, training, mapping and research relating to renewable resources should emphasize a multidisciplinary approach to problems.

There is very little earth science basic research in Canada that anyone would wish to curtail. The level of this research is barely adequate to meet the need for fundamental scientific knowledge relating to national endeavours and research training. By improving the effectiveness of our earth science activities, building on existing strength, and promoting research on typical Canadian problems such as the Precambrian Shield, northern terrains, Quaternary geology and the like, Canada could readily acquire, at relatively minor cost, a greater position of prestige in international science while still nurturing science that is of immediate benefit to the nation. This is why we recommend

A comprehensive and multidisciplinary program of research into the origin and evolution of the Canadian Shield should be undertaken in Canada during the next decade.

Finally, we have developed in this report a basic philosophy on the role of earth sciences and natural resource development in Canada's programs of assistance to developing countries. Several of our conclusions on this subject in Chapter VIII have far-reaching implications, not only for the Canadian International Development Agency but for the Canadian earth science community as well. Thus we conclude

National resources development and its necessary input of earth sciences should be an important component of Canada's programs of external aid. A realistic target for earth science activities in these programs is $30 million by the year 1975, involving 200 man-years of professional and 60 man-years of technical manpower. In this connection, the Department of Energy, Mines and Resources should establish an Overseas Branch, funded by CIDA, to provide a permanent cadre for earth science work overseas.

The Solid-Earth Sciences Study Group
March 6, 1970

Publications of the Science Council of Canada

Annual Reports

First Annual Report, 1966-67 (SS1-1967).
Second Annual Report, 1967-68 (SS1-1968).
Third Annual Report, 1968-69 (SS1-1969).

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Report No. 3, A Major Program of Water Resources Research in Canada (SS22-1968/3, $.75).
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Special Study No. 2, Physics in Canada: Survey and Outlook, by a Study Group of the Association of Physicists headed by D. C. Rose (SS21-1/2, $2.50).
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Part II, Chapter 5, Techniques and Sources (SS21-1/8-2-5, $1.25).
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Part II, Chapter 7, Economics (SS21-1/8-2-7, $1.00).
Special Study No. 9, Chemistry and Chemical Engineering: A Survey of Research and Development in Canada, by a Study Group of The Chemical Institute of Canada (SS21-1/9, $2.50).