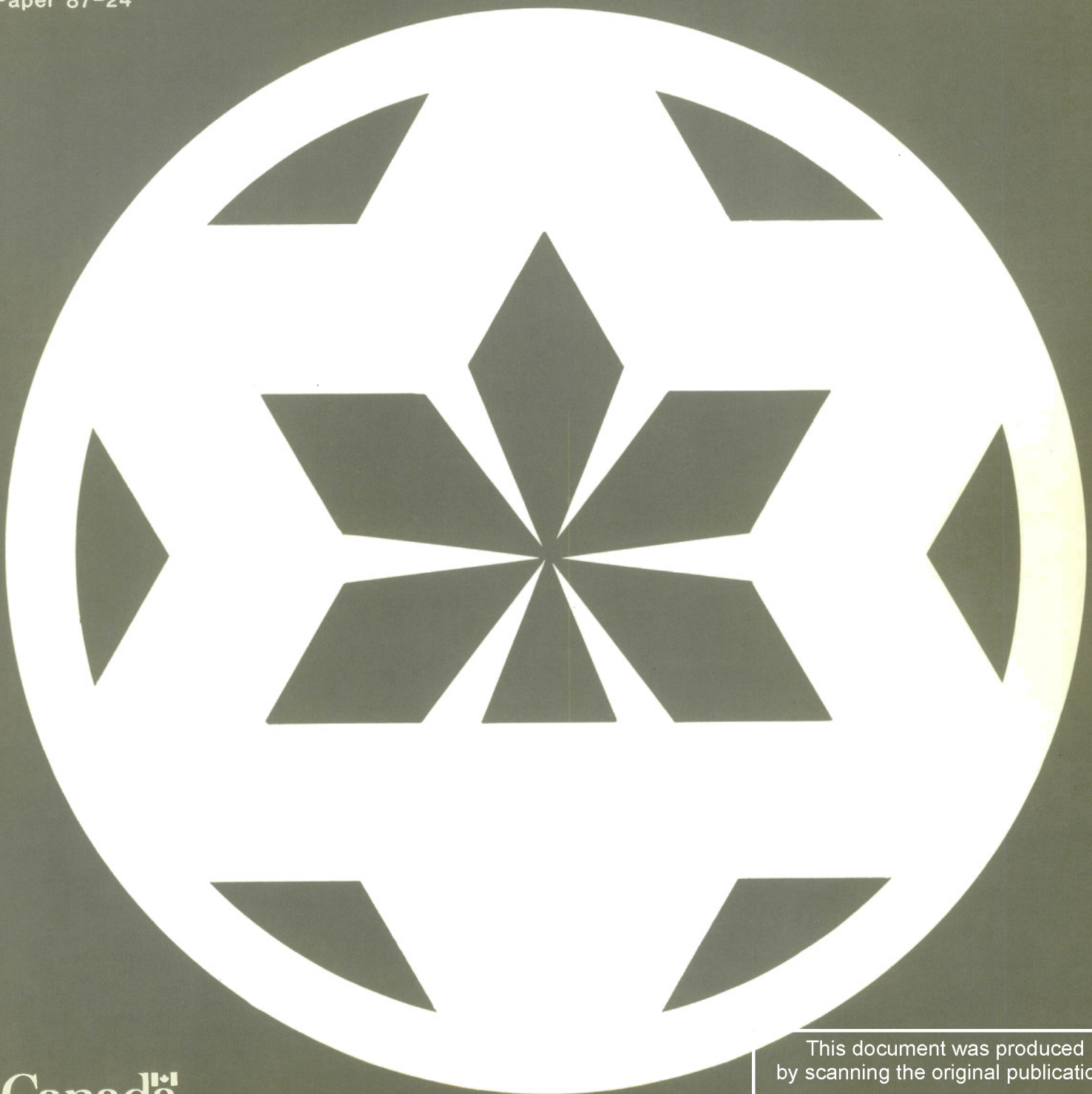
REPORT OF THE REVIEW COMMITTEE ON THE EARTH PHYSICS BRANCH

CANADIAN GEOSCIENCE COUNCIL

by the
REVIEW COMMITTEE
Chairman: G.D. Garland
Members: G. Lachapelle, O. Nuttli, R.D. Russell, J.H. Sass, P.J. Savage and K.K. Wing

Published for the Council by the Geological Survey of Canada as Paper 87-24



Canada

GEOLOGICAL SURVEY OF CANADA
PAPER 87-24

REPORT OF THE REVIEW COMMITTEE ON THE EARTH PHYSICS BRANCH

by the
REVIEW COMMITTEE
Chairman: G.D. Garland
Members: G. Lachapelle, O. Nuttli, R.D. Russell,
J.H. Sass, P.J. Savage and K.K. Wing

1987

Available in Canada through

authorized bookstore agents and other bookstores

or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Canada K1A 0S9

and from

Geological Survey of Canada offices:

601 Booth Street
Ottawa, Canada K1A 0E8

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

100 West Pender Street
Vancouver, British Columbia V6B 1R8

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

Cat. No. M44-87/24 Canada: $5.00
ISBN 0-660-53888-1 Other countries: $6.00

Price subject to change without notice

CONTENTS

RESPONSE TO REPORT OF THE CANADIAN GEOSCIENCE COUNCIL ON THE EARTH PHYSICS BRANCH

PREAMBLE

The concept of the amalgamation of the Earth Physics Branch (EPB) and the Geological Survey of Canada (GSC) has been discussed both formally and informally during the past few years. In particular, the A-Base Review of the GSC in 1982 recommended that Senior Management consider the issue and it was raised during the Ministerial Task Force on Program Review which took place in 1985. Based on the recommendations of this Review, the Government decided in late 1985 that the Department of Energy, Mines and Resources should eliminate the Geothermal program of EPB, reduce EPB resources by 10% of the 1985-86 levels and amalgamate EPB with GSC. In addition Management was requested to consider restructuring the 'new' GSC into four multidisciplinary organizations. Senior Management made the decision to plan and implement these changes as quickly as possible in order to minimize disruption of staff. The substance of all these requirements was put into place on April 1 1986.

As a result of these changes, the Earth Physics Branch as examined by the Geoscience Council of Canada Review Committee, no longer exists. However, all components of the former EPB are now included in the Geological Survey of Canada. Responses to the recommendations of the CGC Review Committee are therefore couched in terms of the role of geophysics and geophysical programs within this new structure.

RECOMMENDATIONS

1. **the EPB be recognized as the centre for the development in the government service of the science of geophysics;**

   This role has now been taken by the Geological Survey of Canada. In recognition of the importance of maintaining national geoscience data bases and national geophysical programs, a Geophysics Division has been established. This has as its role the maintenance of national observatory networks and data bases in seismology, geomagnetism, gravity and geodynamics, the conduct of research in solid earth and global geophysics and the provision of geophysical laboratories for instrument development and maintenance. To promote and enhance the science of geophysics within the GSC, the position of Chief Geophysicist has been created with the specific task (among others) of 'developing policies and procedures to foster excellence in geophysical research in GSC' and to advise the Director-General on all aspects of geophysical operations within the organization.

2. **adequate mechanisms of linkage and mutual cooperation among groups working on geophysics and geodesy be set up and maintained.**

   The Review Committee addressed in detail a number of aspects of liaison between EPB and other agencies. The amalgamation of EPB and GSC and the reorganization into four multidisciplinary units has considerably strengthened many former linkages, principally in the direction of organizationally bringing together geophysicists and geologists to consider common geoscientific problems and goals. At the same time, it is recognized that scientific effectiveness in geophysics is highly dependent upon close communication and interaction so that the bulk of the previous EPB groups and activities in Ottawa remain physically co-located at the Observatory campus. Discussion of further consolidation, such as moving aeromagnetic surveys to Observatory campus, is under way.

   External linkages remain strong and will continue to be strengthened wherever possible (e.g. USGS — Great Lakes Seismic Experiment; University of Toronto — MOSES electromagnetic method, LITHOPROBE; Industry — seismic refraction instrumentation, remotely operating vehicle (ROV), SeaBed II). On the specific linkage of geophysics and geodesy that was recommended by the Review Committee, management believes that the common use of equipment and the pursuance of joint programs ensure that the amalgamation will have little deleterious effect of the close working relationships between the Geodynamics Unit of the Geophysics Division and the Geodetic Survey. As an example, in 1986, a major joint survey will take place on Vancouver Island to determine strain in areas which have high earthquake potential.

3. **"Geophysical Observatory of Canada" as a name which would properly convey the role and scope of the organization.**

   Various variations on this theme were discussed at length during reorganization but it was decided that 'Geophysics Division' best fitted the role of this new unit in GSC. All other geophysical activities are subsumed in the name 'Geological Survey of Canada'.

4. **The addition of the clause (to the Resources and Technical Surveys Act): The Minister shall have the control, management and administration of any geophysical observatories maintained by the Government of Canada.**

   An examination of the usefulness of such a change and possible areas of conflict with the National Research Council over the definition of 'geophysical observatories' will be when the Act is reopened for other purposes.

5. **That the EPB take steps to increase its visibility through such means as publications in non-technical professional journals and regional conferences on topics of popular interest in geophysics.**

   The changes brought about by reorganization have been recognized as requiring an increased effort in the field of public relations to ensure that they are not seen as a reduction in quality of geophysical operations and research within the Federal Government. Two new activities in this field are the production of a Canadian Geophysical Atlas (a series of small scale, digitally compiled, geophysical maps) and a volume entitled 'The Geophysical Framework of Canada'. Both will be coordinated by the Chief Geophysicist and produced by the GSC. A new edition of the popular booklet 'Looking Inside the Earth' is in production as well as a series of Fact Sheets on earthquakes. Two videos for general distribution on 'The Juan de Fuca Ridge' and 'Earthquake Risk' are also in progress.

6. **That the mandate of the EPB be interpreted to include those areas of basic research which, while not strictly involved with the solid earth geophysics of Canada's landmass, are essential to the proper understanding of geophysical processes within it.**

   The GSC (particularly within the new Geophysics Division) will continue with available resources to undertake broadly based studies in support of geophysical studies of the solid earth and its processes.

7. **That when EPB is requested to take part in missions of national priority, additional person-years be made available.**

   GSC will maintain its awareness of the dangers of devoting too many resources to short term missions at the expense of longer term knowledge-base programs. It will continue to strike a balance between these conflicting demands on its services wherever possible and to request extra PY whenever it feels basic activities are threatened in this way.

8. **Therefore a much more positive attempt (be made) to recruit PDF's in Canada and abroad, with appropriate representations to the Public Service Commission to relax the restrictions on the recruitment of the latter.**

   The GSC will continue to make every attempt through direct contacts and international advertising to attract PDF's. Representations have been made to the appropriate Agencies in the recent past with regard to the nationality quota with little effect.

9. **That the EPB, as the centre of solid-earth geophysics in the federal government system, take an active part in promoting the study of geophysics as a career and enlarge its program of hiring summer students.**

   Present conditions in the exploration industry do not provide encouraging career prospects for geophysics. However, through close contacts, university graduate student supervision by GSC staff and through participation in such major geoscience thrusts as LITHOPROBE, the GSC is active in promoting the science. The hiring of summer students for geophysical activities is limited by the government programmes in place and the availability of supervision, space and resources. The maximum use of COSEP, COOP, Challenge 86 programs and operating funds has been made. In mid 1986 there were 298 'summer' students employed in the GSC of which an estimated 20 were specifically involved in geophysical activities. The government-wide implementation of programs of restraint and down-sizing do not offer any prospect of increases in the size of these programs.

10. **The continuation and expansion of this program (of funding higher education) in areas of severe shortage of trained persons with higher degrees.**

At present there are two persons on this program. One is in the Ottawa Geophysics Division and the other at the Pacific Geoscience Centre. Due to restraints on resources there are no plans to continue the program in the immediate future.

11. **The re-establishment of the Division of Geomagnetism within the EPB at Ottawa.**

Government down-sizing together with strong organizational constraints strictly limit the number of Divisions possible within the GSC. However, the management of the Geophysics Division accepts and recognizes the need for continued emphasis on providing leadership in geomagnetic studies.

12. **Increasing emphasis on the two-way temporary exchange of scientific staff.**

The Branch will pursue this activity but recognizes that there are limitations on professional development leave within the present Public Service. University staff and other visiting scientists on sabbatical leave will continue to be hosted whenever space and resources allow. The merger of EPB into a larger organization should provide a more comprehensive framework for this activity and provide a greater range of opportunities for internal movement.

13. **That the joint venture form of cooperation between the EPB and industry be explored as a means of technology transfer, as an addition to the usual contractual relationship.**

This is being pursued in several areas (eg. gravimeter development — Scintrex; airborne gravity — Nortech; seismic refraction instruments — EDA). Although this activity is rewarding, the Branch remains aware of the dangers of preferential treatment in the private sector.

14. **That a committee, of similar structure to the present Review Committee but with the addition of representation from mining geophysics, be established to have on-going missions of assisting the Branch to develop programs and review progress.**

The principle of establishing an external Advisory Committee to the GSC for Geophysics has been accepted and invitations will be issued in late 1986. Representation from industry, universities and international agencies will be sought. In recognition of the present difficulties in the exploration industry, a sub-Committee on airborne geophysics will be suggested for immediate establishment.

15. **That the highest priority in recruitment be given to the following**

Research scientists
— Geomagnetism (with broad outlook and leadership)
— Modern geodynamical techniques
— Seismic reflection interpretation
— Interpretational geodynamics

Physical scientists (in order of priority)
— routine seismogram analysis
— strong-motion seismology
— geothermal laboratory

In general, these recommendations corresponded with Branch priorities before amalgamation. However, senior research scientists in many fields have proved very difficult to recruit. A scientist in reflection seismic interpretation has recently joined the staff and attempts are being made to increase physical scientist recruitment and to provide assistants for routine seismogram analysis.

16. **The changeover from analogue to digital recording in the seismograph network be accelerated, stations in the Arctic be restored to their former status, and senior seismologists be freed from routine record analysis, with the use of summer students, when possible, for the latter:**

The changeover to Canadian Digital Seismograph (CANDIS) is being carried out as quickly as possible given current resources and in the light of demands for the development of instrumentation for other programs. Pending new funding currently being sought, a CANDIS network will be deployed by 1989.

Given present resource constraints and improvements in digital and communications technology, it is not realistic to restore Arctic stations to their former status.

To ensure relevance and data quality, management feels that while assistance is necessary, senior scientific staff should not be isolated from routine data acquisition.

17. **The strong-motion seismic network (including free-field instruments) be fully incorporated into the EPB activity, with appropriate resources in instruments and personnel.**

This has been completed.

18. **Planning be given to the format for distributing seismic information from digital seismographs, to the public and to World Data Centres, with consideration of including analogue playbacks resembling the present short, and long, period seismograms.**

Planning on this is in progress with the intention of continuing to make a representative selection of information available in analog form. On request, analog records for any specific event will be produced.

19. **Regional conferences for non-scientist audiences on topics of popular interest in geophysics (for example earthquakes and their effects) be held.**

An evening public seminar on earthquakes held a few years ago at the Provincial Museum in Victoria was extremely popular. Discussions will be held with the Museums and academic societies in Ottawa to determine if similar events can be arranged for the winter of 1986-87.

20. **More use be taken of opportunities to determine heat flow in the course of investigations where temperatures are measured.**

As a result of the Government decision of December 1985, the geothermal unit was disbanded. However, GSC scientists will continue to make maximum geothermal use of 'holes of opportunity' (to the limit of available resources) where they can be fully documented. Although many temperature measurements exist from many sources, determination of heat-flow requires the measurement of a number of other parameters which are not always directly or easily available.

21. **Heat flow studies in the Cordillera be consolidated into the PGC program.**

The PGC heat flow program is now fully integrated into multi-disciplinary studies at PGC. Geothermal energy programs have been terminated but Branch permafrost programs are regarded as most usefully based in Ottawa where they are now part of the Terrain Sciences Division. Any activities concerning heat flow in the Cordillera are coordinated with PGC wherever possible.

22. **The regional gravity program be modernized and accelerated to meet the needs for the determination of the geoid with sufficient resolution to permit the use of the information available from the Global Positioning System (GPS) for more accurate vertical control.**

Developments within the gravity program (airborne gravity, satellite gravity, absolute gravity) are being specifically geared to new positioning technology. Collaboration with the geodynamics program (where calibration and testing of two GPS systems under field conditions and comparison with astronomically determined positions is being carried out) and the Geodetic Survey is increasing. A major contract for gravity surveys in the Yukon in 1986 will use GPS for station positioning for the first time. Increased funding for the gravity/geodynamics program is being sought.

23. **Consideration be given to coordinating the work in geophysical instrumentation in an interdivisional section.**

Where there is a clear common interest (ocean bottom instrumentation, data telemetry) joint instrumentation 'project' groups have been established. In general, however, dedicated technical groups in close contact with the scientists using the data are regarded as the most efficient structure. Under the new amalgamated organization, the majority of geophysical instrument maintenance and development will be carried out at the Blackburn Laboratories of the Geophysics Division. Consideration is being given to mechanisms and organizational linkages that will ensure that all geophysical instrument maintenance and development wherever it occurs within the GSC, will be fully coordinated.

24. **Joint committees of active workers in fields of mutual interest be established with the GSC, particularly in paleomagnetism, crustal studies and other areas, as needed. These committees should be free of bureaucratic restrictions and should concentrate on the discipline involved and on the means to optimize complementary or joint programs.**

A number of formal and informal committees and working groups for joint programs such as Lithoprobe and Frontier Geoscience, LOREX, Boundary Studies and Nuclear Fuel Waste Management have been established as appropriate. The inclusion of crustal studies and paleomagnetism in the new Lithosphere and Canadian Shield Division and permafrost in Terrain Sciences, ensure that liaison with former GSC groups is now greatly enhanced. A series of internal regional workshops (eg. eastern and Appalachian studies) have been planned to increase and promote close geological-geophysical interaction.

25. **The amount allocated to the EPB under the Department's Capital Acquisition Replacement Plan (CARP) be increased to $4 million per year.**

Funds for the upgrading of the Yellowknife Seismological Station and Array have been approved at a level of $0.525M in 1986/87, $1.68M in 1987/88 and $0.265M in 1988/89. This is in addition to CARP levels of $2.346M, $2.466 and $2.562 already approved for years 1986-1989 respectively. This represents a four-fold increase compared with capital budgets prior to 1984/85.

26. **EMR's program of Research Agreements be refinanced to a level of purchasing power at least equivalent to that at the introduction of the program in 1970, with allowance for future inflation.**

Implementation of this recommendation is not possible at the Branch level without damage to the present A-base operating levels. Administration of this program is now carried out by the Earth Science Sector; increased funding has been requested from Treasury Board in the recent past but turned down.

REPORT OF THE REVIEW COMMITTEE ON THE EARTH PHYSICS BRANCH

EXECUTIVE SUMMARY

a) General

(i) Our two principal conclusions, which provide the context for all of our detailed evaluations, are that:

- **a governmental organization devoted specifically to comprehensive research in geophysics and its application is vital to Canada; and**
- **the Earth Physics Branch within the Department of Energy,Mines and Resources, is the only organization that fills this role.**

The arguments leading to these conclusions, which are developed within our report, are based on considerations both of the general role of governmental scientific organizations and their relationships to industry and universities, and of the optimum organizational structure in the specific, but very broad and interrelated, areas of science known as geoscience. Without repeating the full arguments here, we state our opinion. First, governmental institutions are vital when irreplaceable national assets such as the geoscience data bases are involved. Secondly, to remain in the forefront of the rapidly advancing field of geophysics, the institution must have the autonomy and mandate to balance fundamental research and applications.

(ii) For historical reasons, activities related to geophysics and geodesy have developed in a number of government agencies, to whom certain applications are particularly important. There is a danger that some groups will not keep up with modern techniques and concepts in these sciences. The Committee takes the view that scientific effectiveness, including the best use of scientific manpower and apparatus, would have been optimized if all of the activities of the federal government in pure and applied solid-earth geophysics (seismology, geomagnetism, gravimetry, geothermal studies and geodynamics) and geodesy had been the responsibility of the EPB.

To ensure the effective exploitation of geophysical knowledge in carrying out the responsibilities of EMR, we recommend that:

1. **the EPB be recognized as the centre for the development in the government service of the science of geophysics; and**
2. **adequate mechanisms of linkage and mutual cooperation among groups working on geophysics and geodesy be set up and maintained.**

(iii) From our own investigations and the results of the survey, we conclude that the EPB is fulfilling very well its service role to Canadian scientists in government institutions, industry and universities and to foreign scientists. We are, however, most concerned with the lack of visibility of the branch, and recognition of it as a separate organization. This was particularly evident, for example, in the returned questionnaires from the petroleum industry. The Committee concludes therefore, that **a change in name** is a matter of high priority. To many people, the term "Earth Physics" conveys a different meaning than "Geophysics". Also, people outside of the government find the term "Branch" confusing. For many decades, the present EPB maintained an enviable national and international scientific reputation under the name Dominion Observatory. We recommend:

3. **"Geophysical Observatory of Canada" as a name which would properly convey the role and scope of the organization.**

At an opportune time, the relevant act dealing with the Department should be amended. We recommend:

4. **the addition of the clause: The Minister shall have the control, management and administration of any geophysical observatories maintained by the Government of Canada.**

Enhanced visibility will not come from a change in name only. It will require a positive approach by the Director General and members of the staff in a number of directions which are mentioned later in this Report. Therefore, we recommend:

5. **that the EPB take steps to increase its visibility through such means as publications in non-technical professional journals and regional conferences on topics of popular interest in geophysics.**

(iv) The mandate of the EPB, within the Earth Sciences Sector of EMR, is to provide the solid-earth geophysical information necessary for the understanding and management of Canada's landmass including the offshore areas, from the point of view of both natural resources and natural hazards. While this mandate is appropriate, if interpreted broadly, we feel that there is persistent danger of too narrow an interpretation. As mentioned in our first Conclusion above, it is vital in geophysics to remain in the forefront and this can only be done by devoting an adequate portion of the program to fundamental research. In a country in which geoscience plays such a vital role, it is completely illogical that the governmental organizations devoted to this field are not encouraged to pursue fundamental studies to the extent that the National Research Council (NRC) does in such areas as physics and astronomy. Secondly, because of the unity of the geophysical study of the earth and its environment and of the

growing recognition of complex interrelationships within the sun-earth system, **it is most important that the term "solid-earth" not be allowed to unduly restrict the scope of the research.** This is imperative in the fields of both geomagnetism and geodynamics. Thirdly, the interpretation of the mandate must take into account the essential international character of the geosciences and the responsibility of all countries to contribute, to the extent of their scientific capability, to a global pool of knowledge. The submission of seismological, gravimetric and geomagnetic data to world data centres is one aspect of this responsibility, which we conclude is being well handled by the EPB. The encouragement of Branch scientists to take part in international commissions and fora of many kinds is an aspect which should not suffer under a narrow interpretation of the mandate. We recommend therefore:

6. **that the mandate of the EPB be interpreted to include those areas of basic research which, while not strictly related to the solid earth geophysics of Canada's landmass, are essential to the proper understanding of geophysical processes within it.**

(v) The EPB has a long tradition of successfully balancing research with a service role, for example, in providing the seismograph service and information on seismicity. Because of the central role played by geophysics in special national missions, such as the distribution of permafrost and the disposal of radioactive waste, it was proper that the EPB, because of its unique competence, take a leading role in these programs. The Branch has become increasingly involved, often with an extensive contract monitoring function.

Good science is involved, and the new links with industry and universities that are being developed are contributing to significant and important technology transfer. However, the effectiveness of individual scientists and of the Branch as a whole can be maintained only when adequate resources of scientific manpower are made available to these special missions. Without such resources, the Branch would place its entire program in jeopardy if it addresses any additional special tasks. We recommend:

7. **that when the EPB is requested to take part in missions of national priority, additional person-years be made available.**

(vi) We have been impressed by the contributions to the work of the EPB that have been made in recent years by post-doctoral fellows (PDF's). This is particularly evident in the list of publications, where authorship or joint authorship by PDF's is very evident. Being relatively free from routine administration and coming recently from a university environment, the post-doctoral fellow can do much to stimulate the research environment. It is unfortunate that their number is not greater. We perceive two reasons for this. The first is the unnecessarily strict rule of the Public Service Commission on the offering of fellowships to non-Canadians (1 for every 2 Canadians), at a time when very few Canadian Ph.D's in geophysics are available. But this is intensified by the second reason, which is the lack of visibility of the EPB research program in Canadian universities. We recommend:

8. **therefore a much more positive attempt to recruit PDF's in Canada and abroad, with appropriate representations to the Public Service Commission to relax the restrictions on the recruitment of the latter.**

(vii) The Committee is well aware of the small number of Canadian graduates in geophysics, a condition that continues to produce shortages of trained personnel in industry and in universities. We recommend:

9. **that the EPB, as the centre of solid-earth geophysics in the federal government system, take an active part in promoting the study of geophysics as a career and enlarge its program of hiring summer students.**

The committee endorses the decision of the EPB announced in 1984, to employ a limited number of persons with bachelor degrees and to subsequently finance their graduate studies, and further recommends:

10. **the continuation and expansion of this program in areas of severe shortage of trained persons with higher degrees.**

(viii) We find that geomagnetism has suffered a particular loss of visibility and fragmentation within the EPB, and we consider this regrettable. As we note in our report, the oldest antecedent organization from which the EPB devolves was a magnetic observatory. There are also compelling reasons from the forefront of geophysics to maintain an integrated group in geomagnetism. The geomagnetic field cannot be arbitrarily divided at the earth's surface, since externally-produced disturbances interact with the internal field, and induce electric currents in the earth. The present structure in the EPB tends to separate the areas of observatory operation, magnetic charts, induction studies and paleomagnetism, with a high probability that some aspects of the science will fall in between. We note that one recommendation of a previous ad hoc committee, that research in the morphology of magnetic disturbances be strengthened, has been glaringly overlooked. This occured at a time when the importance of geomagnetic effects in such divergent areas as climate change (a national program) and pipelines through the auroral zone are being recognized.

We are aware of the immediate constraints, at the time of the restructuring of the Pacific Geoscience Centre, which led to the reorganization, but

we conclude that the vigour and adequacy of the EPB to address geophysics would be improved if geomagnetism were given divisional status. Therefore, we recommend:

11. **the re-establishment of the Division of Geomagnetism within the EPB at Ottawa.**

(ix) The links with universities and with industry have been mentioned above. While we note an encouraging number of joint research projects with Canadian universities, we recommend:

12. **increasing emphasis on the two-way temporary exchange of scientific staff.**

One aspect of relations with Canadian industry for which the EPB is to be commended is the transfer of technology for the manufacturing of instruments, as in the case of magnetometers and automatic magnetic observatories. An excellent possibility now exists with the simplified seismic refraction data acquisition system, particularly if LITHOPROBE funding will provide for a substantial initial order. In the future, developments in absolute and relative gravimetry may be possible. We recommend:

13. **that the joint venture form of cooperation between the EPB and industry be explored as a means of technology transfer, as an addition to the usual contractual relationship.**

(x) To ensure that there is adequate external input into the program of the Branch, we recommend:

14. **that a committee, of similar structure to the present Review Committee but with the addition of representation from mining geophysics, be established to have on-going missions of assisting the Branch to develop programs and review progress.**

Individual membership on this committee should rotate after three years. In general, the committee should meet once a year, although when special problems arise it could be asked to meet more frequently. The committee will require adequate secretarial support like this Review Committee.

b) Specific Recommendations

Staff Priorities

We have taken the view that it is unreasonable to recommend a great increase in the size of the scientific staff, at a time of government restraint. But retirements provide vacancies, and new programs such as Frontier Geoscience offer the opportunity for additions, so that it is important for the EPB to have priorities. We recommend:

15. **that the highest priority in recruitment be given to the following.**

- Research scientists:
  - — Geomagnetism (with broad outlook and leadership)
  - — Modern geodynamical techniques
  - — Seismic reflection interpretation
  - — Interpretational geodynamics

Some flexibility is required in assigning an order of priority among these four, because scientists with different backgrounds and interests are required, none of whom will be easy to hire on short notice. The recommendation for a senior scientist in geomagnetism is coupled to our recommendation (#11) that the Division be re-established. Developments of new technologies to measure crustal stress and strain make it urgent that the EPB's expertise on these techniques be strengthened so that opportunities to take advantage of them will not be missed; this is a stage which should precede further interpretational research in geodynamics. There is at present an urgent demand to strengthen the departmental expertise in seismic reflection interpretation, related to the Frontier Geoscience Program and to LITHOPROBE; and it will be very useful and desirable to develop closer collaboration and the exchange of technology with the petroleum exploration industry.

- Physical scientists (in order of priority)
  - — Routine seismogram analysis
  - — Strong-motion seismology
  - — Geothermal laboratory

In addition, we recommend that:

16. **The changeover from analogue to digital recording in the seismograph network be accelerated, stations in the Arctic be restored to their former status, and senior seismologists be freed from routine record analysis, with the use of summer students, when possible, for the latter;**

17. **The strong-motion seismic network (including free-field instruments) be fully incorporated into the EPB activity, with appropriate resources in instruments and personnel;**

18. **Planning be given to the format for distributing seismic information from digital seismographs, to the public and to World Data Centres, with consideration of including analogue playbacks resembling the present short period and long period seismographs;**

19. **Regional conferences for non-scientist audiences on topics of popular interest in geophysics (for example earthquakes and their effects) be held;**

20. **More use be taken of opportunities to determine heat flow in the course of investigations where temperatures are measured.**

21. **Heat flow studies in the Cordillera be consolidated into the PGC program;**

22. **The regional gravity program be modernized and accelerated to meet the needs for the determination of the geoid of sufficient resolution to permit the use of the information obtainable from the Global Positioning System (GPS) for more accurate vertical control;**

23. **Consideration be given to coordinating the work in geophysical instrumentation in an inter-divisional section;**

24. **Joint committees of active workers in fields of mutual interest be established with the GSC, particularly in paleomagnetism, crustal studies and other areas, as needed. These committees should be free of bureaucratic restrictions and should concentrate on the discipline involved and on the means to optimize complementary or joint programs;**

25. **The amount allocated to the EPB under the Department's Capital Acquisition Replacement Plan (CARP) be increased to $4 million per year; and**

26. **EMR's program of Research Agreements be refinanced to a level of purchasing power at least equivalent to that at the introduction of the program in 1970, with allowance for future inflation.**

1 THE COMMITTEE: APPOINTMENT, MEMBERSHIP, TERMS OF REFERENCE

The Review Committee was appointed in 1984 by Dr. W.W. Hutchison, Assistant Deputy Minister, Earth Sciences Sector, Department of Energy, Mines and Resources, from a list of names proposed by the Canadian Geoscience Council. The latter acted on the advice of the Canadian Geophysical Union.

The members of the Committee, and their affiliations, are:

- Professor George D. Garland, Department of Physics, University of Toronto, Toronto, Ontario (Chairman).
- Dr. Gérard Lachapelle, Vice President, Research and Development, Nortech Surveys Inc., Calgary, Alta.
- Professor Otto Nuttli, Department of Geophysics, St. Louis University, St. Louis, Mo.
- Professor R. Doncaster Russell, Department of Geophysics and Astronomy, University of British Columbia, Vancouver, B.C.
- Dr. John H. Sass, U.S. Geological Survey, Flagstaff, Arizona.
- Mr. Peter J. Savage, PanCanadian Petroleum Ltd., Calgary, Alta.

At the first meeting of the Committee, Mr. Kenneth Wing, Program Evaluation Branch, Department of Energy, Mines and Resources, was appointed Secretary.

All members of the Committee were familiar with the work of the Earth Physics Branch (EPB), and five had served as members (or alternates) of the previous Ad Hoc Visiting Committees in specific fields. These members were: Lachapelle (Canadian Gravity Mapping Program); Garland (Magnetic Observatories and Variation Stations); Nuttli (Canadian Seismograph Networks and Seismicity and Seismic Risk Studies); Russell (Geomagnetic Charts and Interpretation); and Sass (Geothermal Studies). The Ad Hoc Visiting Committees work will be discussed in Section II.

The Terms of Reference for the Committee have been described in EMR's Evaluation Assessment Report. They are as follows:

a) Object

To review the activities of the EPB in order to:

(i) assess the relevance and adequacy of its objectives, the design of the operations, the effectiveness and efficiency in meeting the goals, the intended and unintended impacts of the program and alternative means of delivering the program;

(ii) recommend changes that may be necessary to best respond to the needs of the Canadian government and the clients of the Branch.

b) Report

The Committee will submit its report and recommendations to the senior management of the Department through the Assistant Deputy Minister for Earth Sciences. No report, oral or written, on the recommendations and findings shall be made public until agreement has been reached between the CGC and the Department of Energy, Mines and Resources.

c) Items to Evaluate

The specific objectives for this review include the following:

(i) determine whether the objectives and activities of the EPB are reasonably linked with the legal mandate of the Department, and whether the lack of a formal, explicitly stated mandate is hindering the EPB in conducting basic geophysical research;

(ii) examine the operations at the EPB with a view to determining whether the program objectives are being achieved and whether the overall balance is correct and responsive to needs;

(iii) determine the effectiveness of all the outputs of the Branch in meeting the needs of the clients and conduct a survey of users, assisted by the Program Evaluation Branch;

(iv) examine the resources, fiscal and personnel, of the EPB as to their adequacy to support the programs that it has conducted and should have been conducting;

(v) examine the linkages between the EPB and its clients, the Geological Survey of Canada, the Surveys and Mapping Branch, the National Research Council, other government departments, the provinces, mining and petroleum companies, other industry, consultants, universities and international agencies;

(vi) determine whether there is enough external input in deciding on the program of work at the EPB and how this outside influence can be beneficially incorporated;

(vii) determine whether there are better ways of achieving some of the results of operations at the Earth Physics Branch.

d) Selection of Members

The Committee will be appointed from a list of nominees, who have agreed to act, nominated by the Chairman and Executive of the Canadian Geophysical Union and approved by the President of the Canadian Geoscience Council. The Committee should have a broad coverage as regards geophysical disciplines and diversity of organizations. The appointment of five or six members will be made by the Assistant Deputy Minister for Earth Sciences, with the concurrence of the President of CGC, the Director General of the Earth Physics Branch and the Director of the Program Evaluation Branch.

e) Liaison with the Department of Energy, Mines and Resources

A secretariat will be provided by the Program Evaluation Branch, and a representative from that Branch will be a member ex officio of the Committee. The EPB will assign a person to assist the committee in obtaining any information it may require from the EPB.

II THE SEVEN CHARGES TO THE COMMITTEE

The Committee was directed, in its Terms of Reference (p.12) to address seven specific issues. Our conclusions and recommendations, as set out above, do address these issues, but it is appropriate here to summarize them as they relate to the specific charges:

(i) determine whether the objectives and activities of the EPB are reasonably linked with the legal mandate of the Department and whether the lack of a formal explicitly-stated mandate is hindering the EPB in conducting basic geophysical research.

We conclude in the foregoing Executive Summary [General — # (i), (iii), and (iv)], that the objectives and activities of the EPB are not only correctly linked with the mandate of the Department but also essential if it is to fulfill its responsibilities. We do, however, argue [General # (iv)] that this mandate be interpreted rather broadly, to provide an adequate and unified scientific approach, since too narrow an interpretation can indeed hinder basic research.

We recommend (#3) a change of name of the Branch to provide a greater public understanding of its function and we recommend (#4) that this be confirmed in the enabling act of the Department.

(ii) examine the operations of the EPB to determine whether the program objectives are being achieved and whether the overall balance is correct and responsive to needs.

The results of our examination led us to conclude that the objectives are being achieved and the program is responsive to needs. We do, however, note the very extensive involvement, in special national missions, of the Branch and some of its scientists and we recommend (#7) that an adequate provision of person-years be made whenever new missions arise.

(iii) determine the effectiveness of all the outputs of the Branch in meeting the needs of the clients and conduct a survey of users, with assistance from the Program Evaluation Branch.

The Survey was carried out, as described in detail in Chapter IV. One conclusion is that the quality of the outputs is very high. This is appreciated by virtually all users, in Canada and abroad. The scientists associated with the World Data Centres find the data from the EPB to be timely and of excellent quality. Again, the lack of visibility of the Branch was evident in responses, some users being unaware of the organization responsible for the production of the material they were using.

(iv) examine the resources, fiscal and personnel, of the EPB as to their adequacy to support the programs that it has conducted and should have been conducting.

There are fiscal implications in several of our recommendations, particularly the Specific Recommendations. For example, #16 of the latter recommends an acceleration in the conversion from analog to digital recording in the seismograph network. This will entail capital expenditures, but the long-term result will be a saving in station operating costs and staff time in reading records. Fiscal implications are therefore not simple. Similarly, Specific Recommendation #17 calls for the incorporation of the strong motion network into the EPB program. This will have fiscal requirements, but the activity has previously been carried by the NRC, which will realize a saving.

The Committee was impressed by the magnitude of the total capital investment of the EPB in instrumentation: observatory, field, research, etc., and in a period of rapidly improving technology. It will be essential to

budget for depreciation and renewal. The Department's Capital Acquisition Replacement Plan (CARP) should provide for this, but the amounts allocated appear to be far from adequate from the standpoint of accepted practice in depreciation allowances.

We were informed that the current replacement value of the EPB's capital assets (exluding buildings) is $20.75 million. If this were to be written off in 5 years, $4 million a year should be available for replacement. At present, only $2.2 million has been designated under CARP. We recommend (#25) an increase to $4 million per year.

In the case of personnel, we have already mentioned the impact of special missions on EPB activities, and the need for the allocation of adequate person-years. In Recommendation #15 we give our priorities for new staff, as positions become available. We also recommend (#8) that a more vigorous attempt be made to recruit post-doctoral fellows.

(v) examine the linkages between the EPB and its clients, the Geological Survey of Canada, the Surveys and Mapping Branch, the National Research Council, other government departments, the provinces, mining and petroleum companies, other industry, consultants, universities and international agencies.

The linkages are obviously manifold and of differing characteristics, but the Committee has examined, in varying degree of detail, all of the above. They are discussed in Chapter V.

In connection with other federal government organizations, we have looked for possible duplication of effort, and, conversely, for the adequacy of cooperation at the level of the working scientist. We note one restricted area of possible duplication (in geoid studies, with the Surveys and Mapping Branch). We recommend (#24) a closer collaboration between the EPB and Geological Survey of Canada in a number of areas where exchange of geophysical and geological insights is essential, and we propose discipline-oriented working groups in these areas.

With industry, linkages have perhaps been somewhat restricted, again by a lack of visibility, and in the case of the petroleum industry, by a lack of emphasis, by the EPB, on seismic reflection interpretation. The latter condition is changing, and is one of our priority areas for staff appointments. We note that the EPB has a record of technology transfer to industry, but we recommend a move toward a joint-venture type of cooperation.

With universities, we recommend (#12) further emphasis on two-way temporary exchanges of staff.

As for international linkages, we have noted the high regard in which the Branch outputs are held by the World Data Centres, and also the important roles taken by many scientists of the EPB in international geophysical organizations, and we conclude [Executive Summary-General # (iv)] that this is healthy for the development of the science in Canada.

(vi) determine whether there is enough external input in deciding on the program of work at the EPB and how this outside influence can be beneficially incorporated.

Between 1978 and 1981 the EPB was visited by a number of Ad Hoc Visiting Committees in specific areas (p.27). We believe that the external input provided by these committees was beneficial, as was the exercise of the Branch in responding to them. Between 1981 and the establishment of the present Review Committee there does not appear to have been an optimum level of input from the Canadian geophysical community as a whole, although the EPB has responded to national priority missions.

We recommend (#14) that an on-going committee similar in structure to the Review Committee be established to provide this external input.

(vii) determine whether there are better ways of achieving some of the results of operations at the Earth Physics Branch.

Many of our recommendations relate in some way to this charge. On the other hand, we recognize that in many cases (for example, digital seismograph recording) the Branch itself took early initiatives in the desired direction. None of our recommendations call for a drastic change in **modus operandi**, although we do recommend the re-establishment of a Division of Geomagnetism. Recommendations dealing with specific areas of science are as follows: Nos. 16, 17 and 18 deal with seismology, Nos. 20 and 21 deal with geothermal studies and No. 21 with the gravity program. Recommendation No. 8, on the greater employment of post-doctoral fellows, and recommendation No. 13, on joint-venture cooperation with industry, are both intended to lead to improved methods of achieving the aims.

Operation of the Committee

The Committee met for the first time in Ottawa on February 10, 1984. On this occasion, Dr. Hutchison summarized the Terms of Reference, and requested that the committee review how the Earth Physics Branch is doing under the headings:

- quality of the output
- strength and direction of the Branch
- cost-effectiveness of the operations
- strength and morale of the staff

Dr. W.D. Bennett, Director of Program Evaluation, EMR, described the evaluations carried out in other Branches of the Department and also noted the dual role of the Committee, with responsibilities to both the Program Evaluation Branch and the Canadian Geoscience Council. Dr. J.G. Tanner, Director General of the EPB, pointed out some recent trends in the emphasis within the Branch, in particular a shift from basic research to applications. He also noted the complex linkages between the EPB and other national and international organizations.

A draft questionnaire, to be distributed to a (survey) sample of users of the output of the Branch, was prepared by members of the staff. The Committee made a number of changes to the draft, then approved it. The Secretary arranged for translation, and the necessary technical review and formal approval by Statistics Canada. (The questionnaire is given in Appendix 1 of this Report).

At the same meeting, the Committee discussed in detail the construction of a mailing list for the questionnaire, as will be discussed below.

The Committee met next on April 12 and 13, at the Pacific Geoscience Centre, Sidney, B.C. Through the effective cooperation of the Director, Dr. R.D. Hyndman, the committee was able to visit all of the laboratories of the Centre, and interview individually almost all of the geophysicists on the staff.

Meetings were held in Ottawa, June 20 to 22. By this date, a considerable number of returns to the questionnaire had been received and Mr. K. Wing had carried out a preliminary analysis of these, which the Committee considered in detail. Most of the period was spent in discussion with members of the Branch staff, at both the Ottawa headquarters and the Blackburn Laboratory. In addition, the full Committee met with the Director General of the Geological Survey of Canada (GSC), Dr. Ray Price, and his senior staff. Individual committee members also had discussions with scientists of the Geodetic Survey and the National Research Council (NRC), on linkages to the EPB as they perceived them.

The Committee met again at the Branch on October 1 and 2, to consider additional responses to the questionnaire and to explore, with members of the EPB staff, specific matters which had arisen either in the responses or in the Committee's own deliberations. It then met in Calgary, November 8 and 9, to construct the outline of this report.

The operation of the Committee would not have been possible without the cooperation and very effective assistance provided by officers of the Department and of the Branch. In particular, we wish to acknowledge the provisions of Mr. Wing's services and the support given to him for the mailing of the questionnaires and the analysis of the responses. We also wish to acknowledge the unfailing assistance with travel and meeting facilities arranged by Dr. Tanner's office.

III BACKGROUND INFORMATION ON THE EARTH PHYSICS BRANCH

This chapter is intended to provide a background against which the present evaluation of the EPB program can be considered. It will include a brief historical summary, a discussion of the mandate of the Branch and an analysis of the Branch's responses to the previous Ad Hoc Visiting Committees.

a) History of the Earth Physics Branch/Dominion Observatory

The Earth Physics Branch is the direct successor to the Dominion Observatory, whose early history has been described by Don W. Thomson (Men and Meridians, Vol.2, pp. 223-224 and 262-268). The Observatory had its origins in the government's response to memoranda, including several from the Royal Society of Canada, through the 1890's urging that facilities in Canada be developed to provide proper astronomic and geodetic control for the extensive programs of land surveying and mapping then in progress. The response, in 1900, was the voting of funds for the commencement of the original observatory building and for the purchase of a 15-inch equatorial telescope. The title, Dominion Observatory, dates from 1905 when the new building was first occupied. While the original emphasis was undoubtedly on applied astronomy, especially the time service and longitude determinations, it is important to note that solid-earth geophysics was included in the program from the very beginning. This was a group, organized under Dr. Otto Klotz, which included seismology, terrestrial magnetism and gravity, three areas that have remained essential elements of the EPB program. Klotz acquired an international reputation in geophysics and his papers, particularly in seismology, are still quoted.

The thrust of the Dominion Observatory was modified in 1917, when the Geodetic Survey of Canada was separated from it and, in the same year, the Astrophysical Observatory in Victoria was opened, as a unit of the Dominion Observatory. These changes resulted in a shift toward fundamental astronomy, but the solid-earth geophysics programcontinued to expand. Seismology saw the beginnings of the national network of seismograph stations; terrestrial magnetism witnessed the mapping of the absolute vector of the magnetic field over the country; and gravity went beyond pendulum gravity measurements to pioneer studies of the earth's crust and isostasy.

In its earliest years, the Dominion Observatory did not acquire the institution which was the descendant of the oldest governmental earth science organization in Canada, the Toronto Magnetic Observatory. That observatory had been in operation since late in 1839 and had provided a virtually unbroken record of the time changes in the earth's magnetic field at its original site and later at Agincourt, Ontario. It eventually grew into the Meteorological Service of Canada and, as such, the new organization maintained responsibility for magnetic observatories until well into the twentieth century. With the eventual and proper incorporation of the magnetic observatory function into the geomagnetic program of the Dominion Observatory, the latter could indeed trace its roots to 1839.

In addition to fundamental studies in gravity, seismology and terrestrial magnetism including their implications for broad scale crustal structure, the Dominion Observatory participated, with the Geological Survey of

Canada and Canadian universities, in a pioneer investigation of applied geophysics. Because of a growing concern, as early as 1928, that unethical companies were misrepresenting the possibility of locating mineral deposits with "instruments", these organizations were asked to conduct impartial tests of magnetic, electrical and gravimetric methods over known structures. The leading scientists were J.B. Mawdsley of the GSC, A.H. Miller of the Dominion Observatory, L. Gilchrist of the University of Toronto and A.S. Eve and D.A. Keys of McGill University. Miller's torsion balance and magnetic surveys were classics. The results are still shown in textbooks. More importantly, the project led to an enhanced realization that the geophysical work of the Dominion Observatory had implications for the detailed study of the crust and its economic deposits, as well as for larger-scale investigations.

In 1970, responsibility for astronomy, including the time service and astrophysics, was transferred to the National Research Council. This change had great impact on the scope and even the name of the Dominion Observatory. Solid-earth geophysics then became the major component of the program, with two photographic zenith tube (PZT) observatories remaining. Since the PZT observations were considered to be primarily of terrestrial interest, rather than astronomic, they provided the Branch with its initial capability in the increasingly important field of geodynamics.

The name Earth Physics Branch was chosen to replace Dominion Observatory after the reorganization in 1970.

The accompanying graphs indicate the EPB strength (including astronomy and time service before 1970) and budget, from 1959 to 1984. Similar graphs are shown for the GSC for comparison. Both the size of the staff and the constant dollar budget of the EPB show small declines in the years since 1971. The graphs have been plotted in ratio (or logarithmic) scales so that disproportionate changes between the GSC and the EPB appear as divergences from parallel curves. In 1964, the activities in limnology were transferred from the GSC to the Department of the Environment. In 1970, the time service and the astronomical activities went from the EPB to the National Research Council.

b) The Mandate

The statement of the overall objective of the Branch can be found in slightly different form in different places. The report of the Earth Sciences Sector for 1983-1984 states: "The EPB has a mandate to provide a solid-earth geophysics data and information service which is national in scope, but with important international ramifications". The Program Description set out in the program of the Department of Energy, Mines and Resources for 1984-1985 reads:

> Earth Physics: The provision of a comprehensive geophysical knowledge base on the framework, dynamic processes and hazards of the Canadian landmass and offshore areas; the operation of the national networks of geophysical observatories and the provision of geophysical standards.

Similar statements have appeared since 1970-1971, when reference to astronomy was removed.

We believe that the Program Description provides a workable mandate, provided it is not interpreted too narrowly. We emphasize the latter provision for several reasons. First, for a data base to be useful, intelligent decisions must be made on the data to assemble and the methods of obtaining them. This immediately implies that the staff of the organization have a high level of competence in geophysics, so that the organization **must** take on some aspects of a research institute. Secondly, geophysics by its nature is global in scope and even "solid-earth geophysics" is by no means bounded above by the earth's surface. The global character has both scientific and institutional ramifications. Thus, an earth scientist may have to join in the investigation of a problem involving conditions outside of Canada in order to gain insight into conditions within. If the investigation of tectonic processes elsewhere in the world, for example, leads to geodynamical conclusions which can be applied to understand the same process in Canada a scientist should not be discouraged from pursuing the research. The institutional ramification is that geophysics advances through uninterrupted contributions from many countries towards global observation programs, in geodynamics, gravity, seismology and geomagnetism. The compatibility of observations and data reduction and the regular provision of data to the World Data Centres are vital. They imply ongoing links between national institutes in different countries and with international organizations.

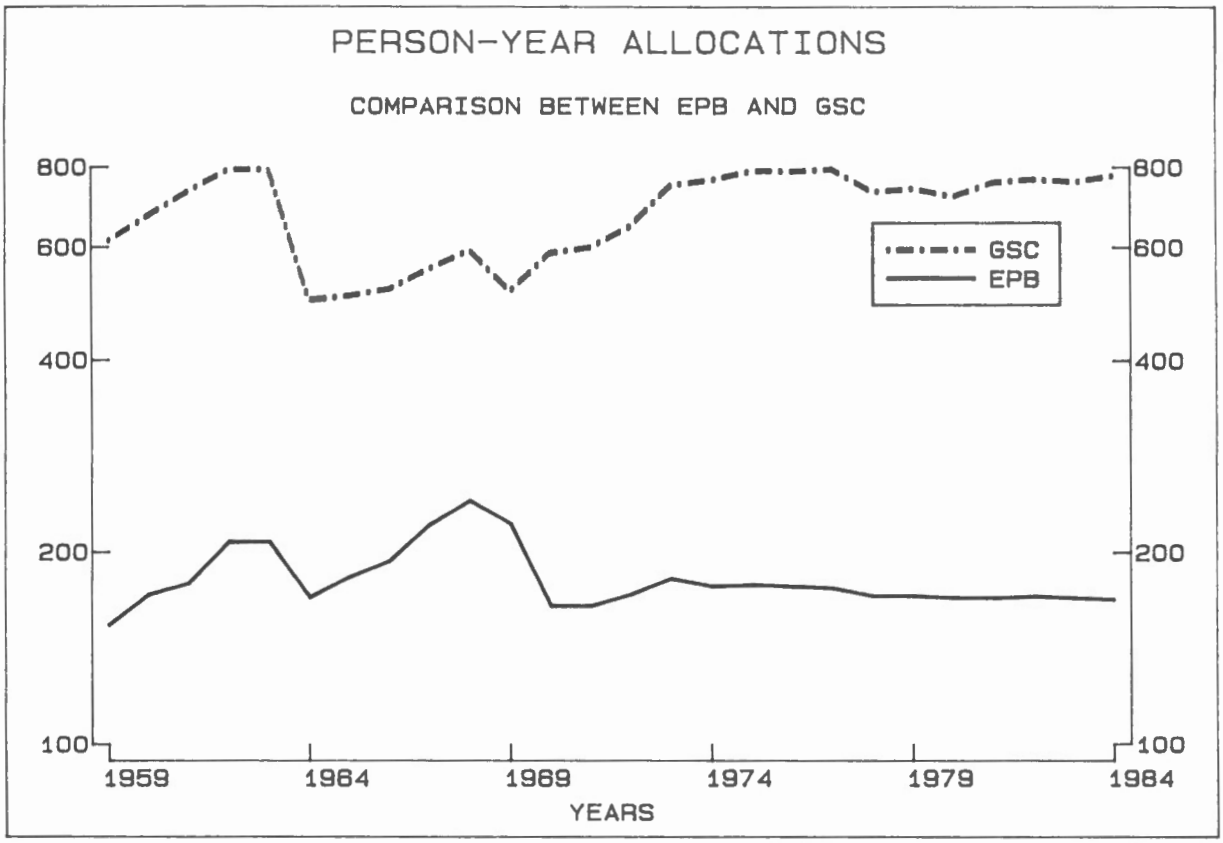
The point that "solid-earth" geophysics does not stop at the earth's surface is best illustrated by geomagnetism, where externally-generated fields have influences within the earth, and by modern geodynamics, where such techniques as satellite observation and long baseline radio interferometry have so much to contribute.

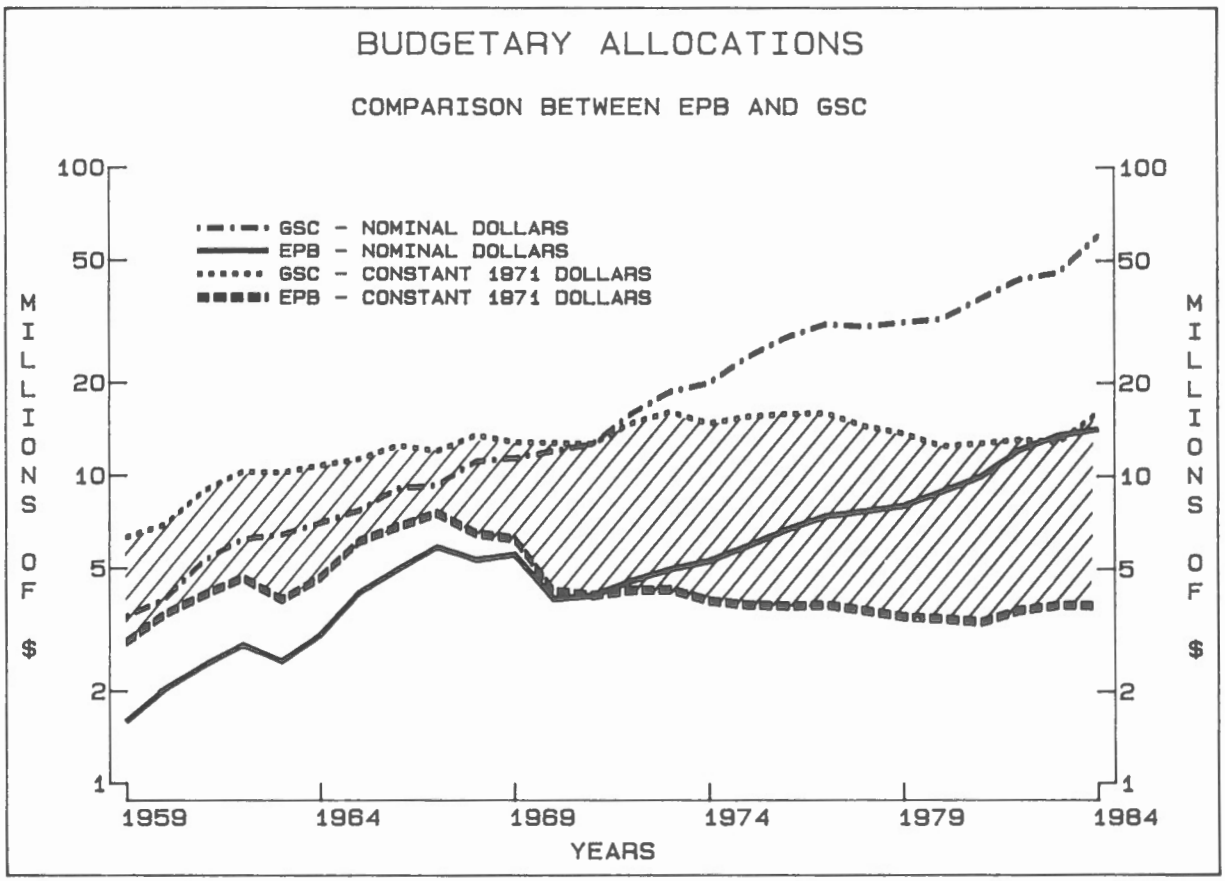
The mandates of the Department of Energy, Mines and Resources are also set out in various acts of Parliament. The Committee has noted that, before 1970, the Resources and Technical Surveys Act contained the clause:

> The Minister shall
> (e) have the control, management and administration of any astronomical observatories maintained by the Government of Canada.

With the transfer of astronomy to the NRC, this clause was removed. We believe that it would be appropriate, when the time is opportune to revise the Act, to reinstate a clause:

> The Minister shall
> have the control, management and administration of any geophysical observatories maintained by the Government of Canada.


PERSON-YEAR ALLOCATIONS
COMPARISON BETWEEN EPB AND GSC
800
600
400
200
100
GSC
EPB
1959
1964
1969
1974
1979
1984
YEARS


BUDGETARY ALLOCATIONS
COMPARISON BETWEEN EPB AND GSC
100
50
20
10
5
2
1
GSC - NOMINAL DOLLARS
EPB - NOMINAL DOLLARS
GSC - CONSTANT 1971 DOLLARS
EPB - CONSTANT 1971 DOLLARS
MILLIONS OF $
1959
1964
1969
1974
1979
1984
YEARS

c) The Ad Hoc Visiting Committees

Between 1978 and 1981, the major part of the program of the EPB was examined by seven Ad Hoc Visiting Committees. Since each committee dealt with a specific area of work and was composed of members with special interest in that area the examination was, in each case, carried out in depth. Although the passage of three to six years has changed the situation in some cases, (for example, through the restructuring in Ottawa and at PGC), we have found these committee reports and the responses of the Branch to them to be extremely useful. The committees' recommendations will be referred to later in this report, when specific activities are discussed, but it is appropriate to summarize here their conclusions and those recommendations which deal with major policy.

A conclusion common to the reports is that a major responsibility of the EPB, the operation of observatories (seismic and magnetic) and the provision of basic geophysical data, is being fulfilled competently and efficiently. Some of the reports call for an increased density of coverage, or for increased interpretation of the observations by EPB scientists. It is most unfortunate that, in certain cases, not only was the Branch unable to devote the resources necessary to respond to the proposals, but the situation has actually changed in the opposite direction. This happened, for example, to the recommendation by the Ad Hoc Visiting Committee on the Canadian Seismograph Networks, that stations in the Canadian Arctic be accorded higher priority. A second recommendation of the same committee dealt with free-field strong motion seismographs, and will be discussed later.

The Ad Hoc Visiting Committee on the Canadian Gravity Mapping Program, while also paying tribute to the effectiveness of the program, recommended, without further specification, that an additional $200,000 per year and three person-years be devoted to the work. As was the Branch, we are puzzled as to why this recommendation was made without detailed program proposals, but the whole question of the future of the gravity mapping program has become more complex for reasons of both need and technology, and will be discussed in detail. A major recommendation of the Ad Hoc Visiting Committee on Geodynamics Service was that "a geophysicist with both global dynamical and regional tectonic interests be appointed". We note that it has not been possible to accomplish this, and we reiterate that the matter is one of highest priority. The total involvement of the present staff with operational work, and with the planning required for new technologies, has led to a hiatus in the research of global significance which characterized the group in the early 1970's. The same Ad Hoc Committee also recommended closer liaison with the Geodetic Survey, a point to which we shall return.

The Ad Hoc Visiting Committee on Geothermal Studies dealt in detail with programs involving contract research and the procedures for the outside review of projects that should be supported. The role of contract research remains an important problem to be addressed.

Three Ad Hoc Committees dealt with the work of the former Division of Geomagnetism such as: magnetic observatories and variation stations, geomagnetic charts and interpretation, and paleomagnetic and electromagnetic induction studies. The situation has significantly changed in these areas, for example, with the disappearance of the Division a separate group in paleomagnetism at PGC was started. The latter development has caused us to look closely at relations and coordination between all groups in the field, a point raised by one Ad Hoc Committee. In some respects, notable advances have been made, particularly in the move to automation and contract supervision of magnetic observatories, which has permitted the magnetic observatory network to be kept intact. But, the first two of the above Committees, while high in the praise of the products (magnetic variation records and magnetic charts), strongly recommended a strengthening in the Branch's capability in associated basic research. We regret that the trend has, in fact, been in the opposite direction.

Many of the Ad Hoc Visiting Committees commented on linkages to universities, industry and to other organizations such as the Geological Survey of Canada. We have examined these linkages and will discuss them in Section V.

The Evaluation Assessment Report of the Department, in commenting on the Ad Hoc Committees, noted that the members themselves were, in some cases, not impartial to the EPB activity. It is difficult to know what more could have been done to overcome this criticism and, at the same time, ensure that the members be knowledgeable in the respective areas. Most committees included scientists from outside Canada and their overall composition, as regards members from universities, other government institutions and industry, was not dissimilar to the present evaluation committee.

IV SURVEY OF USERS

a) Purpose

The survey was carried out in the geophysical community. Essentially, the questionnaire asked:

1. how people use the output of the EPB;
2. how people view the quality of the work and the service of the EPB; and
3. what people think of the EPB's mandate and its program.

Many parties collaborated in preparing the survey questionnaire. The EPB and the Program Evaluation Branch of EMR produced the first draft which was then reviewed, modified and finally approved by the Committee. Statistics Canada gave the finishing touches by attending to the technical details of making the questionnaire a proper survey instrument.

b) The Survey Sample

The survey was conducted by mail; the questionnaire was sent to a stratified sample of users. The construction of the sample consisted of three stages:

1. compiling the master list of clients;
2. stratifying the list by category of user; and
3. randomly drawing subjects from each stratum in proportion to its population.

The master list was made up of other lists as follows:

1. several lists of users prepared by the EPB;
2. a list of members of the Canadian Society of Exploration Geophysicist (CSEG) provided by Mr. Peter Savage of the Review Committee;
3. a list of members of the Canadian Exploration Geophysicists' Society (KEGS) given by Dr. G.D. Garland;
4. a list of American users furnished by Dr. John Sass; and
5. a list of members of the Canadian Geophysical Union (CGU) provided by Dr. Adrian Camfield of the EPB.

The master list was purged of duplicates and non-users such as libraries and high schools. There were 1,732 users in this list. Each name on the list was classified into the following categories:

1. General engineering, insurance companies, general exploration;
2. Universities;
3. Federal government departments, Petro Canada and Crown corporations;
4. Geophysical instrumentation;
5. Mining consultants and contractors;
6. Mining companies;
7. International organizations, e.g. World Data Centres (WDC's);
8. Oil and gas consultants;
9. Oil and gas companies;
10. Provincial agencies or government; and
11. Utilities (e.g. power and telephone companies).

Our survey population was first stratified according to thecategories mentioned above. The subjects in each stratum were then picked randomly using a random number generator. Allowing for non-response, the Review Committee decided to have a sample size of 1,000. The numbers of subjects selected from the various strata are proportional to their respective populations. The result is a survey sample of 1,013, which represents the effect of rounding up. The sample size is adequate for all purposes.

If there was no response from a subject in the survey, standard statistical procedure was followed to select another person. The replacement was chosen at random from the same stratum.

The questionnaire was pre-tested to some extent. Eight users in Vancouver were interviewed to find out whether they had any difficulty in completing the questionnaire and to ascertain that the questions were interpreted as intended. These eight users together represented the following sectors: universities, utilities, mining and geoscientific consultants. The pre-testing showed that the questionnaire was well designed — all the interviewees rated it highly.

c) Results and Findings

(i) Profile of Respondents

Three-hundred and ninety people (i.e. 38% of the sample) responded to the survey; out of that number, 33 apologized for not being able to complete the questionnaire. According to sampling theory and the data collected, this response rate is adequate for drawing conclusions.

The sample is dominated by three groups: the oil and gas industry (at 43%), the universities (at 21%) and the mining industry (at 14%). Together, they account for almost 80% of the respondents. Table 4 C-1 shows the details:

Table 4 C-1 Categories of respondents

Category	*Number*	*%*
Oil and Gas Industry	155	43
Universities	75	21
Mining Industry (including geophysics instrumentation)	50	14
Federal Government (foreign countries included)	30	8
Geoscientific Consultants	19	5
Provincial Governments (foreign countries included)	15	4
Utilities	6	2
Other industries	4	1
International Agencies	3	1
TOTAL	357	98
		(2% rounding error)

Geographically, the clients of the EPB are dispersed worldwide. There were 303 (i.e. 85%) Canadians who responded, 36 Americans (10%) and 17 (5%) from other countries. Among the Canadian respondents, 153 (50%) are from Alberta, 45 (15%) from Toronto, 24 (8%) from British Columbia, 21 (7%) from Ottawa and 18 (6%) from Quebec. Considering the distribution of the survey population by industrial sector and by geography, the sample of respondents is indeed representative.

(ii) Service to Clients

The survey results show that the EPB has been serving the clients well. About 85% of the survey paricipants use the services of the EPB in one way or another. If the oil and gas sector is excluded, the proportion of users is well over 90% of the survey participants. People read the reports and publications of the EPB to keep up-to-date. The university community takes good advantage of the complete range of outputs of the EPB and uses them for

educational purposes as well. In the areas such as seismicity, geomagnetic field and gravity, the EPB collects and compiles basic observational data and is certainly regarded by the users as an authoritative source of data. Table 4 C-2.1 shows the distribution of survey participants by type of output and by industrial sector. Overall, the results of the gravity work are most widely used; about two-thirds of the surveyed subjects use them.

As regards the importance the survey respondents attach to the various products of the EPB, only about 150 (i.e. 40%) expressed their opinion. Between 5 and 15 people thought that the outputs of the EPB were not important. Therefore, most of the survey participants rated the outputs as important.

About 5 people mentioned that the EPB does not produce things on time, nor did they find the products reliable. However, the majority of the survey participants hold the EPB in high regard in matters of timeliness and reliability.

(iii) People's Awareness of the EPB in the Geoscience Community

One-hundred and twenty subjects cited their reasons for not using the outputs of the EPB; 56 people said that they were not aware of what the EPB produces and 48 felt that the outputs are not related to their work. The fact that these two groups of people are mostly from either the mining or the oil and gas industries betrays a significant ignorance of the federal government's effort in geophysics in the private sector.

Table 4 C-2.1 Respondents' utilization of EPB's output

Type of Output	Sectors					Total	
	Oil & Gas	Universities	Mining	Govern-ment[1]	Other Industries[2]	Number	Percent
Gravity	94	50	39	30	9	222	62
Earth Structure	55	57	28	30	10	180	50
Seismology	58	46	11	28	13	156	44
Marine Geophysics	72	37	17	20	6	152	43
Magnetic Field	45	36	39	21	7	148	41
Seismicity	32	49	14	30	21	146	41
Permafrost	47	14	14	15	7	97	27
Geodynamics	20	46	7	18	5	96	27
Geothermal	23	31	15	14	6	89	23
Geophysical Standards	27	15	27	10	2	81	23
TOTAL[3]	112	71	46	46	27	302	85

1. Federal, provincial and international agencies.
2. Utilities, geoscientific consultants and "other" industries.
3. The column totals do not equal the sums of the columns because the rows are not mutually exclusive. For example, if a respondent in the Oil and Gas Sector uses outputs in both gravity and seismicity, he or she is counted only once, not twice.

Table 4 C-4.1 Users' opinion on EPB's mandate

Activity	Sector				Other	Total	
	Oil & Gas	Universities	Mining	Governments	Industries	Number	Percent
I Conduct of Basic Research							
Approve	112	62	39	37	17	267	84
Disapprove	26	9	6	8	3	52	16
II Establishment of Field Standards							
Approve	102	55	36	42	18	253	82
Disapprove	30	11	11	3	2	57	18
III Conduct of Field Surveys							
Approve	78	57	24	36	10	205	66
Disapprove	54	13	23	8	8	106	34
IV Reduction and Interpretation of Field Data							
Appove	74	55	24	36	9	198	64
Disapprove	58	15	22	7	10	112	36

(iv) Users' View of EMR's Earth Physics Program

About 40 survey respondents did not express their opinion on what the EPB's mandate should be. Of those that did, 90% or more approve the following activities in the mandate:

- operation of observatories;
- preparation of national maps of geophysical data;
- maintenance of calibration facilities;
- maintenance of national data bases;
- issuance of warnings of geophysical hazards; and
- publication of data and information on the outputs of the EPB.

For the other activities, the proportions of people who approved are as follows:

- conduct of basic research, 84%;
- establishment of field standards, 80%;
- conduct of field surveys, 65%; and
- reduction and interpretation of field data, 62%.

Table 4 C-4.1 has the details.

By and large, the geophysical community approve the role of basic research for the EPB. However, most opponents felt that basic research should be conducted in collaboration with universities.

The opposition to the EPB establishing field standards is anomalous. People in industry and universities would like to work together with the EPB to set such standards.

The remaining two activities were strongly opposed, about a third were not in favour of the EPB undertaking the tasks. This puzzled the Review Committee. A great part of dissention came from the private sector, especially the mining and oil and gas industries. In fact, all of the field survey work under the EPB's direction is contracted out to geophysical companies. Moreover, most of the field surveys at the EPB are part of some national data grid. They are not prospecting surveys. The Committee conjectured that the respondents who opposed mistook the field surveys carried out by the EPB as prospecting ones. If that were indeed true, then the apparent opposition to these activities of the EPB's mandate is based on a misconception.

In summary, the users approve the mandate of the EPB, with the possible exception of the conduct of field surveys and the reduction and interpretation of such data.

(v) Suggestions for Improvement

Two-thirds of the survey participants did not submit suggestions. Of those that were put forth, the need for public relations stands out. In the words of one respondent, it is phrased thus: ". . . establish a public awareness program by advertising booths at geological and geophysical meetings, setting up a roster of speakers distributed to technical and non-technical organizations, universities to speak on 'popular topics'." Another popular proposal is to publish annually a short summary of projects in popular journals or magazines (e.g. Oil Week, the Northern Miner). There are four other suggestions each of which represents about 5% of the respondents:

1. merge the GSC and the EPB;
2. revive and improve the instrumentation work;
3. revitalize the EPB to spearhead modern developments in basic geophysical research, e.g. geodynamics; and
4. set up advisory committees to coordinate geophysical work between the EPB, industry and universities.

V LINKAGES BETWEEN THE EPB AND GOVERNMENT INSTITUTIONS, INDUSTRY AND UNIVERSITIES

One of the terms of reference of the Committee was to investigate linkages between the Branch and other federal government agencies, provincial governments, the private sector and universities. We have interpreted this analysis as dealing with a number of facets. First, it means determining how the EPB and its output are perceived by the other organizations. Secondly, it entails an examination of the mechanics of coordination in each case to find out whether it is optimum, or whether there is danger of duplication or lack of rapport. Our investigation has drawn upon both the results of the questionnaire and discussions with persons in the organizations concerned.

a) Other Federal Government Organizations

We have concentrated on three organizations: the National Research Council; the Geological Survey of Canada and; the Geodetic Survey, within the Surveys and Mapping Branch of EMR.

(i) The National Research Council

Interaction with the NRC is chiefly with the Division of Building Research in the fields of seismicity and permafrost research, the Energy Division in geothermal studies, and the Herzberg Institute of Astrophysics in geodynamical projects, particularly planning for the proposed Canadian Baseline Array.

Interaction in seismicity is primarily concerned with the network of strong motion seismographs. The primary purpose of these is for establishing ground motions during major earthquakes. These ground motions are, in turn, used for modelling responses for structures in an attempt to perfect designs for structures resistant to earthquake damage. The strong motion instruments trigger at an acceleration of about 1 percent of "g" and make a short record of ground motions.

At present, the Earth Physics Branch assumes responsibility for the stations in western Canada, while the National Research Council assumes responsibility for those in eastern Canada. There is an agreement in principle to the effect that the Earth Physics Branch should take over full responsibility for the network. In June, 1984, this agreement had not been implemented.

The committee that coordinates such work is the CanCEE committee (Canadian Committee on Earthquake Engineering), which includes representatives from several departments. CanCEE is seen to be an effective body, and the Earth Physics Branch is seen by NRC representatives to be a knowledgeable and important member. Informal liaisons with the EPB exist in the area of in situ stress measurements as well as seismicity. As discussed below in the section on Seismology, a number of technical changes in the strong-motion seismic network are desirable, and we recommend that these be implemented when the EPB assumes complete responsibility. We foresee that the cooperation now existing between the EPB and the Division of Building Research of NRC will continue, because of the on-going interest of the latter in the effect of strong ground motions on structures.

A closely related activity is the Nuclear Code Committee, set up in 1975 by Atomic Energy of Canada Limited. This is a technical body that provides the essential background for the establishment of Canadian Standards Association (CSA) standards for nuclear facilities. This is an important matter, for example, in terms of relations with foreign countries. Obviously, the technology is similar and indeed the same names of individuals come up in conversations. Finally, it was emphasized that these activities were only a small part of the NRC's activities, representing two out of about 30 project divisions, in the Building Research Division.

In the area of permafrost research, there has been continual contact over the years. Sites for cooperative research include the Mackenzie Delta, the Beaufort Sea and Alert. The basic data consist of ground temperature measurements. The Earth Physics Branch staff are equipped and qualified to collect these. Those NRC personnel interviewed gave emphasis to the fact that the Earth Physics Branch had essential laboratory facilities on which such cooperative research programs depend. Permafrost research is a natural area of interest for Canada, as over half of it is covered with permafrost of thicknesses varying from 1 to 1000 metres. Liaison is usually informal, but effective. Some of it takes place through the Permafrost Subcommittee of the Associate Committee on Geotechnical Research (of the NRC).

The closest contacts with the Energy Division of the NRC are in the renewable energy area, particularly geothermal energy. Apparently, interest began within the Department of Energy, Mines and Resources, and about three years ago an engineering component was added. This component includes heat extraction technology (by the NRC) and system design (by the EPB). In the view of some of the persons interviewed, the engineering component is still too small.

Briefly, the NRC's efforts are devoted to heat exchangers and heat pumps and utilization, whereas the Earth Physics Branch focuses on geothermal resources. The total activity within the National Research Council is modest, but recent reviews have been suggesting that it should grow. The Earth Physics Branch's role is seen to be appropriate in size. Much of the Earth Physics Branch expenditure is handled by external contracts and is thought to represent about $1 million per year. The National Research Council has a concept that the overall geothermal program will remain about the same size, but that the proportion of the work going to the Earth Physics Branch may decline. Our interpretation of the latter point of view is that the NRC, rather than the EPB, should become involved when geothermal energy is "out of the ground". The Committee concurs with this view. (Very recently, it has been announced that the Energy Division of the NRC is to be disbanded. We are not aware of the implications of this for the geothermal energy program).

Scientists from the Gravity and Geodynamics Division of the EPB have worked continuously with those of the Herzberg Institute of Astrophysics on the design of, and preparation of the submission for, a Canadian Long Baseline Array for Radio Astronomy. As is generally known, the future for this proposal at the present time is by no means bright. Nevertheless, the EPB input has been important. The fact that the array would be used for geodynamical research of special interest to Canada led to design changes, and provided additional weight to the arguments for funding. If the project is revived these arguments will still be valid. In the meantime, the involvement of the EPB scientists has led to the very real possibility of mobile receiving units being obtained, permitting the Branch to participate in this very advanced technique for measuring crustal strain.

(ii) The Geological Survey of Canada

The interface between the Earth Physics Branch and the Geological Survey of Canada is complex. It involves not only cooperative investigations, but also a division of effort. Geophysical measurements are carried out by the GSC divisions based in Ottawa and by the Atlantic Geoscience Centre. While the Division of Resource Geophysics and Geochemistry has the most extensive measurement program, paleomagnetism is the responsibility of the Precambrian Division. In marine geoscience, the Atlantic Geoscience Centre is a division of the GSC while the Pacific Geoscience Centre is a joint operation of the GSC and the EPB. This fact creates a basic asymmetry between the east and west coasts (with some additional uncertainty in the Arctic). All other divisions of the GSC have geophysical interests of some degree, either in their own projects or in addressing national priority missions such as RADWASTE[1], permafrost, and the Frontier Geoscience Program and the proposed LITHOPROBE[2] project. This is not unnatural, given the increasingly interdisciplinary nature of the earth sciences. Any geological

[1] Radioactive Waste Disposal Program

[2] Project to study the relationship between the deep (Lithospheric) structures of the earth and the geologic features of the surface.

survey must draw upon the tools of geophysics (as well as geochemistry) to keep abreast of progress.

The Committee has noted the changes in the Program Description of the GSC, for example from that of 1970-71:

> "Identification of potential mineral resources, provision of data to aid the discovery and exploration of mineral deposits and of data for engineering projects, land use, etc., basic research on the formation of the earth, development of new geological instruments and methods",

to that of 1984-1985:

> "the conduct of geological, geophysical and geochemical research and surveys; estimation of mineral and non-renewable energy resources; investigation of geological phenomena affecting engineering works and the environment; development of geophysical and other technologies; development of national geoscience standards; fostering Canadian geoscience and Canadian international geoscience activities; cooperation with the provinces, provision of advice to government, and production and dissemination of maps and reports".

While it is not strictly our mandate to comment on the program statement of another Branch, we do point out that the two references to geophysics and the use of the blanket term "geoscience" causes confusion in the appreciation of the division of effort between the GSC and the EPB.

Given the present division of actual geophysical activity, the interest of all GSC divisions in geophysics, and the need for geological input to many projects of the EPB, we frankly did not find the spirit of cooperation between the two Branches in Ottawa to be all that is desired. The opinion was expressed, by officers of the GSC, that cooperation between the two Branches had improved in recent years, partly as a result of dual involvement in mission-oriented projects. If this is indeed the case, the trend is to be encouraged, but not at the expense of the identity of either organization. The suggestion has already been made (by one of the Ad Hoc Committees) that a joint committee (between the EPB and the GSC) of workers in paleomagnetism be set up. We reiterate this suggestion, and see the need for working-level, informal committee(s) in other areas (e.g. crustal structure). The management of both Branches should do everything possible to promote mutual trust and scientific cooperation between the members of such groups as well, of course, as between members of the more formal structures concerned with RADWASTE, permafrost, Frontier Geoscience, etc.

The dichotomy in the organization of marine geophysics between the east and the west has certainly produced problems in the past. It is only recently, for example, that gravity measurements made at sea by the AGC (Atlantic Geoscience Centre) have been included in the national gravity data set. We understand that this has now been rectified, and also that there is complete cooperation between the AGC and the PGC on the optimum utilization of Canada's only two sea gravimeters, one owned by each organization. It will certainly continue to be desirable for scientists from the EPB to work at the AGC, for example, on problems of east coast seismicity. Again, we urge an attitude of mutual respect and consideration by both the visitors and the host organization. In the laboratories of the PGC, we observed an atmosphere of completely satisfactory interaction between the scientists of the GSC and those of the EPB. Undoubtedly, the fact that both were more concerned with the real problems of the sea floor and west coast tectonics than with bureaucratic procedure contributed to this, but the Director has greatly encouraged it. Since our visit, we have learned that there have been administrative problems as a result of the joint budgeting process. We again urge the managements of the EPB and the GSC to do everything possible to assist the Director of the PGC in minimizing these problems.

(iii) The Geodetic Survey

The relationships with the Geodetic Survey have changed very markedly over the years. As has been noted earlier, the original purpose of the Dominion Observatory was very much in support of practical geodesy, and the Geodetic Survey grew out of the Observatory. For many years, the Survey, although a separate organization of the Department, was physically located in close proximity to the Observatory, until space was provided for it in the Surveys and Mapping Building. With the proposed transfer of the Surveys and Mapping Branch to Sherbrooke, Quebec, the physical separation of the Geodetic Survey and the Earth Physics Branch could become even greater. Scientifically, many of the aims and technologies of the Geodetic Survey and the Gravity and Geodynamics Division of the EPB have never been closer than at present. The striking recent advances of modern geodesy, particularly those involving space techniques, hold great promise for geodynamic studies as well as for precise positioning. At the same time, many of these new techniques make increased demands for knowledge of the gravitational field. Thus, both the Survey and the Division draw upon each others expertise and provide services to the other, for their respective programs.

We perceive the cooperation between the two organizations to be effective and efficient, largely through the joint committee of scientists that are actively involved. However, there does appear to be some overlap or duplication of effort in the particular area of geoid evaluation. While this is a most important practical problem, the Committee urges that the two organizations examine this area with particular care, to determine if cost effectiveness could be improved.

b) Industry

Linkages between the EPB and the private sector are in a number of very different forms. The Branch is, first,

a provider of services and basic data (e.g. gravity base station values, magnetograms) to the petroleum and mining industries, either directly or through geophysical contractors. The Branch also provides vital information on seismicity to engineering consultants. It monitors government contracts to industry for its core programs (e.g. field surveys) and for the permafrost, energy and RADWASTE programs. An area of limited exchange, to date, but one which could develop much more, is the transfer of instrumental technology to the Canadian geophysical instrument manufacturing sector.

Our information on the first area, the provision of data and services, comes chiefly from the results of the questionnaire, and to some extent, from studies by the Ad Hoc Committees. There is general agreement that the EPB products are of a very high standard. With the petroleum industry, there is a problem in the need for increased visibility, which we address elsewhere. The mining geophysics community, while basically pleased with the services obtained, has made suggestions for further judgment-based interpretation of some of the data, to which the Branch has not yet responded. (For example, a frequent request, and one supported by the Ad Hoc Committee in the field, is for the publication of a map of Canada indicating the regions for which the magnetograms of each magnetic observatory are believed to be representative). But in general, the relations in this area are good. In the field of seismicity, there is acceptance that the role of the EPB is in the overall seismic zoning of Canada, including its implications for codes, but that site-specific studies and recommendations are the proper sphere for private consultants.

The case of contracts to industry for field and other studies has undoubtedly been beneficial to Canadian industry, and has freed some of the personnel of the EPB from routine tasks, at least in the case of the core programs. The Committee is concerned, as we emphasize elsewhere, about the impact of a very large amount of contract monitoring on the careers of individual scientists.

For the benefit of both the EPB scientists and the Canadian industry, we urge the further development of another type of linkage, especially in high-technology areas, and that is the **joint venture.** In other words, the monitor-contractor relationship is replaced by one in which creative scientists from the EPB and industry work together on research, in the same way that some EPB projects with universities are completely joint. This type of relationship provides the optimum environment for technology transfer, and helps to remove the feeling (which the Committee has heard expressed) that the more routine tasks are the ones contracted out. We realize that since, in joint ventures, the risks are shared, the administrative problems are probably more difficult to overcome than in the case of contracts. Nevertheless, the goal is worthwhile.

Technology transfer in the development of measurement systems, to date, has been largely in the area of magnetic sensors and the Automatic Magnetic Observatory System. A very promising possibility at the moment is the simplified seismic refraction recorder developed at the EPB and, for the future, instrumentation systems for the measurement of absolute and relative gravity and others in the area of geodynamics. The relationships between the EPB scientists and the Canadian geophysical instrumental companies appear to be good, and there is no reluctance on the part of the Branch to assist the latter. Problems that do arise are largely outside of the Department's ability to rectify and, in fact, are those which often appear to be poorly understood by the government policy makers. It is not the funding for construction of a prototype instrument which solves the problems of the Canadian industry but the securing of the first multiple orders. Government policy can assist by setting an example, in purchasing the product and in developing markets abroad. But timing is important, and any delay places the Canadian manufacturer at a disadvantage. For example, we believe that there exists today an excellent export market for the seismic refraction recorder, designed by the EPB for LITHOPROBE. We also believe that in a year or so, other countries will develop their own.

c) Universities

Canadian university groups in geophysics and the EPB have common goals in advancing the physical study of the earth and in enhancing public understanding of the subject. Linkages between universities and the Branch exist at many levels: undergraduate and graduate students as potential temporary employees; recent Ph.D's as potential post-doctoral fellows; and Faculty members in a number of roles, including those of contractor or recipient of a Research Agreement or as collaborators in completely joint research projects.

The EPB inherited from its predecessor, The Dominion Observatory, and continued a long tradition in the employment of summer students. Indeed, in all areas of earth sciences in Canada, there are today senior scientists whose first experience was in some branch of the Department. It is a source of great concern that the program of summer employment for students may be drastically reduced (as indicated in a budget statement of the federal government, autumn, 1984). This is obviously a problem but rectification is beyond the power of the EPB alone. The impact on the EPB and on undergraduate students interested in geophysics would be most serious. The government must therefore not reduce the program of hiring summer students. There is an excellent record of graduate students benefitting from employment and from the use, in theses, of material acquired through work within the EPB. This policy is, of course, to be encouraged.

We are convinced that, for the past several years, very substantial contributions to the EPB program have been made by post-doctoral fellows. One evidence of this is the prominence of their names as authors or joint authors in the list of publications. Post-doctoral fellows bring new points of view to any institution and, by virtue of their

freedom from administrative responsibility, can devote full time to research. We find some evidence of a sense of discouragement, at present, in the possibility of fulfilling the program. There appear to be two reasons for this. First, there are rigid restrictions on the number of fellowships tenable by non-Canadian residents, in proportion to those held by Canadian residents. Secondly, the number of Canadian Ph.D's graduating in solid earth geophysics remains very small, and competition for them is very high. More effort must be made to increase the visibility of the EPB to Canadian graduate students, to follow the careers of Ph.D's in-progress, and to attract suitable candidates by personal contact. At the same time, representation should be made to appropriate government Departments to ease the restrictive quota on non-Canadian Fellows.

Relations between the EPB and the geophysics faculty in Canadian universities are generally very good. There are numerous examples of completely joint research projects and more will develop through LITHOPROBE. Indeed, LITHOPROBE, Phase I, has already spawned a number of papers, co-authored by university, EPB and GSC scientists. The field work in seismic refraction measurements is also an excellent example of cooperation in the field. A number of university faculty members hold contracts under the geothermal energy, permafrost or RADWASTE programs and, over the years, many have had Research Agreements. When the latter program was introduced in the early 1970's, the funds available to faculty members provided important support for research projects of mutual interest between the researcher and the Department. Unfortunately, the amounts of money have remained fixed so that the purchasing power of such funds has become very small. Research Agreements now represent only supplementary funding for projects whose main support must be found elsewhere. The effectiveness of mutual cooperation between universities and the EPB has inevitably declined since the early days of the Research Agreement program. We recommend therefore that this program be refinanced to at least its original level in 1970 dollars, with allowance for future inflation.

A most important form of university and Branch interaction is through temporary staff exchanges. While there are numerous cases of Canadian faculty holding temporary positions at the EPB and of EPB staff taking research leave in Canada or abroad, the concept of simultaneous exchanges is relatively new (there is a recent example between a geophysicist of the GSC and a Canadian university geophysicist). Exchanges have the advantage of bringing new insights to both cooperating organizations, with no resultant temporary shortage of staff. We recommend that the EPB initiate an exchange of scientists with universities.

d) Organizations outside of Canada

The staff of the EPB plays an active part in various international bodies; and the Branch is highly regarded by those responsible for the World Data Centre System, for its regular contribution of high quality data. Moreover, there are areas of productive cooperation with other national institutions, for example, in seismicity and geodynamics studies with the United States Geological Survey.

VI ANALYSIS OF SPECIFIC AREAS

a) Seismology

Seismological activities of the EPB can be divided into: (i) observatory or data-gathering operations; (ii) applications or services to the country; and (iii) research. Oftentimes, because of various types of interaction, the distinction between the three becomes blurred. This is desirable.

(i) Observatory-Type Operations

Observatory-type operations include:

1. the maintenance and operation of the national (standard) network of three-component, long and short period instruments;
2. the maintenance and operation of regional and telemetered networks of short period instruments;
3. the preparation of seismological bulletins and earthquake catalogues and maps; and
4. the photocopying of the analog seismograms of the national network so that they are accessible to seismologists throughout the world.

The Canadian national (standard) and regional seismological networks are models of efficient operation. The quality of the seismograms is very good, which is remarkable when one considers the harsh environment in which many of the seismographs are operating. The instruments are calibrated frequently, and calibration curves are included in the seismological bulletins. Extra care is given to the details that make good seismograms, such as the sharpness of the light trace and the photographic processing. Reproductions of the seismograms that are sent to the World Data Centre continue to be made on 35 mm film, resulting in copies that are better than microfiche copies, such as made in the United States.

Nonetheless, there are some matters of concern. Within the past two years the stations at Resolute Bay and Fort Churchill have been downgraded from standard to regional. This resulted in the replacement of photographic recording seismographs (three-component long period and three-component short period) by vertical component seismographs only. The latter record on heat-sensitive paper. Apparently these changes were made to reduce the number of person years required for the operation of the station, and are only short-term changes that precede the conversion of all of the standard stations to broadband three-component digital seismograph systems. It is recommended that the changeover from analog to digital instrumentation take place as soon as reliable systems can be installed to keep Canadian seismographic operations at the worldwide state-of-the-art. Further, it

is recommended that playbacks that are made to resemble the present short and long period seismograms be sent to the World Data Centre, along with the digital data tapes.

The telemetered seismographic networks of eastern and western Canada provide high quality data for the most active earthquake regions and most densely populated regions of the country, as well as for areas of particular concern, such as hydroelectric and nuclear power generating facilities. These networks, together with the standard and regional networks, provide a large quantity of data that must be analyzed and published, along with hypocentral coordinates, in station bulletins. This is a time-consuming operation that presently occupies much of the time of some of the senior seismologists. It is recommended that students, working on a part-time basis and/or during the summer, be hired to do some of the routine work, thus allowing the seismologists to devote a reasonable portion of their time to research. Such a practice also might be effective in interesting students in a career in geophysics.

The EPB deserves special credit for the excellence of its seismological bulletins, including seismicity catalogues and maps. These are fundamental data whose value increases with time. Future generations, both of scientists and non-scientists, will benefit from the careful attention presently devoted to these operations. The promptness of publication makes them very useful to those who require knowledge of the current seismic activity of the country.

Until now the operation of strong-motion seismographs has been the responsibility of the EPB-PGC in the West and of the National Research Council in the East. Soon the eastern installations will be turned over to the EPB — Ottawa. This is an ideal time to plan an adequate network of such stations, particularly because the present one, at best, is minimal by international standards, with regard to the number and type of instruments in operation. Strong-motion data from moderate to large earthquakes are needed everywhere in "eastern Canada" from Alberta to the Atlantic coast, as well as in the Arctic region. Inasmuch as earthquakes large enough to trigger accelerographs occur relatively infrequently in these areas, the country cannot afford to miss any opportunity of acquiring strong-motion data when such earthquakes occur. It is recommended that at least two or three free-field instruments should be placed in every seismic source zone capable of producing an earthquake of body-wave magnitude greater than, or equal to 5. Many more should be placed in the St. Lawrence Valley. In addition, strong-motion instruments should be placed at both free-field points and at several heights within structures located in the metropolitan areas. Long-term consideration should be given to a two-dimensional, or preferably a three-dimensional, strong-motion array near Le Malbaie, or some similar active earthquake area. Because the responsibility for the strong-motion program in eastern Canada is being taken over by the EPB from the National Research Council, the EPB will require both an increase in budget and personnel to carry out this assignment. The responsibilities for eastern Canada cannot be met by the existing staff, who have neither the time nor possibly the special talents required for certain engineering aspects of the data gathering and analysis of strong ground motions. The scientific staff of the Pacific Geoscience Centre should continue to take an active role in the strong ground-motion program, particularly in developing plans for the required expansion of effort in the East. Increasing urbanization of south-eastern Canada, along with continued development of sophisticated lifelines that are vulnerable to strong ground shaking, insure that the strong-motion program will take on even more significance in the future.

Seismic instrument development is a related type of observatory operation. The EPB devotes considerable effort to such activities, with the result that all of its seismographs are state-of-the-art, including the new digital recording systems. By designing and constructing its own instruments, the EPB not only maintains a high level of quality control but also obtains instruments which are made to satisfy its special needs. The new generation of digital seismographs, with broad band frequency response and large dynamic range, will provide data that span the gap between those provided by traditional strong-motion instruments and observatory-type instruments. Therefore, the interpretation of such data will become more sophisticated if they are exploited to take advantage of their potential. Additional data processing will be required, which will result in new banks of information. We recommend that thought and planning should be given to developing the proper formats of digital seismograms and to digitizing analog seismograms for distributing this information to the research community and to interested corporations and the public.

(ii) Applications and Service to the Country:

Operation of the seismograph stations and networks, publication of seismic bulletins and maps, and related observatory-type activities are all examples of service to the country and to the international scientific community. Studies, such as those of seismic risk and hazard and of the state of stress in the crystalline rocks proposed for nuclear and other toxic disposal, provide additional examples of seismological applications and of service to other agencies of the federal and provincial governments, as well as to those segments of industry concerned with lifelines, critical structures and other facilities which could suffer large economic loss or be the cause of loss of life from earthquakes. The extensive refraction and reflection studies of the lithosphere that are being carried out and planned for the coming years bear on these problems, as well as on the exploitation of mineral resources. In a similar vein, seismicity studies of continental margins can contribute significantly. Seismological studies related to the identification, location and discrimination of underground nuclear explosions, along with participation of Canadian experts in disarmament discussions, also represent an important contribution to the country and to all mankind.

In order to carry out properly the above-mentioned activities it is necessary to conduct in parallel fundamental research, because none of these activities can be performed by means of routine methods of data gathering and analysis. This desirable state of affairs provides stimulus and challenge to the investigators, as well as a sense of accomplishment derived both in their role as scientists and as individuals seeking to improve the state of society. However, the reduction in scientific personnel that has taken place in the EPB in recent years, along with added responsibilities, presents the danger of sacrificing the scientific element at the expense of applications and services. If this trend continues, not only will there be lowered morale but also a decline in scientific competence.

It is particularly difficult to single out applications or services which might be reduced. Continuing financial support for the EPB activities requires good relations with the public, the news media, industry and all branches of local, provincial and federal government, as well as the smaller scientific and university communities. However, none of these efforts need be done at the expense of being a slave to the users. For example, neither industry nor government regulatory agencies should normally expect to receive site-specific seismic hazard evaluations from the EPB. Such activity should be carried out by geoscience companies or by consultants, when this is feasible. Furthermore, if these services are provided by the EPB to regulatory agencies there either can be the suspicion of collusion among the different branches of the government or there is the likelihood that one branch of the government will be challenging the work of another. Rather the role of the EPB should be that of senior adviser to the regulatory agencies, providing review and guidance and approval or disapproval on matters of scientific judgement.

The questionnaire distributed by the Review Panel suggests that the EPB has to publicize its activities and services better. One way of doing this, which has worked well for the U.S. Geological Survey and other United States agencies such as the National Science Foundation, the Federal Emergency Management Agency, the Corps of Engineers and Federal Energy Regulatory Commission, is to hold regional conferences and workshops on earthquakes and their effects. Invited participants would include all segments of society, especially those individuals who can be identified as playing a leadership role in their communities, provinces, companies, universities, scientific and technical societies, disaster relief agencies, hospitals and medical systems, and all phases of life that can be affected by damaging earthquakes.

(iii) Research Activities:

As noted earlier, there is a research element in all of the seismological activities of the EPB. In some cases the research inclines toward the geological aspects and in others to the more mathematical-physical. Earthquake prediction, seismicity of the coastal regions, along with LITHOPROBE and related crustal studies, tend to be the former, whereas wave attenuation, the state of stress in the lithosphere and synthetic seismogram construction are examples of the latter. The EPB research on in situ stress measurement is particularly important, because this parameter is now recognised as having important implications for neotectonics and seismicity, yet very few other groups in Canada are involved in its study. Since the last review of Seismology (Uffen Committee) there appears to have been a conscious effort made to increase the amount of research in the EPB. This is an encouraging development, because it controls the quality of seismology in Canada in the future. Furthermore, with some notable exceptions, seismological research at Canadian universities is directed toward lithospheric studies, which make up an important element of the science of seismology but only a part of the total subject. Both the EPB and the university community should be encouraged to broaden their perspective of seismology, consistent with available resources and the interests of the investigators.

b) Gravity and Geodynamics

The Gravity Division of the former Dominion Observatory laid the basis for the gravity survey of Canada in a most effective way. With limited personnel, it carried out a measurement program which, for accuracy and coverage, is the envy of most countries in the world. The present Gravity, Geothermics and Geodynamics Division (Geothermics are discussed separately) is charged not only with completing this work, but with developing tools to measure whole-earth and crustal deformation. This objective began when the two PZT observatories were left with the EPB after the transfer of astronomy to the NRC, but has greatly expanded to include participation in the planning for a Canadian long-baseline array, or for mobile-station alternatives to it. The result has been that there is a mix of science and technology in the Division. We believe that this mix is appropriate to Canada's needs, and for overall contributions in gravimetry and geodynamics. One evidence of the effectiveness of the Division is the extent to which members of it are requested to assist in programs abroad.

The personnel of the Division are aware of the rapid advances in modern technique: geodetic positioning satellites; long-baseline interferometry; absolute gravimetry; and so on. But, it is a rapidly advancing field, and it will be necessary to attract new expertise, to maintain the dynamics of a team which has been in place for more than a decade. This could be partly achieved by suitable post-doctoral fellows; but we recommend that, when possible, the staff in the area of the new geodynamic technologies be increased.

There is, however, an additional need in the area of interpretation. The Division has been forced to concentrate on the technology. Consequently, its output in the area of studies on lithospheric flexure, upper mantle viscosity and post-glacial rebound have suffered. These are subjects of fundamental importance. The latter is of particular significance to Canada. We recommend, as a

matter of high priority, the addition of a scientist with proven capability in these areas. After all, it is to provide the data necessary for such studies that the crustal deformation technology is being developed.

In the matter of the gravity field itself, there will undoubtedly be a problem in the future, due in part to the EPB's early success in mapping that field on a regional basis. The demands of modern geodesy, in terms of station density, precision of the gravity measurement and precision of height measurement, may well exceed those parameters for the present network. At the same time, new techniques, airborne or satellite gravimetry and absolute measurements, will be in place to assist. Some very hard decisions will have to be made, on whether to upgrade the present network (which represents a considerable investment) or to replace it. The decision cannot be made now, and the Committee is obviously not in a position to recommend a specific action. Because a similar decision will face other countries, we do recommend that expertise and international contacts be maintained at a high level to permit an intelligent choice for the 1990's.

c) Geothermal Studies

(i) General Comments

The geothermics section comprises 9.2 PY funded at M$ 2.6, of which 2PY and M$ 2.1 are OERD or "soft" support. The work of this section covers a wide range of activities including permafrost studies, geothermal energy assessment, nuclear waste isolation and the technology of alternate energy. The group's primary research focus is on heat flow and its interpretation in terms of the tectonic evolution and current tectonic regime of the Canadian landmass. It is also concerned with the application of heat-flow techniques, the assessment of geothermal energy potential, the determination of permafrost depths and the evaluation of geologic hazards. In response to national needs, the group has branched out into such areas as nuclear waste disposal, gas-hydrate distribution and moisture migration in frozen soils. To the extent that we have been able to assess it, the work of the geothermics section is of high quality. Laboratories are well equipped albeit insufficiently staffed for optimum results. In our opinion, however, some priorities are seriously misplaced, some, no doubt, dictated by external forces such as specifically targeted funding. Notwithstanding the pressure to achieve specific, directed goals, it should be possible to obtain more fundamental heat-flow data from all of the subactivities described in section 6.2 of the program book of the EPB. For example, permafrost studies should yield heat-flow data of high quality. A thorough understanding of the heat flow field of the arctic region is a prerequisite to a complete interpretation of permafrost distribution, as well as being a necessary constraint for tectonic models. Similarly, a complete understanding of the lateral and vertical variations of **heat flow** (not temperature or temperature gradient) is required to identify and characterize the movement of groundwater within any candidate repository for nuclear waste. These heat flows should be packaged appropriately and published promptly both to fulfill the basic research mission of the geothermics group and to enhance its reputation in the broader scientific community.

(ii) Specific Comments:

Laboratory Support. The geothermics section has responded positively to most of the suggestions of a previous ad hoc visiting committee (The Beck Committee). The Ottawa thermal conductivity laboratory is in the process of being modernized and automated, but there is still a backlog of 1.5 years in conductivity measurements, owing to the lack of technical backup. This problem could be alleviated somewhat by installing "Vacquier" type line-source halfspace apparatuses in both Ottawa and PGC and hooking them up to the existing ADP equipment. The halfspace technique is easy to set up, uses essentially the same software as the line-source "needle probe" (which is already installed, at least in Ottawa) and requires only rudimentary sample preparation. Thus, a research scientist can relieve the pressure on his/her flow of conductivity data by spending a couple of days in the laboratory.

Geothermal Study of the Yukon and the Mackenzie Valley. A great deal of very good and useful work is being done here, but this subproject would benefit from a greater emphasis on the characterization and publication of the heat flow field of the region.

Geothermal Studies for Nuclear Fuel Waste Management Program. Once again, more attention should be paid to obtaining heat flow data and less to esoteric studies of rock properties. There exist sufficient data (particularly for crystalline rocks) to characterize thermal conductivity and diffusivity adequately for general engineering calculations. We note that a study of three boreholes was made near Pinawa and question, why temperatures were not measured in more than three, when (presumably) many more were available.

Studies of the Geothermal State of the Crust in Central and Eastern Canada. Missing from the milestones in the program book is any mention of a systematic "scrounge" of holes drilled by industry in the region. The continuing acquisition of new data should remain a high priority in any geothermal studies program. The Lithoprobe program will study an exposed 25 km vertical section of Precambrian crust. The study should include the distribution of radioactive elements along this section.

Detailed Geothermal Studies in Specific Regions of the Cordillera. This activity seems to be proceeding satisfactorily given the limited resources allocated to it. Tectonically, this is "where the action is" in Canada, and consideration should be given to increasing support for Cordilleran studies even at the expense of some eastern and central studies. We note that milestone #4 (a paper on the geothermal structure along a transect including the Jervais Inlet) is dependent on "thermal conductivity

measurements being available. . . from the Ottawa lab". The deployment of a "Vacquier" type halfspace apparatus might help to alleviate bottlenecks of this sort.

Assessment of Canadian Geothermal Energy Potential.

Cordillera. Overall direction of this study should reside in the PGC as an adjunct to regional heat flow studies, with considerable input from the GSC. The partition of effort between non-volcanic and volcanic terranes is artificial and arbitrary and may hamper efforts at a regional synthesis of prospective Cordilleran resources.

Sedimentary Basins and Technology and Application. The activities of the EPB seem to be migrating away from its area of expertise toward engineering applications which are probably best left to the appropriate specialists in other disciplines.

Atlantic Region. To the extent that this work enriches the regional heat flow data base, this is a very valuable activity. The outlook for economically feasible exploitation of geothermal energy in this region in the forseeable future would appear to be fairly bleak, however.

Permafrost Research. The mapping of permafrost, research into moisture migration, and studies of gas hydrates are all of great importance to an orderly development of Northern resources. The investigators seem to be reaching out to colleagues in other countries and sharing information with them, which is very commendable. The Beck Committee recommended that as these studies reach the level of engineering applications, the leadership of the studies should be transferred to the appropriate segments of the soil physics/fuels/engineering communities. We concur with this recommendation.

d) Geomagnetism

It is natural that the study of the earth's magnetic field should have played a leading role in Canadian geoscience for well over a century. As has been mentioned, the operation of a magnetic observatory constituted the first organized scientific activity in the country. Canadian territory embraces the North Magnetic Dip Pole, and the longest over-land segment of the auroral zone. Use of the compass was vital for navigation until relatively recent times, auroral disturbances continue to influence communication systems, and Canada leads the world in the application of magnetic and electromagnetic methods of geophysical exploration for minerals. All of these factors argue for a strong national capability in the subject.

For many years, the Division of Geomagnetism of the Dominion Observatory/Earth Physics Branch was recognized internationally as a leader in the field. The accomplishments were numerous: precise tracking of the magnetic pole; major improvements in fluxgate magnetic sensors and their development into practical ground instruments for absolute component surveys; development of the first workable vector airborne system and the use of it on long flight lines, not only over Canada, but over the oceans; contributions to the mathematical formulation of the International Geomagnetic Reference Field and its secular change; and development of the automatic magnetic observatory (AMOS). The list could be extended.

The past successes have meant, of course, that certain problems, previously of high priority, are no longer so. For example, the vector field over Canada can now be tracked in time with the relatively limited number of repeat stations, while further instrumental development for the standard magnetic observatory is not urgently required. But the natural development of the subject and its applications presents a new generation of challenges.

The complex interplay of terrestrial magnetic fields of different origin and different time scales is illustrated in the following table, taken from a recent text (W.D. Parkinson: Introduction to Geomagnetism). Not shown in the table are the interrelationships which force the subject to be approached in a unified way. For example, the disturbance fields (3, 4, 5, even 6) constitute noise in the measurement of the local field 2 for geophysical exploration, where they must be corrected for, while they constitute the primary source of the induced field 7, which is also measured in another method of geophysical exploration. Measurement of the "frozen" local field 2 in rock samples provides information on the past history of the main field 1.

Recent trends in the subject emphasize increased interdependence of these effects, and also possible implications for domains beyond the geosciences, for example, in biology (Parkinson's book contains a 5 page section on Geomagnetism and Biology) and climatic change. On the practical side, the improvements in communication systems have not eliminated the effects of geomagnetic disturbances, as witnessed by the continuing research by Bell Laboratories on the subject. Also, the extension of pipelines through the auroral zone has raised the question of the effect of induced currents on the enhancement of corrosion. At the same time, new technologies, such as satellite vector magnetometers (as carried on MAGSAT) provide a completeness in the measurement of the field that was not possible before, while the great increase in sensitivity of magnetic sensors opens the possibility of ground-based measurements of effects not previously subject to observation. With all of these advances, the provision of basic magnetic observatory data to the exploration industry remains vital, and is an excellent example of a very necessary service. There remains, for the future, the possibility of a dedicated system of satellites to monitor the temporal changes in the field. Such measurements, if they could be continued downward through the region of ionospheric electric currents, would eventually obviate the need for magnetic observatories. To be responsible, a national group in geomagnetism must maintain and develop the broad expertise to at least remain abreast of these international developments, and preferably to contribute to them.

Components of the Geomagnetic Field

CONSTITUENT FIELD	LOCATION OF SOURCE	INTENSITY (maximum)	MORPHOLOGY	TIME VARIATION	MEASURED BY	RELEVANCE
1. Main field	outer core	50,000 nT (70 000 nT)	mainly dipole	secular variation order of 1000 yrs; reversals order of 10^6 yrs	regional surveys (aircraft, ships, satellites or ground obs.)	controls all other fields directly or indirectly; used in navigation
2. Local Field	crust above Curie point geotherm	mean 100 nT (as high as 10^5 nT)	very irregular, wave lengths as short as 1m	none	local surveys (surface or airborne)	used for geophysical exploration and ocean floor spreading rates
3. Regular storm field	magnetosphere	150 nT (500 nT)	approximately uniform external field	4 to 10 hour; recovery takes 2 to 3 days	observatory magnetographs	monitors solar activity
4. Irregular storm field & substorms	ionosphere and magnetosphere	100 nT (200 nT in auroral (zones)	global, but more intense near auroral zones	periods of 5 to 100 minutes	observatory and temporary magnetographs	ditto
5. Dirunal variation	ionosphere	50 nT (200 nT at equator)	global; mainly P_3^2 harmonics	periodic 24, 12, and 8 hour periods	observatory magnetographs	indicates ionospheric tidal winds
6. Pulsations	magnetosphere	few nT (100 nT for Pg)	quasi-global, more intense near auroral zones	quasi-periodic 1 to 300 sec	rapid-run and induction magnetographs	indicate resonances in magnetosphere
7. Induced fields	crust upper mantle and oceans	about 1/2 of above four fields	generally global but irregular in places	same as above four fields	observatory and temporary magnetographs	indicate conductivity distribution in crust and mantle

With the reorganization of the EPB, the Division of Geomagnetism was incorporated into the new Division of Seismology and Geomagnetism. We perceive some of the results of the change as beneficial in the establishment of interdisciplinary groups. Examples are in the crustal studies group, where interpretations of electromagnetic soundings can be closely coordinated with the results of seismic refraction and reflection, and in instrumentation. In both cases, scientists previously attached to two divisions were brought together. However, in balance, we are convinced that the loss of a focus for geomagnetism, and the documented loss of visibility, have been detrimental. Our visits have given evidence of first-class work on: rock magnetism and instruments at Blackburn; induction studies, chart production and interpretation at Ottawa; and of paleomagnetism and induction studies, including ocean-bottom magnetic variation measurements, at PGC. But, we saw little evidence of interaction between these projects. We were also concerned that the EPB was not the lead agency in the project MARIA, (Magnetometer & Riometer Array) designed to provide a dense coverage of ground-based magnetic measurements for coordination with measurements in space. It is encouraging, and will be welcomed by the mining geophysics industry, that capability in the area of forecasting magnetic disturbances based on solar activity has been increased. This is an excellent example of fundamental research with practical significance that should be incorporated into the work on geomagnetism.

In recommending the re-establishment of a Division of Geomagnetism within the EPB, we take a position consistent with our view of the broader question of geoscience within the Sector: a disciplinary fabric provides the greatest promise of remaining in the forefront of a given field, while the essential interdisciplinary ties should be encouraged through less formal working groups. Thus, we see no contradiction between restoring the unity of geomagnetism, and at the same time fostering joint efforts in crustal studies, instrumentation and other areas with the other divisions. Also, in future years when positions become available, the existence of a Division will assist in attracting a scientist of the high stature and breadth of outlook that will be needed for leadership in geomagnetism, as it develops over the next decades.

e) Geophysical Instrumentation

Introduction

It can be argued that geophysics is a science of exact measurement. Geomagnetic measurements can resolve variations less than 10^{-8} of the main field. The best gravity measurements can distinguish differences in altitude of one millimeter. The best seismometers can detect ground motions comparable with atomic radii. It follows that a competitive geophysical research laboratory must have the capability of using the most advanced technology.

The Earth Physics Branch achieved its worldwide reputation for outstanding geophysical research and scientific leadership partly because it employed a number of outstanding instrumentalists. This is not the place to recite the full history, but one thinks, for example, of Patrick Willmore and Paul Serson whose contributions to the fundamental physics and applied technology of geophysical measurement were widely recognized in an international sense. As will be mentioned below, there are still areas in which the reputation of the Earth Physics Branch is second to none. Some of the developments of the Earth Physics Branch have been effectively transferred to industry for development and sale. These include: the "Willmore" (Maxwell) bridge for seismometer calibration; precision clocks for timing field experiments; and the automatic magnetic observatory, AMOS.

The remainder of this discussion is based on the premise that the well being of the Earth Physics Branch depends in part upon its ability to attract and support scientists who can help Canada achieve and maintain a technological advantage.

Present Status

Despite some opinion that instrumentation is either outside the mandate of the Branch, or else that instrumentation developments are not appreciated in comparison with geophysical data collection and interpretation, there remains an impressive capability in this area.

Two models of a portable seismic recorder (the "back pack") have been produced in significant number. This is a portable seismic recording station that records data on digital cassettes. More recently, an all solid-state system is being developed; it is intended as a prototype for LITHOPROBE. This records locally in random-access-memory (RAM) which holds the data until they are transferred to a tape recorder. The resulting portable units (the "lunch boxes") are extremely compact and have no moving parts.

A contribution of particular importance is the development of the digital seismic network and particularly, in connection with that, the development of practical techniques for digital telemetry. While digital seismometry is widely discussed, it is surprising that only a small part of the existing seismic networks use digital techniques routinely for data transmission. Established digital networks in both eastern and western Canada, though still not as efficient as analogue networks, point the way to where the future lies. This kind of development is, of course, of particular importance to Canada, for the large land extent and sparse population makes communication a fundamental national concern.

The Pacific Geoscience Centre purchases ocean bottom seismometers from Clive Lister in Seattle, but the Atlantic Geoscience Centre can claim to have made its own contributions in this area, starting with the designs developed by the University of Hawaii. The latter is, of course, a contribution of the Geological Survey of Canada.

After a lean period, geomagnetic instrumentation is enjoying a resurgence at the Earth Physics Branch. At one time the Branch was one of the forerunners in the theory and development of fluxgate magnetometers. In the early 1980's, when there was need to employ the most advanced technology for the CANOPUS-MARIA experiment, much of this advantage had vanished and those scientists who were primarily responsible were about to retire. NASA technology was "imported" through a university laboratory and through that route transmitted to the federal government laboratories. One key factor is the decision that the relevant instrumentation specification and procurement should be through the National Research Council. Since then, the Earth Physics Branch at Blackburn Hamlet has applied significant resources to the development and has made some important contributions to ring core magnetometers.

Other geomagnetic contributions could be cited. The automated magnetic observatory (AMOS) has contributed much to the reliability and ease of operation of the geomagnetic network. There has been some work at the Pacific Geoscience Centre on controlled source electromagnetic experiments and on the development of magnetic gradiometers, both experiments in collaboration with university researchers. We applaud this sort of collaboration. The PGC has played a leading role in the development of recording ocean bottom magnetometers.

In the area of gravity, the most promising development at the present time is the absolute gravimeter. This follows naturally on the early interest of the Earth Physics Branch (Dominion Observatory) in pendulum gravity measurements and in the string gravimeter. The fundamental developments in the new absolute gravimeter were by the Joint Institute of Laboratory Astrophysics at Boulder, Colorado. Their instrument is being made more user-friendly and field-compatible by Earth Physics Branch scientists. We understand that there is the likelihood that the new absolute gravimeter may be developed commercially.

Conclusions

One of the justifications for having a geophysical laboratory that is distinct from a corresponding geological laboratory is that there is a much better possibility of attracting interested physical scientists. Indeed, the out-

standing quality of early Canadian geophysics is often attributed to the contributions of Eve, Keyes, Gilchrist and other physicists. We found in the Earth Physics Branch some very good geophysicists (and indeed, a few very good geologists); but we have doubts in many instances about whether they are being given sufficient opportunity to make an appropriate contribution.

In the case of instrumentation, one finds a conspicuous example. There are some very good instrumentation studies being carried out, but they are not mentioned in the Program Book. For example, try to find a discussion of the absolute gravimeter development. One is tempted to make some inferences from these observations. The fact that a number of examples of first-class instrumentation projects are evident to a visitor to the laboratories is evidence that such studies are considered worthwhile by the managers. Why then are they downplayed or hidden? Presumably, it is because such activities are considered to be less successful in interesting those that allocate resources. While we do not recommend research that merely duplicates technology that can be purchased ready-made, we do think there is a role and a need for instrumentation research of an innovative kind and a high quality.

There seems to be a relationship between these considerations and the recommendations of the **Task Force on Federal Policies and Programs for Technology Development** (Douglas Wright and others, The Science Council of Canada). Such research certainly does improve this department's capacity for the testing and monitoring of programs that are clearly part of its mandate; they relate to establishing codes, standards and regulations, and they are essential for maintaining national and international data bases. The various component parts of the seismic and magnetic networks can be regarded as national facilities of comparable importance to major accelerators. Moreover the instrumentation developments of the Earth Physics Branch are certainly of such a character that they represent responses to the 'pull' of the user community.

It is necessary to try to keep a sense of proportion in making these judgements. The fundamental objective of geophysics is to learn about the earth and its environment. The writers of this report were pleased to see that instrumentation studies are well focused in response to genuine scientific needs. Data acquisition is near the heart of the subject and someone had better be concerned that Canada's capability is maintained. We do not think that the matter can be left entirely to either universities or to industry, although both will contribute their share to the subject. The Earth Physics Branch has in the past made distinguished contributions to instrumentation studies and it should continue to do so.

A particular aspect of the Branch's responsibilities is the maintenance of major calibration, standardization and testing facilities. Federal laboratories of most countries assume a "standards laboratory" responsibility. These facilities are not likely to be developed elsewhere in Canada. The Blackburn Hamlet laboratory contains Canada's best geomagnetic test facilities, but they are no more than adequate for meeting immediate needs. We note that Blackburn Hamlet is not a seismically quiet site, and therefore is not a good place for some aspects of seismic instrumentation development.

We regard the consolidation of the geomagnetic and seismic instrumentation at Blackburn as having some very good features. It certainly raises the visibility of these activities and provides for a level of cooperation and of technology exchange that should be quite beneficial. The Branch should consider whether the joining together of gravity instrumentation with this group would also be beneficial. In making this judgement, one should take into account the fact that Blackburn Hamlet is rather a long way from the Carling Avenue laboratories and, like all separations, this separation from other geophysicists has its costs too.

VII CONCLUDING REMARKS

To evaluate the work of the Earth Physics Branch in proper perspective, it is necessary to consider first the role of scientific institutions in government, then the organization of the spectrum of related disciplines known as earth science, and finally the structure within the Branch itself. The need to evaluate the former, the role of science in government, was intensified by the publication, during the Committee's investigation, of the report by the Task Force on Federal Policies and Programs for Technology Development (the Wright Report, July 1984). This report calls into question some activities of the federal government in science, suggesting that these activities would be more appropriately undertaken in other sectors of our society. We are convinced that, in the case of the basic geosciences, federal government activity is absolutely essential, in order to maintain continuity and to preserve the national data base. One of the Ad Hoc Committees to the EPB stated this very well when it wrote "there are some tasks best done by private industry, some best done by universities and some best done by government agencies,. . . . . we strongly favour government agencies as custodians of national assets such as the (geophysical) data base". The Wright Report does itself recognize certain scientific activities as proper for federal government laboratories: "monitoring air and water pollution, pesticides and radiation levels". It would not have required a great addition to have included "developing and managing the national geoscience data base as it applies to resources and natural hazards".

The Wright Report deals extensively with technology and technology transfer to the private sector. We concur with the encouragement of that transfer, and we suggest elsewhere how it might be encouraged in the case of the EPB. Finally, with respect to the Wright Report, we note that it strongly recommends peer review of federal science activities, to ensure that they remain relevant. The evaluation of the work of the EPB, first by the Ad Hoc Committees and currently by the present committee, constitutes just such a peer review.

Granted that basic solid-earth geoscience: geology, geochemistry and geophysics, is a legitimate government activity, the next question to be addressed is the optimum division of responsibility between administrative units. The interrelationships are so manifold, both between disciplines and between fundamental studies and immediate needs, that it is probably impossible to define an "ideal solution". Other countries with highly-developed earth science programs, including the United Kingdom, United States and Australia, have, in recent years, reorganized their administrative structures in the fields. It is by no means certain that all of the changes have been beneficial in meeting all needs. Provided that all of the linkages we have discussed (particularly those with the GSC and the Geodetic Survey) are fully developed at the working level, the distinctive Canadian pattern of a Branch devoted to solid-earth geophysics probably represents the most effective arrangement, for both fundamental development of the science and for its application. Indeed, we believe it would have been more efficient over the years, and scientifically desirable, to have kept all of the Department's programs in geophysics and geodesy within what is now the EPB.

Within the EPB itself, there are two divisions in Ottawa based on disciplines (but each now covering at least two branches of geophysics), and a third, at the Pacific Geoscience Centre, which embraces all of the disciplines of the other two as they apply to problems of the western margin and adjoining ocean floor. While we have argued for the re-establishment of a Division of Geomagnetism at Ottawa, we believe that the mix of discipline-based divisions and the Pacific Geoscience Divison, is good. The Pacific Geoscience Centre, we found, is an excellent example of geological-geophysical collaboration for a common objective. The Committee was greatly impressed by the morale and the enthusiasm for scientific pursuits which it found there. In most cases, the sharing of programs with the divisions in Ottawa appeared to be completely satisfactory, although we have recommended a change in the case of heat flow measurements, with more responsibility going to PGD.

We turn now more specifically to the quality and relevance of the work and output of the EPB. In any scientific organization, whether in government, university or industry, there is bound to be a range in ability and productivity among members of the staff. The Branch is no exception in this regard. Nevertheless, we found the overall scientific standard to be very high. We believe that more could be done to free senior members of the staff from routine tasks. By increasing their productivity they would in turn increase the cost-effectiveness of the organization. Also, geophysics continues to be a rapidly advancing subject, and the organization must be ever alert to avoid falling behind. We suggest some areas of high priority for new staff, but as staff positions will probably always be limited in number, we urge that more emphasis be placed on programs for post-doctoral fellows and for staff exchanges with universities.

The **relevance** of the program of the Branch is evidenced by the extent to which that program has been drawn upon for missions of national priority: permafrost, energy, radwaste disposal and Frontier Geoscience, and other commitments such as Canada's contribution to the scientific basis of a test-ban treaty. New areas of at least regional priority continue to emerge. For example, since the committee began its work, the re-occurrence of serious rock bursts, this time in the mines at Sudbury, has involved the EPB seismologists again, in a problem which occupied their predecessors in the 1940's. It is, of course, entirely proper that a government institution should direct its expertise to matters of immediate national priority, and the relationships developed can be healthy for the institution. We do have some concern, however, for the total resource demands of such missions vis à vis the ongoing, basic research and data management mission of the Branch, and for their impact on individual scientists. Since much of the work is performed by contract, a great deal of contract monitoring is involved. The Branch management must ensure that such tasks do not endanger the scientific career of any individual scientist. We hold it to be imperative that, if any new specific tasks requiring major staff time are directed toward the EPB, adequate person-years are allocated to cover them. Otherwise, the basic program could be weakened so that irreparable damage, in the form of gaps in the essential observatory data sequences, could result.

The matter of over-taxing of resources cannot be separated from the question of whether any parts of the current program should receive less attention. Of course, in connection with such missions as permafrost, energy, and radwaste disposal, changing national priorities, made at Cabinet level, may automatically correct the problem. Indeed, the recent few weeks have seen reduced emphasis placed on certain areas of energy research. Given the existing priorities, we urge that, in the case of geothermal energy, the involvement of the EPB cease when the energy is "out of the ground", leaving feasibility studies on utilization to other agencies. Of the Branch's own ongoing programs, we are not in favour of any expansion of work in earthquake prediction, in the narrow sense of searching for precursors to Canadian earthquakes (as opposed to basic and highly relevant programs on seismicity and in-situ stress determination). We have noted that, through closer collaboration with the Geodetic Survey, it may be possible to reduce the effort spent on geoid evaluation. These few areas represent those in which some saving of staff time may be possible.

In a similar vein, we have examined the international commitments of members of the EPB staff. While the list appears extensive, we have found no evidence that the impact of these activities on any members of the staff has caused problems with their national responsibilities. As noted earlier, international collaboration is essential in the earth sciences for mutual progress, and the list is an effective statement of the esteem and respect with which the Branch is viewed by scientists in other countries.

On the question of the extent to which EPB scientists should interpret the basic data, the questionnaire produced a variety of responses. There were certainly some expressions of opinion, particularly from respondents in the petroleum industry, that such interpretation was not a proper role. On the other hand, there have been suggestions from the mining geophysics industry that, in some cases, more evaluation is required. An example of the latter, already mentioned in the section on Geomagnetism, is the suggestion that the "regions of reliability" of each magnetic observatory, for corrections to surveys, be somehow indicated. We take the opinion against interpretation as relating to the direct search for structures or deposits of economic significance, rather than to more fundamental investigations.

As was discussed in the section of this Report dealing with Seismology, there will be a continuing need to evaluate the most appropriate format in which to make seismological information available, both to the public and to the World Data Centres, as the move to digital recording in the network is completed. This will be a matter common to other data sets, and one which is worthy of serious consideration.

The Branch's output submitted for publication in the established geophysical periodical literature have an enviable record of acceptance in the leading journals, and appear in recent years to be well distributed among such journals. We do suggest that more effort be made to submit relevant papers to journals more likely to reach the Canadian exploration industry, both petroleum and mining, in order to make the EPB program better known in these quarters. Involvement in LITHOPROBE and Frontier Geoscience, particularly if, as we recommend, expertise in reflection seismology is strengthened, should provide ample opportunity for such contributions. With regard to the quality of the output in refereed journals, we believe it to be satisfactory in total. The Committee has noticed a decreasing output on the part of some more senior scientists who, a few years ago, were well recognized for their productivity. We believe this to be a further manifestation of the need to free some members of the staff from the more routine tasks and allow them to re-establish their productivity.

The need to increase the visibility of the Earth Physics Branch, particularly to industry, but also to other government sectors, to the university community in Canada and to geophysical institutions outside the country (although, ironically, the visibility there may be better than it is domestically) comes through very clearly from the results of the questionnaire, and in other ways as well, for example, in the difficulty in attracting postdoctoral fellows. We believe that this lack of visibility is felt by the EPB staff itself, and may prevent the morale from being as high as it should be. We have suggested some actions the Branch itself could take to improve visibility, but a most important improvement could be made in the name itself. The words "Earth Physics" convey the wrong impression to many people, and the significance of the term "Branch" is not clear to persons unaware of Departmental structure. We urge that action be taken to change the name to **Geophysical Observatory of Canada (Observatoire Geophysique du Canada),** because the role of operating geophysical observatories is indeed central to the organization's entire program, while there are ample precedents from distinguished observatories in other countries to show that such a name in no way connotes any reduced emphasis on the other activities.

Under this new name, with links to a distinguished predessor, we visualize the institution as growing in visibility, developing an increased sense of confidence among its staff, and enhancing its place as a world leader among geophysical institutes.

APPENDIX 1
Questionnaire and covering letter

Canadian Geoscience Council
Conseil Géoscientifique Canadien

Earth Physics Branch Review Committee

Program Evaluation of the Earth Physics Branch,
Energy, Mines and Resources, Canada

At the request of the Assistant Deputy Minister, Earth Sciences, Department of Energy, Mines and Resources, the Canadian Geoscience Council has established a committee to evaluate the program of the Earth Physics Branch. One phase of the evaluation involves the analysis of the responses to the enclosed questionnaire. It is therefore extremely important, to ensure a meaningful evaluation, that the questions be answered with care, and that the answers be explained, as necessary, in the spaces for comments.

The committee has designed the questionnaire to cover all the activities of the Branch on a disciplinary basis, and also all the branch outputs which include formal publications and advice given by personal communication. We realize that not every respondent will have had occasion to interact with the Earth Physics Branch in all areas.

The establishment of a distribution list for the questionnaire has not itself been easy. It is being sent to a selection of individuals and organizations, in Canada and in other countries, who are known to have used some of the publications or services of the Branch. If you feel that someone else in your organization would be in a better position to respond, please pass on the questionnaire. The portion of the response that identifies the respondent will be kept confidential within the committee.

On behalf of the committee, I extend our deep appreciation for your time and assistance.

G.D. Garland,
(Geophysics Laboratory, University of Toronto)
Chairman, Canadian Geoscience Council
Earth Physics Branch Review Committee

INSTRUCTIONS FOR COMPLETING THE QUESTIONNAIRE

In the majority of cases, all that is needed is a check mark in the box(es) corresponding to your answer(s). For other questions you will be asked to circle the appropriate number(s) or to write down your answer(s).

DESCRIPTION OF YOUR BUSINESS/ORGANIZATION

To help us better understand your needs, please complete the following background information questions on yourself/your organization.

1. Type of business/organization

- ☐ Primary business — oil and gas exploration
- ☐ Contractor/consultant — oil and gas exploration
- ☐ Primary business — mineral exploration
- ☐ Contractor/consultant — mineral exploration
- ☐ Geophysical instrumentation
- ☐ University
- ☐ Utility (e.g., pipeline, energy)
- ☐ Federal government
- ☐ Provincial government
- ☐ International agency (e.g., World Data Centre, Bureau International de l'Heure)
- ☐ Other (*Please specify*) _____

2. Please indicate the number of geophysicists, geologists and other geoscientists in your organization (*Please exclude all students*)

Geophysicists _____

Geologists _____

Other geoscientists _____

3. Are you answering this questionnaire on behalf of yourself or your organization?

☐ Yourself ☐ Your organization

USE OF EARTH PHYSICS BRANCH OUTPUTS

4. Instructions for Question 4 — The questions in this matrix concern the use of Earth Physics Branch outputs by you/your organization. The outputs are grouped according to discipline and include:

— published papers

— in-house publications (e.g., open files, geomagnetic series, seismological series)

— maps

— raw or processed data, or information supplied on request

— seminars, papers given at symposia

— consultations, communications, verbal and written.

For each types of output please indicate your answers by circling the appropriate numbers for:

Frequency of Use — Please indicate how frequently you/your organization use (s) each type of output. If your answer is "Never", continue with the next type of output listed in the matrix.

Major Use -- Please indicate your/your organization's major use of each type of output.

Importance— Please indicate how important each type of output is to your activities.

Timeliness — Please rate your level of satisfaction with the timeliness of each type of output.

Reliability — Please rate your level of satisfaction with the reliability of each type of output.

If you use an Earth Physics Banch output not listed, please use the space provided at the end of the matrix labelled "Other" to describe the output. Also, provide answers for frequency of use, major use, importance, timeliness and reliability.

1

4. USE OF EARTH PHYSICS BRANCH OUTPUTS

EARTH PHYSICS BRANCH OUTPUTS	FREQUENCY OF USE				MAJOR USE			IMPORTANCE					TIMELINESS					RELIABILITY				
Data, information and research results on:	At least monthly	At least yearly	Less than once a year	Never	Source of data	Basic science and technology, ideas	Educational	Extremely important	Important	Somewhat important	Not important	Don't know/ no opinion	Very satisfied	Satisfied	Dissatisfied	Very dissatisfied	Don't know/ no opinion	Very satisfied	Satisfied	Dissatisfied	Very dissatisfied	Don't know/ no opinion
	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Seismicity and seismic risk (earthquakes)	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Other aspects of seismology	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Geothermal energy	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Permafrost and gas hydrates	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Magnetic field of the earth and forecasts of magnetic storms	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Gravity (including gravity maps)	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Geodynamics	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Marine geophysics	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Earth structure (seismic, gravity, heat flow, geomagnetic studies)	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Geophysical standards, calibration (use of facilities)	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Other (*please specify*)	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Other (*please specify*)	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5

5. Do you use the Earth Physics Branch Quarterly Index Supplement? (*See attached example*)

☐ Yes ☐ No

6. Do you use data from World Data Centres which originate from the Earth Physics Branch?

☐ Yes ☐ No ☐ Don't know

If your answers to Questions 4, 5 and 6 indicate that you/your organization do(es) not use Earth Physics Branch outputs, go to Question 7

If your answers to Questions 4, 5 and 6 indicate that you/your organization use(s) Earth Physics outputs, go to Question 8

USE OF EARTH PHYSICS BRANCH OUTPUTS (continued)

7. Why don't you use Earth Physics Branch outputs? (*Check all that apply*)

- ☐ Not aware that they exist
- ☐ Not related to work
- ☐ Problems with the outputs (e.g., poor quality, inadequate coverage)
- ☐ Problems with obtaining the outputs
- ☐ Other (*please specify*) _____

Please elaborate _____

Please go to Question 10

8(a). If the Earth Physics Branch outputs used by you/your organization were not available, would you replace them? (*check the answer that best reflects your situation*)

- ☐ Yes
- ☐ No — could not readily be replaced
- ☐ No — output not important enough to your activities to replace
- ☐ No — replacement would be too costly
- ☐ Other (*please specify*) _____

If your answer to Question 8(a) indicates that you/your organization would replace the Earth Physics Branch outputs, go to Question 8(b)

If your answer to Question 8(a) indicates that you/your organization would not replace the Earth Physics Branch outputs, go to Question 9

8(b). Please indicate which Earth Physics Branch outputs you/your organization would replace.

_____

8(c). Please indicate how you/your organization would replace these Earth Physics Branch outputs, if they were not available. Please state the approximate annual cost that would be incurred.

- ☐ Hire more staff $ _____
- ☐ Spend more on consultant services $ _____
- ☐ Other (*please specify*) $ _____

9. Please provide any comments on Earth Physics Branch outputs. We are particularly interested in learning about the uses which you/your organization make(s) of Earth Physics Branch outputs as indicated in Question 4.

_____

3

QUALITY OF SERVICE PROVIDED BY PERSONNEL OF THE EARTH PHYSICS BRANCH

The next series of questions concerns the quality of service provided by the personnel of the Earth Physics Branch, and includes personal contacts as well as those by letter or by telephone.

10. When was the last time you dealt with Earth Physics Branch personnel?

- ☐ Recently (less than 3 months)
- ☐ Between 3 and 6 months ago
- ☐ Between 6 months and a year ago
- ☐ More than a year ago: how long ago? _____ years
- ☐ Never (*go to Question 15*)

11. What were the circumstances?

- ☐ Seeking scientific or technical assistance or information
- ☐ Research contract or agreement with the Earth Physics Branch
- ☐ Field contract for the Earth Physics Branch
- ☐ Making use of facilities
- ☐ Joint research project with the Earth Physics Branch
- ☐ Other (*Please specify*) _____

_____

12. How often do you deal with Earth Physics Branch personnel?

- ☐ At least monthly
- ☐ At least yearly
- ☐ Less than once a year
- ☐ Other (*Please specify*) _____

13. Please rate your level of satisfaction with the following services provided by personnel of the Earth Physics Branch. (*Circle the appropriate number*)

Services	*Very satisfied* 1	*Satisfied* 2	*Dissatisfied* 3	*Very Dissatisfied* 4	*Not applicable* 5
Speed of response to requests	1	2	3	4	5
Usefulness of material received	1	2	3	4	5
Adequacy of communications with Earth Physics Branch personnel	1	2	3	4	5
Cooperation of Earth Physics Branch personnel	1	2	3	4	5

4

QUALITY OF SERVICE PROVIDED BY PERSONNEL OF THE EARTH PHYSICS BRANCH (cont'd)

14. Please provide any comments on the services provided by the personnel of the Earth Physics Branch.

_____

_____

_____

_____

_____

PROGRAM OF THE EARTH PHYSICS BRANCH

Questions 15 to 17 seek your opinions on the type of work and activities of the Earth Physics Branch.

15. Which of the following activities should be part of the mandate of the Earth Physics Branch? (*Please indicate your answer by checking "Yes" or "No"*)

Activity	Yes	No	Please specify which organization (private or government) should have this responsibility
Operation of observatories	☐	☐ ►	_____
Conduct of field surveys	☐	☐ ►	_____
Establishment of field standards	☐	☐ ►	_____
Reduction and interpretation of field data	☐	☐ ►	_____
Conduct of basic research (e.g., dynamics of the Earth's crust, geomagnetic field models)	☐	☐ ►	_____
Preparation of national maps of geophysical data	☐	☐ ►	_____
Maintenance of calibration facilities	☐	☐ ►	_____
Maintenance of national data bases (e.g., magnetic observatory data, gravity and crustal motion data)	☐	☐ ►	_____
Issuance of warnings of geophysical hazards	☐	☐ ►	_____
Publication of data and information on any of the items in this list	☐	☐ ►	_____

PROGRAM OF THE EARTH PHYSICS BRANCH (continued)

16. Are there any other activities that the Earth Physics Branch should undertake?

☐ Yes ☐ No

(Please comment)

17. Do you have any suggestions for improving the outputs and services provided by the Earth Physics Branch?

6

IDENTIFICATION AND BACKGROUND

18. To help us better understand your responses, please provide the following background information. The information will be used strictly for follow-up purposes (i.e., if we have any questions about your responses or suggestions, we may contact you for clarification).

Name of respondent: _____

Title/Position: _____

Name of Organization: _____

_____

Location/Address: _____

_____

_____

_____

Telephone: _____

Thank you for your time and cooperation.

Please return this questionnaire, using the self-addressed envelope, to:

The Secretary
Earth Physics Branch Review Committee
c/o Program Evaluation Branch
Department of Energy, Mines and Recources
580 Booth Street
Ottawa, Ontario
K1A 0E4

7

APPENDIX 2
List of survey participants

NAME	ORGANIZATION	LOCATION
ADAMS, David H.	Cominco Exploration	Calgary
AQUIN Thomas	Lmbds - Sidam Inc.	Montreal
ARAKI, Tohru	Koyoto Univ., Faculty of Sci.	Japan
BAILEY, R.C.	Univ. of Toronto, Dept. of Physics	Toronto
BARCLAY, W.	W.A. Barclay Exploration Services Ltd	Kingston
BARCLAY, William	Trilogy Resource Corp.	Calgary
BARLOW, R.B.	Ont. Geol. Survey, Geophy, Geo chem D.	Toronto
BATE, Simon	MPH Consulting Ltd.	Toronto
BECK, Alan E.	Univ. of Waterloo, Dept. of Geophys.	London
BECKER, A.	Univ. of California	Cal. USA
BEDIZ, P.I.	Bediz Expl. Cons. Ltd.	Calgary
BELL, T.	Drummond Petroleum Ltd.	Calgary
BERG, Brian A.	Energenics Exploration Ltd.	Calgary
BERGER, Milford L.	Texaco Canada Resources Ltd.	Calgary
BERUBE, Pierre	Sa gax Geophysique Inc.	Montreal
BLACKWELL, David	Sou. Methodist Univ., Dept. Geol. Sci.	Texas, U.S.A.
BLASCO, Steve	Geological Survey of Can., BIOG	Dartmouth
BLENKINSOP, John	Carleton Univ., Geology Dept.	Ottawa
BLUNDELL, D.J.	Chelsea Coll., Geology Dept.	London, Eng.
BOEY, Peter K.	Champlin Petroleum Co.	Calgary
BOTTOS, Frank	Urtec Instrument Sales	Markham
BOUILLON, Andre	Service D'Amenagement	Quebec
BRADLEY, Ward J.	Gulf Canada Resources Ltd.	Calgary
BRAGG, John	Seis - Pro & Consultants Ltd.	Calgary
BRISTER, M.	Husky Oil Operations	Calgary
BRUNDRIT, Dr.	Shell Canada Resources Ltd.	Calgary
BRUNE, James	Inst. Geophysics & Plan Physics	Cal. U.S.A.
BRUNETTI, Gino	Factory Mutual Engineering Assoc.	Cote St. Luc
BUCHANAN, R.G.	B.C. Govt., Min. of Transport	Victoria
BURKE, K.	Univ. of N.B., Dept. of Geol.	Fredericton
BURR, Douglas C.	Aqua Terra Consultants Ltd.	Calgary
BURTON, Garth B.	Garth B. Burton & Assoc.	Toronto
BURWASH, Ronald	Univ. of Alta., Dept. of Geol.	Edmonton
CAMERON, G.W.	Geological Survey of Canada	Ottawa
CAMPBELL, Douglas D.	Dolmage Campbell & Assoc (1975) Ltd.	Vancouver
CAMPBELL, Ralph H.	Texaco Canada Resources Inc.	Calgary
CANNON, Wayne H.	York University	Downsview
CARD, K.D.	Geol. Survey of Canada	Ottawa
CARSWELL, Duncan A.	Compagnie Generale de Geophysique	Calgary
CARTWRIGHT, Paul	Phoenix Geophysical Ltd.	Vancouver
CASS, Richard	Arvec Consulting Ltd.	Calgary
CAVEN, Robert J.		Don Mills
CHAKRACARTTY, Gopa	Esso Resources Can. Ltd.	Calgary
CHANDRA, James J.	Dept. of Nat. Resources, Geol. Surveys	Fredericton
CHAPMAN, David S.	Univ. of Utah, Dept. Geol. & Geophys.	Utah, U.S.A.
CHARLWOOD, R.G.	Klohn Leonoff Ltd.	Richmond
CHASE, Richard	Univ. of B.C., Dept. Geol. Sci & Oceon.	Vancouver
CHEN, David	Pan Canadian Petroleum Ltd.	Calgary
CHORNOPSKY, M.L.	Cdn. Reserve Oil & Gas Ltd.	Calgary
CHUNG HAI-MAN	Cdn. Superior Oil Ltd.	Calgary
CLARKE, Garry K.C.	Univ. of B.C., Dept. of Geo. & Ast.	Vancouver
CLINCK, John W.	Geophysical Services Inc.	Calgary
COLLETT, Leonard	Geol. Survey of Canada	Ottawa
COLVIN, Douglas J.	Anadarko Petroleum of Can. Ltd.	Calgary
COOPER, Norman M.	Mustagh Resources Ltd.	Calgary
CORBETT, J.D.	The Anaconda Co.	Colorado,USA
CRAIG, William A.	Husky Oil International Inc.	Calgary
CRONE, J. Duncan	Crone Geophysics Ltd.	Mississauga
CROSSLEY, David	McGill University	Montreal
CROUS, C.M.	Aberford Resources Ltd.	Calgary
CUMMING, G.L.	Univ. of Alta., Dept. of Physics	Edmonton

NAME	ORGANIZATION	LOCATION
DAHLMAN, O.	Res. Inst. of Nat. Defence	Sweden
DALY, Dennis J.	Home Oil Company Ltd.	Calgary
DARGIE, Barrie G.	Tricentrol Oils Ltd.	Calgary
DARNLEY, Arthur G.	Geol. Survey of Canada	Ottawa
DAVIES, Carole E.	Alberta Energy Co.	Calgary
DAVIES, J.L.	Mineral Resources Branch	Bathurst
DAVIS, Thomas L.	Colorado School of Mines	Col. U.S.A.
DAVITT, W.E.	Chevron Canada Resources Ltd.	Calgary
DE CAEN, R.F.B.	Husky Oil	Calgary
DELLECHAIE, Frank	O'Brien Resources Corp.	Cal. USA
DENSMORE, A.A.	Geol. Survey of Canada	Calgary
DERBOWKA, Robert M.	Shell Can. Resources Ltd.	Calgary
DERRY, Duncan R.	Derry, Michener, Booth & Wahl	Toronto
DEUTSCH, Ernst R.	Memorial Univ. of Nfld.	St. John
DIORIO, Peter	Utah Mines Ltd.	Toronto
DMITROCA, Walter	Mobil Oil Canada Ltd.	Calgary
DOREY, Kathleen	Boyd Exploration Consultants Ltd.	Calgary
DORNIAN, Nick	Dornian Consultants Ltd.	Calgary
DOSSO, H.W.	Univ. of Victoria, Dept. of Physics	Victoria
DOUGLAS, A.	UK Ministry of Defence	UK
DOWHANIUK, James	Can. West Nat. Gas Co. Ltd.	Calgary
DOYLE, Michael E.	Dome Petroleum Ltd.	Calgary
DRUMMOND, Kenneth J.	Mobil Oil Canada Inc.	Calgary
DRUMMOND, F.M.	Amoco Can. Petroleum Co. Ltd.	Calgary
DU BERGER, Reynold	Univ. du Que. A Chicoutimi	Chicoutimi
DUFF, Gordon C.	Atomic Energy of Canada	Mississauga
DUNCAN, D. R	Morrison Beatty Ltd.	Toronto
DUNLOP, D.J.	Univ. of Toronto, Dept. of Physics	Toronto
EBEL, John E.	Weston Obs., Boston College	Mass., U.S.A.
EBNER, Erwin	Petro-Canada Resources	Calgary
EHRLICH, Marvin	Marvin Ehrlich Consult. Eng.	Washington,USA
EINARSSON, T.D.	Geophysical Service Inc.	Texas,USA
ELLWOOD, Brooks B.	Univ. of Georgia, Dept. Geology	Ga. U.S.A.
ENG, George	Placer Cego Petroleum Ltd.	Calgary
EVANS, A.H.	Amoco Petroleum Corp.	Calgary
EWING, G.N.	Dept. of Fisheries & Oceans	Ottawa
FARQUHAR, R.M.	Univ. of Toronto, Physics Dept.	Toronto
FARRAR, Edward	Queens Univ., Dept. of Geol. Sc.	Kingston
FENWICK, D.K.Bruce	Voyager Petroleums Ltd.	Calgary
FERRIS, Craig	Gravimetrics Inc.	Okla. USA
FILO, John J.D.	Cambrian College	Sudbury
FISCHER, Alfred	Gulf Canada Resources Ltd.	Calgary
FISCHER, Gaston	Observatoire Cantonal	Suisse
FOLINSBEE, R.Allin	Petro Canada	Calgary
FOO, Wayne	Chevron Canada Resources Ltd.	Calgary
FORTIN, Gilles	Geomines Ltée	Montréal
FRANCHETEAU, Jean	Deolen Locmaria-Plouzane	France
FULOP, Joseph (Rev.SJ)		Toronto
FURLONG, Kevin P.	Penn. State Univ.,Dept. Geoscience	Pa. U.S.A.
GAGNON, Pierre	Univ. Laval, Dept. Geodesie et Cart.	Quebec
GAUCHER, Edwin	E. Gaucher & Associates	St. Foy
GENDZWILL, Don	Univ. of Sask., Dept. of Geology	Saskatoon
GIRDLER, Dr. R.W.	School of Physics	U.K.
GLOVER, Wayne	Shell Canada Resources Ltd.	Calgary
GREENHOUSE, John	Univ. of Waterloo, Dept. Earth Sc.	Waterloo
GREF, Beverley S.	Petro-Canada	Calgary
GREGORY, A.F.	Gregory Geosciences Ltd.	Ottawa
HAJNAL, Z.	Univ. of Sask., Dept. of Geol. Sci.	Saskatoon
HALLE, Francois	Mesures d'Urgences Municipales	Valleyfield
HALPENNY, Frank	Cdn. Superior Oil Ltd.	Calgary
HALVORSEN, R.A.	Suncor Inc. Resources Grp.	Calgary
HARROW, G.A.	Dupont of Can. Explor. Ltd.	Vancouver
HAWORTH, Richard T.	Instit. of Geol. Sciences	U.K.

NAME	ORGANIZATION	LOCATION
HAYATSU, A.	Univ. of Western Ont.,Dept.Geoph.	London
HAYLES, J.G.	Atomic Energy of Canada Ltd.	Ottawa
HEDGES, J.R.	Export Development Corp.	Ottawa
HENDRY, Ken	Cominco Ltd.	Toronto
HENLEY, David C.	Shell Canada Resources Ltd.	Calgary
HERRMANN, Robert B.	St. Louis Univ., Dept. Earth & At.Sc.	Miss., U.S.A.
HERZ, Alex	Hertz Industries Ltd.	Toronto
HINCH, Alan J.	A.J.Hinch Consultants Ltd.	Calgary
HOBSON, G.D.	Polar Continental Shelf Project	Ottawa
HOFFMAN, Paul F.	Geological Survey of Canada	Ottawa
HOLDER, Andrew P.	Home Oil Co. Ltd.	Calgary
HONG, Marie	Chevron Canada Resources Ltd.	Calgary
HORNE, E.A.	Rangland Resources Ltd.	Calgary
HORNFORD, H.E.	H.E.Hornford Geophysical Cons.	Calgary
HOWELL, Eric C.	Norcen Energy Resources Ltd.	Calgary
HOWELLS, Kenneth	N.S. Research Foundation, Geo.Div.	Dartmouth
HRYCYK, Victor W.	Regency Resources Ltd.	Calgary
HUME, James R.	Home Oil Co. Ltd.	Calgary
HUNTLEY, Ross	BP Exploration Can. Ltd.	Calgary
HUTCHISON, Dave	NAJ Exploration Ltd.	Calgary
JACKSON, J.H.	Teledyne Exploration Ltd.	Calgary
JACKSON, H.Ruth	Atlantic Geosc. Centre	Dartmouth
JAGODITS, F.C.	Excalibur Int. Cons. Ltd.	Mississauga
JAIN, Sudhir	Commonwealth Geoph. Dev.C.	Calgary
JENSEN, Oliver G.	McGill Univ., Dept. of Geol. Sc.	Montréal
JOHNSON, Ian M	Scintrex Ltd.	Concord
JOSE, Barrie F.	Esso Resources Canada Ltd.	Calgary
JUSTICE, James	Univ. of Cal.,Dept. of Geol. & Geophys.	Calgary
KANAMORI, H.	California Inst. Seismological Lab	Cal. USA
KATAY, John	Petro Canada Exploration Inc.	Calgary
KATIGEMA, F.D.	Sunco Inc. Resources Grp.	Calgary
KAY, Anthony	Hardy Associates (1978) Ltd.	Calgary
KEEN, C.E.	Atlantic Geoscience Centre	Dartmouth
KELSCH, W. Lorne	Pan Canadian Petroleum Ltd.	Calgary
KERR, Aubrey	AK Assosciates Ltd.	Calgary
KHAN, Dr. N.A.	Bennett Bldg., The Univ.,Dept.Geol.	U.K.
KIERULE, Frederick	Husky Oil Operations Ltd.	Calgary
KILTY, S.	Dighem Ltd.	Toronto
KIM, Isaac	Scripps Instit. c/Oceanography	Ca. USA
KIMMINS, Reginald L.	Mobil Oil Canada Ltd.	Toronto
KIRKBY, S.C.	EDA Instruments Inc.	Toronto
KLASNER, John	Dept. Geol., West Illinois Univ.	Ill., U.S.A.
KNAPIK, Dennis W.	D. Knapik Geophysics Ltd.	Calgary
KNOLL, Frank	Nicolet, Chartrand, Knoll	Montreal
KONINGS, Marcel H.	Questor Surveys Ltd.	Mississauga
KRAMERS, J.W.	Alta. Research Council	Edmonton
KRAUSE, B.R.	Cdn. Nickel Co. Ltd.	Copper Cliff
KREBES, Edward S.	Univ. of Calg., Dept. Geol.& Geoph.	Calgary
KROUSE, H. Roy	Univ. of Calgary, Physics Dept.	Calgary
KRYZAN, Andrew Z.	Gulf Canada Resources Ltd.	Calgary
LACHAPELLE, Gerard	Nortech Surveys (Canada) Inc.	Calgary
LAHR, John	U.S. Geol. Survey, Off. of Earthqu.	CA., USA
LAING, William E.	Conoco Inc.	Texas, USA
LANGE, A.G.	Sask. Oil	Regina
LANGLEY, Richard B.	Univ. of N.B.,Dept. of Survey Eng.	Fredericton
LAURIDSEN, E.Kring	Danish Meteorological Institute	Denmark
LAWTON, Dr. D.C.	Univ. of Cal., Dept. of Geol. & Geoph.	Calgary
LAZIB, Andre A.	Pan Canadian Petroleum Ltd.	Calgary
LEBLANC, Gabriel A.	Weston Geophys. Corp.	Mass. U.S.A.
LECOMTE, Paul	Hydro-Quebec	Montreal
LEE, Albert	Cdn. Superior Oil Ltd.	Calgary
LIZOTTE, Henri	Soquip	Ste. Foy

NAME	ORGANIZATION	LOCATION
LEE, L.O.	Canada Exploration Ltd.	Calgary
LESLIE, John A.	Geological Consultants	Bedford
LEWIS, Alan C.	Husky Oil Operations Ltd.	Calgary
LEWIS, C.F.M.	GSC, Atlantic Geoscience Centre	Dartmouth
LIMION, H.	Newmont Expl. of Can. Ltd.	Toronto
LINARD, John R.	Shawinigan Consultants Inc.	Montréal
LINDSETH, Roy	Teknica Resources Dev.	Calgary
LINSSER, Helmut	Linsser Geophysical Services	Calgary
LIZOTTE, Henri	Soquip	Ste-Foy
LODHA, Ganpat S.	Canterra Energy Ltd.	Calgary
LUND, John W.	Oregon Inst. Tech.,Geo-Heat Util. Ctr.	Oregon,USA
MACDONALD, W.D.	S.U.N.Y., Dept. Geology	NY, U.S.A.
MACKEITH, Neil J.	Bow Valley Industries Ltd.	Calgary
MACNAB, Ron	Bedford Institute of Ocean.	Dartmouth
MADOKORO, Dennis G.	Skandia Reinsurance	Toronto
MAIR, J.A.	Dome Petroleum	Calgary
MAJUMDAR,S.C.	Esso Resources Canada Ltd.	Calgary
MARKS, Larry W.	Shell Canada Resources Ltd.	Calgary
MATHEWS, W.H.	Univ. of B.C., Dept. of Geology	Vanc.
MATTHEWS, Larry	Amoco Canada Petroleum Co. Ltd.	Calgary
MAYER, G.M.	Ivaco Inc.	Marieville
MAYERS, I. Richard	Suncor Inc.	Calgary
MCCAFFREY, Greg	Golden Eagle Oil & Gas Ltd.	Calgary
MCCANCE, John A.		Willowdale
MCKELLAR, Roger	Pika Marine Enterprises Ltd.	Vanc.
MCKEVITT, W.E.	H.A. Simons Internat. Ltd.	Vanc.
MCMULLAN, S.R.	Uranerz Expl. & Mining Ltd.	Saskatoon
MCNEILL, J.D.	Geonics Ltd.	Mississauga
MEREU, R.F.	Univ. of Western Ont.,Dept. Geoph.	London
MILNE, V.G.	Ontario Geological Survey	Toronto
MONAHAN, David	Cdn. Hydrographic Service,EMR	Ottawa
MOON, Wooil	Univ. of Manitoba, Dept. Earth Sc.	Winnipeg
MORAVER, A. R.	Carleton Univ., Geol. Dept.	Ottawa
MORELLI, Carlo	Univ. di Triese, Inst. Miniere Geof.	Trieste,Italy
MORGAN, K.A.		Willowdale
MORGAN, Paul	Purdue Univ., Dept. Earth Sc.	IN., U.S.A.
MORRIS, Drew	Union Oil Company of California	Alaska
MORRIS, Leslie D.	Geomagnetic Data Centre	Boulder,Co.
MORROW, William	Amoco Canada Petroleum Co.Ltd.	Calgary
MURRAY, Gordon H.	North West Hydrographic Surveys Ltd.	Surrey
NATRUE, L.	Pan Canadian Petroleum	Calgary
NELSON, C.S.	Esso Resources (Can.) Ltd.	Calgary
NICHOLLS, James	Univ. of Calgary, Geol & Geophys. Dept.	Calgary
NYBERG, C.B.	Gulf canada Resources Ltd.	Calgary
NYLAND, Edo	Univ. of Alta., Inst. of Earth & Pl.Ph.	Edmonton
OAKLEY, William	W.M. Oakley & Associates Ltd.	Calgary
O,BRIEN, L.J.	EMR, Surveys & Mapping, Geodetic Div.	Ottawa
OLDENBURG, Doug	Univ. of B.C., Dept. Geoph. & Ast.	Vanc.
OLSEN, Elizabeth A.	Cdn. Occidental Petroleum	Calgary
OPDYKE, Neil D.	Univ. of Florida, Dept. of Geol.	Florida, USA
ORGNERO, U.J.	Amoco Canada Petroleum Co.	Calgary
ORR, Archie C.	Empress Exploration Consult.	Calgary
O'HARA, Thomas F.	Yankee Atomic Electric Co.	Ma., USA
PALMASON, Gudmundur	Orkustofnun, Grensasvegur	Iceland
PAMENKA, J.	Dome Petroleum	Calgary
PAP, Andrew	Amoco Canada Petroleum Co. Ltd.	Calgary
PAPAZACHOS, B.C.	Univ. of Thessaloniki, Geophys.Lab.	Greece
PARROTT, Richard J.E.	Oil Co. of Australia, N.L.	Australia
PARSNEAU, Paul	Dome Petroleum Ltd.	Calgary
PATERSON, Norman R.	Paterson, Grant & Watson Ltd.	Toronto
PAVLIK, Bohuslav	Urtec Ltd.	Markham
PAYNE, J.G.	RMB Technical Services Ltd.	Montreal West
PEIRCE, Dr. J.W.	Gravity Magnetics Group	Calgary

NAME	ORGANIZATION	LOCATION
PELLETIER, B.R.	Geological Survey of Canada	Ottawa
PELTIER, W.R.	Univ. of Toronto, Dept. Physics	Toronto
PEMBERTON, R.H.	Noranda Exploration Ltd.	Toronto
PEZARRO, T.A.	TA Pezzaro and Assoc. Ltd.	Calgary
PHILLIPS, Bonnie	Union Texas Petroleum	Texas, U.S.A.
PINCHIN, Edwin J.	Merland Explorations Ltd.	Calgary
PITCHER, Douglas	Ontario Geological Survey	Toronto
POCZYNIAK, C.A.	Carruthers & Wallace Ltd.	Rexdale
PODMORE, Francis	Univ. Zimbabwe, Physics Dept.	Zimbabwe
PORTSMOUTH, Jackie	Canadian Superior Oil Ltd.	Calgary
POWERS, William H.	Marsus Exploration Ltd.	Halifax
PROCTER, J.E.	Dome Petroleum Ltd.	Calgary
PROVINS, D.	Gulf Canada Resources Ltd.	Calgary
PUNSTEL, Neil O.	Geo. Instruments	Tottenham
RANALLI, G.	Carleton Univ., Dept. Geology	Ottawa
RAPP, Richard H.	Ohio State Univ., Dept. Geodetic Soc.	Ohio, U.S.A.
READ, Peter B.	GeoTex Consultants	Vancouver
READER, John F.	Nevin Sadlier - Brown Goodbrand Ltd.	Vancouver
RECTOR, R.J.	Gulf Canada Resources Ltd.	Calgary
REDEKOP, Glen	Canadian Superior Oil Ltd.	Calgary
REDMOND, W.R.	Enertec Geophysical	Calgary
REESOR, T.R.	Chevron Canada Resources Ltd.	Calgary
REILLY, George A.	Urangesellschaft Canada Ltd.	Toronto
RILEY, C.J.	Eldorado Resources Ltd.	Ottawa
ROBB, G.A.	Home Oil Company Ltd.	Calgary
ROSE, Jeff	Texaco Canada Resources Ltd.	Calgary
ROTH, Murray	Geophysical Services Inc.	Calgary
RUFFMAN, Alan	Geomarine Assoc. Ltd.	Halifax
RUSH, Charles M.	Institute of Telecomm. Science	Co., USA
RUSSELL, R.D.	Univ. of B.C.,Dept.Geoph. & Ast.	Vancouver
RUSSELL, David J.	Forest Oil Corp.	Ok., USA
RUSSELL, Brian H.	Veritas Seismic Ltd.	Calgary
RUYGROK, Gerald M.	Mobil Oil Canada Ltd.	Toronto
SAMSON, Laval	Terratech, une div. de SNC Inc.	Montréal
SAVAGE, P.J.	Pan Canadian Petrol	Calgary
SAWYER, Charles S.	Merland Explorations Ltd.	Calgary
SAWYER, Chester G.	Rochester Resources Ltd.	Calgary
SAXOV, Svend	Findlandsgade 6, Lab Geophysics	Denmark
SCLATER, John G.	Mass. Inst. of Tech.	Mass.,U.S.A.
SCOTT, W.J.	Hardy Associates (1978) Ltd.	Calgary
SEXSMITH, R.	Riocanex Ltd.	Toronto
SHAW, Kenneth L.	Union Oil Company of Canada Ltd.	Calgary
SHEPPARD, R.H.	Ameranda Minerals Corp.	Calgary
SINGH, Ronald	Mountain Minerals Co. Ltd.	Lethbridge
SLAYMAKER, Olav	Univ. of B.C., Dept. Geography	Vancouver
SMITH, James A.	J.A.S. Explor. Conslt. Ltd.	Calgary
SNEDDON, D.T.	Alta. Forest Service	Spruce Grove
SOUTHER, J.G.	Geological Survey of Canada	Vancouver
STANGER, Ron	Mobil Oil Canada Ltd.	Calgary
STAUDER, J.	B.C. Hydro & Power Auth.	Vancouver
STAUFFER, M.R.	Univ. of Sask.,Dept. Geol. Sc.	Saskatoon
STEENLAND, Nelson C.	Geophysical Explor. Corp.	Texas,USA
STEMP, R.W.	Kenting Earth Sciences Ltd.	Ottawa
STEPHENSON, R.	Australian Nat. Univ.	Australia
SWAB, M.E.	M.E. Swab Holdings Ltd.	Calgary
SYDORA, Larry J.	Chevron Geosciences Ltd.	Cal.,USA
SYKES, Gerald J.	ICG Vista Resources Ltd.	Calgary
SYMONS, D.T.A.	Univ of Windsor, Dept. Geology	Windsor
SZEWCZYK, Z.J.	Mobil Oil Explor. S.E.	Louis, USA
TESKEY, D.J.	Geological Survey of Canada	Ottawa
TESSMAN, John D.	Western Geophysical Co. of Can.	Calgary
THOMPSON, J.G.	Panarctic Oils Ltd.	Calgary

NAME	ORGANIZATION	LOCATION
THOMSON, David James	Defense Research Establishment Pacific	Victoria
THORNTON, J.	Placer Development Ltd.	Vancouver
THORPE, Ralph	Geological Survey of Canada	Ottawa
THORPE, John E.	Canterra Energy Ltd.	Calgary
THURSTON, P.C.	Min. of Nat. Res.	Toronto
TIMLECK, P.	Communications Res. Ctr.	Ottawa
TREMBLAY, Pierre	Petro Canada Explorations Inc.	Calgary
UFFEN, J. Douglas	Texaco Canada Resources Ltd.	Calgary
VAN EVERDINGEN, R.O.	National Hydrology Research Inst.	Calgary
VAN HEES, Ec	Pamour Porcupine Mines Ltd.	Timmins
VAN WAGONER, Nancy A.	Acadia Univ., Dept. of Geology	Wolfville
VERDIEL, M.A.	Amoco Canada Petroleum Co. Ltd.	Calgary
VIGRAS, Laurence W.	Univ. of Regina, Dir. of Energy Res.	Regina
VOHRA, D.R.	Petro Canada Exploration Inc.	Calgary
VON ENGELHARDT, Wolf	Mining Petrograph Institute	West Germany
WALKER, James A.	Walker Exploration Ltd.	Mississauga
WALMSLEY, Mark E.	Pedology Consultants	Victoria
WASILENKOFF, J.M.	Energics Explor. Ltd.	Calgary
WATANABE, T.	Univ. of B.C., Dept. Geophys. & Ast.	Vancouver
WATSON, J.C.	Shell Canada Resources Ltd.	Calgary
WEBER, W.	Min. Res. Div.	Manitoba
WEIR, H.	Memorial University, Dept. Physics	St. Johns
WEIR, Ronald M.	Norcen Energy Resources Ltd.	Calgary
WELCH, Donald E.	Golder Associates	Mississauga
WEST, G.F.	Univ. of Toronto, Dept. Physics	Toronto
WHITAKER, Sidney H.	Atomic Energy, Whiteshell Nuclear Res.	Pinawa
WHITE, Dwaine	Kahnawake Dev. Res. Prog.	Kahnawake
WHITING, Pat	Pegasus Earth Sensing Corp.	
WICHERTS, Eric	Amoco Canada Petroleum	Calgary
WILCOX, Dr. L.	Defense Mapping Agency Aerospace Centre	Mo., U.S.A.
WILLIAMS, H.	Memorial University, Dept. Geology	St. Johns
WILSON, J.R.	Comer & Wilson Ltd.	Calgary
WINSOR, Robin	Gulf Canada Resources Ltd.	Calgary
WITHERLEY, Ken	Utah Mines Ltd.	Toronto
WONG, C.L.	Dept. of Highways & Transportation	Winnipeg
WOODFORD, Dennis	Manitoba Hydro	Winnipeg
WOODSIDE, J.M.	Atlantic Geoscience Centre	Dartmouth
WOOTON, Arthur	The Consumers Gas Co. Ltd.	Scarborough
WREN, Easton	Petrel Consultants Ltd.	Calgary
WRIGHT, James A.	Memorial University, Dept. Physics	St. Johns
WRIGHT, James L.	Sulpetro Minerals Ltd.	Toronto
YOUNG, Keith	Alberta Energy Co. Ltd.	Calgary
ZOETEMELK, J.M.A.	Shell Canada Resources Ltd.	Calgary