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Aller au sommaire du numéro

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APPENDIX

Allocation Report (1994) prepared by the Earth Sciences Grant Selection Committees of the Natural Sciences and Engineering Research Council of Canada (NSERC) as part of a research grant budget reallocation process. The report provides a status report for the discipline and a vision for the future.

EARTH SCIENCES ALLOCATION REPORT

Introduction

Earth scientists study the constitution, function and evolution of the Earth, from its gaseous envelope to its deep interior. The breadth of the subject matter makes Earth sciences a highly diverse discipline with close links to most other sciences. Research progress requires a high degree of interaction between Earth scientists in different subdisciplines.

Canada has the second largest landmass in the world, and the longest coastline of any nation. The land embraces vast wealth in the form of ore, hydrocarbon and industrial mineral deposits, and freshwater, and the continental shelf of the adjacent oceans remains to be thoroughly explored. The land area includes 25% of all ice-free Arctic/sub-Arctic terrain on the planet, exhibiting geographical and ecological features that are unique. It is essential, and should be axiomatic, that Canada trains sufficient Earth scientists to realize the economic potential of, and to be effective stewards of, this national heritage.

Canada's standing in the world economy is sustained in large measure by the exploitation of its natural resources, including minerals, energy, forests, soils and fisheries. Earth sciences have been crucial in locating, understanding, and developing this wealth. As easily exploited resources become more scarce, competition intensifies, and regulations for environmental protection more stringent, a thorough knowledge of Earth sciences is required to enhance Canada's position in the global economy and to ensure that the appropriate decisions are taken to maintain a healthy environment.

Historically, studies of the core, mantle, crust, land surface, oceans, cryosphere and atmosphere have tended to evolve as separate disciplines. However, the advent of plate tectonics as a unifying theory of the Earth, together with the current concern about global-scale environmental issues, has produced an unprecedented integration of geological sciences, geophysics, geodesy, physical geography, hydrology, soil science, oceanography and atmospheric science into a single overarching subject - Earth sciences. The intellectual challenge of understanding Earth processes on local, regional and global scales has become more urgent as society struggles to minimize the adverse effects of environmental change.

Canadian Earth scientists are responsible for a disproportionately large share of the world's publications in the discipline [1]. In the latest available international comparison (1986), Canadian Earth and space scientists attained the largest share of scientific output, relative to our GERD (Table 1), had the largest Revealed Comparative Publication Advantage (RCPA, Table 2), and had the second largest growth in this share over the period 1983-86. This impact is emphasized in a national comparison with other disciplines (Table 2), which shows that Canadian Earth and space sciences have the second highest RCPA after Biology among the fields indicated. These results are reinforced by the fact that the Canadian Journal of Earth Sciences and the Canadian Journal of Fisheries and Aquatic Sciences have the highest impact factors amongst Canadian science journals (ISI Citation Summary), and by analyses of the national publication patterns of individual international Earth sciences journals given in the reports that follow. In proportion to the resources invested, Canadian Earth scientists are the international leaders of the discipline.

Earth scientists have been awarded a total of 10 of the prestigious E.W.R Steacie Memorial Fellowships since the award was first made in 1966. NSERC's newest medal, the Canadian Gold Medal for Science and Engineering, has been awarded to two chemists, an engineer and an Earth scientist (W.S. Fyfe, 1992-93). Beginning with H.V. Warren in 1969, Earth scientists have received 10% of the 132 Canada Council Killam Research Fellowships awarded since 1968 to scientists and engineers. The number of these premier awards is out of proportion to the size of the Earth sciences community, and is an indication of the national standing of the discipline amongst the sciences.

The American Geophysical Union, with 30,075 members of whom 1,534 are Canadians, is the premier international association for solid Earth geophysics, volcanology, mineral physics, physical and chemical oceanography, hydrology and space physics. It publishes three international journals with very high Impact Factors (Journal of Geophysical Research, Geophysical Research Letters and Water Resources Research). 2.7% of the members are Fellows of the Union, and no more than 0.1% of the total membership can be so elected each year. Canadian geophysicists comprise 2.5% (15) of the Fellows: outside the United States (84% of Fellows), only the United Kingdom has a greater number (20). J.Tuzo Wilson was the President in 1980-82, the only non-U.S. scientist so honoured. Canadians have also won a large share of the Union and section awards, including 2 of the 16 Walter Bucher Medals (J.T. Wilson in 1968 and E. Irving in 1979), 2 of the 69 Macelwane Awards (R.A. Freeze in 1973 and J.L. Smith in 1987), one of the 17

Table 1. National share of world scientific output by field, 1986[1]

Country	GERD*	Biology	Chemistry	Physics	Earth/ Space	Engineering	Maths	All Fields
Canada	**5.962**	**1.409**	**0.520**	**0.520**	**1.124**	**0.822**	**0.788**	**0.738**
France	17.871	0.173	0.313	0.364	0.241	0.201	0.263	0.274
W Germany	26.167	0.164	0.264	0.264	0.153	0.268	0.302	0.222
Japan	46.627	0.139	0.229	0.184	0.079	0.272	0.073	0.165
Netherlands	4.313	0.441	0.325	0.348	0.348	0.232	0.441	0.417
UK	16.743	0.567	0.340	0.334	0.472	0.448	0.448	0.490
USA	127.855	0.298	0.174	0.237	0.333	0.292	0.315	0.278

[1]. *Data are normalized to Gross Expenditures on Research & Development (GERD) for each country.*
* *GERD in Billion $PPP (Purchasing Power Parity) for 1987 (Source: OECD Main Science & Technology Indicators, 1993, Part 2, Paris).*

Table 2. Revealed comparative publication advantage by field* for 1986[1]

Country	Biology	Chemistry	Physics	Earth/ Space	Engineering	Maths
Canada	**1.92**	**0.71**	**0.71**	**1.54**	**1.12**	**1.08**
France	0.64	1.15	1.34	0.89	0.74	0.96
W Germany	0.74	1.18	1.18	0.69	1.20	1.35
Japan	0.85	1.39	1.12	0.48	1.65	0.44
Netherlands	1.05	0.74	0.88	0.83	0.53	1.05
UK	1.16	0.70	0.68	0.96	0.91	0.91
USA	1.07	0.62	0.85	1.20	1.05	1.13

* *RCPA = (Country A's share of publications in field X)/(Country A's share of publications in all fields)*

Maurice Ewing Medals (J.T. Wilson in 1980), and 3 of the 50 R.E. Horton Awards (R.A. Freeze in 1971 and 1973 and J.A. Cherry in 1985).

The Geological Society of America is the second largest Earth sciences society, with 13,669 full-time members of whom 2,910 are fellows. Canadians comprise 3.3% of members and 5.4% of fellows. 9.6% of its Presidents have been Canadians, the most recent being R.A. Price (Queen's) in 1990; J. Tuzo Wilson received the society's premier award, the Penrose Medal in 1968, and other awards (Arthur Day Medal, Meinzer Award, Kirk Bryan Award) have had a disproportionately high number of Canadian recipients.

The Society for Sedimentary Geology is the premier society in its field, with a total membership of 4,472, of whom 348 (7.8%) are Canadians. The first non-U.S. President of the society, N.D. James (Queen's), took office this year. The Pettijohn Medal, the society's distinguished award for sedimentology, was awarded this year to G.V. Middleton (McMaster).

Canadian Earth scientists also serve prominently on several ICSU unions and committees, including two of the largest and most active scientific associations in the world, the International Union of Geodesy and Geophysics (G.A. McBean, AES, formerly UBC) is on the 6-member Bureau and the International Union of Geological Sciences (W.G.E. Caldwell, Western Ontario) has recently ended his term as one of the 10 officers, and W.S. Fyfe (Western Ontario) has assumed the Presidency for 1992-96). In addition, Canadian Earth scientists serve as officers of the constituent associations of a wide range of these Unions. Notably, J.R. Mackay was the first Secretary-General of the International Permafrost Association (1983-1993).

While the research of individual Canadians has been especially productive in Earth sciences (and while continuing support for individual efforts is vital to maintain a researcher's autonomy), a significant trend in recent years has been the rapid growth of multi-disciplinary, collaborative research programs in Earth sciences. A particularly good example of this development is Canada's LITHOPROBE project, which is regarded internationally as the model for the conduct of interdisciplinary Earth sciences research programs. The Ocean Drilling Program, another major interdisciplinary endeavour, involves collaboration between several countries to study the geology and geophysics of the deep-sea floor, the deep sea sedimentary record and the oceanic lithosphere. Other international programs dealing with global aspects of environmental sciences and the biosphere are developing rapidly. Canadian researchers are either already involved, or are poised to play important roles in such activities. Collaboration is a particular strength of Canadian Earth sciences research.

Two Grant Selection Committees serve Canadian Earth scientists, one for the Solid Earth (Committee 08) and one for the Environmental Earth Sciences (Committee 09). Two Allocation Reports, with this common Introduction, provide a full image of the community as well as the particular challenges facing the two sectors. However, the work of researchers across the whole field of the Earth sciences is relevant to almost all other scientists who study the Earth and, for that matter, other planets. The study of fluid dynamics, for example, is relevant to groundwater, ocean and atmospheric circulation (all Committee 09), and the behaviour of the Earth's core (Committee 08). Stable and radiogenic isotopes are studied by economic geologists and petrologists (08), geochronologists (both committees), hydrologists, marine geochemists and soil scientists (all 09), and much of this work, in turn, is relevant to understanding the composition and chemical evolution of the Earth (08). Much of the major equipment base is shared by Earth scientists from both committees and applications for new equipment are judged jointly by them. Until recently (1989), there was only one Earth Sciences Grant Selection Committee, so we report here aspects of discipline dynamics and personnel trends for which there is insufficient historical basis to make separate commentaries for Environmental and Solid Earth Sciences.

Discipline Dynamics

The Earth sciences are a major discipline within the NSERC community. The group ranks second in proportion (8.2%) of research grants and infrastructure funds distributed, but it also has one of the largest participant groups in the NSERC system, so that the average grant size in the Earth sciences falls very close to the overall average. Earth sciences is one of the few groups in which the number of renewal grants has declined significantly over a decade. This reflects the increasing commitment of the Grant Selection Committees to fund leading researchers at internationally competitive levels while maintaining broad participation to ensure effectiveness of advanced training, identify emerging excellent scientists, and allow newcomers a fair chance upon entering the system.

Comparison of the average performance of Earth scientists with those in other disciplines masks significant trends within the Earth sciences community. Demographic evolution and the funding strategy described above have reduced applicants' success rates over a decade from 72.6% to 69.6%: the group has entered the range of "low success rates" (less than 70%) and is lowest among the physical sciences. These circumstances are causing significant discouragement and loss of good scientists from the lower end of the funding spectrum. On the other hand, the leverage achieved by Earth science grantees, now averaging 2.95 (ratio of total funding to Research Grant level) for the top 10% of researchers, is higher than that of any other non-engineering group. International leverage is remarkably high (18% of all levered funds in 1993-94), reflecting both the international character of Earth sciences and the international standing of Canadian Earth scientists. High leverage means that Earth scientists' reliance on Research and Infrastructure grants appears relatively low (54.2% of total NSERC funds in 1992-93). However, in Earth sciences, the continuation of basic research is vital to nearly every grantee to achieve leverage because the application of the research is relatively immediate (in mineral exploration or environmental management, for example). Leverage in the Earth sciences may also change dramatically in the short term. The federal government (through the Geological Survey of Canada) and some provincial governments (notably Ontario) have recently cancelled subvention programs for Earth sciences. We have already observed research programs handicapped by such sudden developments.

Superficially, discipline demography appears to be average. NSERC estimates that the average annual turnover of Earth sciences university faculty in the period 1994-2000 will be 4.1% of 1991 members. However, this does not reflect the demography of the Earth sciences grant population. The proportion of grantees over (estimated) 60 years of age is low (5.8%, versus 7.3% in the NSERC community), so there will be a relatively low rate of retirement in the remainder of the decade. On the other hand, there is a demographic "bulge" in the 35-44 years age cohort (38.7% versus 32.1% in the overall community). In the Earth sciences, this is the period when most international leaders emerge. We need to fund a large new generation of the best performers in the next half-decade to ensure the continuing international effectiveness of Canadian Earth sciences.

Highly Qualified Personnel

The supply and the demand for Earth scientists over the next decade are out of phase, reflecting the length of the recent economic recession and the cyclical nature of employment in a resource economy. Student enrollments in conventional Earth sciences undergraduate programs have fallen by roughly 20% over the last 10 years (NSERC Highly Qualified Personnel (HQP) Tables 1 and B1). But enrollments in Master's programs have remained steady, and the number of doctoral students has increased substantially (HQP Table 2). Projections of enrollments show no significant change over the next 5 years (HQP Table 5).

It appears that the demand for Earth scientists will also be sustained. In the universities, the percentage of recently advertised positions in Earth sciences ranks 4th among all science and engineering disciplines (HQP Table 28). Faculty departures projected to 2000 amount to 25% of total positions.

A second source of demand for Earth sciences graduates is in government departments, where the retirements in Earth sciences-related areas over the next decade will be high (HQP Table 44). In Earth sciences, a great deal of the basic R&D is carried out by government; in Canada mostly by the Geological Survey of Canada. Provincial Geological Surveys maintain significant R&D efforts, and there are considerable Earth sciences activities in Environment Canada, Agriculture Canada, and the Department of Fisheries and Oceans. Hence, the "market" for Earth sciences skills will be larger than the figures for traditional geological and geophysical activities suggest. Data in HQP (pages 73-75) indicate that there will be high demands for qualified personnel in the federal government early in the next century, but this prospect must be tempered by the likely continuing efforts of governments to downsize.

The demand for scientific personnel in the private sector is very difficult to quantify. The recessionary period since 1986 has seen dramatic down-sizing of most R&D activities and radical restructuring in the mineral and petroleum industries. Mining is not an R&D intensive industry and most R&D in the petroleum and related industries is done outside Canada. However, recruitment is expected for new industrial exploration activities, notably for diamonds, rare earth metals and hydrocarbons. A study carried out in 1992 [3] shows that the demand for highly qualified personnel in the upstream oil and gas industry will exceed supply from 1997 until 2000 and beyond in many sectors of the industry.

More generally, Canada's resource industries have been the mainstay of the country's prosperity, and they remain our strongest asset in the international marketplace. They are widely regarded as a key to the country's capacity for wealth creation [4], and are currently the largest contributors to the positive trade balance (almost $25 billion). They are responsible for 45% of total exports and they provide 16% of all jobs. The resource industries provide the origin and stable base for successful international consulting and exploration activities, which have grown 20 fold since 1975 [4]. Canadian mining companies have had considerable success in adding value to their products, and are pioneering novel processes, such as biotechnology, for metal recovery. In view of the mature stage of the minerals industry (sensu [2]) in Canada and the country's excellent research infrastructure in Earth sciences, the Canadian mineral and petroleum industries have good long-term potential.

Predicting future demands for Earth scientists must also take into account likely developments in the discipline (*see* the Vision Statements) and likely social needs for the future. These encompass activities with large growth potentials, including novel methods of resource exploration (especially remote-sensing), environmental stewardship (categorization of environmental resources, understanding of biological, chemical and physical processes at the Earth's surface, especially climate change), and environmental remediation (contaminant fluxes and fates, waste management). The world meeting of national science academies in New Delhi in October, 1993, on the topic of Population, Development, and the Environment, concluded that scientists must urgently study global and regional environmental change, contribute to the formulation of national and international policies to mitigate its effects, and undertake to develop indigenous scientific, engineering and managerial capacity in developing nations [5]. The capabilities of Canadian Earth scientists - including their international experience - make them ideally qualified to take a leading role in these tasks. And Canada itself constitutes a superb natural laboratory to undertake the novel Earth sciences research programs and to train the corps of Earth scientists that will be required worldwide.

References

1. Martin, B.R., J. Irvine, F. Narin, C. Sterritt and K.A. Stevens. Recent trends in the output and impact of British science. Science and Public Policy 17(1): 14-26, 1990.
2. Wojciechowski, M. Research and Development in the Earth Sciences. Canadian Geoscience Council, 1989.
3. Employment and Immigration Canada. Human Resources in the Upstream Oil and Gas Industry, 1992.
4. National Advisory Board on Science and Technology. Committee on the Competitiveness of the Resource Industries, 1993.
5. Terra Nova 6: 115, 1994