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ISSUES IN CANADIAN GEOSCIENCE

Geoscience in Canada: Current Status

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INTRODUCTION

Geoscience has considerable potential to contribute more than it does now to the health and wealth of Canadians. One of the goals of the Canadian Geoscience Council (CGC) is to realize that potential, and this article – the first of three on this theme – emphasizes the strengths of Canadian geoscience and notes some of the many opportunities that the geoscience community can grasp, given appropriate flexibility and ingenuity. Our collective relevance to the health and wealth of Canadians has not yet been promoted with the effort that other science disciplines have brought to their advocacy. We need to move forward from the strong foundations provided, for example, by Barnes et al. (1995). We need to present new visions for the future of Canadian geoscience, even to our scientific peers, that compare, for example, with those from astronomers and astrophysicists (NRC-NSERC, 1999) or those of the Subatomic Physics Five-Year Planning Committee (2001), in order that we do not lose further ground in areas of traditional strength and support. It is, therefore, timely to take stock of our roles, look at what Canadians need, and then direct our energies to ensuring that Canadians benefit from a reinvigorated geoscience effort.

Assembling a statement of the current standing of our science is fraught with problems of diversity, statistical sparsity, and uneven comparability of data. Geoscience is employed in a wide range of situations, and a satisfactory analysis of any one would require detailed discussion. Consequently this will be a rather superficial study: publication of more profound studies of the sectors described would be welcome. Herein, the status of geoscience in Canada is presented from three viewpoints: that of various private sector users - the resource, geotechnical and environmental industries; that of government; and that of academia. The viewpoint from industry is presented first, because the private sector is by far the biggest employer of geoscientists in Canada. Within the private sector, there is a variable dependence on geoscience carried out in government and academia, for regional overviews and databases, specialist expertise, and the provision of skilled human resources. Government and academia have other priorities also, related to education, knowledge, and public good. Simple measures of the levels of geoscience-related activity in different sectors over the last thirty years or so are presented for comparison in Figure 1.

GEOSCIENCE IN CANADIAN INDUSTRY

Geoscience has played a pivotal role in the development of Canada's world-renowned non-renewable resource industries, particularly minerals and hydrocarbons. For a summary of the basic facts on Canada's natural resources, visit the Natural Resources Canada government website at www.nrcan.gc.ca/statistics/. We are now at a crossroad, where known reserves in traditionally strong areas of activity – base metals, conventional oil from western Canada – are in decline, but new opportunities are being pursued: diamonds, natural gas, oil sands, and offshore hydrocarbons. These industries are market driven and so their vitality is strongly influenced by major variations in world prices of the commodities they produce.

Petroleum: Development Booming Now, but Adjustments Coming

Hydrocarbons contribute strongly to the Canadian economy, providing $28 billion (close to 50%) of Canada's positive trade balance of just over $60 billion per year. Approximately 200,000 people are employed in the oil and gas industry, and from annual oil company revenues of over $60 billion, governments receive around $16 billion in royalties and taxes. Hydrocarbons currently provide 65% of Canada's primary energy to industry and individuals.

Oil and gas prices vary over periods of several years by a factor of two or so and, since price dictates the level of activity in the industry, the hydrocarbon sector tends to cycle through periods of boom and bust. Currently, the level of exploration and development drilling activity for hydrocarbons in Canada is at an all-time high (Fig. 1a). This reflects the current high price of oil, the growing demand

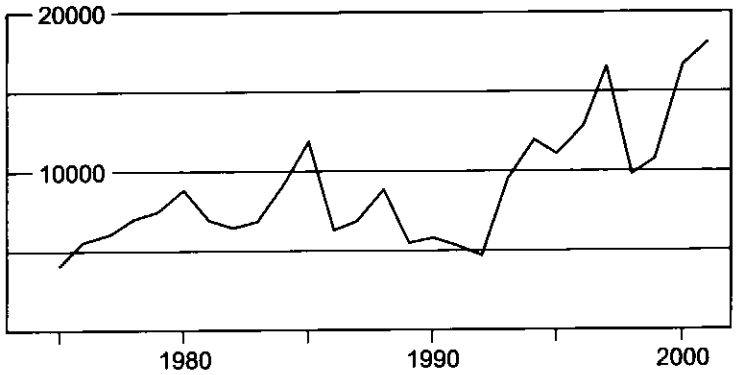

Figure 1a Number of wells per year drilled in Canada for hydrocarbon exploration and development, 1975–2000. Redrawn from information available from Canadian Association of Oil Drilling Contractors (http://www.caodc.ca/public_pdf/Well 20Completions 20-20Annual 20Breakdown.pdf) supplemented for 1975–1982 by data from Energy Sector, Natural Resources Canada.

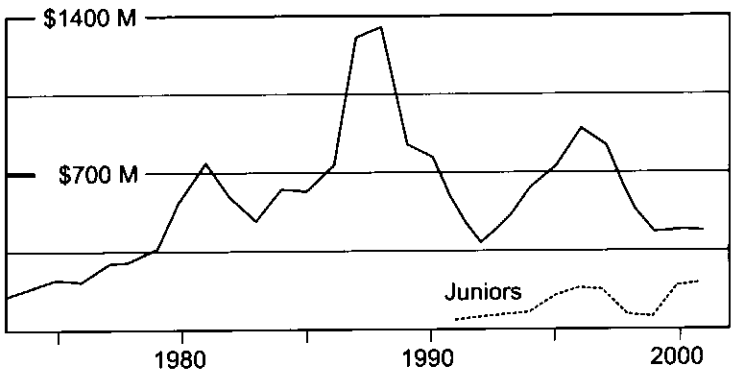

Figure 1b Mineral exploration and deposit appraisal expenditures per year in Canada, 1973–2001; dollar totals not corrected for inflation. Solid line redrawn from Figure 16, Overview of trends in Canadian mineral exploration, Natural Resources Canada, Minerals and Metals Sector (http://www.nrcan.gc.ca/mms/efab/invest/exploration/toc01 e.pdf). Dashed line shows exploration expenditures by junior mining companies in Canada, taken from PDAC information (http://www.pdac.ca/pdac/pub/papers/MM2000_files/frame.htm and http://www.pdac.ca/pdac/pub/papers/pdf/Canadian_Junior_Exploration_Up.pdf).

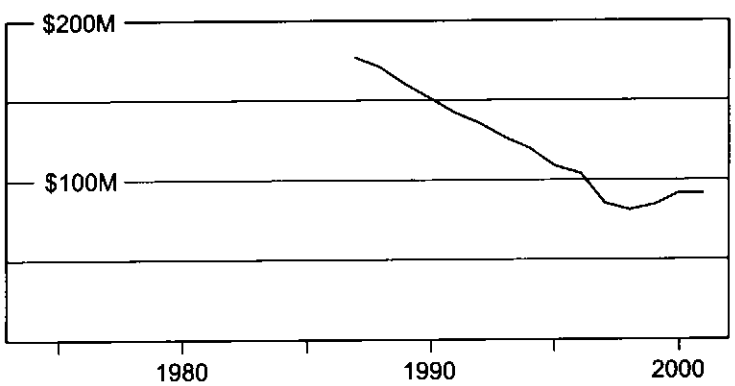

Figure 1c Funding of Canadian geological surveys, 1987–2001, in constant 1986 dollars. Redrawn from figure provided by the Geological Survey of Canada from an update of Inter-Governmental Working Group Task Force Report on"Alternative Funding Arrangements for Geological Surveys", presented to the 55th Mines Ministers' Conference in Calgary, July 1998.

for natural gas from U.S. markets, and the investments in developing oil sands. It is not clear that this all-time high is reflected in comparable levels of associated geoscience activity, since much of the increase in expenditures is in development rather than exploration, and some of it is driven by market demands (for example, from royalty trusts). On the other hand, much of this activity is dependent on the existence of a regional geoscience framework that has been developed over the years.

The long-term outlook is to some extent uncertain, yet holds much promise for the geoscience sector. Will there be a downturn in activity if or when oil prices drop again? Companies are moving away from conventional oil toward oil sands in the Western Canada Sedimentary Basin, to conventional oil offshore of eastern Canada, and to international production. Exploration effort is being directed to both conventional and unconventional gas resources in the west, driven by high demand from the United States, and there is renewed interest in exploration in the North, and other frontier areas. Despite the current high level of drilling, the ratio of proven reserves of conventional oil in Canada to production is static at a modest 9 years or so: when proven oil sands reserves and production are included, the lifetime of Canadian proven oil is increased to only 16 years. Where is our oil going to come from, decades hence? Offshore conventional oil and western oil sands represent the likeliest answers. Production from oil sands is already economic relative to world oil prices, but it requires more energy to produce than conventional sources of oil. The federal government's commitment to the Kyoto Accord will affect the viability of such projects to some degree, but there will be opportunities for smart geoscience to be applied to complementary climate-change activities, such as sequestration of carbon dioxide in producing reservoirs. Gas hydrates, hidden at shallow depth in regions of permafrost and below the seabed on our deep-water continental margins, represent a major hydrocarbon resource. In the longer term,

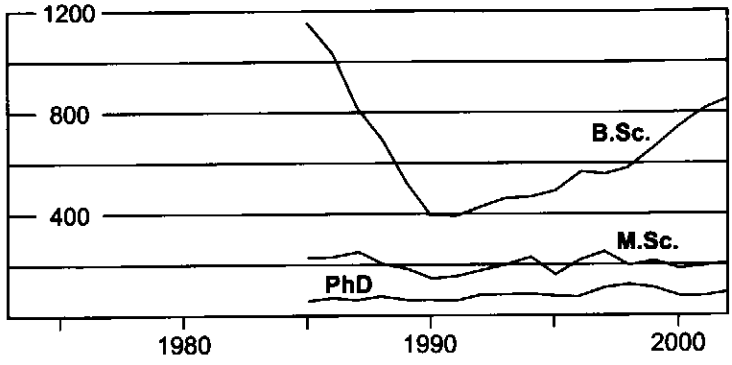

Figure 1d Statistics of Canadian Earth Science Departments: annual graduations. Redrawn from information available from the Council of Chairs of Canadian Earth Science Departments website (http://www.uwo.ca/earth/cddgc/rep2002.html).

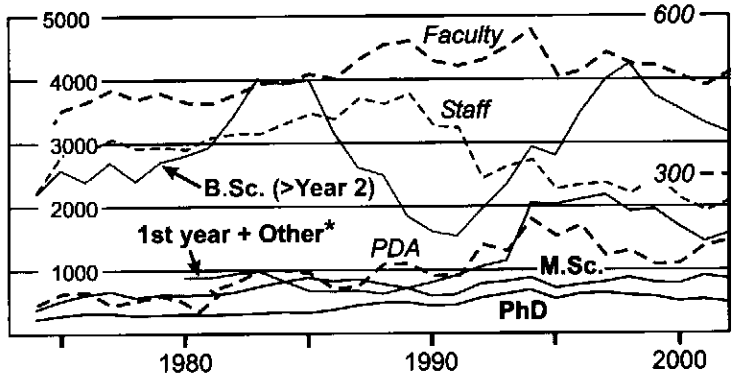

Figure 1e Statistics of Canadian Earth Science Departments: registrations (solid line, bold left-hand scale is number per year) and employees, italic scale, PDA = postdoctoral assistants. *Other means courses for non-majors and other courses taught in other faculties. Redrawn from information available from the Council of Chairs of Canadian Earth Science Departments web site (http://www.uwo.ca/earth/cddgc/rep2002.html).

they may be a significant contributor to Canada's hydrocarbon production, if geoscientists and engineers can work out how to harvest these broadly distributed resources safely and efficiently.

As we move into more intense searches for offshore hydrocarbons, and to new technologies for in-situ production from oil sands, geoscience will be expected to play a role in both, though the opportunities in oil sands will be focused on production and long-term remediation, rather than exploration. It will be interesting to see how the changing emphasis on the kinds of geoscience needed by the petroleum sector in Canada, is reflected in the demographics of the work force. Data from the Association of Professional Engineers and Geoscientists of Alberta (APEGGA) (Fig. 2) indicate that 50% of the geoscientists working in the petroleum sector in Alberta are in the 40 to 49 age group. With the retirement of that group, there could be a shortfall in mid-career talent in 10 to 15 years or so, though new entrants to the profession may be well-poised to take advantage of the changing nature of the geoscience needs for the hydrocarbon industry.

Investment in research and development in the energy sector is weak (Fig. 3) relative to most other industrial sectors and, in Canada, declining (Fig. 4). This may be caused partly by the increasing impact of the branch company syndrome in Canada, with concentration on production. However, even those companies headquartered in Canada are making major new investments overseas to provide longer term oil production (e.g., http://www. petro-canada.ca/eng/about/businesses/international/3147.htm, and http:/www. encana.com operations_and_projects/offshore_and_international.shtml).

Minerals: Metals at the Bottom of the Cycle Right Now, but Junior Company Exploration Increasing; Great Potential for Improvement!

Mining of primary metals accounts for 14% of Canada's exports, contributes around $36 billion (around 4%) of Canada's gross domestic product, and directly employs more than 350,000 people (1 in 40 of the Canadian workforce), with as many people again employed indirectly.

Like hydrocarbon exploitation, mining is affected by commodity prices. Overall, exploration for, and appraisal of, solid mineral deposits in Canada is currently at as low a level as it has been for decades (Fig. 1b), and base metal reserves in Canada are declining. By contrast, spending on exploration in Canada by junior companies has been increasing since 1999 (Fig. 1b) helped by the benefits of the "Super" Flow Through share program (http://www.pdac.ca/pdac/pub/papers/pdf/Canadian_Junior_Exploration_Up.pdf). Furthermore, diamond extraction in the North has been a major boost to the Canadian mining scene in the last decade. In addition, gold prices are on the rise and that could mean greater activity in Canadian gold mining. Platinum prices have reached a 23-year high.

Primary metals represent another industrial sector with a low level of investment in research and development relative to net sales (Fig. 3). There are other parallels with the petroleum sector, in that Canadian mining companies are also very active worldwide, having expanded their relative investments overseas substantially. Over the last decade or so, Canada's senior mining companies have reduced the proportion of total exploration expenditure spent in Canada from just over half to around 20% (Fig. 5); for Canada's junior companies, the corresponding change is

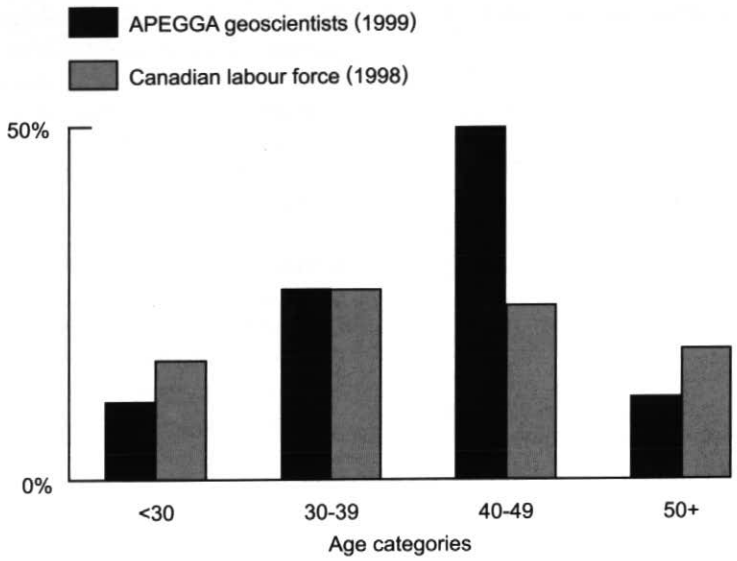

Figure 2 Demographics of geoscience respondents to a compliance survey contracted by the Association of Professional Engineers, Geologists and Geophysicists of Alberta (APEGGA). Redrawn from survey information provided by APEGGA.

from 60% to 30% (see http://www.pdac.ca/pdac/pub/papers/MM2000_files/frame.htm).

The long-term global outlook for metals is very strong, with expectations that demand for nickel, for example, can be expected to increase at an average of 1% per annum for the next 50 years, as the demand for stainless steel continues to grow. Demand for platinum for catalysts in industrial processes is also expected to continue to rise steadily. Where will our future metals come from? Canada is not mined out, but will need smart exploration to replace its dwindling reserves with new ones. Geoscience has a crucial role to play in finding those new reserves.

Shipments of stone in Canada have an annual value of close to $1 billion. In addition to its dollar value, stone is a crucial commodity without which our infrastructure could not be maintained. It is produced for a wide variety of purposes, from dimension stone for ornamental use, through salt for our winter roads, to limestone for agriculture, road building and steel making. Aggregates, such as sand and gravel used in the construction industry, represent 17% of the value of the Canadian minerals industry, with shipments of around $2.5 billion per year. Geoscience plays a modest role, relative to the shipment values, in the development, operation and remediation of the sites exploited by these parts of the Canadian mineral sector.

Land-use issues will demand a greater role for geoscience in the minerals industry in the future. The concept of sustainable mineral development is being actively pursued by Canadian geoscientists, but building effective partnerships with the wide range of stakeholders will take substantial time and stamina.

Geotechnical, Environmental, Groundwater: Booming Quietly!

These sectors of activity are diverse and commonly involve small companies that need to recruit trained professionals, rather than new graduates. Because of their diversity, small size, and indirect recruitment (of graduates), it is difficult to obtain hard information on the economic impact of these sectors, but a recent survey of Canadian geoscientists by CGC (Morgan et al., 2002; Coultish, 2002) indicated that there

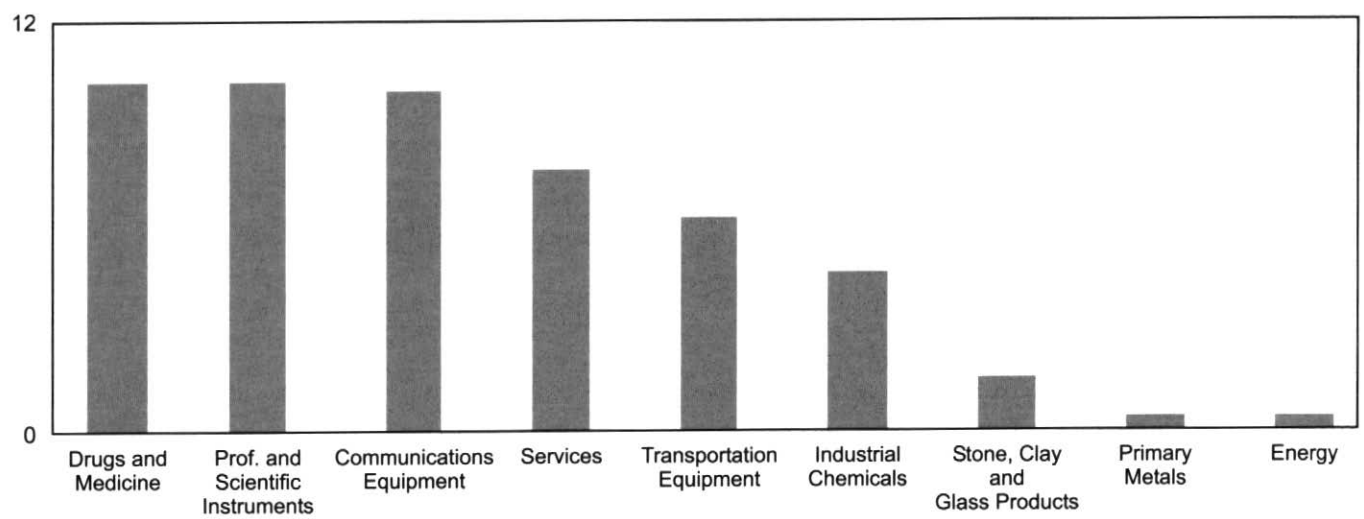

Figure 3 Research and development expenditures as percentage of net sales for various industrial sectors in the United States, for 1995. Redrawn from figure in web paper by K. Larner (www.seg.org/publications/webonly/larner.pdf), based on Margolis and Kammen (1999).

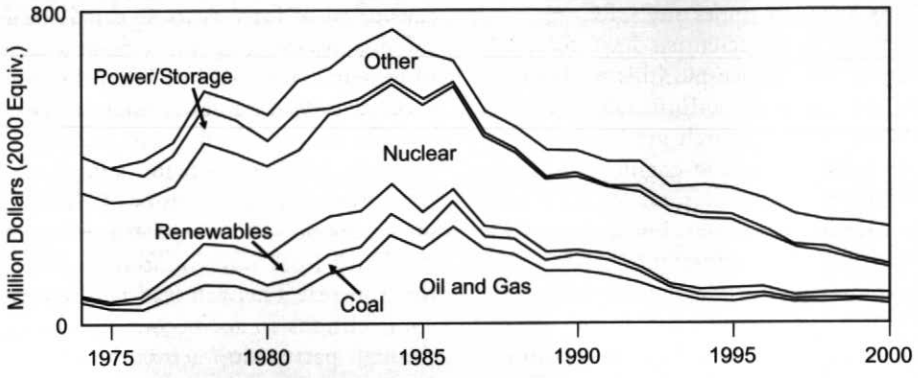

Figure 4 Funding of energy research and development in the energy sector in Canada. Redrawn from IEA Statistics, 2000; courtesy of R. Mansell, University of Calgary.

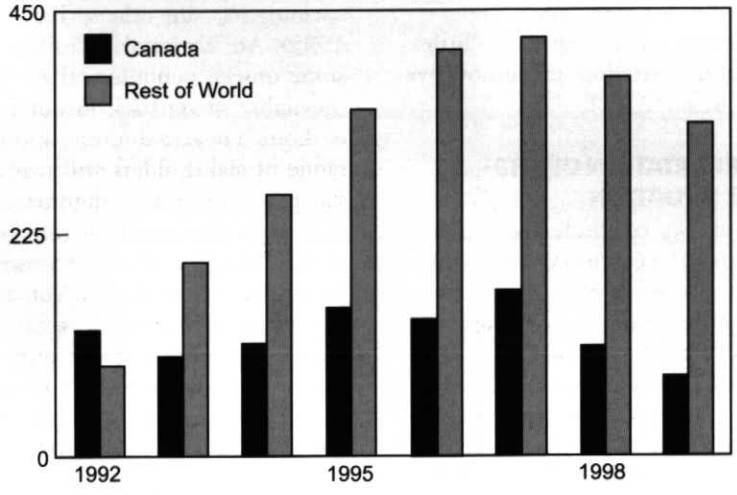

Figure 5 Worldwide exploration expenditures by Canada's top senior mining companies. Redrawn from PDAC web site information (http://www.pdac.ca/pdac/pub/papers/MM2000_files/frame.htm).

were as many geoscience respondents employed, in total, in these sectors as in either the mining or hydrocarbon sectors. The needs of Canadians for secure supplies of potable water and, consequently, for acceptable treatment of waste, are having a significant impact on recruitment of geoscientists into this area. Additionally, there is an increasing requirement for geoscience to be applied in environmental planning, monitoring and remediation, and in land-use planning, where natural hazards, such as floods, landslides and earthquakes, and global change (e.g., climatic change and sea-level rise) have potential impact.

The application of concepts of sustainable development (meaning exploitation that leaves minimal negative legacy for future generations) to our extractive industries is a growing requirement of them. There will be a correspondingly growing need for geoscientists to work with engineers, biologists, chemists, social scientists and economists in advising those developers and their regulators, and in monitoring to ensure good practice.

GEOSCIENCE IN CANADIAN GOVERNMENTS

Geoscientists are employed by a diversity of government departments, but the vast majority are employed by provincial geological surveys, the Geological Survey of Canada, the Canada-Nunavut Geoscience Office, the C.S. Lord Geoscience Centre (NWT) and the Department of Energy, Mines and Resources in the Yukon.

Public funding of Canada's geological surveys has declined dramatically over the last decade (Fig. 1c), as part of widespread attempts to stabilize or reduce government expenditures. Recovery has been slow or nonexistent. In British Columbia, the Geological Survey is being reduced significantly, with some of the geoscience complement redistributed in other business units. In this climate, it has been heartening to acknowledge the advocacy by the Prospectors and Developers Association of Canada (PDAC) to Mines Ministers, for the need for geoscience mapping in providing the framework for mineral exploration. This helped get the Targeted Geoscience Initiative funded. This initiative, on strategic geological mapping, has been very successful in identifying mineral potential, and as an example of how federal-provincial cooperation should work (even though the budgets allocated are less than desired by some). Provincial jurisdiction over mining provides ready justification for their geological surveys, though federal and provincial surveys provide increasing value in many other areas, such as mitigation of natural hazards, groundwater supply and contamination, a host of land-use issues, national standards, databases and integration, marine geology and seabed habitat, and seabed geotechnics, to name a few. Geological surveys will continue to support activities in aid of mining exploration, within the broadening use of geoscience data for other purposes.

GEOSCIENCE IN CANADIAN ACADEMIA

The Council of Chairs of Canadian Earth Science Departments publishes figures on student registrations, degrees completed, and faculty and support-staff numbers, for geoscience programs at Canadian universities (Fig. 1d, e). These show oscillations in undergraduate numbers that follow the economic cycles of the resource industries. Increasing registrations in service courses have helped geoscience departments enhance their faculty/student ratios, but declining numbers of faculty and, particularly, support staff, together with a large number of impending retirements present

problems for the future viability of certain programs, which are only partly offset by departmental mergers.

Funding of academic geoscience research is dominated by that provided through the Natural Sciences and Engineering Research Council of Canada (NSERC). Nearly half of that funding is contributed through basic research grant (Discovery Grant) support for individual faculty members, while the rest is obtained through various targeted, strategic, and large-scale collaborative programs (Hall, 1999). A bellwether for the performance of Canadian academics in geoscience is the Reallocation Exercise repeated every four years, by NSERC, to change the proportions of the basic research grant envelope assigned to the 20+ science and engineering disciplines that NSERC sustains. The reallocation redistributes 10% of the funding for each discipline, according to the perceived excellence and vitality gauged by peer-review of reports submitted by the various disciplines. Three competitions have been held in the last decade, and the Earth sciences have lost ground each time, so that we have lost more than 10% of the basic research grant income we would now have with even just 'par' performances. Earth scientists (including those involved in both solid earth and environmental earth science) now receive about 7.5% ($20 million) of the Discovery Grant budget (total around $270 million). Our declining performance relative to most other science disciplines is shown in Figure 6 (derived from http://www.nserc.ca/about/stats/2001-2002/en/tables/table_42e.htm).

Overall NSERC funding declined in real terms in the mid-1990s but has been recovering significantly in recent federal budgets. Geoscientists have done well by this across-the-board increase, and do quite well in some of the large-scale collaborative programs of NSERC (Hall, 1999). In addition, the Canada Foundation for Innovation (CFI) and the programs of Canada Research Chairs (CRC) represent major new funding opportunities for Canadian geoscientists. So far, in both CFI funding of new research infrastructure and in the number of chairs awarded under the CRC program, Earth scientists have received 10% of the science pie (this is about the same level of performance as in NSERC basic research grants, after correction to exclude engineering disciplines, which account for 25% of the NSERC envelope). But in both CFI and CRC, our performance relative to the number of academics receiving NSERC Discovery Grants in the respective disciplines (Fig. 7) is below the levels set by our competition. The published reports of reallocation committees give us a view of how others perceive us: "an old discipline taking on new technologies to be applied to new areas", but with "little evidence about exciting and innovative contributions...".

AN INTERPRETATION OF THE CURRENT SITUATION

What should we conclude about this snapshot of the geosciences in Canada? One view that the public has of us is that we are doing the same things we have been doing for so long – supporting, in their opinion, sunset resource industries. Our scientific peers perhaps see us as chasing second-order loose ends of the plate tectonic revolution of forty years ago. It is time for our discipline to move from a series of loosely connected but internally well-focused subdisciplines aiming at very specific issues – finding oil, finding minerals, nailing down the solid Earth processes of plate tectonics, defining global change – to an understanding of the Earth from interconnections among the 'spheres'. This will lead us towards contributions to socioeconomic policy through partnership across the spectrum of geoscience practitioners and with other disciplines, including engineers, biologists, economists, politicians, health specialists, sociologists, and others (Barnes et al., 1995). Are we involved in the swing of some unseen pendulum that will inevitably swing back in our favour, without our active intervention? Are we recognizing the impacts of the global village, in the increasing interest of Canadian companies in foreign stakeholdings, and in the downsizing, centralization, and often consequent exporting, of industrial research effort? Each of us will make our own interpretations, and argue in favour of them. But this discussion should not be about optimism, or outlook, at the personal level. Instead, we should be

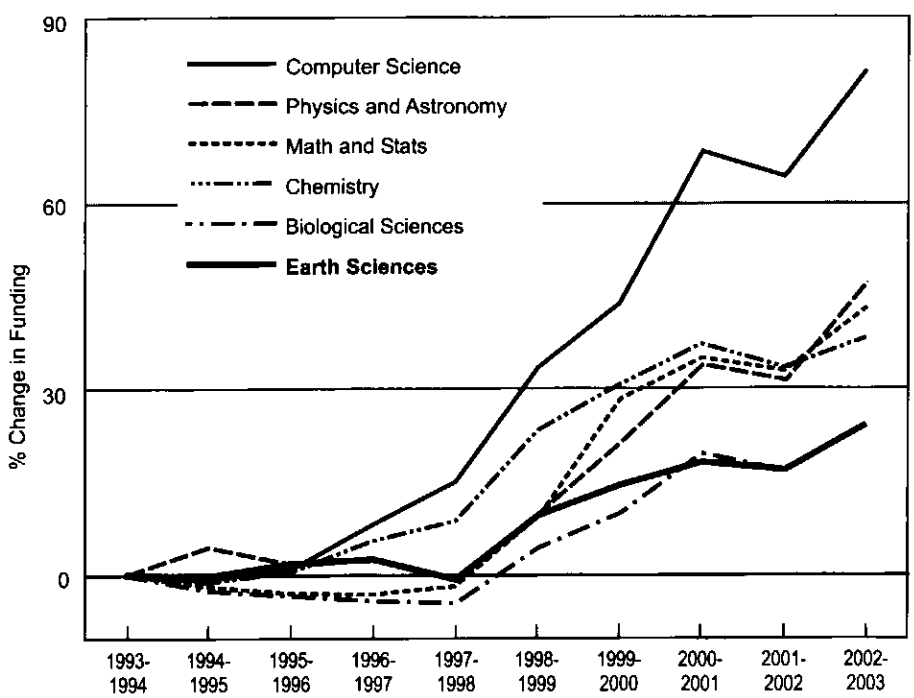

Figure 6 Per cent change in NSERC Discovery Grant funding to the sciences since 1993–1994. Data from http://www.nserc.ca/about/stats/2001-2002/en/tables/table_42e.htm.

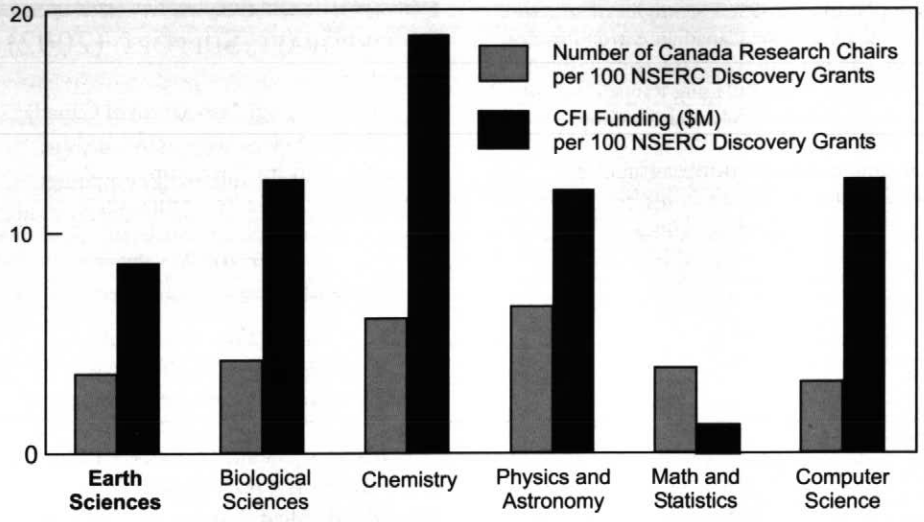

Figure 7 Research intensity of academic Earth scientists in Canada relative to other disciplines, as measured by success in Canada Research Chairs (CRC) and Canada Foundation for Innovation (CFI), normalized to the numbers of faculty members in each discipline.

concerned about building an effective community of geoscientists in Canada, a community that is willing to invest in improving the image of geoscience in Canada by promoting new ways of doing business that are intellectually exciting and, at the same time, can be seen in very simple ways to be beneficial to the future health and wealth of Canadians, and relevant to the needs of modern society. We must also recognize the need to compete and collaborate internationally, so that our geoscience skills can be honed on our truly global science, to the benefit of Canadian companies and, ultimately, to applications in Canada.

The future of geoscience in Canada depends on having a much more integrated and enthusiastic community than we have at present. An indication of our fragmented nature is that the Canadian Geoscience Council has 18 different sustaining member institutions, and this is only a minority of all of the geoscience-related organizations in Canada. This makes for insularity, inefficiency, ineffectiveness and, ultimately, impotence. It remains to be seen for how long some of our organizations will drift towards non-viability before recognizing the need for change. We advocate an earlier wake-up call.

THE AGE OF OPPORTUNITY: IS IT UPON US?

There is no better time than now to seek resources for innovative geoscience activities. The federal government, through the research councils, CFI, Canada Research Chairs, and its newly-promoted Innovation Strategy, is providing funding for innovative science in the expectation that this will spin-off into private sector uptake of R&D, leading ultimately to better performance by the Canadian economy. Typically so far, the reaction of Canadian geoscientists to these opportunities has been weak and dominated by the old way of doing business! Take marine science, for example (while conceding that geoscience is only a part of this discipline). In 1997, NSERC sponsored a workshop on the status of and opportunities for marine science in Canada. The recommendations from that workshop (http://www.geoscience.ca/papersandreports/marinegeo.html) have gone virtually nowhere with the creation of either a national marine science council, or a national marine infrastructure system. With respect to CFI, we have small groups working in relative isolation, with no cohesive plan for the whole community evident. The same is true of all our geoscience.

Please do not blame others for this vacuum of leadership. Where are our geoscience Networks of Centres of Excellence (NCEs) or equivalents to the Cooperative Research Centres in Australia or Norway? Yes, we have done well with a few, specific, leading-edge programs such as NEPTUNE, a Canada-U.S. project to set up a seabed observatory of fibre-optic connected nodes, and POLARIS, a project to use new, portable seismographs to map the deep lithosphere in earthquake prone-zones in order to understand hazards, and in the north to enhance our understanding of the mantle that sources diamond-bearing kimberlites. These projects are as exciting in prospect today as Lithoprobe was twenty years ago, and may prove to be even more directly beneficial to Canadians. We just need to do these things within a larger framework of collaborative ambition.

Humankind lives on the Earth's surface, we draw our resources from it, and we deposit our waste on it. Geoscientists have a tremendous understanding of the Earth's surface, and of the dynamics of its change and of transport across it. While we are content to attend our national and regional geoscience conferences and meetings, to talk with one another, we must articulate our understanding to others in ways that they can (a) understand, and (b) buy into. If we do not do so, geoscientists and geosciences in Canada will move haphazardly towards a future in which they may well become marginalized, by Canadians' needs for geoscience being provided by those that appreciate how to meet them better.

The Canadian Geoscience Council is one medium for effecting the kind of transformation we seek, and is looking at new ways of doing business to enhance its role. This includes giving its member organizations more immediate control over direction. Does CGC have the right structure to lead the change required? The commonalities among its diverse member organizations have not yet proven strong enough to yield the resources to drive this agenda. Part

of CGC's new direction is to encourage its members to seek operational efficiencies, through collaboration, that might lead to significant economies of scale. This could then lead to a redirection of some of the existing resources to address CGC's two roles: firstly, to get the geoscience community involved in this discussion; secondly, to get geoscientists talking with Canadians about their needs and our ability to help fulfil them.

So, let's get our act together! A good place to start would be by assessing the potential roles for geoscience in tomorrow's Canada. That is the subject of the next paper in this series. Once agreed on this new agenda and the corresponding new structures needed to pursue it, we can plan a bright, innovative future, in which Canadians can once more benefit from its strong geoscientific heritage.

ACKNOWLEDGEMENTS

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