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CHAPTER 11 TOWARDS A MODEL FOR ADVANCING AND COORDINATING THE EARTH SCIENCES IN CANADA: TURNING CRISIS INTO OPPORTUNITY

This study could have generated a myriad of specific recommendations targetted both to the discipline and to the sectoral participants/agencies. Many have been offered in earlier reviews, and many still await implementation. As our study progressed, we became more firmly convinced that many of the crucial problems are structural or relate to attitudes and historical patterns. This concluding chapter aims to offer a new model of advancing and coordinating the earth sciences in Canada.

There is no doubt that geoscience research, in fact nearly all R & D in Canada, is underfunded and many recent reports have advocated a doubling of funding for basic research (*e.g.*, Association of Universities and Colleges in Canada 1990; Sparrow, 1990; Royal Society of Canada 1991; National Advisory Board on Science and Technology, 1991). However, given the financial state of the nation, there is little chance of significant new funding in the near future even though it would naturally aid the economic recovery. Such new funding will not come without clear articulation and a more unified vision of how earth sciences can better serve society, and with nationwide agreement on research priorities. In the interim, however, much progress can be made through greater cooperation between sectors.

Table 11.1 A model for advancing and coordinating the earth sciences in Canada with 10 key components

- Development of new ideas
- Advocacy of Earth System Science
- Lifelong education and training
- Accelerating advances in science and technology
- Establishing priorities in research
- Maintaining the scientific continuum
- Enhancing the innovation cycle
- Rationalizing national and provincial mandates
- Promotion of the public awareness of earth sciences
- Radical changes in attitude, behaviour and leadership

From the issues raised in the earlier chapters, we identify a model comprising 10 key components (Table 11.1). that will advance and coordinate the earth sciences in Canada. To bring the model to fruition we provide a single complementary recommendation for each component.

All ten recommendations together should be considered as building a new fabric for managing the discipline, rather than being considered in isolation. Implementation of these 10 recommendations will help design our destiny rather than stumbling into an unknown future

1. Development of New Ideas

A fundamental objective is to rejuvenate the environment for basic and applied research that fosters the development of new ideas and concepts. Creative intellectual dynamism is difficult to attain and sustain. In particular it requires encouragement for, and development of, new ideas; open and objective criticism; excellence in research; entrepreneurship; and enhanced scientific exchange.

Recommendation 1:
That, as the Canadian economy recovers, funding from government and industry for research should at least double over about a decade in order to spur the generation and application of new ideas and concepts.

2. Advocacy of Earth System Science

As outlined in the Introduction and Chapter 3, the paradigm shift within the earth sciences over the last decade has fostered the concept of Earth System Science. The interactions, processes and reaction rates among the different shells in the planet Earth (core to atmosphere) have become critical to understand along with the scale, impact and consequence of anthropogenic forcing on natural systems. The future imperative is for earth scientists to regard

themselves foremost as students of the planet Earth rather than of discrete components (*e.g.*, geology, geophysics, oceanography and atmospheric sciences). This has wide implications for the advocacy of the discipline, curriculum reform, interdisciplinary research, and the intellectual framework of the discipline.

Recommendation 2:
That the geoscience community advocates and accommodates to the concept of Earth System Science which has produced a paradigm shift within the discipline.

3. Lifelong Education and Training

The concept of Earth System Science should be the basis for many of the undergraduate and graduate degree programs in earth sciences. The next generation of students will see during their lifetime a doubling of the global population to 15 million with profound environmental and resource consequences. Students must appreciate the systems approach, have a sound quantitative science background, and develop a range of scientific, technical and people skills to cope with possibly as many as 5 career changes in their lifetime. Flexibility to rapid change will be essential as will openness to lifelong learning. Specific future developments are outlined in Chapter 7.

Recommendation 3:
That the academic community reforms curricula to provide a quantitative earth systems foundation and, with programs in other sectors, promotes systematic lifelong learning opportunities to sustain a highly qualified creative workforce.

4. Accelerating Advances in Science and Technology

The world's knowledge has doubled in the last 18 months. Science, technology, social and economic structures are changing with astonishing and increasing speed often in a chaotic, non-linear fashion. The report outlines many of the recent and predicted changes in the geosciences and in related technology (Chs. 3, 4). Profound changes have been driven in part by the rapid development of computers/supercomputers, satellite technology, and analytical methods. These have completely changed the nature, manipulation and application of geoscience databases. The future challenge is not only the generation and application of new knowledge and ideas, but the most effective assimilation, management, dissemination and visualization of information.

Recommendation 4:
That appropriate information systems and technologies be established and improved to cope not only with the exponential growth of knowledge but with the effective use and management of geoscience information.

5. Establishing Priorities in Research

The generation of wealth to maintain an equitable standard of living for a burgeoning global population is a future challenge for society. In moving from the Industrial Age to the Information Age, research and development will have increasing importance to the social and economic development of society. Resource exploitation, environmental protection, and health and safety are all important future societal needs for which the earth sciences are critical (Ch. 5). Given fiscal restraint, priorities must be established for supporting earth sciences research and related activities. A matrix diagram is presented in Chapter 6 which can be compared with high priorities established for the solid earth sciences in a recent U.S. study (National Research Council, 1993); together they form the basis for an open discussion of future priorities in Canadian earth sciences. The Canadian Geoscience Council is charged with facilitating that ongoing debate.

Recommendation 5:
That an ongoing open process be implemented, coordinated by the Canadian Geoscience Council, to consider, debate and establish broad priorities for funding geoscience research, megaprojects, and related collaborative activities.

6. Maintaining the Scientific Continuum

Science proceeds and evolves within a continuum of basic to applied science. New ideas come from basic research within a relatively undirected framework; serendipity is a strong force along with a creative intellectual environment and well-educated researchers. In Canadian geoscience most of the basic research is undertaken in academia and this focus is unlikely to change. The application of new ideas is and will remain primarily the purview of the government and industrial sectors. The new information highway (infobaun) will facilitate the rapid dissemination of ideas and concepts as well as information. The Canadian earth sciences must have a balanced continuum of basic to applied geoscience.

Recommendation 6:
That future changes in policy and funding within and among the government, academic, and industrial sectors ensure a balanced continuum of basic to applied earth science in the nation.

7. Enhancing the Innovation Cycle

For Canadian earth science industries to be competitive internationally, they must be enhanced or transformed by higher technology and rapid information flow (Chs. 4, 5, 8). In many cases this will be achieved by effective technology transfer involving the transfer of people, ideas, concepts, information and technologies. New management policies, and changes to regulations affecting pension plans and benefits will be necessary to encourage the transfer and exchange of specialized earth scientists between sectors. An objective is to create an industrial environment where new ideas and technologies can be introduced rapidly,

shortening the innovation cycle. The present age structure of researchers in academia and government agencies will remain a serious problem for another decade unless flexible arrangements/transfers can be pursued aggressively.

Recommendation 7:
That to be internationally competitive, the industrial and other sectors must effect a major increase in technology transfer between basic and applied geoscience (people, ideas, concepts, information and technologies) in order to increase values and efficiencies and shorten the innovation cycle.

8. Rationalizing National and Provincial Mandates

In the Canadian confederation, the division of responsibilities between federal and provincial governments is likely to be an ever-changing situation. Nevertheless, the state of the economy alone will force a more distinct separation of responsibilities. For the earth sciences, we suggest in Chapter 8 a general division of responsibilities using geological surveys as the prime example. A new era of collaboration is suggested where government surveys are considered more as facilitators and coordinators rather than sole participants in programs. Open cooperation from the planning phase through final publication phase, with strong interaction with academia and industry, is required; the management style used for the Lithoprobe and ODP Legs or the NATMAP projects are useful models. The new scale of collaboration and sharing of expertise and facilities should extend to the special capabilities developed within the GSC in areas such as geochemistry, geophysics, paleontology and geochronology.

A more comprehensive and collaborative database system for the Canadian earth sciences should also form the scientific basis from which sound provincial and federal policy decisions evolve.

Recommendation 8:
That federal and provincial geoscience departments/agencies establish a clear division of responsibilities and become joint leaders in facilitating and coordinating a network of geoscience databases and expertise for use in all sectors. The improved information network will be of use to all sectors and aid in developing sound policy advice.

9. Promoting the Public Awareness of Earth Sciences

The growing public awareness of the finite limits, carrying capacity, and environmental degradation of our planet is now a strong force shaping political decisions. If clearly articulated, the messages from the earth sciences should be prominent in many future public debates. Political support for requests for earth sciences funding and special projects will be conditional, in part, on a strong awareness of the earth sciences within a broad constituency (Ch. 7). Those with commitment and special talents should be encouraged to develop science networks, and to participate with the schools, museums, science centres, the media and other avenues to portray the excitement and relevance of the earth sciences.

Recommendation 9:
That all sectors aggressively support programs to promote the public awareness of the earth sciences.

10. Radical Changes in Attitude, Behaviour and Leadership

The Earth's resource endowment has been a principal contributor to the wealth and high standard of living of Canada (Ch. 2). The good life has unfortunately fostered attitudes of complacency, arrogance and distinct territorial claims for responsibilities in some quarters. The future economic realities demand a rapid change in both attitude and behaviour to one of cooperation, sharing, communication and technology transfer (Ch. 10). The increased flow of individuals, ideas, and technologies between sectors is essential. Canadian geography demands further efficiencies and cooperation in field work logistics. A more clearly defined concept of earth system science, combined with a new urgency to make Canada more productive and effective, should break down old barriers and foster new opportunities.

The earth sciences are a natural and important discipline for which Canada's geography and resource endowment provide special emphasis. Their potential contributions, opportunities, discoveries, industrial applications, and role in wealth generation, environmental protection and public safety must all be articulated clearly and consistently. While each sector can advocate its own role, it is critical that some agency assume the lead for advocacy and coordination. The federal GSC has assumed this mantle in the past but seems reluctant to continue in this capacity. Alternatively the sectors and agencies and the whole geoscience community should support the Canadian Geoscience Council to fulfill this role (Ch. 10). This would require continued evolution of the CGC to develop into a stronger, more effective and representative agency. In the interim, the leaders from all key sectors should agree to act as a supportive subset within CGC to arrange the long term financial viability of the CGC to fully represent the earth sciences on the national and international stage. If CGC cannot attain this new structure, then the earth sciences community should consider establishing a new agency,

Recommendation 10:
That all sectors commit to a new era of changed attitude, behaviour, and leadership with a shared concept of earth system science, a recognition of the severe future global environmental and resource issues, and a responsibility to make Canada more efficient, productive, and sustainable, thereby turning crisis into opportunity.