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# Chapter 1: Introduction

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# CHAPTER 1 INTRODUCTION

## 1 (a) The Changing Earth Sciences

*"The boundaries between component parts of the earth sciences . . . have become blurred . . . It is this profound change in the flow of information and ideas across traditional barriers that is liberating many fields of endeavour and instilling a new sense of excitement and opportunity."*

The earth sciences are undergoing a paradigm shift in which the earth processes occurring on our planet are studied as an integrated, dynamic system rather than as separate components. This concept, commonly referred to as "earth system science", involves both modern and ancient processes from the earth's core to the upper atmosphere. The knowledge base ranges from the origin and early history of the planet, through the differentiation and degassing of the interior, the structure and plate motions of the lithosphere, the surface terrestrial and marine processes, and the biodiversity and evolution of life, to the changing nature of the coupled ocean-atmosphere climate system. Earth system science attempts to discriminate between the complex patterns generated by a mix of linear and non-linear dynamics across a wide range of temporal and spatial scales. In tackling such global systems, earth scientists are increasingly involved in complex, multidisciplinary, national and international programs. An added new challenge is to differentiate the degree to which the nature and variability of natural systems have been modified by anthropogenic factors.

Photographs of the Earth taken by lunar explorers and space satellites brought home to humankind as never before the finite limits of our planet. The Earth is essentially a closed system, with only energy being received and reflected and some escape of minor gases. Within this closed system there are a variety of complex open subsystems, within and between which there is a flow of both energy and materials (*cf.* leaf, tree, forest, biome). The volume published jointly by the National Aeronautics and Space Administration (NASA), National Oceanographic and Atmospheric Administration (NOAA), and National Science Foundation (NSF) in the U.S. (Earth System Science Committee, 1988) illustrated the complex interrelationships and hierarchies involved, of which one, the fluid and biological processes, is reproduced (Fig. 1.1). Humankind now perturbs an increasing number of these subsystems and, in some instances, such activities exceed the rate and scale of natural processes (Fyfe, 1990).

The boundaries between component parts of the earth sciences (geology, geophysics, oceanography, atmospheric science) have become blurred, as have those between earth sciences and several other fields of knowledge. It is this profound change in the flow of information and ideas across traditional barriers that is liberating many fields of endeavour and instilling a new sense of excitement and opportunity. Relatively closed intellectual subsystems have become

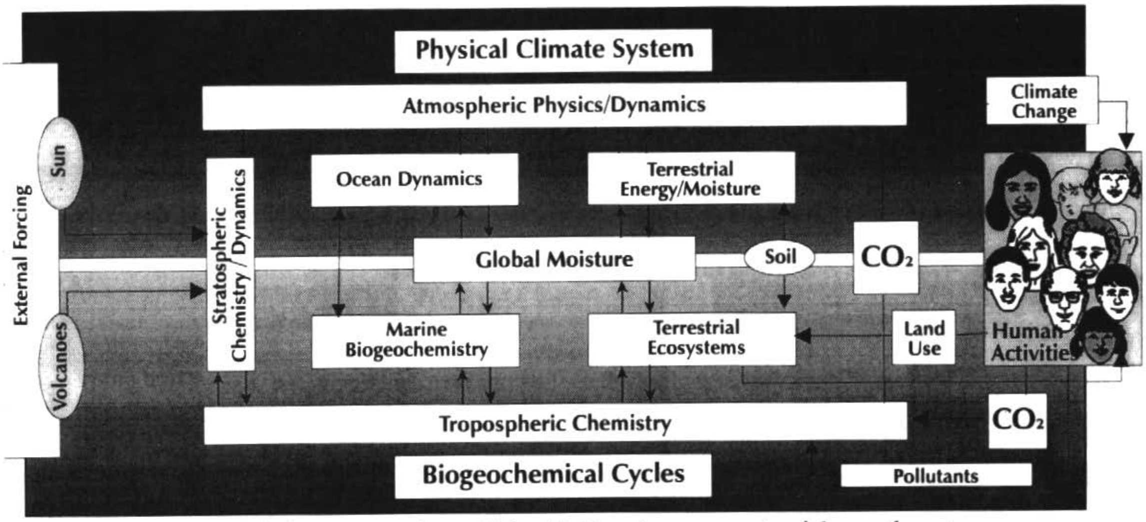


*Figure 1.1 Interconnections of identifiable subcomponents of the earth system (International Geosphere-Biosphere Programme, 1990)*

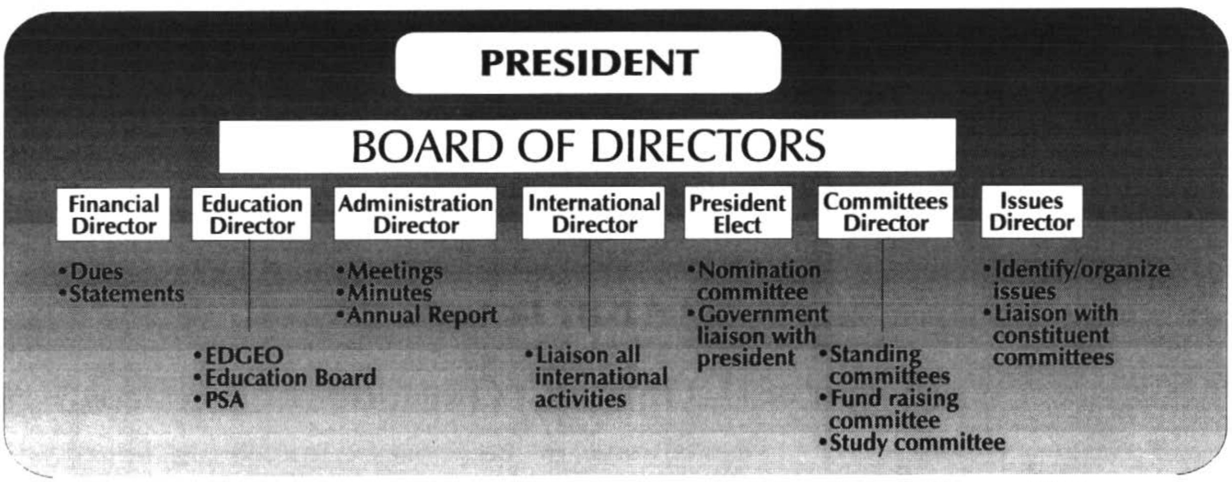


*Figure 1.2 Suggested structure for the new Canadian Geoscience Council (Gartner, 1994).*

more open, having an impact on concepts, applications, organizations, and training.

Canada has been a leading nation in expressing concern for the global environment, hosting some of the first meetings of world leaders on this issue. Canadians have been leading participants in the later Rio Conference and the resulting Rio Declaration on Environment and Development (United Nations, 1992). With Norway, Canada has made a policy decision to accept the concept of sustainable development and has set some specific planning targets (e.g., in reducing $CO_2$ atmospheric emission levels). Such concerns for the Canadian and global environment demand a strong focus on the earth sciences, requiring a more comprehensive knowledge base, multidisciplinary earth system approaches, and a new scale of collaboration between specialists.

Until the last decade or two, the knowledge base of earth sciences was used mainly by the earth-resource sector (in the exploration for and exploitation of mineral, hydrocarbon, and water resources). With the sharp increase in world population, public concern over environmental and conservation issues, and specific public interest in waste disposal, ozone depletion, climate change, resource depletion, and biodiversity, the integrated earth-science knowledge base is being applied more widely and is of increasing interest to many outside the discipline.

These radical changes in the issues and style of earth-science investigations, combined with the increasing breadth of applications, have emerged during a period of economic depression. Requests for additional funding needed for new ways of gathering and managing earth data (e.g., deep drilling, aerial surveys, remotely operated vehicles, satellite observations, complex computer modelling) come at a time of severe economic restraint. In Canada and other nations, the size of the national deficit is forcing a restructuring of government agencies, research organizations and programs, and further reducing the proportion of funding (as a percent of GDP) applied to research and development (R & D). Many such agencies, granting councils, and corporations are examining their policies, structures, and *raisons d'être*, often in isolation. Such is the case, for example, for the Geological Survey of Canada, most provincial geological surveys, some university earth science departments, the Canadian Geoscience Council, and many companies. Some decisions are required immediately and others require considerable internal review. It is never

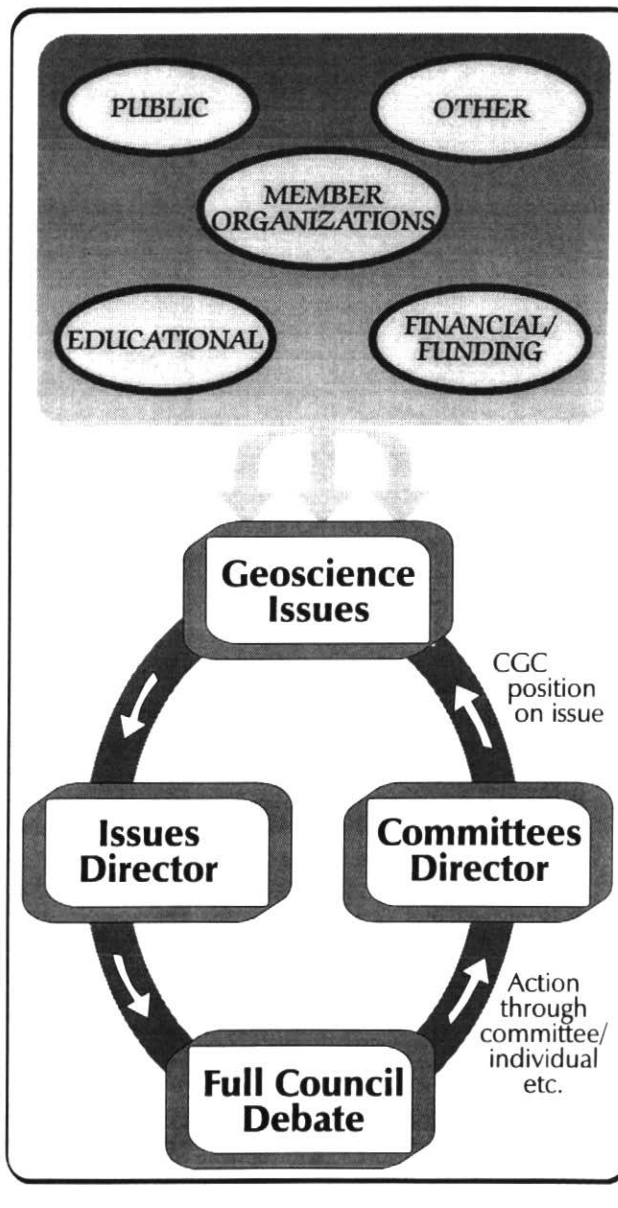


*Figure 1.3 The "issues loop" proposed in a new Canadian Geoscience Council (Gartner, 1994).*

possible to completely assess the future impact of changes, to consult with all client groups, and to consider the effects on the national fabric of, and infrastructure required for, the earth sciences.

## 1 (b) The CGC Study on the Future of the Geosciences

Two such agencies, The Canadian Geoscience Council (CGC) and the Geological Survey of Canada (GSC), agreed that a study would be valuable at this time to advise broadly on the new challenges for, and trends in, the geosciences in Canada. The CGC has been examining its modus operandi and considering how it can debate and better represent the broad policy issues on behalf of the geoscience community (Figs. 1.2, 1.3). The GSC is facing a budget reduction of about 30% over the 1994-96 period which will affect many of its existing staff and programs, its ability to collaborate, and its traditional leadership role in Canadian geoscience. The GSC agreed to support financially, and in principle, a CGC study on this theme. Both organizations wished to have a report prepared within a three-month period, by January 31, 1995.

*The mandate of the CGC Study is to provide advice both to CGC (and the geoscience community) and to the Assistant Deputy Minister of the GSC on the new and continuing challenges for, and trends in, the geosciences in Canada to meet changing economic and societal demands.*

The study is to build on existing reports, such as *Building a Federal Science and Technology Strategy* (Industry Canada, 1994a), *Earth Sciences in the Service of the Nation* (Lindseth, 1989) and the U.S. National Research Council (USNRC) Report entitled *Solid Earth Sciences and Society* (National Research Council, 1993).

CGC and GSC agreed upon a committee of seven geoscientists from government, industry, and academia representing a range of geoscience disciplines (Table 1.1). A larger committee would have been more costly and unwieldy; a smaller one would not have been adequately representative of all sectors and disciplines. The activities of the Committee included the following phases and meetings:

1. Background material researched and distributed (Appendix and References);
2. Conference call to discuss the scope and approaches of the study, the nature of the final report, further information required, and assignment of subcommittee tasks;
3. Meeting in Ottawa for wide discussion of issues and review of pertinent information; meeting with Management Committee of GSC;
4. Preparation of draft text by subcommittees, circulation for comment and revision;
5. Meeting in Ottawa for in-depth discussion of final report draft text; agreement on final modifications and illustrations; separate meetings with CGC Executive; representatives of the Committee of Directors of Provincial Geological Surveys; and the Minister's Industrial Advisory Committee (MINIAC) to the GSC;
6. Submission of report to President, CGC; submission by CGC to Assistant Deputy Minister of GSC.

The Committee agreed to produce a reasonably brief report, that it was unnecessary to duplicate the substance of the USNRC Report (National Research Council, 1993), and that a wide range of pertinent reports had appeared over the last decade (Appendices; References; Bibliography) – many with important recommendations still ignored. It further agreed that its main role should be to review critically this wealth of status reports and, in the light of the new paradigm for the earth sciences and the rapidly changing economic climate and societal needs, to attempt prediction of some future challenges, trends, and requirements. The Committee was fully aware of the diffi-

### Table 1.1 Members of the Committee

**Chris R. Barnes, Chair**
Director, Centre for Earth and Ocean Research
Univ. of Victoria, Victoria, British Columbia
(Sedimentary geology)

**Brian D. Bornhold**
Pacific Geoscience Centre
Geological Survey of Canada, Sidney, British Columbia
(Marine geology & global change)

**Larry Mayer**
Dept. of Geodesy and Geomatics Engineering
Univ. of New Brunswick, Fredericton, New Brunswick
(Marine geoscience, ocean mapping, paleoceanography)

**Ian A. McIlreath**
Pan Canadian Petroleum Ltd.
Calgary, Alberta
(Petroleum and sedimentary geology)

**Brian J. Skinner**
Dept. of Geology and Geophysics
Yale University, New Haven, Connecticut
(Economic geology)

**Douglas VanDine**
VanDine Limited
Victoria,British Columbia
(Geological engineering, hazards)

**Roger Wallis**
Senior Geological Consultant
Billiton Metals Canada Inc.
c/o Shell Canada Products Ltd. North York, Ontario
(Economic geology, Precambrian geology)

*The Committee was ably supported by* **Bill Colins** *as a part- time researcher. It maintained contact with* **Dr. Glen Caldwell** *(President, CGC) and* **Dr. Jim Franklin** *(Chief Scientist, GSC) during the study.*

culties of predicting future scenarios in a world in which physical and social systems display predominantly chaotic, non-linear dynamics and in which diverse to polarized views exist within the geoscience community on several issues.

The report was submitted on January 31, 1995, considered by the Canadian Geoscience Council and the Geological Survey of Canada over several months, and revised in September, 1995.

## Definitions

For the report, the future is considered as three intervals: short term (0-5 years; essentially an electoral term or that of a longer scientific grant), medium term (5-10 years; where predictions may be secure, but less influenced by past/present conditions), and long term (10-50 years; to a point when the global population will likely have at least doubled and significant climate change may have occurred, but for which many predictions are imprecise or impossible).

A definition of geosciences for the purposes of this report was difficult. The Committee agreed to adopt the terminology used by the US NRC Report (page 1):

> "*We use the term* **solid-earth sciences** *to specifically apply to terra firma - the solid surface and the planet's interior; the term includes geology (and all of its subdisciplines) along with significant portions of geophysics and geochemistry.* **Earth Sciences** *(also geoscience) refers to all of the disciplines that study the planet and includes oceanography; atmospheric science; hydrology; and parts of ecology, biology and solar-terrestrial physics.* **Earth system** *is used in reference to all of those disciplines and emphasizes their interactive processes*".

While the CGC Committee accepts this terminology and will freely interchange the terms *earth science* and *geoscience* in the report, we appreciate that the report is being prepared for the CGC and GSC, both of which have more of a focus on the solid-earth sciences than on the broad oceanic and atmospheric sciences. We do, however, recognize and support the paradigm shift that has occurred over at least the last decade whereby the Earth, and both its past and present processes, are studied as the earth system. The Committee membership, likewise, has an emphasis on the solid-earth sciences. Consequently, the report is written in support of an earth system science approach but with an emphasis on the solid-earth sciences. It remains a fundamental challenge to the earth science community, GSC, CGC, the Canadian Meteorological and Oceanographic Society (CMOS), industry, and academia to articulate better a broad concept of earth system science as a unifying and natural discipline.

The reader is encouraged to view the findings and recommendations of the report critically and with a healthy skepticism in places. The report should engender debate and promote new thinking on the future challenges and trends in the geosciences. It should also promote more integrated and collaborative medium to long-term planning of scientific programs. It seems evident that both the scale and rate of physical and social change will increase markedly in the long-term, in contrast to even those significant changes that have occurred during the Industrial Age.

# 1 (c) The Present is a Key to the Future

A review of the future challenges and trends in the geosciences in Canada should be undertaken in the context of the present status of the discipline. The earth sciences in Canada have been developed to a high international level, perhaps not surprisingly given that the country has the second largest area and the longest coastline in the world, fronts onto three oceans, and includes a range of polar to semi-arid environments. Canada is a remarkable natural laboratory. As a consequence of the country's low population, it has a small cadre of scientists to investigate this exceptional setting and natural-resource endowment. Canadian applied science, industrial development, and new technologies have likewise been fostered and have attained international recognition. Earlier studies have examined the status and health of the Canadian earth sciences or major components or sectors (*e.g.*, Neale, 1968; Blais *et al.*, 1971; Neale and Wynne-Edwards, 1976; Neale and Armstrong, 1981; Wojciechowski, 1989; Blais *et al.*, 1989). As part of a process to review the health of all fields of science and engineering, the Natural Sciences and Engineering Research Council of Canada (NSERC) asked its discipline grant selection committees to prepare overview statements. That for the Earth Sciences included a review of the current status and future directions of research on the major component shells of the planet (core to atmosphere) (Natural Sciences and Engineering Research Council, 1993). Last year, NSERC established a new process to allocate funds among its disciplinary grant selection committees. The two Earth Science Grant Selection Committees (ESGSC) prepared an Allocation Report that discusses and documents the current health and status of the geosciences and presents a future vision of their future in Canada. This is an important document (see Appendix) and will be referred to elsewhere in this report. Chapters 2 and 5 include data that indicates the strength and significance of the industrial earth science sector.

Overall this information suggests that the earth sciences have played, and continue to play, a significant role scientifically and socio-economically in the nation, and that they can be expected to do so into the foreseeable future. As one measure of the international stature of the discipline, the *Allocation Report* (Natural Sciences and Engineering Research Council, 1994; Tables 1, 2) analyses the ranking of Canadian contributions to earth-science research. In terms of scientific output, earth sciences was second only to biology for six fields of science and engineering in Canada, and Canadian earth sciences output led the 7 OECD countries (with data being normalized to Gross Expenditures on Research and Development (GERD)). Later tables in this NSERC Allocation Report document similar strength across a broad cross-section of subdisciplines in the earth sciences, established through a comparison of contributions by authors from several developed countries in a wide range of leading international journals.