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Once Again We Face a Challenge

Andrew D. Miall

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FEATURE

Pyroclasts

Once Again We Face a Challenge

Andrew D. Miall
Department of Geology
University of Toronto
Toronto, Ontario M5S 3B1
Phone: (416) 978-8841
Fax: (416) 978-3938
miall@quartz.geology.utoronto.ca

The earth sciences are not doing very well these days. The Canadian earth science community, despite strenuous efforts, did not manage to convince NSERC to increase its funding levels during the recent re-allocation exercise. In fact, our allocation continued to decline. The Academy of Science of the Royal Society of Canada has recently carried out its own reallocation exercise, relating to the distribution between the sciences of the number of new Fellows that may be elected each year. The Earth, Atmospheric and Oceanic Sciences Division was reduced from four to three new Fellows each year, the Mathematics and Physical Sciences Division went from eight to seven, the Applied Sciences and Engineering Division remained at three, while the Life Sciences Division was increased by two, to 11. What this means is that there are now significantly more mature scientists that have created distinguished careers for themselves in the life sciences than in the earth sciences and related fields, and membership in the Academy must be adjusted to reflect this apparent reality.

Lest we take this too personally, it is worth pointing out that this downsizing of the earth sciences is happening elsewhere. In the February 1999 issue of *Geotimes,* David Applegate reported that in the United States "key geoscience-related agencies and programs have not kept pace with overall science budget increases." He stated, "the ability of science to garner funding depends almost entirely on the ability of agencies and their supporters to provide Congress and the White House with a compelling rationale for their activities. It would appear that the traditional arguments invoked for funding science have not been as convincing for the geosciences as they have been for other disciplines, most notably biomedical research." He noted that funding for research in the United States is based primarily on the economic argument that research leads to new technologies and to economic growth. He then went on to say, "the economic rationale works best if the scientific community's arguments are echoed by the private sector. The biotechnology and computer industries have been particularly vocal in this regard. In contrast, the energy and mineral industries have been rapidly reducing their own research efforts, hardly a ringing endorsement. Moreover, policy-makers do not view them as future growth industries."

Applegate's comments in *Geotimes* indicate a similarity in the United States to the Canadian experience. The report of the NSERC Reallocation Committee (which may be viewed on the web at www.nserc.ca) stated "the most convincing submissions [from the various discipline committees] were those that described a vision and strategies for the discipline in Canada... The most compelling arguments for additional funds came from those disciplines whose submissions made a clear case that their research was developing rapidly and moving into new and exciting areas." With regard to solid earth sciences and environmental earth sciences (Committees 08 and 09) the report stated that it found the description of the current state of earth sciences in Canada "too general and ... failed to provide a compelling view of emerging areas and priorities for the future. ... Major issues like global change were barely mentioned. Hydrocarbons and mining have been, are, and will be important to Canada, but these are relatively mature fields while, for example, the biobased fields are just emerging. The environmental sciences field is indeed an emerging one but a strong case was not made for it in the submission. Neither the interaction of Earth Sciences with Biology nor its impact on other fields was discussed."

Clearly, this is the moment to engage in a major rethinking exercise, including asking the fundamental question: do the earth sciences matter any more? We had our plate-tectonics revolution. Are we now just in the "mopping-up" phase, doing "normal" science? Why should the public, through disbursements of tax dollars, continue to support our careers when apparently there are so many more exciting things going on in other disciplines, especially biotechnology, genetic engineering, and the computer sciences?

While in no way trying to be wise after the event, a re-reading of the report submitted to NSERC for the earth sciences does tend to suggest that a different kind of focus might have worked better. The report tries to indicate how good we are at chemistry and physics and ecology and oceanography, to the extent that perhaps the geological core of the discipline may have lost out. There is plenty about global change in the earth sciences report. If this did not come through to the reviewers and the reallocation committee perhaps this is because it was not focussed on what earth science does best, but was dissipated by mention of all the interdisciplinary programs we are members of.

The NSERC conclusions are all the more frustrating because a particularly detailed examination of the earth-sciences in Canada was carried out by the Canadian Geoscience Council only 4 years ago, partly in response to an earlier reallocation exercise, and provided a wealth of documentation and numerous ideas for revitalizing the discipline (Barnes *et al.*, 1995). Any scientist reading this document would conclude that a scientific community that could produce a report of this breadth and scope must surely be in a healthy state.

I was very excited by the emergence of "earth system science" and the publication of books like *The Blue Planet* (Skinner and Porter, 1995). The concept of the earth as a dynamic system is a very powerful and instructive one. It explains surface processes and events as the product of interaction between the four "spheres" — lithosphere, hydrosphere, biosphere and atmosphere — drawing on all the sciences to illustrate the complex nature of natural processes. This a powerful approach for teaching purposes. Church (1998) argues the same case in his recent fascinating *Geoscience Canada* article, and Nowlan (1998) similarly voiced enthusiasm for the new approach in his GAC Presidential Address. Several earth science departments in Canada have been merged with such other departments as geography, as a recognition of the trend toward earth system science and as an attempt to capitalize on it. However, this approach possibly contains the seeds of a strategic error for our discipline: environmental biologists, chemists and physicists and even environmental engineers have been very successful at carving off pieces of this dynamic earth system for their own ends, and developing very successful research programs of their own, some of them taking a little of the earth sciences with them. In the process, the geological core (no pun intended) of earth system science, and our part of it, may have been neglected to our cost as a discipline and profession. Knill (1998) noted that "meteorologists, oceanographers, glaciologists and ecologists have been remarkably successful in mounting major international community research programmes to study global environmental change ... But geologists, in the main, have made a disappointingly small contribution to our understanding of these processes of recent change."

It seems to me that earth scientists are the keepers and nurturers of some unique mindsets, or ways of thinking, that should be essential components of any view of Earth. All of these form the core of what we used to call geology, a term now largely abandoned in favour of earth science because of its broader, multidisciplinary connotation. I list four of these ways of thinking about Earth.

Concepts About Time

It is not just the way earth scientists casually toss millions of years around in their conversations, nor is it even the concept of "deep time", that even the general public may be beginning to understand; it is the hierarchical nature of time that is important to the earth sciences. It is the fact that many processes with vastly different frequencies or time scales can all be proceeding at once. Orbital forcing of climate is an excellent example of this. There are several periodicities that, together, combine to generate a very complex pattern of climate forcing, for which many details remain to be worked out.

Concepts of Physical Scale

At the one extreme, whole-earth plate tectonics. At the other extreme, crystal growth as imaged in the SEM or the atomic-force microscope.

The Three-dimensionality of Earth Science Problems

Orogens that have undergone many tectonic events are extremely complex entities. Ore bodies and toxic waste plumes and most of the other features that earth scientists deal with require visualization in three dimensions for effective management. Some unique tools have been developed to assist us, such as 3-D reflection seismic and seismic tomography. As Dott (1998) remarked, "Geology is a very geometric science."

Scientific Complexity

The interaction of physical, chemical and biological processes in earth systems.

While the last of the four is important, it is this one that may have gotten us into trouble as far as promoting our own discipline is concerned, as noted above. Nonetheless, it remains a critical strength of earth science and of earth scientists. To these characteristics of our discipline Dott (1998) would add the visual nature of earth science: its reliance on diagrammatic devices, such as maps and sections, for the portrayal of data and ideas. The need to keep these ways of thinking about Earth in the forefront of human thought is, to me, the main reason for continuing to urge that mainstream earth science programs be maintained at high schools and in universities.

Now to turn to research aspects of earth science: not only has the NSERC reallocation exercise suggested that we need to rethink our future as a research discipline, but the imminent winding-down of our successful LITHOPROBE program is also forcing us to ask the question "What do we do next?" Is there a post-LITHOPROBE something or other that will bring us all together again in a common purpose for the public good that will be sufficiently important to reverse our declining fortunes in the realm of research funding? There is a danger of perceived irrelevance or at least of dullness, if we continue to promote the kind of "normal" (although excellent and useful) science we have been doing for the last decade.

Knill (1998) asked, with reference to the multidisciplinary research currently underway in the field of global environmental change "What then, in this vast scenario, is the role of the geologist?" And he answered: "We are not leading the science of global environmental change although there is potentially much to be offered. ... The profession is not sufficiently anticipatory or proactive." He identified the main opportunities in the following areas: "a) reducing climate change; b) geological resources: quantum and impact; c) infrastructural development; d) waste management and pollution; e) extreme events; f) environmental vulnerability and conservation; g) ethics." He went on to discuss earth science input into a range of studies in these seven areas.

Two years ago I rounded up a couple of dozen Canadian colleagues to put together a proposal under the federal Networks of Centres of Excellence program for a Network to carry out interdisciplinary research in the area of sequence stratigraphy. Co-operation was enthusiastically offered from the academic community and from several leading members of the Geological Survey of Canada, and many excellent ideas were melded into what we all thought was an impressive proposal document. A few enthusiastic individuals in Canada's petroleum industry also took part, but primarily at the working-geologist level. Serious management support was not forthcoming, and this may have been one of the critical weaknesses of the proposal, similar to that lack of "ringing endorsement" for geoscience research noted by David Applegate in *Geotimes*. In any event, our Letter of Intent was not even selected as one of the short list for the second round of appraisals, and the effort died. However, I think we were on to something, and it is a desire to remind the earth science community of the need for a further development of these kinds of ideas that is the main reason for publishing this commentary. As a community we need urgently to debate where we go next. Can we apply our unique skills and mindsets better than anyone else to solve a problem that society has not even seen clearly yet? (not necessarily through the NCE Program, which seems to be designed to favour research with strong industrial links.)

Our sequence stratigraphy network proposed to combine existing *ad hoc* academic, government and corporate research in sequence stratigraphic mapping and basin modelling, drawing on the skills of stratigraphers, sedimentologists, biostratigraphers, geophysicists (particularly those working in the area of seismic stratigraphy) and numerical modellers. On a smaller, less ambitious scale, this was an attempt to copy the interdisciplinary success of LITHOPROBE. Ron Clowes (personal communication, 1998) indicated to me that if the Canadian earth science community is looking for a similar type of post-LITHOPROBE project, research focussing on the shallow crust to address problems relating to environmental matters, such as the subsurface flow of toxic wastes, may be one direction to head. There are others; we need to stimulate widespread thinking and discussion.

There is another potential benefit of sequence research that I deliberately did not develop in our network proposal (which was intended to focus on the industrial benefits, in hindsight, perhaps a mistake), but which draws particularly strongly on our "geological" mindsets and plays to our strengths. This is the study of the geological record as an analogue for future global change. Just about every climatic condition imaginable has already happened on Earth, and there are detailed records of this stored in the stratigraphy of sedimentary basins. It would be a very productive exercise to engage in a meticulous unravelling of this stored climatic record in order to constrain and provide "ground truth" for climate models. Current computer simulations tend to be rather too generalized and cannot readily incorporate local geographic detail, such as the climatic effects of mountain ranges and large inland water bodies. The stratigraphic record could lay all this bare, if we sharpened our skills in such areas as chronostratigraphy and sedimentary geochemistry in order to develop climatic reconstructions for regions that were meticulously correlated with each other. A highly detailed climatic reconstruction for, say, the 53 Ma time slice of the Eocene Earth would then be an enormously powerful illustration of how the Earth's climatic system actually worked under given conditions of orbital forcing, global sea level, and so on. Many of the projects of the International Geological Correlation Program and of the Ocean Drilling Program are already engaged in similar kinds of tasks, but I submit that a concerted attack on the Earth's climatic record would focus earth science research in a way that has not yet happened. ODP work can only, of course, deal with the marine record, primarily that of the deep oceans.

Rather than try to describe everything going on in our profession, as the last reallocation report attempted, perhaps our energies as a group of Canadian professionals should now go into developing focussed proposals, comparable to LITHOPROBE, that the non-specialist (like NSERC reviewers) can understand and be excited by. But proposals have to stand up against the Human Genome Project and cloning and all the other biological and computer-related marvels if earth science is to continue to hold its place as a thriving research enterprise. And we have to face it: we are going to have to do a far better job than we have so far if we are to reverse the downward trends in expenditures and employment on resource-related earth science (as documented by Nowlan, 1998). In fact, there seems little point in basing new proposals for large-scale earth science research on the presumed relevance of the research to the resource industries.

An opportunity presents itself to work on these ideas, with the forthcoming GeoCanada 2000 conference in Calgary, to be hosted by the major Canadian geoscience societies, including GAC, MAC, CSPG and CSEG. Preliminary discussion among members of the Canadian Geoscience Council, the Royal Society of Canada, and the conference organizers have begun in this area, and input will be required from everybody if we are to succeed.

Do the earth sciences matter? Of course they do: to us. The challenge is to convince the rest of the scientific community, and the public at large, that our profession and our research is vitally important. Nice posters and web-sites about dinosaurs and earthquakes are not enough. We need to develop educational and research programs that make the case for the uniqueness and essential character of our discipline for the future health and wealth of the global community. In doing so, let us not forget that at its centre, and forming its vital heart, are the "ways of thinking" about Earth that we used to be unashamed to call "geology." Nobody else can lay claim to this type of science. Let us reclaim it.

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