PRESIDENTIAL ADDRESS

Trend-Spotting in the Geosciences

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"Are we nearly there?" Alice managed to pant out at last.
"Nearly there!" the Queen repeated. "Why, we passed it ten minutes ago!"

INTRODUCTION

The Geological Association of Canada (GAC) Presidential Address is an exceptional opportunity for Presidents at the end of their term of office to share personal thoughts and comments with fellow geoscientists on just about any geoscience matters they wish. Free of any obligation to submit a technical paper, this essay provides a light summary of my personal reflections and forecasting on aspects that I believe will govern and influence the future success of geosciences in Canada and abroad. For a good recent review of the current status of geosciences in Canada see GAC President's address by Lebel (2010).

In 1871 Lewis Carroll wrote his most famous poem *Jabberwocky* which some historians believe was written at that time as a reflection on the rising popularity of paleontology and geology in Victorian England (Fig. 1). It was a critical time for our discipline (see GAC President's address by Johnston in 2011), one that was influenced by many notable visionaries including Hutton, Lyell, Cuvier and others. With his creation of *Jabberwocky* I take liberty and stretch the link between geosciences and Lewis Carroll and therefore propose him to be one of several 19th century visionaries. Accepting this reasoning, I look towards another one of Carroll's accomplishments, in particular his 1865 *Alice's Adventures in Wonderland*. The quotes by Alice and the response by the Queen at the start of this essay are offered as a caution to Canadian geologists to not dwell on the good old days. As a community we can celebrate centuries of success, we should accept the competitive economic realities that exist today between disciplines and we must avoid questioning the *raison d'être* of geology. Disciplinary self-doubting, lamenting over days long gone and an intransigence to adapt will not sustain our discipline's relevance and longevity. Indeed the 'geoscience train' left the station a long time ago (Fig. 2). New ideas, interesting questions and fantastic possibilities are available to all of us in geosciences if we accept a significant shift in our paradigm of collaboration.

The title of my presentation is obviously a play on the term 'Trainspotting' which was popularized in the 1996 British cult film based on Irvine Walsh's book of the same title. Ignoring the lively and underlying bizarre content of the book and movie, it is noteworthy that the term trainspotting is linked to a special group of train enthusiasts and hobbyists, aptly called train spotters, who spend much of their time watching, collecting data, photographing, analyzing, interpreting, discussing and debating issues related to trains. Apparently it is not unusual for train spotters to gather *en masse* along rail tracks and share in their collective delight to catch glimpses of otherwise ordinary looking trains; as far as the rest of the world is concerned (Fig. 3). Although many people would look upon train spotters with some trepidation, the same can likely be said by others on the outside that look at this strange group of pro-

Figure 1. Lewis Carroll's *Jabberwocky*. This rendition of the beast has the leathery wings of a pterodactyl and the tail of a sauropod. Digital image credit: Lenny's Alice in Wonderland site. Accessed 28 August 2013. http://www.alice-in-wonderland.net/jabberwocky.html.

Figure 2. Train madness in India. Digital image photo credit: Mojito Loco, 24 August 2011. Accessed 28 August 2013. http://www.mojitoloco.com/2011/08/train-madness-in-india/.

Figure 3. Train spotters in the UK. Digital image photo credit: Peter Van Den Bossche, 13 September 2002. Accessed 28 August 2013. http://www.flickr.com/photos/12814307@N00/197102980.

fessionals called geologists. Our chosen career paths in geoscience allows us to watch, collect data, photograph, analyze, interpret, discuss and debate all types of topics related to geosciences. And in this regard my commentary herein will focus on spotting certain trends that will influence the future of Canadian geosciences for decades to come. To do so, my essay comprises three parts: 1) a brief review on the future priorities for geoscience research as reported by the global community outside of Canada; 2) a social commentary on the shifts in public perception, direction and opportunities amongst the key geoscience sectors around the world over the past 25 years (conveniently corresponding to the 25 years since completion of my PhD), and finally; 3) a synopsis of recommendations for the future of geoscience research.

GLOBAL GEOSCIENCES

During the past several years I have had the chance to regularly interact with representatives from a number of international non-governmental organizations (NGOs), surveys, institutes and other organizations who focus on the Earth Sciences (during 12 years as part of the International Union of Geological Sciences (IUGS) Executive Committee). Many if not all such bodies guide their own future as a consequence of audit results, think tank outcomes and strategic reviews in the form of outputs we know as 'strategic plans.' For the purposes of this essay I provide a snapshot of some of the key observations that can be extracted from a few of these strategic plan documents.

A large number of non-governmental organizations deal directly or indirectly with global geoscience issues. In this cluster of organizations I include such NGOs as the International Council for Sciences (ICSU), IUGS, American Geophysical Union (AGU), American Geosciences Institute (AGI) and many others. In all cases their strategic plans and deliverables are very high level, play a facilitating role and share broad political appeal. A good example of an international activity at the NGO level that involved geoscience contribution was the International Polar Year facilitated by ICSU.

As an example of the focus given by an international NGO, I summarize the 2012–2017 vision tabled by ICSU (ICSU 2011). Since 1931 ICSU has provided a focal point for strengthening all science for the benefit of society. Closely linked to the United Nations (UN) system this body represents 120 national members (representing 140 countries) and 31 international scientific unions (all disciplines). To do this, ICSU mobilizes the knowledge and resources of the international science community to: a) identify and address major issues of importance to science and society; b) facilitate interaction amongst scientists across all disciplines and from all countries; c) promote the participation of all scientists, regardless of race, citizenship, language, political stance or gender in the international scientific endeavor, and; d) provide independent, authoritative advice to stimulate constructive dialogue between the scientific community and governments, civil society, and the private sector.

In their most recent strategic plan, ICSU recognized the importance of international research collaboration, science for policy and the universality of science as key operational drivers. From a research perspective they plan to address the following 7 high level issues over a 5 year period: 1) Earth system sustainability research and global environmental change; 2) Global Earth Observing Systems; 3) Polar Research; 4) Disaster Risk; 5) Ecosystem Change and Society; 6) Sustainable Energy, and; 7) Human Health and Wellbeing. Interestingly, even though ICSU serves 31 disciplines, all seven of their high level research topics touch upon geosciences. To me, this offers a tacit confirmation that the geosciences provide integral foundation to any multidisciplinary science activity that purports to be relevant to the global community.

Shifting from the UN linked, high level, all science based ICSU strategy to an example of a large, but strictly geoscience based NGO, the American Geosciences Institute (AGI) provides a suitable snapshot of global issues that can drive geosciences into the future. The AGI is a non-profit federation of geoscientific and professional associations representing a community of approximately 250,000 individuals through about 50 member societies. Recognized as a world leader with an applied and socially relevant agenda, the AGI has a platform that identifies the following 7 critical needs for society that should steer geoscience research into the next decade (AGI 2012a, b): 1) energy and climate change; 2) water; 3) waste treatment and disposal; 4) natural hazards; 5) infrastructure modernization; 6) raw materials, and; 7) geoscience workforce and education.

An excellent indicator for global priorities and trends for the Earth Sciences is captured by the EuroGeoSurveys (EGS) organization. The EGS has represented the collective interests of the major European Geological Surveys for 41 years and now has a membership of 33 state surveys. Their statutory aims are to address European issues, but this Eurocentric focus must also simultaneously encompass the national diversity of its membership. Consequently the EGS views the Earth Sciences bilaterally: from its 33 members and from the position of Europe relative to the rest of the world. The role of EGS leadership in launching OneGeology supports this pragmatic view. The EGS recognizes seven major global 'drivers' that should influence the future directions of geoscience and therefore the research addressed by the geological surveys (Varet 2011): 1) climate change; 2) mineral resources; 3) natural hazards; 4) globalization; 5) unsustainable inequities; 6) information Society, and; 7) state reform. Bearing in mind their global drivers, formulation of priorities and actions would then revolve around five overarching major thematic objectives: 1) master and disseminate knowledge on energy resources, storage and management; 2) mineral resources; 3) pass from surveillance to active management of water resources; 4) provide tools for risk assessment, mitigation and resilience, and; 5) establish national geological frameworks. In turn, the EGS targets five broad mission objectives to direct geoscience work: 1) take a responsive place in R&D; 2) become a major partner for innovation; 3) become the reference centre for all geographic based information; 4) properly back public policies, and 5) contribute to international engagement. And finally, the latest 'vision' for the geosphere in Europe sees the following 11 challenges and opportunities: 1) non-energy raw materials; 2) energy; 3) environmental impact of resource exploitation; 4) underground spatial planning; 5) environmental pressures on near-surface geology; 6) natural and man-made hazards; 7) climate change; 8) geodiversity and geoheritage; 9) the international dimension; 10) virtual Earth, and; 11) public resources under pressure (EGS 2013). The drivers, overarching themes, mission objectives, challenges and opportunities apply equally well, with minor modifications, to the geoscience being undertaken in Canada by industry, academia and government.

On the international scale a few national institutes are recognized as global leaders in Earth Science research. For instance, the British Geological Survey (BGS) is a world-leading supplier of objective, authoritative and up-to-date geoscientific information and expertise (BGS 2009a, b). The current BGS strategic plan addresses six global challenges:

- Acquire, interpret and enhance the UK geoscience knowledge base and make it accessible and interoperable;
- Improve the communication of geoscience knowledge so that it can better support policy and decision-making by government and society;
- Enhance external partnerships to improve the quality, research and impact of our science;
- Apply a whole-systems approach to our science and improve understanding of the nature and potential impact of hazards and the sustainable use of resources;
- Understand, quantify and predict the response of the Earth's 'zone of human interaction' to future environmental change;
- Increase the economic impact and relevance of our work.

Coupled with this, the BGS identifies four strategic objectives to address the aforementioned challenges: a) making the observations; b) making sense of the observation; c) managing the data, information and knowledge, and; d) exchanging and exploiting the knowledge.

In 2010, one year after the release of their five year strategic plan, the BGS convened a think tank workshop (Earth Sciences in the 21st Century: a forward look) that concluded that the main driver(s) for Earth Sciences in the future should be societal needs including energy, water (and food), minerals, security of supply issues, waste management and mitigation of natural hazards (Burke and Hards n.d.).

Other prominent geoscience institutes such as the United States Geological Survey (USGS) and Geoscience Australia (GS) have their own strategic visions identifying what issues will influence the direction of Earth Sciences in the years to come. In 2010 the USGS restructured their focus under the following seven mission areas (Gunderson et al. 2011): 1) climate and land-use change; 2) core science systems; 3) ecosystems; 4) energy and minerals; 5) environmental health; 6) natural hazards, and; 7) water. Whereas in Australia the GS centers on six strategic issues: 1) responsible resource development; 2) cleaner and low emissions energy technology; 3) community safety; 4) improving marine planning and protection; 5) national geoscience infrastructure, and; 6) national geoscience capability (Geoscience Australia 2012).

My short review of future geoscience research strategies adopted by international NGOs and institutes indicates more similarities than differences. Social relevance, information sharing, public health and safety, resources, international cooperation, changing climate, and so on are some of the key drivers that will guide most geoscience research opportunities well into the future. Outside the box, other drivers on the horizon include medical geology, forensic geology, geoheritage, geoethics and more. One other factor has yet to be considered: exactly who is doing what in geoscience research? In the next section I provide my personal view (and therefore hearsay) on the changing roles, perceptions and characteristics of geoscience practice and how all of this may answer the previous question.

SOCIAL COMMENTARY

Around the world geoscientists are frequently categorized through a variety of schemes often based on their field of specialization or employment sector. Although such categorization is fraught with misconception and misunderstanding to non-geoscientists, to clarify my position in this essay I opt for a sector based distinction (academic, government and industry/private). I approach my sectoral comparison of characteristics and perceptions in two points in time: 1988 and 2013. I refer to 'traditional beliefs' as those attributes that likely typified geosciences in 1988 and 'current beliefs' to attributes in 2013. All of the observations, facts, suggestions and conclusions are personal interpretations and unsubstantiated.

Traditional beliefs (by the public, decision makers, some geoscientists and many others) once viewed geoscientists in the academic sector as those individuals who:

- Have attained their PhD in a subject specialty;
- Are inclined to only address basic or fundamental research issues;
- Must be solely responsible for educating, training and vetting future generations of highly qualified personnel;
- Who work in an atmosphere of unregulated direction (freedom of speech and research focus);
- Sometimes engaged in collaboration with other academics, and;
- Are not influenced by politics, the public, special interest groups or others.

Traditional beliefs viewed geoscientists in the industry/private sector as those individuals who:

- May have a Bachelor of Science or higher degree in Earth Sciences;
- Address only issues as defined by a corporate mandate or chain of command;
- Focus on the sole mission/goal of their employer (bottom line);
- Work in an atmosphere of regulated direction (external dialogue managed by communication officers), and;
- Are constantly influenced by a Board of Directors, shareholders and politics.

Traditional beliefs viewed geoscientists in the government sector as those individuals who:

- May have a Bachelor of Science or higher degree in Earth Sciences or other discipline;
- Address research issues as necessary;
- Are expected to focus work for the good of the government;
- Work in an atmosphere of diverse expertise and extensive access to resources, and;
- Are aligned with the government in power and the chain of command.

Some 25 years later, the perception, expectations and conditions for geoscientists in all three sectors have changed dramatically. Current beliefs (again by the public, decision makers, some geoscientists and others) view geoscientist in the academic sector as those individuals who:

- Do not necessarily have PhD in a subject of specialty;
- Address primarily fundamental research issues;
- No longer solely responsible for educating and training future generations of geoscientists;
- Work in a constrained and accountable atmosphere;
- May engage in research collaboration with others in all three sectors, and;
- Are strongly influenced by politics, the public and special interest groups.

Current beliefs view geoscientist in the industry/private sector as those individuals who:

- Employ the best trained individuals in Earth Sciences (from Bachelors to PhD degrees);
- Address fundamental and applied research issues;
- Focus on more than just the goal of their employer;
- Work in an atmosphere that is highly regulated and accountable, and;
- Are strongly influenced by a Board of Directors, shareholders, politics, the public and special interest groups.

Current beliefs view geoscientist in the government sector as those individuals who:

- May have a Bachelor of Science or higher degree in Earth Sciences or other discipline;
- Address research issues as necessary;
- Are expected to focus work for the good of the government;
- Work in an atmosphere of reduced expertise (fewer people) and access to resources, and;
- Are aligned with the government in power and the chain of command.

The primary sector characteristics then and now can be compared as summarized in Tables 1 and 2. In the past the academic community scored highest in terms of likelihood to meet the list of critical attributes whereas the industry/private sector scored lowest for such positive traits as abundant financial resources, unlimited equipment access, human resources, etc. Today conditions have changed drastically and the roles have been reversed. Large companies (in contrast to the very small private sector examples) can financially sustain independent inquiry, hire the best people and can examine pertinent geoscience questions; whereas geoscience departments in most universities around the world are obviously under duress (diminishing funding, shrinking departments and so on).

Trends and driving forces (Table 3) can be proposed to explain the radical shifts in the three sectors described in the preceding paragraphs. For the academic sector, host institutes are cutting and reducing Earth Science departments, faculty positions and their facilities/equipment. Financial support to academic institutes and researchers has been progressively declining globally. The public perceives fundamental research at the university level as a luxury and waste. And the very nature of an Earth Sciences department in a university is often put under question. In contrast, the industry/private sector realized that their success is based on a solid foundation of internal expertise. Problem solving is best accomplished internally with less expectation and reliance on other sectors or outsiders. They now appreciate that public perception and influence cannot be ignored. The increasing numbers of larger companies ensures they have access to significant human and financial resources. This sector has strongly embraced greater corporate social responsibility. And finally, the government geoscience sector is strongly influenced by the global economic environment. Around the world there has been a progressive reduction in human and financial resources spent in the public sector. Any basic and fundamental research has been replaced with greater attention to applied studies. Public perception and public needs strongly influence the government mandate. This sector has also strongly adopted a greater corporate social accountability.

Table 1. Sector characteristics 25 years ago (~1988). High, Moderate, Low refers to the likelihood of the parameter characterizing the sector in question.

	Academic	Industry	Government
Comprises diverse expertise and specialities	HIGH	LOW	HIGH
Access to a large number of internal experts	HIGH	LOW	HIGH
Access to an extensive internal suite of facilities	HIGH	LOW	HIGH
Access to abundant and secure financial resources	HIGH	LOW	HIGH
Provide a direct benefit to society and the public	HIGH	LOW	HIGH
Leading edge discoveries and innovation	HIGH	LOW	HIGH

Table 2. Sector characteristics today (~2013). High, Moderate, Low refers to the likelihood of the parameter characterizing the sector in question.

	Academic	Industry	Government
Comprises diverse expertise and specialities	LOW	HIGH	MODERATE
Access to a large number of internal experts	LOW	HIGH	MODERATE
Access to an extensive internal suite of facilities	LOW	MODERATE	MODERATE
Access to abundant and secure financial resources	LOW	HIGH	LOW
Provide a direct benefit to society and the public	MODERATE	MODERATE	HIGH
Leading edge discoveries and innovation	MODERATE	HIGH	LOW

Table 3. Trends and driving forces currently affecting the three geoscience sectors. High, Moderate, Low refers to the likelihood of the parameter characterizing the sector in question.

	Academic	Industry	Government
Public expectations from the sector members	HIGH	MODERATE	HIGH
Public perception of the sector members	MODERATE	LOW	MODERATE
Expected research study longevity	MODERATE	MODERATE	MODERATE
Likelihood to succeed under current conditions	LOW	HIGH	MODERATE
Possibility for research opportunities and collaboration	HIGH	MODERATE	LOW
Public trust of sector members	LOW	LOW	LOW

PRÉCIS AND RECOMMENDATIONS

The brief review of strategic directions in geosciences presented here suggests considerable overlap in research drivers, shared concerns/constraints as well as opportunities to be common around the world and these will significantly influence geo-research in the next several years. Resources, hazards, climate change, information/data access and other topics will remain prominent drivers for our research. Global economic constraints, reductions in the number of highly qualified personnel, limited access to equipment/technology and so on are only a few of the barriers which will continue to challenge geoscience research. But the opportunities to overcome such barriers are clear and are based primarily on the need for greater collaboration, cooperation and partnerships between universities, governments, industry, and nations. This is especially so because the roles and characteristics of these sectors has changed appreciably in the past 25 years. Most geoscientists in Canada have participated in field work with others or contributed to a multi-authored paper as individuals. But these efforts unfortunately do not constitute the level and degree of collaboration, cooperation and partnerships that are needed for long-term success. The time is perfect to capitalize on synergies, since the changes which all sectors have undergone in the past 25 years provide new possibilities for progress and success.

In 2011 the Committee on Global Science Policy and Science Diplomacy Development, Security, and Cooperation Policy and Global Affairs recognized, that for science (including geology), engineering and technology, three key barriers will affect the ability to advance science and solve problems in the future (US NRC 2011): 1) personal relationships in an age of virtual innovations; 2) educating and empowering a new generation of scientists, and; 3) engaging early career researchers around the world. The panel tabled a series of solutions to maximize scientific advances in an increasingly global research community: 1) overcome access to facilities and equipment; 2) pool resources (countries, agencies, industries); 3) combine local relevance with global intellectual engagement, and; 4) learn from industry. The observations and solutions by this committee very much focus upon and stress the need for expanding collaboration where possible (more than edge of one's desk work).

But what about the BIG research directions for geosciences in the future. The US National Science Foundation (NSF) commissioned a study by the US National Academy of Sciences who concluded 10 grand research questions for the 21st century will drive the Earth Sciences (US NRC 2012):

1. How did the Earth and other planets form?
2. What happened during Earth's 'dark age' (the first 500 million years)?
3. How did life begin?
4. How does Earth's interior work, and how does it affect the surface?
5. Why does Earth have plate tectonics and continents?
6. How are Earth's processes controlled by material properties?
7. What causes climate to change – and how much can it change?
8. How has life shaped Earth – and how has Earth shaped life?
9. Can earthquakes, volcanic eruptions and their consequences be predicted?
10. How do fluid flow and transport affect the human environment?

These big questions, the research drivers and the barriers to success discussed here coupled with a mutual respect and formal dependency amongst professionals in our three main sectors will ensure the geosciences remain relevant. Two insightful quotes from the British Geological Survey regarding the future of opportunities to succeed in geosciences provide a fitting summation to the basic premise of this essay.

"There are valuable prizes to be won – if the issues are tackled with industry. But industry will do their own research and acquire the results regardless of government input since it is a global market"

"Taking advantage of the current opportunities, this is best achieved through collaboration between different groupings of Earth Scientists, within universities, public bodies and industry"

The 'geoscience train' has already left. Those who yearn for the good old days will be left behind but those who embrace a new paradigm in cooperation will undoubtedly succeed. I end this essay on the future of Canadian geosciences with a final extract from Lewis Carroll.

"Would you tell me, please, which way I ought to go from here?" "That depends a good deal on where you want to get to," said the Cat. "I don't much care where ____" said Alice. "Then it doesn't matter which way you go," said the Cat. "___so long as I get somewhere," Alice added as an explanation. "Oh, you're sure to do that," said the Cat, "if you only walk long enough."

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