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Reviews

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WORKSHOP REPORT

The State of Earth Science Outreach in Canada and an Action Plan for the Future: Results of a Session and Workshop Held in Yellowknife, N.W.T., May 24-27, 2007

Godfrey S. Nowlan
Geological Survey of Canada
3303 -33rd Street N.W.
Calgary, AB T2L 2A7, Canada
gnowlan@nrcan.gc.ca

Donna Schreiner
N.W.T. Geoscience Office
P.O. Box 1500
Yellowknife, N.W.T. X1A 2R3, Canada

This report outlines the nature and content of a major session on geoscience outreach held at the annual meeting of the Geological Association of Canada and the Mineralogical Association of Canada (GAC®-MAC) in Yellowknife in May 2007 and the output of a workshop aimed at developing a clear framework for the planning of geoscience outreach activities in Canada, which took place on the weekend following the sessions.

THE SESSIONS

The largest session in the technical program at the Annual Meeting of the Geological Association of Canada and the Mineralogical Association of Canada in Yellowknife in May 2007 was a session on earth science outreach entitled: *Geoscience Skills for Canadian Communities*. A total of twenty-six presentations were made at this session that started in the afternoon of Thursday 24 May 2007 and ran through to the end of the conference on Friday 25 May 2007.

The early talks in the session dealt partly with national programs like the Canadian Geoscience Education Network (Fran Haidl, Saskatchewan Industry and Resources), the new book on the geology of Canada to be published in honour of the International Year of Planet Earth entitled *Four Billion Years and Counting: Canada's Geological Heritage* (Godfrey Nowlan et al., Geological Survey of Canada), and the EdGEO program of workshops for teachers (Eileen van der Flier Keller, University of Victoria). Al Donaldson (Carleton University) provided convincing evidence of the importance of interpreting earth sciences for those on cruises, citing many examples of the value of this kind of outreach. Jan Aylsworth (GSC) outlined NRCan's new program of outreach associated with the Hazards Program and Walt Humphries of Yellowknife provided an overview of the NWT Mining Heritage Society that is actively preserving aspects of the mining heritage in the Yellowknife area. The group who stayed on for the workshop (see Appendix) got a chance to see some of this work first hand.

Two talks dealt specifically with the importance of education in mining: Laura Clinton outlined the great success of the Mining Matters program in Ontario aimed at school-age children and Kate Bruce highlighted the Mine Training Program offered to both secondary and post-secondary students in Yellowknife. It is a joint program of the Kimberlite Career and Technical Centre and Aurora College.

Another two talks were delivered on industrial minerals and the importance of information about them. Dixon Edwards, who received the 2007 Geological Association of Canada E.R.W. Neale Medal for contribution to earth science outreach at the session, spoke on building stone as an outreach resource. Lesley Hymers of Dufferin Aggregates spoke on her company's outreach program that encourages a better understanding and awareness of the aggregate industry.

Seven talks were presented by elementary and high school educators, most of whom had received some financial support from the Canadian Geological Foundation or the Northwest Territories and Nunavut Association of Professional Engineers, Geologists and Geophysicists (NAPEGG). Their talks provided key threads for understanding the classroom environment at different grade levels and excellent insights into curriculum in various jurisdictions. Jane Londero (Vanier Catholic Secondary School, Whitehorse) gave a vivid impression of the challenges and advantages of being a geologically trained high school teacher. Linda Popoff (Hugh Cairns School, Saskatoon) described the elementary school environment, through a presentation prepared by her Grade 5/6 class. Steve Daniel (Department of Education, Culture and Employment, N.W.T.) outlined the new experiential science 10-20-30 curriculum in the territory. There is a substantial practical hands-on aspect to this curriculum and a substantial amount of earth science content. John Etches (Etches Environmental Education) described a geological mapping interpretation exercise that can be conducted on a badminton court in a school gymnasium. Again this is a hands-on activity that teaches students the importance of keen observation. Brian Briggs (Calgary Separate School District) advocated strongly for

inquiry-based learning in elementary classrooms, a theme that recurred several times in the session. Michael Jackson (St. Michael's University School, Victoria) described the use of the Seismic Eruption program in the classroom, using live links to this interactive web-based system. Erica Williams (Riverside Secondary School, Port Coquitlam) provided a critical analysis of geoscience in Kindergarten to Grade 10 curriculum in British Columbia, pointing out some serious flaws. Talks within this suite built really well on each other and provided the non-teachers in the audience with some very useful insights into elementary and secondary education.

Two talks dealt with education at the university level. Eileen van der Flier Keller gave an account of a survey of students in a first year earth science course at the University of Victoria that addressed their high school experience with earth science. Lesley Reid (University of Calgary) provided information on a study at the University of Calgary whereby students are being actively polled and interviewed on their course experience with a view to changing the way courses are taught.

Masa Goto of the National Institute for Education Policy Research in Tokyo, Japan described the development of an innovative television program for children 13-15 years of age. The program focuses on minerals, both the study of them in the field and their societal uses. It was broadcast throughout Japan.

Finally, Godfrey Nowlan addressed the state of earth science outreach in Canada, indicating that while there had been many advances in the last thirty-five years, there was still a long way to go. The small scale, high quality, hand-made products that characterize cottage industries resemble the state of earth science outreach in Canada: great quality but not very widely available. He pointed out that it is still true that most Canadians do not really appreciate where all their stuff comes from and that they remain largely unaware of how Earth processes may affect them. This presentation was an introduction to the workshop entitled *Towards an Integrated Future in Geoscience Education and Outreach* that followed the session on Saturday and Sunday 26, 27 May, 2007.

THE WORKSHOP

At 8:30 a.m. on Saturday 26 May 2007, more than thirty geoscientists and educators convened at the Prince of Wales Museum in Yellowknife to address issues related to better integration of geoscience outreach in Canada (Fig. 1). The conveners of the workshop (Godfrey Nowlan and Donna Schreiner) outlined the program for the workshop and explained that the objective was to develop a framework for activity in geoscience outreach and education over the coming decade. The workshop had originally been conceived to address the geoscience outreach needs of northern Canada and to have only participants engaged in northern outreach, but the scheduling of the Geological Association of Canada–Mineralogical Association of Canada annual meeting in Yellowknife provided a perfect opportunity to take a broader national perspective. The first item on the agenda was for individuals to introduce themselves and explain why they were attending the workshop and how they expected to be able to contribute to the proceedings. The assembled group had representatives from most regions of Canada, but the highly active groups from the Atlantic provinces were sadly not represented, probably because of the high cost of air travel from that region to Yellowknife.

On Saturday afternoon, in the middle of the workshop deliberations, the participants took to the field (Figs. 2 and 3) for a visit to a section of superbly exposed Archean volcanic and sedimentary rocks located on the Giant mine property. The trip, ably and enthusiastically led by Al Donaldson, provided an opportunity for learning about geology and for discussion on how to convey geological ideas to the general public and in classrooms. It also afforded time for people to get to know each other better and for informal discussions of the session and first half of the workshop. The evening dinner at signature Yellowknife restaurants allowed for even more extended and animated discussions. Overall, the trip was likely a key element in the success of the workshop.

Earth Science in School Curricula

The workshop took the form of focused, open discussion around a series of questions posed by the conveners. The first question to be addressed was: *How can earth sciences increase its representation in school curriculum?*

The group first addressed the objectives of trying to get earth science

Figure 1. Workshop participants working hard at the Prince of Wales Museum.

more widely recognized in school curricula. After a wide-ranging discussion, the following reasons were identified:

- Produce earth science literate citizens;
- Make school students aware of earth science and its related career possibilities (resources, environment, oceans, atmosphere, hazards);
- Attract a proportion of high school graduates into earth science-related jobs.

The reasons are a mixture of wanting all citizens to be reasonably geoscientifically literate so that they can make educated decisions locally, nationally and globally and a desire to attract the notice of potential students in geosciences. The extreme shortage of geoscientists that is anticipated as the baby boomers start to retire is a particularly compelling reason for urgency in this matter.

Then attention was turned to *how* to accomplish an increase of earth sciences in the curriculum.

The first suggestion was to get earth science "wedged" into the existing curricula for science and social studies. It was noted that a great deal of earth science lies within the geography component of the social studies curriculum in most provinces and territories and that it would not be hard for geoscientists to make significant contribution to this area of curriculum. In addition, earth science can be wedged into many aspects of the existing science curriculum, for example paleontology should be worked into that part of the biology curriculum that deals with evolution and environment. Similarly, in the effort to make science socially relevant, many of the main scientific principles have excellent examples within the earth sciences, for example Earth's magnetic field and thermal properties in physics and the natural and anthropogenic distribution of toxic elements in environmental chemistry. All of this fits with the notion of geology as a synthetic science that uses aspects of all the other sciences.

The key actions defined for this requirement were to:

- Become active on subject advisory committees at the provincial level;
- Conduct a survey of earth science content in existing curricula.

Figure 2. Workshop participants on the field trip to the Giant Section on the shores of Great Slave Lake.

Figure 3. Workshop participants on the field trip to Giant Section, standing on pillow basalts.

It was thought that these two activities are early necessities. It was agreed that the best agency to complete a study of earth sciences in Canadian curricula is the Canadian Federation of Earth Sciences (CFES) through the Canadian Geoscience Education Network (CGEN). It was observed that an attempt was made to do this in 1995 and that a report was completed. However, the report contained some gaps and flaws due to the fact that there was a very limited budget for the

study and none available for travel. It might be easier to do now on a shoestring budget because of the increased amount of material and references available on the internet.

The second principal suggestion was to make the importance of earth science in society known to educational authorities. The key actions defined for this requirement were:

- Have CGEN/CFES contact ministers of education and possibly natural resources with an explanation of the importance of earth sciences and a request for an interview;
- Engage the Prospectors and Developers Association of Canada and the Canadian Association of Petroleum Producers in approaching governments.

It was agreed that the combination of these actions immediately following the assessment of earth science content in curriculum would be a powerful follow-up.

The third principal suggestion was to improve the capacity of educators to teach and understand earth science and its associated employment opportunities. The key actions identified to achieve this goal were:

- Professional development for teachers;
- Professional development for school career counselors;
- Outreach to parents;
- CFES to support curriculum evaluation.

It was observed that the success of the EdGEO Program of Workshops for Teachers over more than thirty years has probably done a lot to improve the knowledge of teachers, but even so, much more needs to be done. It was further agreed that there had been little effort to contact high school career counselors and that there were likely many misconceptions about the opportunities for work in Canada's resource economy. It was observed that this is the domain of human resource councils, but it was agreed that much more needed to be done and that it should be driven by the professional associations and industry.

The fourth principal suggestion was to improve the profile of earth science in post-secondary institutions. Many of the academics present bemoaned the fact that earth science was often seen as the poor relation in the science faculty and treated accordingly. Several participants observed that there is a bias against earth science even before students enter university: it is less taught in the curriculum and rarely taught in the senior part of high school. Even where it exists in senior high school curriculum (e.g. Ontario and British Columbia), it is not recognized as a valid entry science subject (teachable subject) in most universities.

Within universities, earth science is often the science subject taken by those who need a science requirement (the so-called "Rocks for Jocks syndrome"). The workshop participants saw a need to engage university career counselors in the same way as high school career counselors in order to defuse some of the myths and misunderstanding around employment in Canada's resource and environmental sectors for earth scientists.

A final and significant observation made under the discussion of the profile of earth science in universities was that earth science should be promoted as a very different science to Physics, Chemistry and Biology, in that it promotes three-dimensional skills, requires dealing with fuzzy datasets and has a strong need for teamwork. These are all desirable skills in modern society.

The key actions identified to rectify this situation were as follows:

- Get earth science recognized as a valid entry science subject in universities;
- CGEN/CFES contact Canadian Council of Chairs of Earth Science departments;
- Put pressure on post-secondary to recognize earth science as a teachable subject;
- Combat the "rocks for jocks" reputation;
- Engage university counselors;
- Point out unique values of ES: 3D skills, fuzzy datasets, team work.

The workshop contributors concluded that action was needed on all of the fronts identified.

The Gaps

The second major question posed to the workshop participants was: *What obvious gaps are there in the array of earth science outreach products and services available in Canada?*

It was noted at the top of the discussion that there was no complete current inventory of outreach products or services in Canada. It was observed that EarthNet, the existing on-line database of educational items available in Canada was not well supported in most years, despite the tremendous volunteer efforts of many people, especially those affiliated with the Atlantic Geoscience Society. It was agreed that there is a strong need for an excellent, up-to-date, searchable web site that would provide a one-stop shop for those engaged in earth science outreach and education.

In this context it was noted that Canadian earth science outreach efforts are almost completely volunteer in nature. There is really no supply of paid people to complete such inventories and maintain them. It was agreed that this may be the largest single stumbling block to improvement in the availability and promotion of earth science outreach materials in Canada.

One of the major gaps identified is the lack of a current careers web site. It was noted that there had been excellent booklets produced by the Canadian Geoscience Council (the forerunner of the Canadian Federation of Earth Sciences) but these were now dated and out of print. The CD/web site developed as its replacement was likewise deemed to be dated. Therefore there was strong support for a new interactive earth science career web site as one of the key requirements in the near future. Workshop participants were heartened to learn that CFES/CGEN are currently developing a new Careers in Earth Science web site that will be launched by early 2008 at the latest, as part of the program emanating from the International Year of Planet Earth.

Another gap identified was the general lack of geoscience outreach products related to tourism. A number of notable exceptions were identified such as the Nova Scotia Rocks brochures that are distributed at tourist stops in Nova Scotia and geological highway maps that are available to tourists in some provinces (e.g. Saskatchewan). It was recognized that there are many new opportunities for

travel brochures, improved signage in parks and narrations on radio and satellite navigation systems.

It was also noted that there is a general lack of geoscience-related programming on television. One suggestion was something along the lines of the old but successful Hinterland Who's Who. It was noted that the Canadian Broadcasting Corporation and the National Film Board have produced a five-part TV series called A Geologic Journey. At the time of writing, this program is being aired and is co-sponsored by the International Year of Planet Earth.

A subject that received considerable discussion was the general lack of good interpretation of geological features in national and provincial parks. It seems that most park interpreters are biologists and that there needs to be an increase in earth science trained people in park interpretation. There was a short discussion of the new concept of Geoparks that is being promoted by UNESCO and all agreed, these represented an opportunity in Canada, especially in regions without major tourist traffic at present.

There was also a brief discussion of the internet as a tool for earth science outreach. The suggestions were for going beyond the traditional educational web site to embrace interactive opportunities such as exist on Face Book and a variety of other chat rooms.

The integration of earth science outreach initiatives into environmental initiatives was advocated by some workshop participants. They noted that "green" initiatives are commonly well funded and that they represent major opportunities for earth science outreach. Links to existing environmental groups such as River Keepers were also encouraged as a way of linking earth science to the community.

This wide-ranging discussion of the gaps in earth science outreach led to a host of suggestions for action:

- Complete an exhaustive inventory of existing earth science outreach products;
- Promote existing products more effectively;
- Build a careers-related web site as soon as possible;
- Create a one-stop shop for all earth science outreach materials; build on the example of EarthNet or establish a new shop that is well funded;
- Find a way to hire people to conduct and maintain the inventory of earth science outreach products and to promote them;
- Establish more links to tourism: travel brochures, road-side signage, radio narrations, satellite navigation content;
- Broaden the presence of earth science in television;
- Get earth science interpretation (back) into National and Provincial Parks by establishing contacts with the interpretation community and providing workshops for park interpreters;
- Establish contacts with parks to encourage employment of earth scientists;
- Establish internet-based initiatives on interactive media such as Face Book and chat rooms;
- (Re)Establish contacts with environmental, heritage and historic societies to explore linkages within them for earth science outreach;
- Promote stronger links between earth sciences, education and corporations;
- Attach outreach efforts to "green" initiatives which are commonly funded.

Reorganization of Outreach

The final question posed to the workshop participants was: *How can we reorganize earth science outreach in Canada in order to accomplish more funded outreach in government, academe and industry?*

There was a general discussion of the need for some sort of infrastructure to support earth science outreach in Canada. It was acknowledged that some paid people exist in organizations such as museums and science centres and that perhaps they might be a starting point for establishing a permanent office of public outreach. It was also noted that some of the "issues" in earth sciences, such as natural hazards (e.g. earthquake awareness) may have paid people. Some thought that there might be people within geological surveys for whom outreach was at least a partial responsibility. Despite all these potential resource people, it was acknowledged that there really is a need for an office somewhere in which there are people whose responsibility it is to complete and maintain inventories of outreach products, research the effectiveness of various outreach approaches, and play a role in developing new products. Such an office does not exist at present. There used to be a limited office in the Geological Survey of Canada in Ottawa a number of years ago but it has been superseded by communications offices that more directly serve the needs of the minister and not science in general.

It was therefore agreed that there is a need for an independent office of earth science outreach with perhaps 1.5 FTE as a start to begin the process of providing a framework for all the volunteer efforts in earth science outreach that are currently under way. The workshop participants considered the following actions required to achieve this goal:

- Establish a CGEN/CFES Office of Earth Science Outreach with 1.5 full time employees by raising funds to pay salaries for staff and producing a work plan;
- Encourage professional secondments from industry, government and academe to the new office.

As a supplement to this office, all reasonable use should be made of existing professionals in other institutions to focus their efforts collectively on earth science awareness by:

- Partnering with existing professional labour in museums and science centres;
- Using provincial geotourism coordinators where they exist;
- Partnering with staff in geological surveys and universities who may from time to time have some outreach responsibilities.

Once this office is established, the workshop participants identified the need for a survey of earth science awareness in Canada, along the lines of the science literacy surveys conducted in the 1990s. This would establish a baseline of awareness against which future progress can be measured and future plans can be made. Some initial actions could set this process in motion:

- Contact CFES/professional survey agencies/media outlets to gauge

interest
- Conduct studies of the effectiveness of existing outreach programs such as EdGEO and Geoscape posters;
- Contact the NSERC Crystal Project for potential partnerships.

CONCLUSIONS

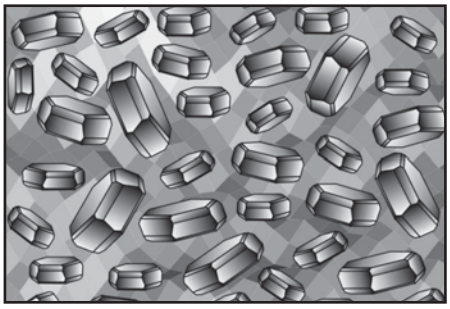
The workshop held in Yellowknife in May 2007 was the largest assembly of earth science outreach experts to have met in Canada to date. Through the intensive deliberations of this group an action plan for the future of earth science outreach in Canada has been clearly laid out. It involves several parallel thrusts: a move from the entirely volunteer efforts at present to establishment of a funded office to ensure that the framework of earth science outreach is maintained and volunteers do not burn out; an expansion of the existing efforts in earth science outreach, particularly to teachers, career counselors, parents and decision makers; a more prominent role for earth sciences in school curricula. A first draft of the detailed actions required to effect these changes are contained in this document and it serves as a starting point for the reformation, reorganization and reinvigoration of earth science outreach in Canada. The coming of the International Year of Planet Earth (2007-2009) should provide a wonderful catalyst for the achievement of some of the goals identified in this report.

The conveners of this session would like to thank the participants for their tremendous energy during the session and workshop. They would also like to thank the Canadian Geological Foundation and the Northwest Territories and Nunavut Association of Professional Engineers, Geologists and Geophysicists for their financial support for teachers attending this session and workshop. Thanks are also due to the Canadian Geoscience Education Network for their support of refreshments during the workshop.

APPENDIX: List of participants in the workshop *Towards an Integrated Future in Geoscience Education and Outreach,* held in Yellowknife, 26, 27 May, 2007

Jan Aylsworth	(Geological Survey of Canada, Ottawa)
Diane Baldwin	(NWT Geoscience Office, Yellowknife)
Charly Bank	(Department of Geology, University of Toronto)
Catherine Barrett	(Canadian Federation of Earth Sciences, Calgary)
Brian Briggs	(Calgary Catholic School Division)
Kate Bruce	(Yellowknife Catholic School Board, Aurora College)
Laura Clinton	(PDAC Mining Matters, Toronto)
Steven Daniel	(Govt. of N.W.T., Dept. of Education, Yellowknife)
Tania Demchuk	(School of Earth & Ocean Sci., Univ. of Victoria)
Allan Donaldson	(Geoheritage Canada, Ottawa)
Jon Dudley	(Canadian Natural Resources, Calgary)
Dixon Edwards	(Alberta Geological Survey, Edmonton)
John Etches	(Etches Environmental Education, Lakefield, ON)
Fran Haidl	(Saskatchewan Industry and Resources, Regina)
Linda Ham	(Indian and Northern Affairs Canada, Iqaluit)
Russell Hartlaub	(British Columbia Institute of Technology, Burnaby)
Brian Hitchon	(Geoscience Publishing, Edmonton)
David Huntley	(Geological Survey of Canada, Calgary)
Mike Jackson	(St. Michael's University School, Victoria)
Larry Lane	(Geological Survey of Canada, Calgary)
Karen Lochhead	(DocMatrix Canada, Gatineau, QC)
Gayla Meredith	(Yellowknife Education District No. 1)
Ward Neale	(Retired geologist, Calgary)
Godfrey Nowlan	(Geological Survey of Canada, Calgary)
Linda Popoff	(Hugh Cairns School, Saskatoon)
Donna Schreiner	(N.W.T. Geoscience Office, Yellowknife)
Eileen van der Flier Keller	(School of Earth & Ocean Sci., Univ. of Victoria)
Christy Vodden	(Canadian Geoscience Education Network, Ottawa)
Miriam Vos-Guenter	(Belmont Secondary School, Victoria)
Erica Williams	(Coquitlam School Division, B.C.)
Ian Young	(Can. Federation of Earth Sciences, Encana, Calgary)

ARTICLE



Brucite – Industrial Mineral With A Future

George J. Simandl[1], Suzanne Paradis[2] and Melanie Irvine[1]

[1]British Columbia Ministry of Energy, Mines and Petroleum Resources, PO 9333 STN PROV GOV'T, Victoria, BC, V8W 9N3 Canada. Corresponding author e-mail: George.Simandl@gov.bc.ca

[2]Geological Survey of Canada, Sidney, Natural Resources Canada, 9860 West Saanich Road, Sidney BC, V8L 4B2 Canada

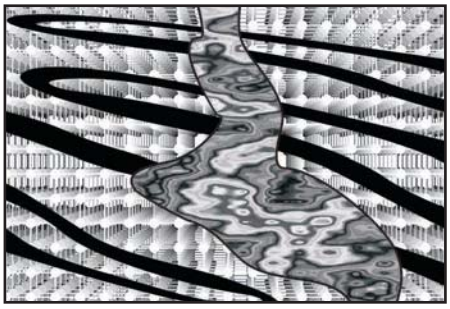
SUMMARY

Brucite, $Mg(OH)_2$, is an uncommon mineral primarily known to mineral collectors, and to specialists studying contact metamorphic and ultramafic rocks. It is an environmentally friendly flame-retardant and is in commercial demand; it also represents a potential ore source for the metal, magnesium, which is itself in great demand. The present brucite market for flame-retardants is less than 50 000 tonnes annually, but it is increasing exponentially. Brucite has the advantage of not containing CO_2; hence none is released during calcination, a positive feature in today's society concerned with climate change. This review paper summarises the topic for scientists studying the thermodynamic properties of brucite, geologists studying its contact metamorphic characteristics, exploration geologists and potential end-users. Given the demand for the mineral and metal, high-grade brucite deposits may become hot exploration targets within the next few years.

SOMMAIRE

La brucite, $Mg(OH)_2$, est un minéral plutôt rare connu surtout des collectionneurs de minéraux et des spécialistes du métamorphisme de contact et des roches ultramafiques. La brucite est un matériau ignifuge écologique qui est en demande commercialement; il représente aussi une source potentielle de magnésium métallique, pour lequel existe une forte demande. La demande actuelle de brucite comme matériau ignifuge est de moins de 50 000 tonnes annuellement, mais elle croît exponentiellement. La brucite a l'avantage de ne pas contenir de CO_2; et donc, aucun CO_2 n'est produit lors de sa calcination, caractéristique très appréciée en ces temps d'inquiétudes en regard des changements climatiques. Notre article de synthèse présente un résumé de la question à l'intention des scientifiques intéressés par les propriétés thermodynamique de la brucite, aux géologues intéressés par ses caractéristiques de minéral de métamorphisme de contact, ainsi qu'aux géologues en général et aux utilisateurs. Étant donné la demande de brucite comme minéral et comme source de métal, les bons gisements de brucite pourraient constituer des cibles d'exploration dans un avenir rapproché.

ARTICLE



Are Your Data Good Enough: A Checklist for Mining Prospects

Keith Dewing
Geological Survey of Canada
3303-33rd St NW
Calgary, AB, T2L 2A7 Canada
E-mail: kdewing@NRCan.gc.ca

SUMMARY
This checklist is intended to help geologists collect or review geological data on mining prospects in a manner that will conform to the increasingly stringent reporting requirements. Survey, assay, and geological data are the key initial inputs required to build a robust computer-based resource model. Once the resource model is built, a geologist reviewing the model should understand the methods and assumptions used in interpolating from the initial data to the gridded resource model. Closer cooperation between project geologists and resource modellers should improve the way data are collected initially as well as identifying biases, weakness and inconsistencies within the resource model.

SOMMAIRE
Voici une liste de vérification à l'intention des géologues qui ont à collecter et analyser les données de gisements minéraux, liste qui leur permettra de se conformer aux normes de compte rendu de plus en plus strictes. Les données de levés, de teneur et de géologie constituent les éléments clés initiaux indispensables pour l'élaboration d'un modèle informatisé de la ressource fiable. Le modèle de ressource retenu doit permettre au géologue de comprendre la méthode suivie ainsi que les hypothèses d'interpolation appliquées aux données initiales conduisant au modèle matriciel de la ressource. Une meilleure collaboration entre les géologues de projet et les modélisateurs de la ressource devrait permettre d'améliorer la qualité des données initiales collectées et de repérer les biais, faiblesses et incongruités du modèle de la ressource.

COMMENTARY

Geoscience Literature: Greater Volume – Less Access *or* Ignorants in the Sea of Knowledge

Peter Laznicka
Consultant
[www.Totalmetallogeny.com]
64 Lochside Drive, West Lakes 5021, SA, Australia
E-mail: plaznicka@dodo.com.au

INTRODUCTION

In 1913, when Louis de Launay published his monumental *Traité de Métallogenie*, the book that created the first factual synthesis of global ore distribution and laid the foundation for the discipline of metallogeny, he utilized at least 75% of the published global knowledge of his period, which comprised a list of references that counted only several thousand titles. The bulk of the literature was in six major European languages because there was virtually no scientific or technical writing to be found in the rest of world languages. At the onset of the 21st century we are blessed with more than four million accumulated references in the field of geology and related mining, and the list is growing at a rate of some 200-400 k/year (Fig. 1). To produce a 2007 equivalent of *Traité de Métallogenie*, would require familiarity with perhaps one million relevant references in at least thirty major languages (and eight different alphabets); this number could be reduced to some 200,000 citations if superseded and low-quality references were ignored, and further cut to a bare minimum of 10-20,000 citations to deal with the "key facts" only. In reality, however, the most recent books and databases pertaining to global metallogeny rely on 2000 citations or less. Furthermore, once a synthetic book is published, the reference list is already obsolete. Now, not many people aspire to comprehensively review global metallogeny, or any other broad subject for that matter, because there are few rewards, financial or otherwise.

Even "original research papers" are not 100% original because every piece of research has a history, including its framework, vertical and lateral relationships, transitionality, and conflicting interpretations, which is contained in the published literature. This literature has to be collected, compiled, summarized and critically assessed before the new research increment can be added. Missing crucial facts because of insufficient literature review can invalidate new research at the very onset. "Re-discovering the wheel" is an all too common event at many seminars and conferences these days. At a recent symposium on breccias, several speakers espoused ideas that had been published decades earlier, and in greater detail, in widely available (pre-digital) publications, of which they were not aware. One might expect this from junior researchers of the digital world but even prominent experts in their respective fields are not immune, especially when the missed

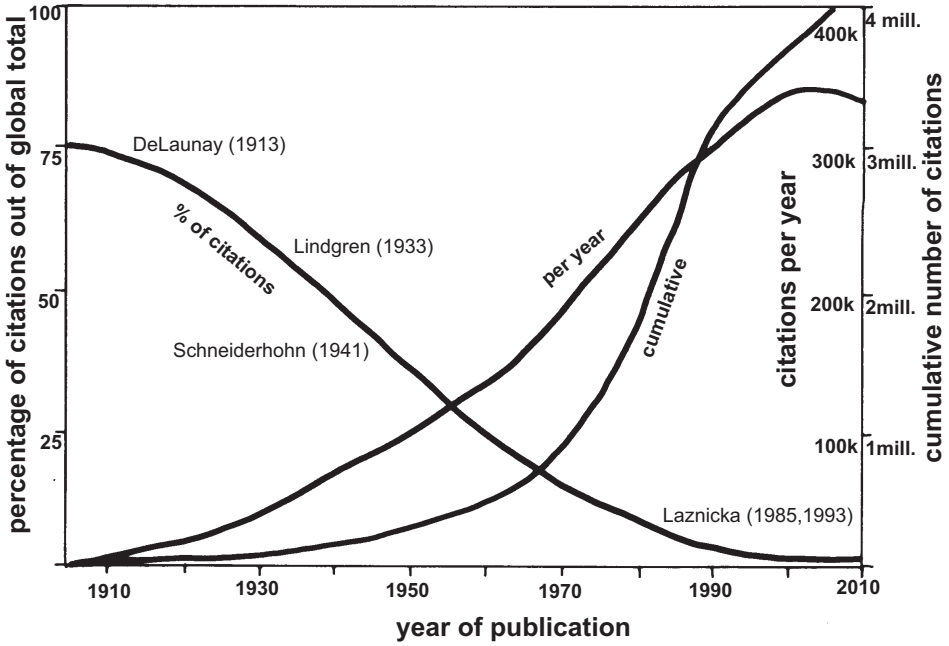


Figure 1. A graph showing an approximate relationship between the annual and cumulative growth of new scholarly citations in geosciences, and the percentage of citations out of the world's total actually consulted by authors of comprehensive monographs on global topics, e.g. metallogeny. Although the citations utilization is clearly much higher in more restricted studies, the general trends remain the same.

components are in foreign-language literature or come from different fields of expertise.

Scholarly literature is the repository of most of the existing, accumulated knowledge that has to be studied (even before that, translated if in an unfamiliar language). To do so one has to first compile a list of references, then obtain the texts. Generating a bibliography has been greatly facilitated by electronics; however, the ability to acquire publications to read has steadily deteriorated over the past half century because the cost and time to acquire them have greatly increased. In spite of the proliferation of publications, overall availability has decreased. Increased costs have beggared the under-funded researchers and condemned many to professional semi-literacy. Although colleagues in poorer countries are the hardest hit, substantial contrasts in terms of access to literature prevail, and increase, even in the richest societies. While the volume of knowledge increases, we read less, partly because it is so frustrating to get hold of a paper or a book that just might be relevant to our research. It remains to be seen if the new technologies and new thinking will reverse this decline of professional literacy in the future.

The published professional knowledge, in print as well as in the electronic media, is heterogeneous. However, more than 50% of reports in geosciences have regional implications and are mostly published by local (national) government agencies. At least in the industrialized countries, much of this information is available at nominal, reasonable cost; furthermore, the volume of entirely free, downloadable material from government websites rapidly increases. U.S. Government agencies send (or at least used to) many of their publications to the farthest corners of the world, and they maintain open access to a number of respected information sources on their websites. This includes the Mineral Resources Data System (MRDS) database and electronic successor to the annual Minerals Yearbooks, now compiled by the U.S. Geological Survey. Government publications can generally be regarded as stable, improving and predictable. This, unfortunately, is not the case with academic and research publishing and the rest of this article concentrates mainly on this genre.

ACADEMIC AND RESEARCH PUBLISHING

Until about 1960, most research serials were published by learned societies, academies and universities, under "gift exchange" arrangement with the authors. The publishing relied heavily on voluntary or underpaid labour driven by devotion to the cause, service to the profession and/or pride in the journal. The subscription costs approached the break-even point and were often subsidized, or free, to members. Most books, in contrast, were printed by private publishers. During the wave of Western prosperity in the 1960s, new universities were established, staff hired, and research grants initiated. Ultimately this led to the development of the now all-pervading positive feedback loop; grant-research-publish paper, which resulted in an avalanche of new papers that existing learned journals could not accommodate. The private publishers recognized a profit potential in publishing research serials, "achieving profit margins of 40% or more" (*The Economist*, 1998). The "scoundrel", Robert Maxwell, "made his early fortune from the worthy business of publishing the scientific world's latest discoveries" (*The Economist*, 1998). Other publishers followed and new journals of increasingly more specialized titles proliferated. The subscription prices kept increasing, devastating library budgets and almost wiping out personal subscriptions, which were still widespread with the society journals. *The Economist* (1998) described the predicament of 121 American libraries, which spent 124% more on journals in 1996 than in 1986 for 7% fewer titles. The price increases were far above the rate of inflation. As a result many of the newer journals have never been subscribed to by libraries and existing subscriptions to other journals gradually have been cancelled.

In our local library, mass extinctions have occurred; gone are the *Journal of Sedimentary Geology* (extinct since 1993), *Journal of African Earth Sciences* (1994), *Geologische Rundschau* (1994), *Lithos* (1998), *Earth Science Reviews* (1999), *Tectonophysics* (1999), *Earth & Planetary Science Letters* (2000), *Ore Geology Reviews* (2001), *Mineralium Deposita* (2003), and many others. By 2007, virtually all the printed for-profit journals in geosciences have disappeared here and one cannot blame the library. The 2007 subscription cost of only those journals mentioned above would come to some US $30k. The consequence is that the research published in these serials is now out of reach of the regional readers (the nearest, richer public library where some of these serials still survive, is 750 km away); hence, this research remains mostly unread and unacknowledged. The word "publish" for making information public has lost its meaning; now, information is printed and subsequently locked away from many readers, like the gold in Fort Knox. Are the contributing authors and the organizations that grant-supported their research happy?

In the 1990s, the computer revolution and the spread of the internet led to the emergence, and rapid growth, of electronic on-line journals. Initially it looked like a possible end to, or at least alleviation of, the sequestration of knowledge due to excessive subscription costs, but things returned to normal in the 2000s. In fact, a library now has a choice of subscribing to either a printed or an electronic edition of a journal, usually at the same cost (even though the electronic edition costs 30% less to produce and market), or to subscribe to both at a still higher cost. Moghaddam (2007) compared subscription prices of 4,415 electronic journals produced by the ten largest western publishers: five of them for-profit (FP), five non-profit (NP). She found, not surprisingly, that the FP publishers charge on average 2.8 times more for a subscription than the NP publishers (a very conservative multiple given my own experience). However, it is true that many of the FP journals have publication runs of several hundred copies only, compared with thousands or tens of thousands of copies for the longer established NP journals. Small print runs sharply increase the production costs. In terms of quality, expressed by the number of citations, FP and NP journals were almost equal. However, NP journals

were historically better because many former top tier NP journals, like *Geochimica et Cosmochimica Acta*, have been captured by FP publishers in the past 20-30 years. More bits and pieces from the Moghaddam (2007) paper follow:

- The subscription price of scientific journals rose 260% between 1975 and 1995; the per-page increase between 1985 and 2003 in FP journals was 300%, compared to 50% (less than the cost of living increase) in NP journals. This caused subscription cancellations by libraries, forcing publishers to hike the costs even more (another positive feedback loop);
- In 1999, 76% of one U.S. library budget for scientific journals went to 10 publishers (the Big Three: Elsevier [with Pergamon], Springer [with Kluwer], and Blackwell). The Big Three each published, in 2003, 69; 47; and 31 electronic journals, respectively, and the average subscriptions were US$ 1,589; 896; and 455 (all science subjects) and US$ 1,692; 1,090; and 448 (earth sciences only). The average subscription price of physics and chemistry journals was higher than for geoscience journals, whereas for medicine, the sky was the limit.
- Journal subscription costs to American libraries increased annually by 8.5% between 1986 and 2001. My former Departmental Council in Canada met twice yearly to argue which subscriptions to cull.

By 2007 journal subscriptions increased further; some almost doubled. The following sampling of per year subscriptions to libraries comes from the Elsevier NL website: *Chemical Geology*, $4,228; *Earth & Planetary Science Letters*: $4,181; *Tectonophysics*, $5,462. A comparison of the per-page and per-word costs in FP journals with some NP journals for the year 2000 follows. The FP journal *Chemical Geology*, Volumes 162 to 171 (representing the subscription year 2000), comprise 3292 pages and about 2.2 million equivalent words so one word is worth approximately 0.2 cents. The behemoth NP *Journal of Geophysical Research* (JGR), Volume 105 totals 29,730 pages. It has about 750 words per page, with some 22.3 million equivalent words, so one word is worth 0.01 cents. Another NP journal *Economic Geology* (EG), Volume 95 totals 1,826 pages and has 840 equivalent words per page, so one word is also worth 0.01 cents. However, EG did not have a compulsory charge to authors, which JGR had, so it represents the best value per printed word of the two journals.

The involvement of the FP publishers in research serials publishing has been a mixed blessing. It accommodated the avalanche of submitted papers throughout the 1970s and later, and in some cases provided a second tier sanctuary for papers rejected by the first tier NP journals. Some such papers have proven their worth. But the FP journals also locked away a substantial proportion of knowledge, largely generated using public money, which only the richest can now access. The FP publishers do a better job on books because they publish fast (especially on camera-ready or electronic copy basis) and they fill the gap in the review literature and conference proceedings where the NP's mostly lag behind. The FP books are expensive but the buyer has a choice to purchase or not. Fortunately NP journals still exist and some, like *Economic Geology*, are an excellent value. The *Canadian Journal of Earth Sciences* (CJES), published by a government agency that also supports much of the research, is about 3-4 times as expensive per word as EG and JGR. Several electronic journals (but none in geosciences) offer open access (Navin and Starratt, 2007), which are free to the reader, but the author (or his/her organization) has to pay the editing and publication costs. I consider this the logical way to rapidly communicate publicly funded research (e.g. by NSERC).

COPYRIGHT: THE ROADBLOCK TO KNOWLEDGE CIRCULATION

When I was a teenager, I hand-copied my favourite reference book, rarely available in the library and now out of print, and even made some copies for my rock collecting friends. I did not think that I had violated any laws then, but I would most likely now if I used time saving devices such as a photocopier or scanner. Although most western copyright laws, based on the U.S. law [www.knowyourcopyrights.org], permit reproduction of a single article for personal scholarly use, some journals permit even more. The CJES allows reproduction of short excerpts, with author's consent, but if the author is on sabbatical or in the field consent may not be forthcoming for many months. Some organizations (like the Brazilian DNPM or the South African Chamber of Mines) give automatic reproduction consent if credit is given: a courtesy ingrained in the brains of most of us. The U.S. Government agencies (e.g. USGS) produce copyright-free publications. Copyright rules, like other regulations that slow-down communication and progress are destined to be routinely violated; just observe the goings on around a university library copier before exams. Behind the closed doors of corporate offices, guarded by receptionists and security, mass reproduction and circulation of copyrighted material is endemic. The above applies to paper copies; it is even easier and more efficient with electronic materials for those who know. The inexperienced may get caught.

Some publishers allow photocopying beyond the "single article for personal use" if credit is given. Most, however, cling to the traditional copyright rigidity, request payment via the Copyright Clearance Center, and place a hurdle of time-consuming correspondence in the way of requests for permission to use material for research or education. This slows the circulation of knowledge, if adhered to. Every student creates an anthology of photocopies of articles on a certain subject, which is legal ("personal use"), but it is an offence if a lecturer does it for their class. Notwithstanding the for profit publishers, it is hard to see why it has to take months and repeated correspondence to secure an eventually free permission to reprint a duly cited figure or graph from a publication by Canadian, Australian, or other government survey, when equivalent material from the USGS is open access.

Copyright is a two way street: it protects the intellectual property of the authors and profits of the publishers on one hand, but it also restricts the movement of knowledge on the

other hand. As an author, I want to see my work reaching others while at the same time recognizing the right of the publisher to cover costs (Moghaddam, 2007, estimated the average cost of publishing a research article at around US $5,000- to 6,000) and earn a return on investment. However, there should be a reasonable balance between the two.

Copyright protection does not last forever (usually 50 years, or 100 years to be on the safe side) so some classic books that have shed their copyright, even entire libraries of them, are now freely available on the web. So, if you are after *Macbeth*, *War and Peace*, or *Les Miserables*, all you need is an internet access and the Google Books Library Project might deliver. You should also be able to adopt Agricola's (1556) *De Re Metallica* as your copyright-free textbook on mining geology. However, the more recent literature is mostly copyrighted and it takes time, effort and money to pass properly acknowledged ideas on to convenience-expecting audiences, in the form of handouts, notes or audio-visuals.

KNOWLEDGE IN THE INTERNET AGE

The spread of PC computers since the 1980s allows us to use machine-searchable bibliographic (and other) databases, like Georef. Although not perfect, these databases have greatly speeded up the task of building a bibliography on any subject. The addition of short abstracts to some databases has helped to screen out non-essential reading material. In the early 2000s, the internet and high capacity servers have been revolutionizing the ways knowledge is gathered, stored and distributed. This revolution is comparable in impact with the invention of the printing press in the 15th century. Journal and book publishing is some 40% digital at present; in a few more years, printed matter will be the minority, although it is unlikely that printed books and journals will soon disappear (they actually thrive right now). The increased digitization of information is providing a respite to libraries from the never ending pressure to accommodate more and more paper volumes. Global access to information via home computer terminal has further boosted our individualistic culture, like the widespread ownership of automobiles did forty years ago. We can now download some individual journal articles on line, from a growing list of FP and NP publishers and other providers. The cost is high and selection limited. Geoscience World [www.geoscienceworld.org], a nonprofit consortium of seven geoscientific organizations, offers access to material published by its members; so far, in English only. A one day access to a nine-page, year 2000 article comes to US $35 (2007 price). I estimate the selection of papers available covers some 10-15% of the whole. What about the rest?

Do we still need libraries (alias knowledge/information centres)? We do. Although it would be perfectly feasible now to place our completed research on personal or institutional websites for everybody to read for free, tradition, and profit motives continue imposing serious restrictions. However, some inroads have been made and open access electronic journals keep appearing here and there. Most are funded from fees paid by the authors (Navin and Starratt, 2007). As no individual and only a few organizations can alone afford to maintain subscriptions to a number of e-journals, public libraries are gradually evolving into journal (and book) subscription agencies through which an individual can reach the electronic knowledge, without actually taking the hardcopy volumes off the shelves. The reading can be done either on-line from your living room, or from the library terminals. However, all the traditional library and readers woes, i.e. increasing costs, copyright hassles, delays, inability to read everything on your list, remain. Our individualist society has inoculated us against banding together to cooperatively and non-profitably exchange the fruits of our research.

There are some interesting technological developments that are already here or on the way. One is direct machine translation: put an article in Mandarin on a desktop, and out comes a copy in English (not yet perfect). Some freely available online resources are appearing, mostly to foster public awareness and education (e.g. the Canadian Museum of Civilization website; American Memory Project of the Washington, D.C. Library of Congress). Google is rapidly evolving from a search engine stuffed with billions of bits and pieces of information into a provider of a more coherent knowledge. The Google Books Library Project now offers free on-line access to whole libraries of digitized (mostly classic) books, for which the copyright has expired or has been waived. Google Scholar has greater potential for an active geoscience researcher. It is basically a classified library catalogue that can also provide free access to some abstracts and entire articles, although the copyright hurdle still remains. The rapidly growing internet-based Wikipedia is an experiment in on-line populism and it provides free information on anything by means of self-help. The encyclopedic articles are contributed spontaneously by anonymous volunteers (you and me) and everyone can edit the information already there; a sort of peer control by the masses, which Chairman Mao would have loved. However, the credibility of Wikipedia-sourced facts is low, although improving. More importantly, the Wikipedia experiment suggests one possible way for the future of scholarly publishing. i.e., post a paper (as a preprint) on the internet as soon as completed by the author(s), and then subject it to review in full public view.

FINAL THOUGHTS

The convenience of one-stop literature research in a well equipped library of the 1950s-1960s is long gone. Instead, we are faced with an avalanche of papers in journals most libraries can no longer afford to subscribe to and a growing number of providers trying to sell us a restricted range of published articles on-line at an ever increasing cost. Much of the newly created knowledge thus does not reach the research community and is sequestered in out-of-reach journals. Circulation of knowledge is further restricted by copyright laws.

Scientific research has its production and dissemination phases. The former is substantially more expensive than the latter (knowledge dissemination can be achieved for free by the word of mouth or via personal website) and is mostly paid for by the public. The labouriously prepared and ref-

ereed conclusions are then given freely to journals whose production costs and profits restrict knowledge circulation. We would all be wiser if the publicly funded research producers also assumed the obligation to disseminate the peer-vetted results upon project completion, at least in a preliminary way (as open file reports), for free to the reader or at a nominal cost. Websites and the growing server capacities now make this possible. Many geological surveys are now half way there, but the research grant providers like NRC are yet to follow. There is also a pressing need to allow copyright-free circulation of the publicly funded knowledge, provided the source is properly acknowledged. I believe that the time-consuming, referee-short, and over-priced publishing process as we know it will become an add-on in the near future: nice to have but no longer indispensable as the principal means of knowledge dissemination.

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REVIEWS

Disposal of Hazardous Waste in Underground Mines

Edited by V. Popov and R. Push
The Sustainable World, Vol 11
WIT Press, 2006
ISBN 1-85312-750-7
US $170.00, hardcover, 288 p.

Reviewed by Ivan Dimitrov
University of New Brunswick
2 Bailey Drive
Fredericton, NB, E3B 5A3, Canada

This book contains a collection of articles aimed at presenting the current experience in the utilization of underground mines for the safe storage of hazardous waste and forecasts future developments related to this topic. This collection is based upon the results of an international collaborative research project sponsored by the European Commission. The articles are assembled in a coherent manner, so that all the main aspects are covered. The content of the book partially duplicates other environmental collections, particularly those related to the safe disposal of low-level radioactive wastes. However, this book is not a repetition of previously published materials because the editors made sure that other hazardous wastes, such as alkaline batteries, pesticides, consumer goods and products containing dioxins, furans, etc., are included. More importantly, the economic and legal aspects of waste disposal are treated in a comprehensive manner, so legislators, businessmen or environmentalists willing to acquire a practical knowledge of the subject can use parts of this book to their advantage.

The book has 6 chapters and an appendix spread over 260 pages. The first chapter examines hazardous waste generation and management in Europe. Statistical data are shown about the amount of waste generated per person, the main waste streams and emission trends, and expectations up to the year 2010. At the end of the chapter a brief but informative overview regarding the wastes of concern, such as heavy metals and persistent organic pollutants, is presented.

The second chapter reviews the need and potential for underground disposal and provides an overview of underground mines in Europe. This chapter is helpful for a general reader, because it presents the fundamentals of the problem and discusses the two principal standing points of this technology, namely the availability of underground storage space in industrialized countries and the advantages of underground disposal compared to surface disposal.

The third chapter reviews the criteria for selecting repository mines. Different scenarios are analyzed such as mines in crystalline rocks, argillaceous rocks, salt rocks and other rock types. The favourable and unfavourable conditions dictated by the rock structure, hydrology and stress conditions are presented in a concise way. Although the significance of rock properties is discussed in more detail in the next chapters, the empirically deduced criteria and sound sense presented in this chapter should be sufficient for non-academic readers to grasp the basic principles of site assessment.

The fourth chapter deals with engineering barriers most commonly used in underground mines. The emphasis is on the application of clay materials for isolation, because of the cost effectiveness and good isolation properties of clays. The basic manipulations and processing of clays are discussed using as an example two brands of clay, namely MX–80 and Friedland Ton. Properties of the clays such as rate of hydration, chemical interactions between smectite and cement, and conversion of the smectite to non-expandable minerals (illitization) are examined quantitatively. At the end of the chapter, important remarks about the cost of disposal of given amounts of batteries and pesticides are given.

The fifth chapter is devoted to the mechanical integrity of the mines. The rock mechanic properties are discussed with respect to the Coulomb failure criterion. The suggestions for modelling of stress conditions offered in this chapter are illustrated with 3D diagrams from particular mines. The modelling is based on the boundary-element method and it is applied using specially customized software (GiD, [http://gid.cimne.ups.es]). The nature of the customization and the principles of the calculation methodology are not discussed in detail. In general, the treatment of the problems in this chapter is rather brief, and some important details regarding the connection of the model to a particular geological environment are missing, as well as the theoretical justification for choosing a particular model. In other words, although the models described in this chapter may be of significant value, it is unlikely that the reader can use them unless he or she is a specialist in this subject.

The sixth chapter is the longest (pp. 151-207) and theoretically most complex, because it deals with risk assessment of underground repositories using numerical modelling of flow and transport in porous and fractured rocks. The chapter begins with

an overview of the theoretical problem, with emphasis on the differences in approach to modelling for the near-field and far-field zones around underground openings. Next, the governing equations for flow in porous and fractured rock media are discussed, which are needed for the development of flow models. This is followed by general discussion of the boundary-element method. In the second half of this chapter, the models are applied to particular tunnel geometries for migrants such as dichlorvos and zinc.

The appendix contains a list of inactive and active mines in Belgium, Denmark, Finland, France, Greece, Ireland, Italy, Luxemburg, Portugal, Spain, Sweden, Nederland and the United Kingdom. The list provides data about the mine operator and the annual mine capacity in cubic tonnes of mined material.

In general, the first three chapters of the book contain a variety of data that can be used by non-specialists to acquaint themselves with the problems associated with underground storage of hazardous wastes. The last chapters treat stress and flow models and are relevant to qualified engineers who have previous experience in hydraulics calculations and applications of numerical models. The book is richly illustrated but some of the illustrations are detached from their context in the book. Little is said about data collection procedures and the availability of data needed for building the numerical models. My personal opinion is that this book contains a good introduction to the procedures and practices of hazardous waste storage but it is most suitable for qualified geo-engineers rather than students.

Magnetic Fabric: Methods and Applications

Edited by F. Martin-Hernandez, C. Luneburg, C. Aubourg and M. Jackson

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Hardcover – 560 p.

Reviewed by Randolph J. Enkin
Geological Survey of Canada - Pacific
9860 West Saanich Road
PO Box 6000, Sidney, B.C.,
V8L 4B2, Canada
E-mail: renkin@nrcan.gc.ca

The history of a rock's formation and deformation is recorded, in part, by the alignment of its constituent minerals. Petrofabric, the study of the preferred alignment of minerals and rocks, is used as a proxy measurement for paleocurrent directions in sedimentary rocks, emplacement flow directions in igneous rocks, and strain directions in deformed and metamorphosed rocks. These proxies do not necessarily mimic their targets, so a great deal of clever field work, lab work and analysis must be done to determine their applicability.

Most techniques used to measure petrofabric (pebble long-axis counts, universal stage optical microscope measurements of oriented thin sections, and x-ray or neutron goniometry) are tedious and time consuming and only account for the orientations of small numbers of grains. In contrast, measurement of anisotropy of magnetic susceptibility (AMS) is a rapid and sensitive petrofabric tool. It takes less than 3 minutes a sample, and integrates the fabric of all the grains in a core specimen.

Application of magnetic anisotropy is often complicated because the relationship between magnetic fabric and petrofabric is not direct. In rocks that host ferromagnetic minerals, such as magnetite, the magnetic fabric signature is dominated by those grains. Iron oxides and sulfides are sensitive to the primary, metamorphic and environmental history of the rocks, leading to both the strength but also the complexity of the method. In rocks lacking a ferromagnetic component, the alignment of paramagnetic (mostly silicates) and diamagnetic (mostly carbonates and quartz) minerals is observed. Usually the major axis of the AMS ellipsoid is parallel to crystal lineation, and the minimum axis is perpendicular to foliation. The magnitudes of the ellipsoid axes, however, depend, in a complex way, with the alignment forces such as finite strain magnitude.

In 1954, John Graham published "*Magnetic Susceptibility Anisotropy, an Unexploited Petrofabric Element*". On the golden anniversary of that trail-blazing publication, the Geological Society of London published its Special Publication No. 238 on "*Magnetic Fabric: Methods and Applications*". This book reveals the development of this research field over the last 5 decades. There are papers on the history of the method, its physical foundations, instrumental aspects, and current examples of how anisotropy results can be applied to many areas in the earth sciences. The papers do not shy away from presenting important limitations and unresolved problems.

Based on special sessions in 2003 at the Joint Assembly of the EGS-AGU-EUG in Nice and the AGU Fall Meeting in San Francisco, this volume is more than a collection of unrelated current research papers. Several reviews are featured, including the fine overview by the editors. The centrepiece is Borradaile and Jackson's 62 page review of "Anisotropy of magnetic susceptibility (AMS): magnetic petrofabrics of deformed rocks", including an extremely useful 3 page glossary. This paper is rigorous but fully readable. It also introduces a clever new polar plot to display fabric data.

The book is divided into 5 sections. The first, "Magnetic Fabric Characterization Methods and Mineral Sources" (6 papers), includes reviews on laboratory methods (Potter) and statistical methods (Jezek and Hrouda). The second section, *Sedimentary Fabrics*, features 6 case studies. Unfortunately, only one of these deals with the important application of depositional flow directions (Matasova and Kazansky's

impressive study on Siberian loess formation including analysis of wind direction). The rest investigate deformation recorded in sedimentary rocks, and thus should be placed in one of the last sections.

The next section on *Igneous Fabrics* is quite humbling for the method. While the study by Petronis et al. concludes that magnetic fabrics are parallel to emplacement directions in a lacolith, the other 3 papers suggest that magnetic fabrics in igneous rocks are, at best, complicated functions of flow direction, mineralogy, and boundary conditions. In contrast, the fourth section on *Tectonic Fabrics* (6 papers) includes several successful studies for magnetic methods. I would like to highlight the paper by Chadima et al. who compare neutron goniometry to low and high field magnetic fabrics on deformed Bohemian metasediments.

The last section, on *Complex Fabrics, Superposition and Alteration* has 4 papers revealing difficulties in magnetic methods on rocks with rich geological histories. A particularly impressive work (De Wall and Warr) used heat treatment on the rocks to oxidize siderite in order to the more magnetic magnetite to make better measurements. They applied a paleomagnetic tilt test to the magnetic fabrics to establish the relative timing of diagenesis and deformation.

The book includes most of the significant members of the magnetic fabric community. Two authors stand out in the collection: František Hrouda with four papers, and Graham Borradaile with three. They have been leaders over the recent decades, and it is good to see them properly represented here. I am sorry not to see a paper by Ken Kodama or his colleagues who have been working on magnetic fabrics and the deflection of magnetic remanence (e.g. inclination shallowing) which has an important application to paleomagnetic studies.

This Geological Society Special Publication is a substantial book, much larger than their typical 200 to 400 pages. While it may be too expensive for individuals to purchase, it should be included in all earth science library collections. Researchers in all fields concerned with rock fabric and deformation will find it useful.

Fine Wine and Terroir: The Geoscience Perspective

Edited by R.W. Macqueen and L.D. Meinert
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Reviewed by R.A. Wilson
New Brunswick Geological Surveys Branch
PO Box 50, Bathurst, NB
E2A 3Z1, Canada
E-mail: reg.wilson@gnb.ca

There is an apocryphal story that many readers may have heard, about the geology student (sometimes a geochemist) whose summer project involved catching lake trout so their livers could be collected for geochemical analysis. Regardless of the feasibility of this method for identifying exploration targets, or of whether or not one enjoys angling, the implication is clear – nice work, if you can get it. A similar sentiment arises when admiring photographs of the sunny climes and spectacular scenery that provide the backdrop for diverse studies of world viticultural regions presented in *Fine Wine and Terroir: The Geoscience Perspective*. Certainly, the element of humour is not lost on some of the authors, who, for example, may point out that wine samples from studied vineyards were tested to fully understand the meaning of terroir, and that "some samples required repeated evaluation" (Meinert and Busacca, p. 51). I have a suspicion that my declared fondness for wine led to my being asked by a certain *Geoscience Canada* co-editor to pen this review. Be that as it may, it has led to an appreciation of the vine-growing/wine-making science (art?) at a whole different level, and one might say that I have become a terroir-ist. But for the uninitiated, an explanation of what is meant by terroir is in order.

The term "terroir" has its origin in Burgundy, and has no precise English translation, or, stated differently, a translation may potentially run to several sentences. It encompasses all aspects of the physical environment of vine cultivation underlying and shaping the character and quality of the wine including meteorological, physiographic, pedological, geological and (often) viticultural controls. The significance of terroir may be understood by the simple occurrence of two adjacent vineyards that share most aspects of physical environment and viticulture, but produce very different wines. A corollary is that any given terroir may vary in quality from, say, a warm dry year to a cool wet year, where vineyard A produces better wine under the former conditions, and vineyard B better wine under the latter conditions. Outside of France, the concept of terroir is commonly misrepresented or misunderstood, and geologic and physiographic considerations may be ignored. In France, no such confusion exists, the French having had thousands of years of hands-on viticultural experience in matching particular grape varieties with specific settings. In one of the subdistricts of Burgundy, for example, *vignerons* have known for hundreds of years where the vineyards that produce top-quality wines should be located; it is only recently that geologists have shown that, in this instance, the borders of vineyard designations correspond almost exactly with stratigraphic boundaries. As testament to the importance attached to the subsoil/bedrock, the French Appellation Laws of 1935 protect the quality of winemaking regions under the auspices of L'Institute National des Appellations d'Origine, whose team of six scholars includes two geologists.

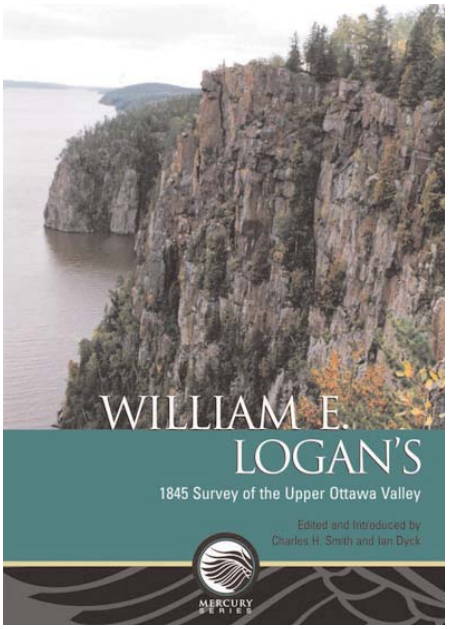
Fine Wine and Terroir is a collection of seventeen papers and two short "overview" articles; thirteen of these have previously been published in *Geoscience Canada* as part of the "Geology and Wine" series, whereas the remaining six are taken from the Simon J. Haynes special session, held at the GSA annual meeting in Seattle, in 2003. Simon Haynes is widely considered to be the godfather of terroir studies, at least on this continent, and the book is dedicated to the former Brock University Earth Sciences Department professor, who served as founding editor of the "*Geology and Wine*" series until his death in 2002. Seven papers describe the terroir of specific grape-growing districts, includ-

ing Ontario (Niagara Peninsula), Washington (Walla Walla and Red Mountain), Idaho (Snake River plain), California (Napa Valley), South Africa (western Cape Province) and Italy (two selected areas). Aside from two papers explaining the history and meaning of terroir, the remainder generally deal with thematic studies of specific aspects of terroir, or with means of processing the diverse, inter-related terroir components to generate "suitability" maps for guiding future vineyard development in particular areas.

Focusing on any single factor will not reveal the difference between an average and an exceptional wine. Hence, terroir designations, especially at local scales, require exploration of the permutations and combinations possible when coping with multiple varieties of grape and changing physical environments. To quote Meinert and Busacca once more, "This is not to say that any one component is *insignificant*, but…that no one factor is *transcendent*" (p. 39), and "What remains to be done …is to examine the relationship between specific physical factors…and the quality of wine produced from individual vineyards" (p. 50). Several papers set out to address this problem. Taylor et al. conclude that trace-element concentrations in wine can be correlated with vineyard of origin, and can be traced, at least in part, to bedrock geology, although the influence of wine processing methods also plays a role. Similarly, Greenough et al. use discriminant analysis to show that trace-element "fingerprints" of wine from five regions across Canada are predominantly related to region of origin (along with wine colour). In this case, trace-element solubility and concentration are attributed to variations in climate. Eggers et al. perform a statistical analysis of the concentration of 31 organic volatile compounds to demonstrate that fermentation and processing factors constitute a strong overprint on geographical variations. The implied goal of such quantitative studies is to establish a link between chemical compositions and the *sensory* characters that come together to make fine wine (e.g. flavour, aroma, texture, etc). Because of the dynamic interplay of so many other factors, however, such a formula seems likely to remain elusive.

A different approach is taken by Jones et al., who mapped terroir potential by spatial analysis of several of the major terroir components (e.g. climate, soil, physiography) using GIS software to produce suitability maps for each component. Similarly, a GIS was used by Bowen et al. in comparing patterns of varieties planted with wine quality (as determined by medals received) to show significant differences in varietal suitability. The results of such studies point to potential for increased development and production in the former case, and for improvement in wine quality by fine-tuning varietal choices and viticultural methods in the latter case. The paper by Jones et al. explores the possible impacts of climate change on viticultural regions, pointing out that the best terroirs have narrow climatic windows and are therefore vulnerable. Although in some areas this may be beneficial because of longer growing seasons and less frost risk, global warming may alter wine quality in traditional viticultural regions, and different varieties may have to be planted. Geophysics may also contribute to terroir studies. Hubbard et al. used ground-penetrating radar to investigate the influence of small-scale soil variations and moisture content. Using different frequencies to penetrate to varying depths, a soil-water-content block diagram can be constructed, opening the way to a precision irrigation approach to vineyard development.

The editors have carefully alternated thematic studies and descriptions of individual terroirs, but it's clear that the final product is a collection of stand-alone articles as opposed to a true textbook treatment. However, there should be no surprises as it is clearly identified as a reprint volume, and at a member price of just over $37, the handsome, hardcover text is a reasonable value. The individual papers are amply illustrated with maps, figures, graphs, tables and photographs. They also feature a certain uniformity of style and structure, so the reader is assisted by an expectation of how an article will develop. As stated in the introduction, "what ties all the studies together is the application of science to better understand the physical environment that affects grape and wine quality". To a geoscientist, it is somewhat satisfying to see the extension of geoscience principles into a "non-traditional" field. And, terroir studies may represent a largely untapped method of selling geological field work to students. The final paper in the book (Suthren et al.) describes a "terroir, wine, and geoscience" field school (in southern France no less), in which terroir is touted as a theme to "link aspects of regional and applied geology, introduce new geological field skills, and increase student engagement" [!!]. In the words of the authors, "superb outcrop exposures and scenery, and excellent regional museums, as well as fine wines, make for instructive and memorable student experiences". Of that I have no doubt. They did not have field schools like this when I went to university.



William E. Logan's 1845 Survey of the Upper Ottawa Valley

Edited and introduced by
Charles H. Smith and Ian Dyck
Canadian Museum of Civilization, Mercury Series, 2007
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Reviewed by Christy Vodden
398 Hinton Ave. South
Ottawa, ON, K1Y 1B1, Canada
E-mail: cvodden@sympatico.ca

We know Sir William Edmond Logan, in all his impressive and inspirational glory, as one of Canada's greatest scientists, as the Father of Canadian Geology, and as the founder of the Geological Survey of Canada. Indeed, it is hard to imagine what the state of earth science research in Canada would be today without his imprint and the kickstart he gave it in the 1840s. Or for that matter what our national museums would be like, seeing that the geological museum he founded in the mid-1850s spun off, over time, into the Canadian Museum of Civilization and the Canadian Museum of Nature – both of which have at their core the Logan-instilled imperative that solid research must support the public displays.

The heart and soul of *William E. Logan's 1845 Survey of the Upper Ottawa Valley* is a journal kept by Logan during fieldwork that took him up the Ottawa River to Lake Timiskaming from late June to November in 1845. The back-story of the book is an interesting one. Charles Smith, who has devoted much time and effort over the past two decades to tracking down and transcribing Logan's voluminous correspondence, hit the motherlode at the McGill Archives when he unearthed this journal, which had long been hidden from view; he immediately realized that it was important on many levels. More informal than Logan's field notes and correspondence, the journal reveals the human, everyday Logan, in his very own words. Jotted down at the end of a long day, usually after his field notes were written up and his maps updated, Logan's journal also provides a glimpse of life and work in Canada in the 1840s.

The chatty, anecdotal entries have a remarkable freshness, immediacy and candour, as if Logan were recounting his adventures and tribulations to a close friend and confidant, which, of course, is exactly what the journal was for him during that long trip. Logan had as keen an eye for the detail of everyday life as he had for geology. He provides vivid thumbnail sketches of the people and places he encounters, all infused with his indefatigable good humour. We meet, through his words, the "mighty talkative" landlady who had chickens and pigs strolling in and out of her inn, we witness the ceremony at which Logan was given the Indian name "Tanya rhita" (meaning "breaker of rocks), we share his frustration at the despised green tea he was offered everywhere and the hard biscuits he had to break with his geological hammer, as well as his delight in some of the meals he had along the way – including an exotic mixed boil of duck, pigeon and pike seasoned with the edible weed, lamb's quarters, that received a rave review from him.

All this is not to say that geology is not a recurring theme. That would be an impossibility for Logan who told many a disappointed Montreal matron with daughters to marry off that he was "wedded to the rocks." Most entries include a comment on the geology encountered during the day and often refer to how the work was carried out – the finicky equipment and the incredibly tough slog of it all. Logan, who was 47 years old at the time of this expedition (an advanced age for the times when the average life span was 50), kept up a punishing schedule of hard work and long hours.

To appreciate Smith's challenge in transcribing Logan's words, one has only to look at the reproductions provided of actual pages from the journal. At first glance Logan's handwriting gives the impression of elegant penmanship, but upon closer inspection the individual words are devilishly hard to decipher. Smith's co-editor, Ian Dyck, is an archaeologist with the Canadian Museum of Civilization who has a keen interest in the history of the Geological Survey of Canada. He brings to the book a strong sense of the human history significance of Logan's journal.

Smith and Dyck have pinned the journal into the context of its times using a wealth of supporting information. These include background materials about the 1845 expedition, a description of the Geological Survey in the 1840s, and the field tools and methods in use at that time. The significance of Logan's 1845 fieldwork is discussed from various points of view including geology, topographical mapping, economic development, national museum development and the history of the upper Ottawa Valley. Appendices provide a biographical sketch of Logan and notes about the members of his field party; a discussion of the 1845 Geological Survey Act, which renewed the Survey's mandate, and Logan's take on it; an inventory of the minerals, fossils and water samples collected during the 1845 expedition; a catalogue, prepared by Logan in 1851, of the economic minerals and deposits to be found in the Ottawa Valley; a description of the Rochon micrometer telescope, which Logan introduced to Canada for topographical surveying; and correspondence relating to the expedition. All in all, this is an excellent collection of materials that nicely rounds out Logan's journal.

I can offer up only one half-hearted quibble. The book has a hand-

some colour cover showing Devil's Rock on Lake Timiskaming, which Logan passed on October 31, 1845, but the interior photographs are a bit fuzzy and faded, apparently due to a cost-cutting method of printing. It does not diminish the book overly much, but it is truly a shame that the fabulous portrait of Logan in his field clothes, taken by the great Montreal photographer William Notman, is a mere shadow of itself.

There is no rule that a book reviewer has to be objective and I will confess that William Edmond Logan is one of my great heroes, so naturally I am going to like and recommend any book that brings him to our attention. But what is so compelling and unusual about this book is that it gives you the opportunity to meet Logan on the same ground as he addressed his journal – as his friend and confidant. At the end of the read, I think you will have reached my conclusion that the great man Logan was also a great guy! Plus you will have been given a fascinating glimpse into life in Canada in the 1840s, warts and all. Well worth a read, and not just for the earth science community. Historians, anyone living along the Ottawa River and genealogists will also find this book to be a treasure trove of information from a time long past.

Available from the Canadian Museum of Civilization (1-800-555-5621 or publications@civilization.ca).

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