



Special thanks to Rob Bowell for assembling focus topics for this issue on Environmental Geochemistry.

A different kind of ore-identifying mine waters suitable for metal recovery

Rob Bowell

SRK Consulting, Windsor Court, 1 Windsor Place, Cardiff CF10 3BX, UK

Few geochemists have missed reading at least some of the plethora of environmental geochemistry data generated in the last few decades on mine water chemistry from operating and abandoned mines.

Mine water chemistry is highly dependent on many factors including geology (Figure 1), ore deposit composition and mineralogy, mining methods, climate and so on.

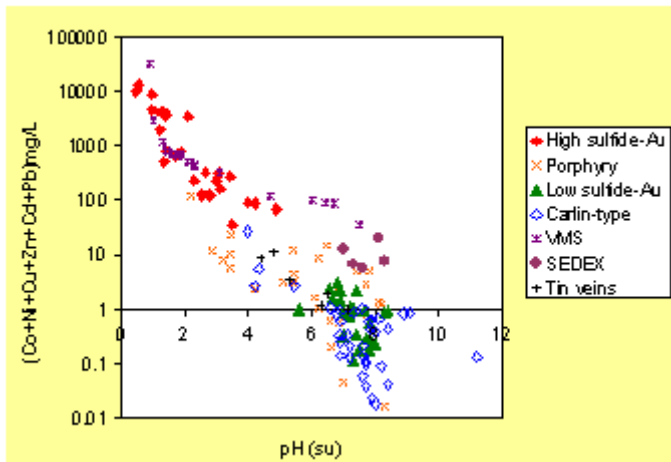
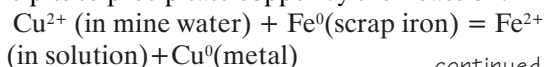


Figure 1: Ficklin plot of mine waters from different ore types showing contrasting base metal concentration dependent on ore deposit geology

Mine waters are typically $\text{Ca-Mg-SO}_4 \pm \text{Al} \pm \text{Fe} \pm \text{HCO}_3$ with a broad range in pH and metal content. In many cases these waters contain metals that exceed trigger limits that indicate a potential to impact human health or cause an impact to flora or fauna (Table 1).

In a few cases such waters may host metal concentrations, particularly base metal concentrations, to levels that are similar to mineral process solutions (Table 1). If sustainable could it be possible that these waters represent a different kind of ore?

Such ideas are by no means new, Phoenician miners in the Iberian peninsula, almost 3000 years ago, would build pits and load these with roasted goethite-rich boulders (pig-iron ore) and then divert copper rich mine water through the pits to precipitate copper by the reaction:



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AAG Presidential Address



David Kelley

By the time that you read this, the Society of Economic Geologist's Symposium, Predictive Mineral Discovery Under Cover, will have taken place in Perth, Australia. If you would like to read the abstracts of the talks given by AAG members at the symposium, please see our website.

Paul Morris and Nigel Radford have worked hard to ensure that the AAG will be well represented. In addition to having a booth in the exhibit hall, AAG members will convene to hold the Annual General Meeting for 2004. This will give local members a chance to have a voice in the association and to hear first hand what is happening with the AAG. The timing of the SEG meeting is also fortunate for us, as it precedes our own international conference to be held next year in Perth, the 22nd International Geochemical Exploration Symposium and the 1st International Applied Geochemistry Symposium.

Other symposia will also keep the AAG busy over the next several years. Next year, we plan to co-sponsor the Goldschmidt Conference in Moscow, Idaho, USA (<http://www.uidaho.edu/gold2005>) and the Geologic Society of Nevada Conference in Reno, Nevada, USA (<http://www.gsn2005.org>). We have received an excellent bid for the 2007 IGES/IAGS to be held in Oviedo, Spain. We are also in discussions with the Exploration 2007 Organizational Committee regarding possible co-sponsorship of that meeting. And for you forward-planning types, the Australian Geoscience Council (AGC) will host the 34th International Geological Congress in 2012 in Brisbane, Australia. As a small member of the AGC, the AAG will have an opportunity to play a role in this important meeting. These co-sponsored symposia are an important part of our growth strategy. They allow us to interact with other geoscientists in a broad range of disciplines, promote the activities of the AAG, and recruit new members for the Association and articles for GEEA.

It is time again to solicit Fellows to serve on Council for the 2005-2007 term. I have spoken to many of you already about running for Council. This is a critical part of our organization as we need active participants to help guide the Association. If you are interested in being on Council, or know of someone who is, please contact David Smith (dsmith@usgs.gov). If you are not a Fellow, please convert your regular membership. There is no extra cost, and it allows you to vote in the affairs of the Association.

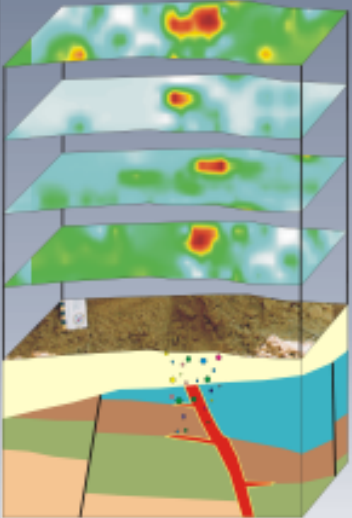
It's now official, Canadian authorities have approved our name change and changes to the By-Laws. On behalf of the AAG, I would like to thank everyone that was involved in seeing this lengthy process through to a final conclusion.

continued on page 2

Newsletter for the Association of Applied Geochemists

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President's Message... *continued from page 1*

We will be distributing the new By-Laws to all members in the near future.

Is it just my impression or are things looking up for applied geochemists? Most of the consultants I know have a full plate, soil gas probes are being shipped all over the world, and there seems to be renewed interests in hiring young graduates in the geosciences. I hope that this trend continues, and that each of you have the opportunity to make an impact with your expertise in applied geochemistry.

Sincerely,

David Kelley
WMC Exploration
 8008 E. Arapahoe Ct, #110
 Englewood, CO
 80112 USA
 Tel: 720-554-8318
 dave.kelley@wmc.com



News of Members

Robert Jackson has recently moved from Elko, NV, U.S.A. to Dartmouth, N.S., Canada (see advertisement pg 9) for contact information. He continues to offer consulting services in 3D geochemical vectoring with down-hole geochemistry and in the application of soil and water geochemistry to the search for blind deposits.



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Focus on: A different kind of ore-identifying... *continued from page 1*



Table 1: Typical composition of some mine waters and process waters. Parameter concentrations in mg/L except pH (various sources)

Parameter	Volcanogenic Massive Sulfide	High Sulfidation Epithermal	Mantos deposit	Porphyry	Copper SXEW (porphyry)
pH	<1-6	2-4	<2-6	2-8	<2
Cu	<0.1-6800	<0.01-5400	<0.01-790	<0.01-2100	~6000
Zn	<0.1->10000	<0.1-3900	<0.01-4300	<0.01-80	<500
Fe	10->10000	<1-28000	<1-5500	<0.01-1700	~2000
Pb	<1-165	<0.1-12	<1-210	<6	<100
Ag	<1-630	<1-90	<1-580	<2	~5

Such processes were used throughout the following four millennia including places such as Parys Mountain in North Wales (Figure 2). Copper obtained in this fashion is fairly pure with the precipitate obtaining a purity of 90% and better.



Figure 2: Copper cementation pits from the nineteenth century, Parys Mountain, Anglesey, Wales.

As many ore bodies reach full maturity or are exhausted possibly the legacy of former mines could represent a new lease of life for these mining districts providing an “ore” source in perpetuity, truly “sustainable mining”!

But is that really value in such an exercise? An evaluation on mine waters in southern Spain identified that mine impacted waters hosted significant “ore-grade” concentrations of several metals with often quite noticeable discolouration of surface water (Figure 3).



Figure 3: Mine water discharge impacts, Rio Tinto, Southern Spain. Mine waters at this location typically contain 300-700 mg/L Cu; 800-2000 mg/L Zn; as well as measurable concentrations of other metals such as Pb, Cd, Ag, Be, Fe, Mn, Co and Ni.

The calculated value of gross metal product being released into the Rio Tinto river in southern Spain is estimated at being in excess of US\$12000 a day (based on November 2003 metal prices), primarily as copper and zinc but also a wide range of valuable trace components as well (such as Ag, Pb, Cd, Li, Be, Ga, Ge, Sn, Te, Tl, U and REE). However, the reality is there is a big difference between total metal value and that which can be economically recovered. So what options exist for metal recovery from mine waters? Mine water treatment options typically employed to mitigate environmental clean up tend to precipitate or remove metals as one or two products from which it is generally not economic to refine to recover the value. But options do exist for selective removal of certain metals, particularly copper, zinc, silver and uranium based on existing metallurgical recovery processes. The most commonly applied of these are copper cementation (as described above), electrowinning and biological reduction of sulphate or sulphur to produce a metal sulfide concentrate.

Solvent Extraction coupled with Electrowinning is the standard technique for copper cathode production from heap leach operations. Typically feed solutions for such a plant contain from 0.5-6 g/L Cu although operations such as Dos Amigos in Chile produce copper from a low tenor feed of 300 mg/L with an extraction efficiency of 70%. However the solvent extraction is not without difficulties and significant clay content in the copper loaded or pregnant solutions can reduce the SX process efficiency. The recovery

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Figure 4: Traditional zinc tankhouse where metal is recovered by electrolysis. KCM, Bulgaria.

of zinc through acid pressure leaching and electrolysis is also fairly standard and applied widely throughout the world.

A benefit for mine water recovery from this process is that SX has been applied to a very wide range of acidic solutions; typical feed solutions have a pH of 1-2. In recent years a number of companies such as Paques in the Netherlands and BioteQ in North America have developed

mine water treatment plants that reduce metal loadings by reacting sulfide gas with the mine water so as to form metal sulfides. The basic principles behind this process are the production of hydrogen sulfide (H_2S) from elemental sulfur via the action of anaerobic bacteria.



The sulfide is reacted with a solution containing target metals and the metals are precipitated from solution as the insoluble sulfide. Dependant upon the solution chemistry and the target metals, pH adjustment of the solution may be required. In the case of copper, the metal sulfide will form at a wide pH range so typically no pH adjustment is required. The basic equipment layout for such an operation is shown in Figure 5.

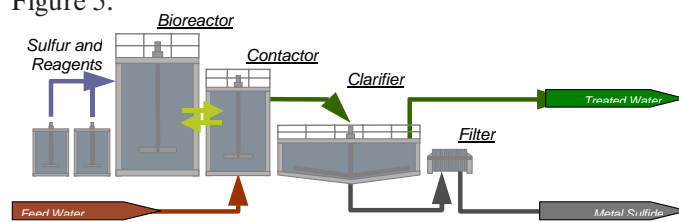


Figure 5 Typical plant layout for a sulfate reduction- metal precipitation plant.

Such plants have been installed in several places around the world including the BioteQ plants at the Caribou and Raglan mines in Canada and the Bisbee mine in Arizona (Figure 6). In these locations the metal sulfide precipitate produced can be processed by conventional smelting operations and metals that would be otherwise lost are recovered and the operations have proved to have positive cash flows.



Figure 6: BioteQ plant, Bisbee mining district Arizona

The economics are adversely affected by the presence of ferric. Ferric will also precipitate as a metal sulfide and so will consume sulfide increasing costs (both capital and operational). Additional reagents such as ethanol or acetic acid as well as nutrients are required. The bacteria require to be kept within an optimal temperature range typically 20-35°C.

At the Bisbee project in southern Arizona the BioteQ plant has a design capacity of 10,900 m³/day with a solution composition of; Cu = 350mg/L; Fe³⁺ = 550mg/L. The project capital costs are of the order of US\$2.5 million and operating costs are US\$0.20/lb Cu plus US\$0.18/lb transport/smelting costs.



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Focus on: A different kind of ore-identifying... *continued from page 4*



Metal recovery from mine waters such as at the Bisbee plant represents a potential source of revenue to offset water treatment costs and in some places may even represent an economic project in its own right. A caveat exists however, that even if the “ore potential” can be proven, and that the technology will recover economic amounts of metal there may still be little incentive to “re-mine” many old mining districts. New mining ventures may be held responsible for

all past mining legacy as well as any new disturbance and the mere mention of metal value from these old districts could result in legal action from property owners or bankruptcy trustees who will lay claim to any recovered value.

However, in the current environment of high metal demand and exhaustion of historically important metal sources, different sources of metals will have to be found. The challenge for the exploration geochemistry community is to be able to identify such opportunities and be equipped to evaluate them.



Readers' Forum



In a recent issue of EXPLORE (April, 2004), David Cohen asked the question “Who will deliver the last classical exploration geochemistry course?”. The ensuing discussion addressed some of the reasons for falling demand for exploration geochemistry in undergraduate courses, but perhaps the future is not as bleak as it appears. As the subsequent focus on academic institutions demonstrated, exploration geochemistry remains a priority at a number of institutions. One not covered by the review was Curtin University’s Western Australian School of Mines (WASM), where exploration geochemistry has been taught in various forms going back at least to the time of Clifford James, whose passing was also noted in the same issue. Recently, the name of the undergraduate unit was changed from Exploration Geochemistry to Applied Geochemistry for many of the same reasons that the Association of Exploration Geochemists has changed its name, although the focus of the course remains very much on mineral exploration. Therein lies the hope of continuing exploration geochemistry education. It must be incorporated into a broader perspective of applied geochemistry and made relevant to environmental scientists, as well as explorationists, given that the underlying processes, techniques and interpretation of data are broadly similar.

As a new initiative, planning is well advanced to introduce a graduate diploma in Mineral Exploration Geoscience next year that will mainly be delivered remotely to those already working in the minerals industry, or those seeking to develop a better understanding of the geosciences as they relate to mining and exploration. Course materials will be supplied on CD ROM, with support and interaction provided over the internet. Geochemistry is one the subjects in geology well suited to remote delivery, although this necessarily comes at the cost of field experience. However, the nature of education is changing, and the short answer to David’s question is that the last classical exploration geochemistry course is likely to be delivered over the web.

In answer to David Cohen’s second question as to what should be covered in an “ideal” applied geochemistry course, our evolving distance course outline looks very much like this:

An introduction to regolith geology and groundwater hydrology

Review of basic geochemical principles
 Geochemical dispersion
 Sampling and sample preparation
 Selective extractions
 Analytical techniques
 Data analysis and interpretation
 Survey techniques
 Drainage surveys
 Soil surveys
 Litho-geochemistry
 Hydro-geochemistry
 Bio-geochemistry
 Environmental geochemistry

Each topic would be supported by tutorial problems (it would be the first time I had a TA by the way!), and there *continued on page 6*

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Readers' Forum

continued from page 5



would be major projects focused on drainage and soil surveys involving the manipulation of large data sets. Students would also be required to report on a recent article out of an applied geochemistry journal. As for field work, regolith characterization and mapping techniques would cover two of the three days, with a day devoted to sampling techniques and an assay lab visit. These aspects can obviously not be provided in a distance unit, but will be covered during intense field units held annually as part of the graduate diploma. As an awareness of environmental geochemistry issues increases, the unit could evolve to include more techniques and case studies relevant to this field. It would also be possible to vary major projects and assignments to reflect the particular bias of the student.

In summary, there is a clear challenge facing those teaching exploration geochemistry. However, by adapting our teaching methods and ensuring our units appeal to a broad spectrum of student, exploration geochemistry can survive, even if it's called applied geochemistry!

Dr. Dennis Arne

Senior Teaching Fellow

Western Australian School of Mines

Curtin University of Technology

Kalgoorlie, Western Australia

e-mail: arned@wasm.curtin.edu.au

<http://www.curtin.edu.au/curtin/dept/wasm/>



Email from Boudewijn de Smeth

In one of the last EXPLORE newsletters there was the question: "Who will be the last to teach Exploration Geochemistry?" Well we still do that here at ITC including field training in the south of Spain but it is all seriously downsized due to dwindling numbers of fellowships from the Dutch government for students from developing countries. Fortunately we also work in training and research of groundwater geologists in water quality analysis and environmental problems. We try to attract more short-course students to ITC with fellowship funds from other sources but with limited success especially in earth sciences. There is considerable interest from earth scientists in GIS, RS and data management courses but topics such as survey design, data acquisition and data quality control are not popular. This trend can be observed in exploration as well as environmental geochemistry. We get great data manipulators and mergers who mostly lack the understanding of what they are handling or the insight that better analytical data based on optimal samples could tell you a lot straight away and often much more.

At the Utrecht University's Institute for Earth Sciences it is only Simon Vriend who still gives geochemical exploration and environmental classes, research and field training in the Pyrenees but that's it for the Netherlands as far as practical geochemical training is concerned. At Dutch

universities there is research going on a variety of fundamental aspects in the behavior of elements near or at the earth surface. I've little insight in what happens in the rest of Europe. From last years conferences on Exploration Geochemistry in Dublin and the Environmental Symposium (ISEG 2003) in Edinburgh a pattern of isolated research groups in Europe emerged in both disciplines. There is no doubt about the quality of most of these groups but with so few and diverse activities in Europe it is a bit like with the Siberian tigers on the verge of extinction; too isolated and far apart for maintaining the population and also their genes don't match any more.

However with four AAG members on one corridor here at ITC we are an odd anomaly in Europe with a bit of influence world wide: Phil Westerhof is active in ITC' Bureau of Project and Consulting with projects at present in Mozambique, India and Bhutan. Frank van Ruitenbeek is researching the relation between near-infrared spectroscopy and geochemical and geological parameters in hydrothermal alteration systems. John Carranza completed his thesis Geologically-constrained Mineral Mapping and is writing a book on this topic. My own relevant activities concern teaching exploration and analytical geochemistry here and abroad as well as running our small geochemical, water and soil laboratory. Our students keep coming from Africa, Asia and Central/South America and we sometimes get proof of successes with our courses; New Year cards from Indonesian students casually mention their participation in successful exploration programs, many of the geologists on the fast developing Tanzania goldfields are ITC alumni and we see old students from Cuba and Zimbabwe working together in Namibia in exploration. Lots of their lecture and exercise material while at ITC came from the AEG publications!

With kind regards,

Boudewijn de Smeth

Assistant Professor Department of Earth Systems Analysis,

Student Advisor specialisation courses in Mineral Exploration

Head Geochemical, Water and Soils Laboratory

ITC, International Institute for Geo-information Science and Earth Observation

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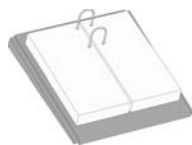
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Updates from Regional Councilors

It is intended to dedicate space in future Explores to updates on geochemical activities and initiatives from Regional Councilors. There are currently 7 regional councilors and a regional councilor coordinator. Details are given on page 30.



CALENDAR OF EVENTS

International, national, and regional meetings of interest to colleagues working in exploration, environmental and other areas of applied geochemistry.

■ September 19-22, 2004, **8th International Congress on Applied Mineralogy (ICAM 2004)**, Aguas de Lindoia, Sao Paulo, Brazil, by the International Council for Applied Mineralogy (ICAM); International Mineralogical Association - Commission on Applied Mineralogy (IMA-CAM). (Dogan Paktunc, 555 Booth Street, Phone: 613-947-7061 FAX: 613-996-9673 EMail: dpaktunc@nrcan.gc.ca Web: <http://www.icam2004.org>)

■ Sep 27-Oct 01, 2004, **SEG 2004: Predictive Mineral Discovery Under Cover**, University of Western Australia, Perth, WA, Australia, by the Society of Economic Geologists (SEG), Geoconferences WA, and Society for Geology Applied to Mineral Deposits (SGA). (Susan Ho, P.O. Box 80, Bullcreek WA 6149, Australia, Phone: (61 8) 9332 7350 FAX: (61 8) 9310 6694 EMail: susanho@geol.uwa.edu.au Web: <http://www.cgm.uwa.edu.au/geoconferences/index.asp>)

■ October 10-15, 2004, **SEG International Exposition & 74th Annual Meeting**, Denver, Colorado, US, by the SEG. (Debbi Hyer, 8801 S. Yale, Tulsa OK 74137, Phone: (918) 497-5500 Email: dhyer@seg.org Web: <http://meeting.seg.org>)

■ November 7-10, 2004, **Annual Meeting of the Geological Society of America**, Denver Colorado, . INFORMATION: TEL 1-800-472-1988, meetings@geosociety.org.

■ November 10-11, 2004, **SEG Workshop on Gold Deposits**, Moscow State University by the SEG. Part commemorate 250th anniversary of Moscow University Email: andrey@tsvetkov.msk.ru Web: <http://www.segweb.org>)

■ November 10-12 2004 CRC LEME Regional Regolith Symposia – Regolith 2004. Ian.Roach@anu.edu.au .<http://crlceme.org.au>

■ November 25 – 27, 2004, **International Karakorum Conference**, Islamabad, Pakistan. Information: Prof. Dr. F.

A. Shams, Lahore, Pakistan. pags@yahoo.com or telefax: 092-42-9230236.

■ February 28-March 2, 2005, **2005 SME Annual Meeting and Exhibit**, Denver, CO. INFORMATION: Meetings Department at 800-763-3132 or 303-973-9550. http://www.smenet.org/meetings/calendar/event_calendar.cfm

■ April 24th-27th Canadian Institute of Mining & Metallurgy **CIM-AGM Toronto 2005**. www.cim.org/mce/toronto2005/

■ May 15-18, 2005, **Geological Society of Nevada Symposium 2005** Sparks, Nevada USA, INFORMATION: Geological Society of Nevada (gsnsymp@unr.edu)

■ May 20-25, 2005 **15th Annual Goldschmidt Conference – A Voyage of Discovery**. University of Idaho, Moscow, Idaho, USA email gold2005@uidaho.edu. <http://www.uidaho.edu/gold2005>

■ August 8-11, 2005 **Earth System Processes 2**, Co-convened by Geological Association of Canada and GSA, Calgary, Alberta, Canada. <http://www.geosociety.org/meetings>

■ August 29-2 September **STOMP 2005 – International Conference on Structure, Tectonics and Ore Mineralization Processes**. Townsville, Australia. Email Stewart.Parker@jcu.edu.au. Website www.es.jcu.edu.au.

■ September 19-23 2005 **22nd IGES Perth Western Australia** – see this **EXPLORE**. www.aeg.org

■ October 25-November 5, 2005, **10th Brazilian Geochemical Congress and 2nd Geochemical Symposium of the Mercosul Countries**, Porto de Galinhas, Recife, Brazil (Dr. Valderez P. Ferreira, President, Dept of Geology, UFPE – Universidade Federal de Pernambuco, POBox 7852 CEP 50670-000, Cidade Universitaria, Recife, PE, Brazil, Phone/Fax (55)-81-2126.8242, Email: valderez@ufpe.br Web: www.ufpe.br/xcbgq).

Please check this calendar before scheduling a meeting to avoid overlap problems. Let this column know of your events.

Chris Benn, BHP Billiton

2400/1111 West Georgia St,

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The Association of Applied Geochemists *is pleased to announce the* **2004 AAG Student Paper Competition**

SGS

The Association of Applied Geochemists will hold the fifteenth biennial Student Paper Competition this year. Papers eligible* for the competition must address an aspect of exploration/applied geochemistry and represent research performed as a student. The student must be the principal author, and the paper must have been published in any referred scientific journal no more than five years after completion of the degree for which the research was performed. A nomination may be made by anyone familiar with the work of the student. Nominations must be accompanied by four copies of the paper. The deadline for receipt of the nominations is December 31, 2004.

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This prize consists of a \$500 Canadian cash prize, donated by SGS Canada, a two-year membership to the Association of Applied Geochemists with receipt of Geochemistry - Exploration, Environment, Analysis and EXPLORE, photograph and curriculum vitae of the author and an abstract of the prize-winning paper will be published in EXPLORE as soon as possible after the announcement of the award.

Mail to: Dr. Ian D.M. Robertson
Chairman, Student Paper Competition

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*Full details are available from the Chairman of the competition (address above) or from the AAG Home Page under 'Students' (www.appliedgeochemists.org)

Focus on: Catchment Pathways and Controls: A Geochemical Bridge to Applied Environmental Studies — Examples from Nova Scotia



By Peter J. Rogers

INTRODUCTION

Modern man is now the most potent geologic force on this planet and it is gratifying to see that we - the Association of Applied Geochemists - are facing up to this reality by increased emphasis on environmental studies in the journal (GEEA Volume 1 part 1 2001, Volume 2 parts 2 and 3, 2002). The extent of man's activities is manifest in a number of ways, one of the most important of which is a chemical one. This provides a great opportunity for the Association to make a real difference, as we are a group of scientists with extensive knowledge of the movement, classification and determination of chemical pathways within the environment in which we all live.

Nova Scotia presents a good example of the separation between - and the potential synergy - of the disciplines of exploration and environmental geochemistry found in most jurisdictions in Canada, and I suspect the rest of the world. Nova Scotia has approximately 970,000 people inhabiting an area of about 53,000 km² a population density of around 18 that is quite high by Canadian standards. The economy is largely resource-based with fishing, forestry, agriculture, mining and manufacturing with a marked expansion noted since the mid 1950s resulting in ever increasing landscape pressure. Nova Scotia possesses extensive databases of chemical and biological information from lakes, streams, soils, bedrock, tills and plants in various regions of the province (Rogers and Lombard, 1991).

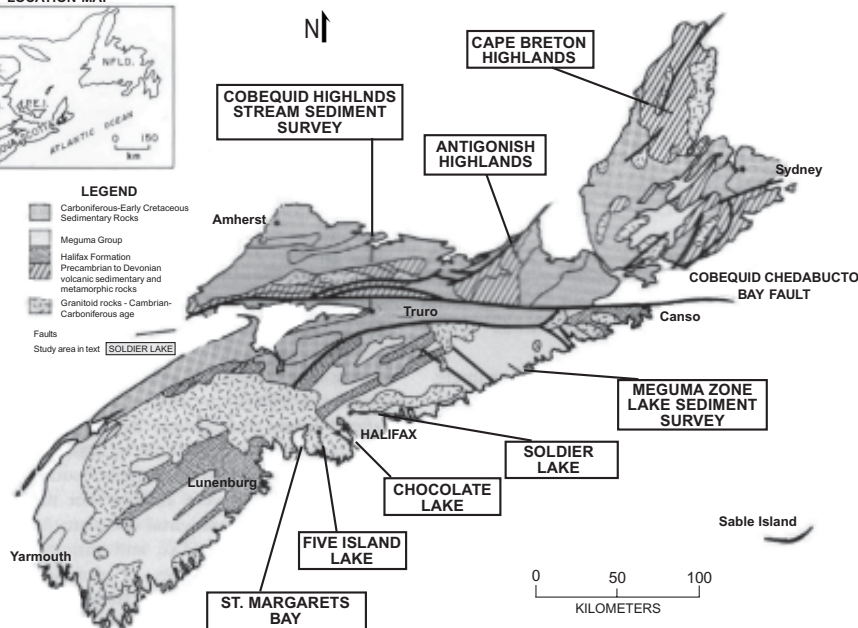
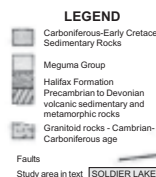
Most environmental studies in Nova Scotia have focussed on acidic precipitation, acid drainage and intracoastal pollution due to the impact of the oxides of nitrogen, sulphur and organic molecules on ecosystems. These studies indicate a significant man-made

(anthropogenic) component to the environment of Nova Scotia (Rogers and Ogden 1992).

In Nova Scotia most geochemical exploration activity has concentrated on stream or lake drainage systems by sampling sediments and (or) surface waters. Lake and stream catchment basins are important repositories of geochemical information concerning the composition and characteristics of their drainage areas. Modern drainage systems can be considered as mass storage devices (Ogden et al., 1988) which contain the 'geochemical genetic code' for each catchment. The extension of the catchment basin concept to exploration geochemistry (Bonham-Carter et al., 1987) forms a potent



LOCATION MAP



bridge to environmental geochemistry. This paper relates the results of several applied geochemical studies of catchment basins, which illustrate the potential synergy and application of applied exploration geochemical methods to environmental issues in Nova Scotia and elsewhere.

METHODS

The exploration geochemical samples were collected from lakes and streams using field sieving (-1 mm) for streams and helicopter grab sampling for lakes (Rogers and Lombard, 1991). In the lake studies, sediment-water interface samples from short piston cores (coring drives were initiated 10-40 cm above sediment and penetrated 40-80 cm into sediment) were collected near defined inlets and outlets. Surface water samples were collected at lake inlets and outlets. Lake bathymetry was compiled using a boat-mounted sounder. All water and sediment samples were analyzed for major ions and heavy metals using the Environmental Chemistry Laboratory of Victoria General Hospital, Halifax, and various commercial laboratories including facilities of the Geological Survey of Canada (Rogers and Lombard, 1991). At each lake coring station a sub-sample was taken with a 1.0 cm³ volumetric piston

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Focus on: Mechanisms of Metal Transfer Through Transported Overburden within the Australian Regolith



Mehrooz F Aspandiar⁺, Ravi R Anand^{*}, David Gray^{*} and Joe Cucuzza[#]

Cooperative Research Centre for Landscape Environments and Mineral Exploration

⁺Department of Applied Geology, Curtin University of Technology

^{*}CSIRO Exploration and Mining

[#]AMIRA International

As mineral exploration moves into regions dominated by shallow transported cover (5-50 m), bulk surface geochemical techniques are considered less applicable, and partial, selective and sequential leaches and gas analysis are increasingly being considered to delineate anomalies. However, these techniques have found mixed success in Australia, because the particular mechanism(s) and their effectiveness in transferring metals associated with mineralization upwards through the often complex transported overburden is poorly understood, thereby complicating and limiting the interpretation of datasets, and precluding the discrimination of negative and false anomalies. There is a major need to critically study potential mechanisms capable of transferring metals from buried mineralization upwards through barren cover to the surface. A project coordinated by AMIRA International proposes to test the effectiveness of different mechanisms to transfer metals to the surface or near surface in Australian regolith, and the efficacy of surface geochemical techniques in identifying anomalies through transported cover.

A review of potential mechanisms, especially within the Australian environment, found four dominant categories (some covered by Cameron et al. 2004): groundwater, gases, vegetation and bioturbation. Most of these categories have variants or sub-mechanisms, and may be influenced by microbial processes.

Groundwater in association with infiltrated water is the main agent of chemical weathering, and facilitates the dispersion of metals from the ore body. Flow directions, solution properties, aquifer heterogeneity, adsorption, complexation and inherent interactions and feedbacks between these processes influence the extent of *lateral and vertical dispersion* within the unconfined aquifer. Redox processes and formation of a possible stagnant zone at varying depths affect vertical migration and fractionation of specific elements (rare earths, Fe, Mn, V, As) at or within the fluctuating zone of the water table. *Capillary* forces at and above the water table can induce upward migration of solutes, with the rise being dependant on aquifer grain size and evaporation rates. *Seismic* or *dilatancy pumping* occurs in neo-tectonic active areas where faults and fractures act as conduits for upward transfer of mineralized groundwater (Cameron et al. 2002). Earth tremors promote compressional stresses along faults and force groundwaters upward, with possible surface discharge resulting in a near surface anomaly. This mechanism is limited to low-rainfall and neo-

tectonic areas that have regular seismic activity after overburden deposition. *Free convection* or buoyancy driven currents within the groundwater can arise due to density differences induced from point or diffuse heat sources. These can promote faster solute migration in a particular direction and the possible formation of irregular fronts. The oxidation of sulphides in an ore body is an exothermic reaction that produces heat and is capable of increasing groundwater temperatures and facilitating rapid increases of solute concentrations above ore bodies (Figure 1). The ability of convective flow to rapidly transfer solutes upwards up to the water table remains unexplored and has only been

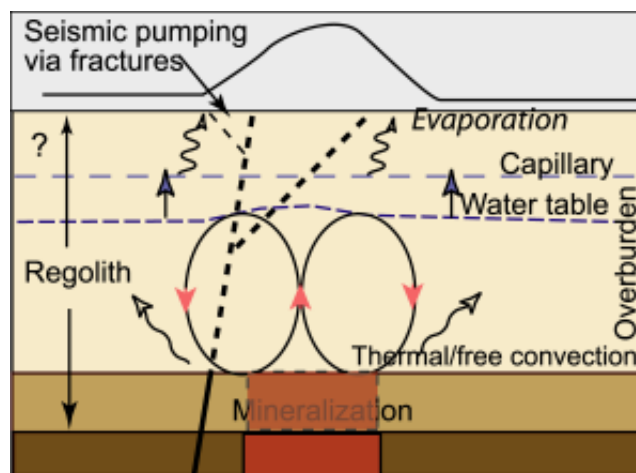


Figure 1. Some potential hydrogeochemical mechanisms for dispersion through transported regolith. The genesis and evolution of electrochemical processes within saturated transported cover are covered by Hamilton (2000).

investigated via simulations and laboratory tests for point source contaminant transport. The formation of *electrochemical cells* around an oxidizing-reducing sulphide body within groundwater can provide excess cation concentrations at the oxidized upper edges of the sulphide body, and the proposed pattern of (“rabbit ear”) surface anomalies in regolith suggests its possible operation (Govett, et al. 1984). A particularly relevant model positions the onset of redox anisotropy between the buried sulphide body (reducing) and water table (oxidizing) after the deposition of sediments. Self-potentials arise and are maintained due to reducing conditions at the sulphide body front and oxidizing conditions at the water table, leading to upward and outward migration of reduced species and their subsequent oxidation and formation of a reduced column above the ore body (Hamilton 2000). This voltaic cell model suggests a capability to rapidly transfer metals upwards through thick (30 m) saturated cover (Cameron et al. 2004). All the groundwater supported transfer mechanisms are limited to the upward limit to which groundwater rises or the water table (and capillary fringe), except that of seismic pumping. In the Australian environment dominated by Mediterranean, semi-arid, and arid settings, groundwaters are commonly more than 5 m below surface except in lower, discharge landform sites, and other, or additional, mechanisms are necessary to transfer metals from the water table upwards.

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Gases migrate via molecular diffusion, advection and gas streaming. Diffusion and advection appear to be the main sources of rapid upward migration of ore related gases (CO_2 , SO_2 , COS) and possibly of volatile metals. *Diffusion* of ore body related gases as a potential mechanism is limited by the individual gas stability and tortuosity of the weathered and often cemented regolith medium. *Atmospheric pumping*, the depression front set up by large barometric pressure change, causes rapid upward migration of air present in pores and conduits, and has the capability to transport volatile (I, Hg) and radiogenic elements from nuclear blasts (Cameron, et al. 2004). Atmospheric pumping is restricted to fractured media, and whether it may operate in a connected heterogeneous sedimentary overburden needs testing. *Gas streaming* or bubble migration is the upward transfer of microscopic gas bubbles that form within the groundwater due to overpressure, and are then released from the water table. Specific metals (Cu, Zn, Pb, Hg, actinides) and ultra-fine particles (clays, oxides, bacteria) can attach to the surfaces of ascending gas bubbles (dominantly composed of CO_2), especially if the gas bubbles have an organic coating acquired from trace organics in groundwater. The bubbles can then be transported upwards to the near surface environments, where pressure changes induce bubble instability and release metals. The stability of bubbles during their transfer from a saturated to an unsaturated medium is unclear. Furthermore, the fate of adsorbed particulate matter in a heterogeneous, but enclosed medium such as weathered sedimentary material, is unproven. In any case, most, if not all, studies of gas anomalies at the surface indicate rapid migration along conduits such as faults, fractures and shears, above which the gas anomalies are present, and this confirmation holds promise to at least accurately demarcate structural features (Figure 2).

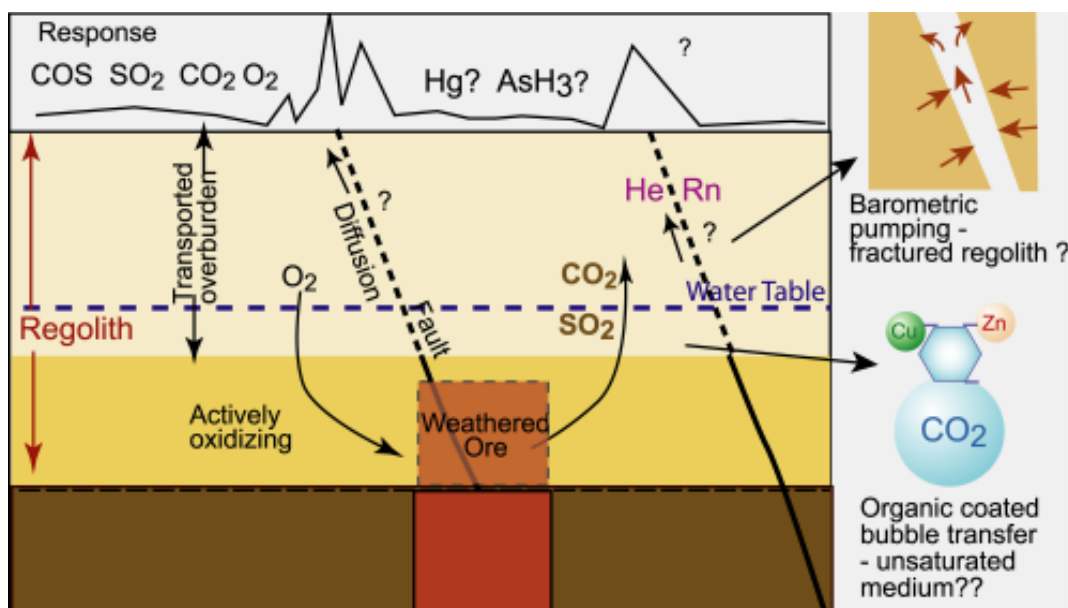


Figure 2. Illustration of potential gas based migration mechanisms through transported regolith.

Vegetation or plant physiological uptake of elements from subsurface and their release to the surface via litter is a potential mechanism of rapid metal transfer. In drier climates, as exist in most regions of active exploration in Australia, plants have evolved myriad adaptive capabilities to water and nutrient stress. One pertinent adaptation is the facultative phreatophytes –dimorphic roots systems with laterals and sinker or tap roots (vertical), the latter roots acquiring water and nutrients from deeper groundwater source, especially during summer (Pate, et al. 1999). Recent work on plant metal relationships in Northern Yilgarn suggests plants do uptake ore related metals from groundwater at depth. Additionally, hydraulic lift – redistribution of deeper water acquired by sinker roots to near surface soil horizons to be used by laterals (Caldwell, et al. 1998) - is capable of rapid transfer of water and possibly metals within the overburden. Diurnal uptake and transfer of groundwater to surface soil has been confirmed, but no data exist on ore metal transfer.

The depth of rooting is critical to the ability of vegetation in transferring water and possibly ore metals upwards. A global survey indicates that deep roots, especially sinkers, are ubiquitous with > 10 m depths regularly reached and confirmed in several climatic settings (Canadell, et al. 1996). Plants are known to take up mineralization associated elements that are essential micronutrients (Zn, Mo, Se) plus other ore metals (Au, Ni, Cu, Pb) and even potentially toxic metals such as As in significant concentrations (Meharg and Hartley-Whitaker 2002). Plants do biotransform specific metals, impacting the effectiveness of selective leaches and element mobility once released on the surface via litter. For example, gold absorbed in the dissolved form can be converted into colloidal form within the plant tissues, and arsenic and other elements are combined with phytochelatin to reduce toxicity. Release of these organo and colloidal species on the surface and their impact on leaches needs evaluation. Preliminary results point to the potential of

phreatophytes and other specific plants to transfer metals from 10 m deep current or paleo (redox fronts) groundwater tables or capillary fringes.

Bioturbation within the biotransform specific metals, impacting the effectiveness of selective leaches and element mobility once released on the surface via litter. For example, gold absorbed in the dissolved form can be converted into colloidal form within the plant tissues, and arsenic and other elements are combined with phytochelatin to reduce toxicity. Release of these organo and colloidal species on the surface and their impact on leaches needs evaluation. Preliminary results point to the potential of phreatophytes and other specific plants to transfer metals from 10 m deep current or paleo (redox fronts) groundwater tables or capillary fringes. **Bioturbation** within the biotransform specific metals, impacting the effectiveness of selective leaches and element mobility once released on the surface via litter. For example, gold absorbed in the dissolved form can be converted into colloidal form within the plant tissues, and arsenic and other elements are combined with phytochelatin to reduce toxicity. Release of these organo and colloidal species on the surface and their impact on leaches needs evaluation. Preliminary results point to the potential of

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dispersion of surface anomalies over time. However, unlike vegetation, barring a few exceptions from Africa, the effectiveness of bioturbation decreases rapidly downwards, with activity mostly ceasing at a depth of 2 m. On the basis of optical luminescence in quartz, Pillans (ANU, pers comm.) estimates that the soil to a depth of 2 m can be recycled over a period of about a million years or less.

The role of **microbes** in transferring metals upwards is restricted, but they affect most of the processes responsible for metal transfer. Microbial metabolism affects the kinetics of many hydrochemical processes, especially sulphide oxidation and other redox transfers. Microbial metabolism can impact on gaseous migration of elements by generating methanogenic, CO₂ and sulphur gases, and by generating volatile metal species via biomethylation (As, Se, Sb, Mo). They can influence the efficiency of metal uptake by roots via redox reactions, symbiotic associations and organic secretions. Microbes participate in intracellular and extracellular formation of minerals (and gold particles) within the saturated zone and soil, and can affect efficiency of partial and selective leaches (Figure 3). Microbial induced biomethylation (with As, Sb, Se, Hg) can significantly affect the “loosely” bound metal fraction or the efficacy of selective or partial leaches. For example, recent studies demonstrate microbial role in biomethylation of commonly used pathfinders with some of the metal differentiating into volatiles (Craig, et al. 2003), possibly followed by demethylation. Microbial roles need to be investigated to address the question of whether the results of selective leaches or gas analysis are dependant on microbial

populations and soil conditions rather than transfer mechanisms.

The critical, but often neglected aspect of evaluating the operation of the diverse mechanisms responsible for upward metal migration is the **nature** of the transported overburden (pre- and post- weathering) and its **depth**. Also related are the **time** and **landscape** factors that are equated to the age and type of weathering. Weathering of the overburden (sometimes multiple weathering profiles are superimposed with plant and bioturbation interaction between each) and concomitant water table increases the possibility to transfer metals upwards via a combination of mechanisms such as vertical hydrogeochemical gradient and electrochemical effects, vegetation uptake and bioturbation, to form “incremental” anomalies over time (Figure 3). This has been shown to occur at Lancefield goldmine in Western Australia where the oxidized orebody is overlain by sediments comprising 10-20 m of mottled Permian fluvio-glacial sediments, 3-8 m of mottled Tertiary palaeochannel clays, and 2 m of silicified colluvium (Anand et al., 2004). Alternatively, younger, fresh to slightly weathered sediments, even of shallow depth, will afford a much lesser opportunity for diverse mechanisms to operate, except gaseous diffusion and advection and possibly plant uptake, depending on porosity, anisotropy and hardness (Figure 3). However, specific partial leaches, gas measurements and on the principle of a rapid migration mechanism even in recent, fresh cover, and therein lies the need to understand the rate, extent and overall effectiveness of electrochemical techniques work on the mechanism(s) to mobilize ore metals upwards under different transported cover settings, so surface geochemical techniques can be efficiently and predictively applied, or discarded.

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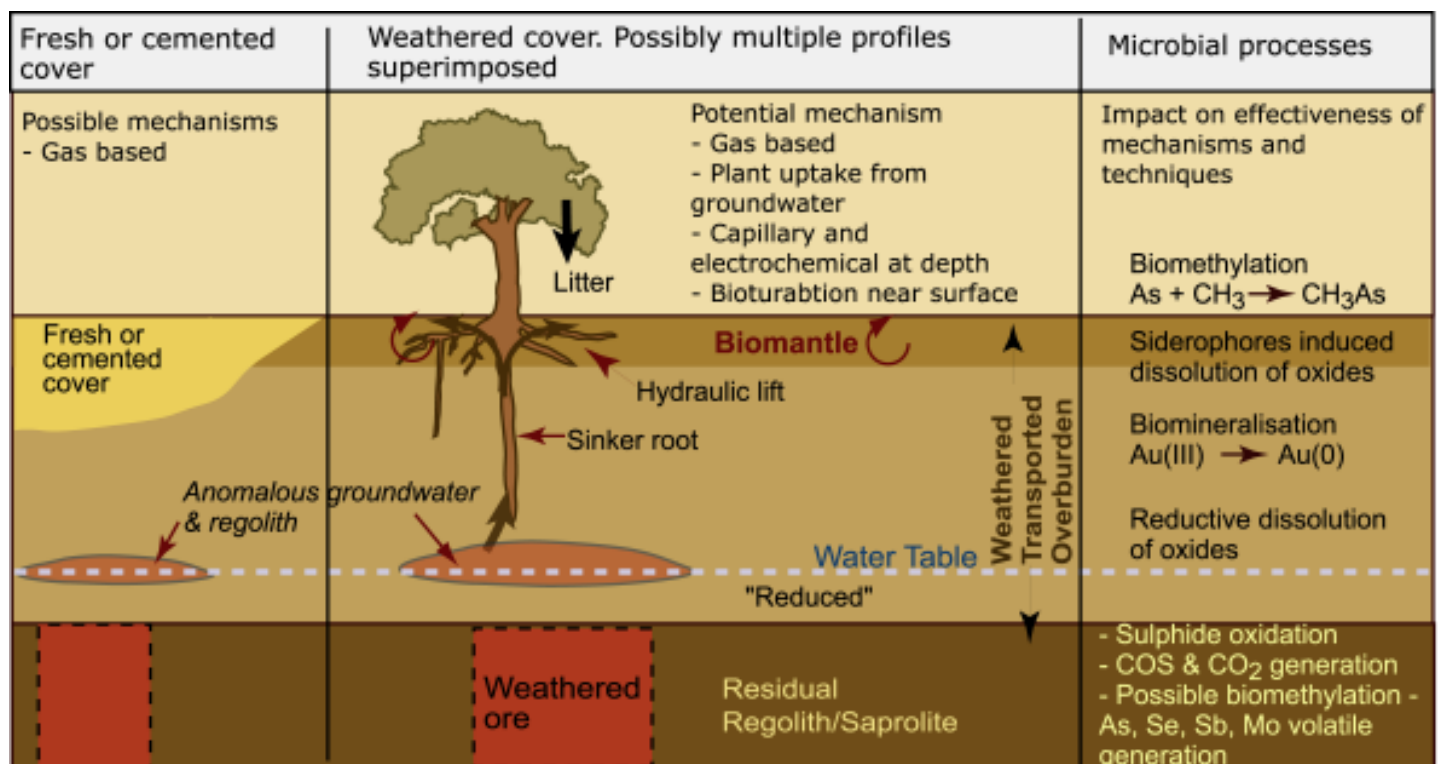


Figure 3. Illustration showing the operation of potential mechanisms depending on nature of cover (fresh or cemented as compared to deeply weathered with minimal cementation) and influences of microbial processes.

Focus on: Mechanisms of Metal Transfer...

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The AMIRA project to follow on from the review aims to evaluate the efficacy of the different mechanisms that are likely to disperse ore and pathfinder indicator elements through transported cover in well controlled dynamic 3D regolith-landform Australian environments, with emphasis on above water table mechanisms such as gas, vegetation and bioturbation. It also attempts to evaluate the impact of biotransformations on the effectiveness of several surface geochemical techniques. The study will use sites that manifest a surface geochemical signal and those that don't for comparison, and apply a range of techniques such as groundwater depth geochemistry and redox analysis, microbial characterization and their role in gas generation and biotransformations throughout the profile, isotope analysis to establishing source of metal in plants and soil, and soil desorption analysis to test gas migration possibilities.

AMIRA International is a not-for profit industry association established in 1959, currently with 68 industry members worldwide (www.amira.com.au). Its role is to develop and manage jointly funded collaborative projects addressing industry's problems around the globe. Such projects cover exploration, mining, mineral processing and sustainable issues. At present it's managing 40 projects with a contract value of over AU\$36 million and is currently developing more 20 new projects. AMIRA is developing this project with the **CRC for Landscape Environments and Mineral Exploration**, a partnership between **CSIRO**, the premier government research laboratory in Australia, three Universities including **Curtin University of Technology**, Government Geological Surveys and industry. Work is currently being carried out to identify both negative and positive (with no contamination) field sites in various environments and over different deposit types that will provide the laboratories to identify the operating mechanisms. Once this phase is completed an AMIRA proposal will be prepared for circulation to industry seeking support. At this stage we expect that the proposal will be ready late this year or early in 2005.

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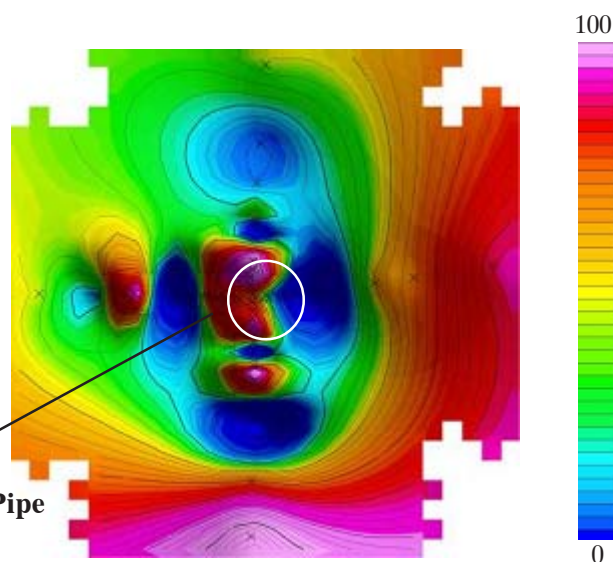
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Errata

Correction: Apologies are extended to readers and authors for the mistake in Figure 1 of the ACTLABS Group of Companies update in the previous edition of **EXPLORE** 124. The correct location for the outline of kimberlite pipe on the SGH neural net score for light alkanes is shown here:

Figure 1. Kimberlite Case Study #1 – SGH Neural Net Score Map for Light Alkanes.



Focus on: Catchment Pathways and Controls...

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sampler (Rogers and Ogden, 1992). The sub-samples were placed in snap-cap vials before processing for dry and ash weight determinations and microfossil analysis. Sediment long cores were recovered using a modified Livingstone piston sampler in 1.0 m contiguous segments. Core segments were sealed in the field and returned for storage at the laboratory. Sediment density and organic matter content were determined on the sub-samples of sediment cores. Cores were sealed in plastic stretch wrap after sampling and archived at 5°C. For lake sediment samples, organic matter was determined by loss on ignition (450°C >6 hr) from oven-dried sub-samples ground to pass a 100 mesh screen (1.0 cm³ at 105°C for 24 hr). Chemical analysis was achieved using a combination of methods, including Atomic Absorption, Neutron Activation and Inductively Coupled Plasma (Rogers and Lombard, 1991; Rogers and Ogden, 1992). Preparation of samples for microfossil analysis followed standard procedures and involved wet sieving at 125 μm, deflocculation in 10% KOH, demineralisation in 48% HF, acetolysis (acetic anhydride: concentrated sulphuric acid 9:1) for pollen, and digestion with H₂O₂ (30%) and concentrated H₂SO₄ for diatoms.

Study Example 1:

Estimating, Modeling and Monitoring Land Use Impacts from Induced Hydrogen Ion or Proton Imbalance: Soldier Lake Geochemical Gradients Study.

RATIONALE

PostSecond World War cumulative acidification of lakes in Nova Scotia has been noted in numerous studies (Peterson et al., 1986; Gorham et al., 1986) including those at Soldier Lake (Figure 2). Soldier Lake is a large, deep (20m) and highly oligotrophic brown water lake of about 0.8 km² (198 ha) in surface area with a catchment basin of around 36.2 km² (Ogden and Rogers, 1988). The catchment geology includes both Halifax Slate and Quartzite of the Meguma Group, which intersects portions of the Halifax International Airport and the Bicentennial Highway (N.S. Route 102). Since the 1960's, construction activities at the airport and along the Bicentennial Highway exposed highly fractured, mineralised and numerous pyritic units of Halifax Slate. Oxidation and leaching of these sulphide minerals has created an acidic leachate with a pH of 2.9, which resulted in fish kills, closure of a federal fish hatchery and relocation of a municipal water supply at Enfield. The Johnson River sub-watershed (D, Fig.2) constitutes 49% of the system watershed and has an average inlet pH of 4.2. In comparison, the airport runway segment (Sta. 8, Fig. 2) covers 1.7% of the catchment area, yet is responsible for 63% of the total hydrogen ion loading to Soldier Lake (Ogden and Machell, 1985).

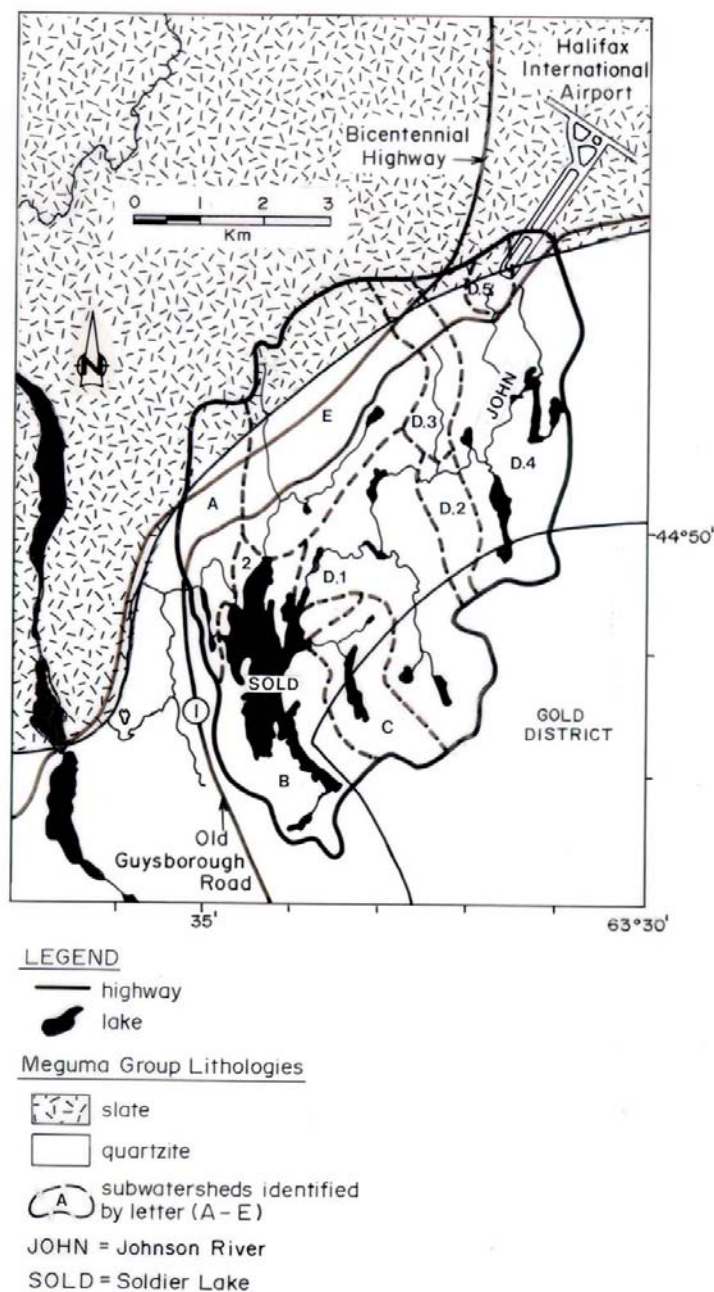
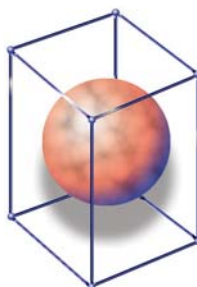


Figure 2. Location, geology, and catchments of the watershed of Soldier Lake, Sub-Watersheds are labelled A to E.

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RESULTS

In 1987, nine water samples were taken as short cores from just above the sediment-water interface below the main upstream inlets in the northern part of the lake system (Figure 3). Stations 1, 4 and 5 below the Johnson River inlet show an acidic pH from 4.2 to 4.5 with a corresponding drop in Fe and Al and with higher Zn in the sedimentary column which indicate a mobility barrier related to differing pH of the lake bottom (Figure 4). Although aluminium shows a slight increase in deposition from pH 4.2 to pH 6.2, there is nearly a three-fold increase in iron deposition at the higher pH values. Virtually all of the aluminium and at least 88% of the iron comes from the Johnson River watershed (inlet pH 4.2) according to mass balance studies reported in Ogden and Machell (1985) for a two-week period in July, 1983 which also showed that 33% of the aluminium and 85% of the iron entering the lake was retained in the lake. In contrast the Holland Brook inlet shows a more basic profile, with pH from 4.9 to 6.2 and increased Fe and Al and lower Zn compared to the Johnson River inlet (Table 1). The increased hydrogen ion concentration and acidic pH values of around 4.5 are attributed to a build-up of excess protons from the acidified drainage due to oxidation of pyritic slate exposed during the construction of the airport runway.

Repeat sampling in 1990 detected no gradients and an increased pH of outlet water by 0.5 pH units. This

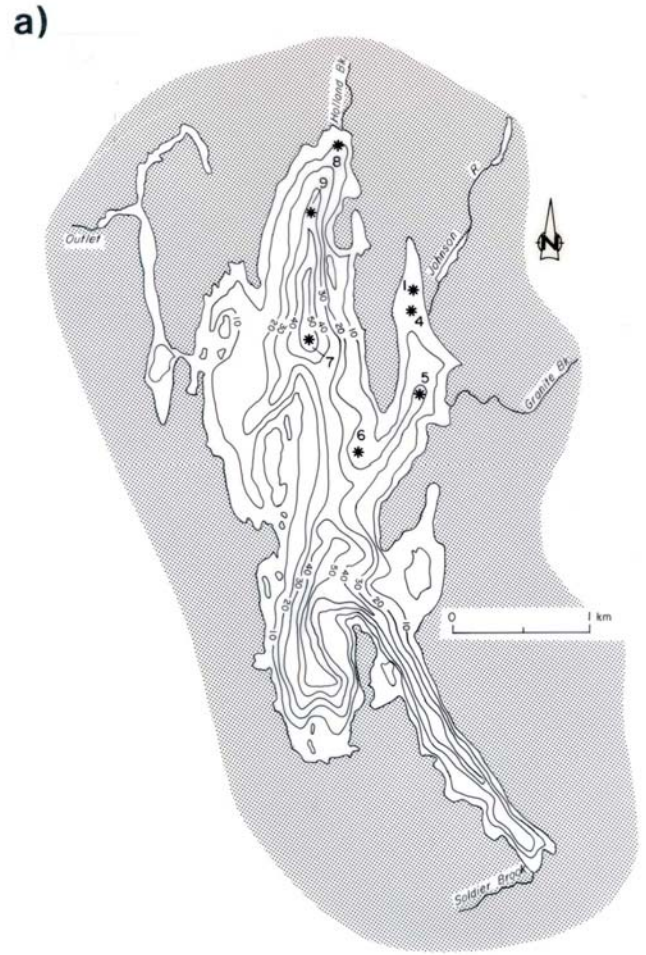


Figure 3. Sample locations and bathymetry of Soldier Lake.

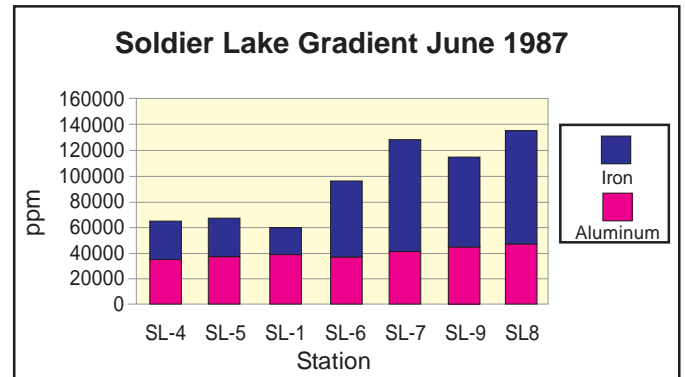


Figure 4. Plot of Al and Fe at sampling stations with pH gradient.

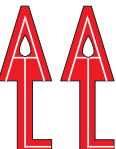
amelioration is due to sheet-creting (cement, fly ash and polypropylene fibre) of the exposed bedrock at the airport which has prevented further proton imbalance.

Although the difference in water column length may explain the differences in sediment density and loss on ignition for these two samples, overall the major factor appears to be the hydrogen ion gradient imposed by Johnson River and consequent geochemical precipitation.


Surface pollen samples from Johnson Brook (Sta. 4), Mid-lake (Sta. 7), and Holland Brook (Sta. 9) are shown in Figure 5 and imply relatively uniform deposition of allochthonous air-borne materials (multiple Spearman correlation coefficients $r_s = >.85$ (N=23) and epilimnetic mixing across the lake basin.

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ASSAYS AND GEOCHEMICAL ANALYSES



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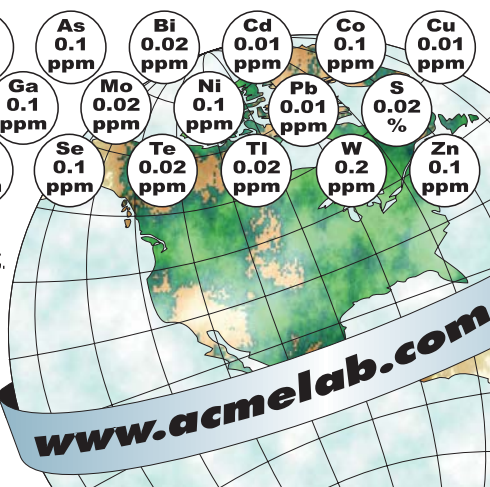
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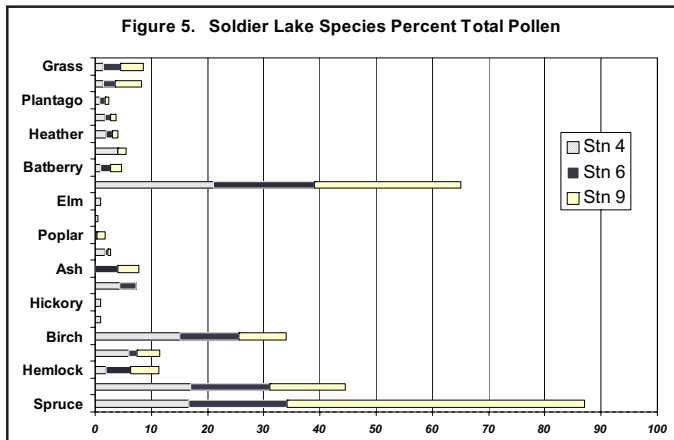


Table 1

SITE	SL-0.4	SL-0.5	SL-0.1	SL-0.6	SL-0.7	SL-0.9	SL-0.8
pH	4.2	4.3	4.5	4.5	4.9	5.8	6.2
Aluminum	36760	38900	40420	36390	42340	48110	47560
Barium	185	190	245	160	180	245	240
Calcium	2070	2470	1690	1760	1190	1690	1410
Chromium	41	51	51	33	42	46	40
Copper	110	110	50	57	82	64	72
Iron	29900	29600	21000	59020	86780	66290	86490
Magnesium	1910	2060	2400	1720	2400	3070	3050
Manganese	360	410	450	350	710	880	1850
Nickel	93	100	57	40	39	49	39
Lead	67	70	55	67	82	73	80
Vanadium	74	71	73	70	110	98	110
Zinc	900	190	550	210	140	120	76
ORGANIC (mg/g)	159	220	205	301	380	353	416

Metals near or below detection limits:

Boron	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5
Beryllium	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Cadmium	<2.0	<2.0	2.7	<2.0	<2.0	<2.0	<2.0
Cobalt	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0



Diatom samples, on the other hand, are almost wholly autochthonous, and reveal the presence of very distinct domains within the lake system. The acidic Johnson Brook Inlet (pH 4.2) samples and more alkaline Holland Brook (pH 6.2) samples are compared in Figure 6. Spearman rank correlation coefficients for these samples give $r_s = .46$ ($N=81$), and ranges from 0.32 to 0.74 for other pairs in the sample series. In the comparison shown here, 9 species are restricted to the more acidic environment, and 10 are found only in the more alkaline Holland Brook Bay samples. Dramatic differences in percent abundance of diatoms common to both environments are indicated in Figure 6 (see page 16).

Ordination analysis using root-root transformations to minimize differences between zero cells and large cell moments were performed using the Czekanowski quantitative index measure of association (Legendre and Legendre, 1983). Standard Q analysis revealed a linear association of stations corresponding to the pH gradient. Reverse, or R-analysis provided 8 groups among 81 species

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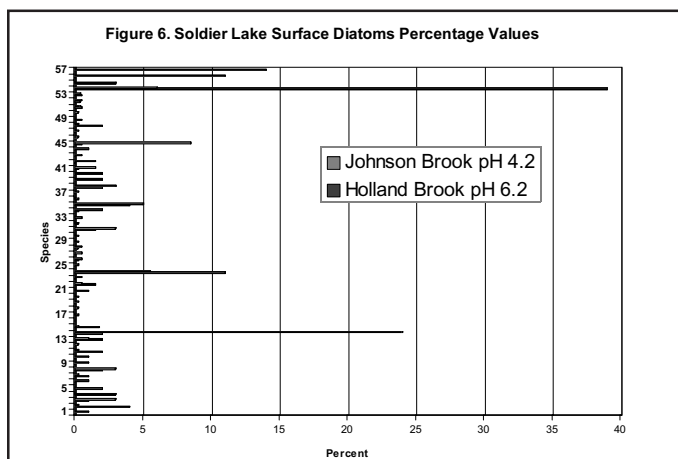
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Focus on: Catchment Pathways and Controls... *continued from page 15*




of diatoms implying a close degree of association between diatom assemblages and pH domains.

Study Example 2: Estimating and Modelling Land Use Impacts from Large Scale Geochemical Reconnaissance Surveys.

RATIONALE

One of the principal aims of exploration geochemistry is the estimation of geochemical background to define threshold levels and indicate anomalies. Recognition of 'natural' background levels in surface materials of various elements is needed to define baseline element levels and principal controls and to monitor changes in the ecosystem. Widely different element levels can be found in stream and lake systems. It is possible to define various natural and imposed geochemical controls present in stream and lake drainage systems. Principal geochemical factors governing background levels include catchment lithology, chemical mobility, and dispersion and dilution of metals during transport; pH is one of the most active geochemical factors and also the one most readily affected by imposed external loading such as from acidified rainfall. To estimate the pH effect on heavy metal mobilities, background levels and vector properties of these metals in natural systems must be elucidated (Ogden et al., 1988).



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Results

The results of numerous studies of reconnaissance geochemical data for background monitoring have been presented elsewhere (Rogers and Lombard, 1991) and will not be considered further. In Central Nova Scotia one such study was performed by the Geological Survey of Canada in conjunction with the Nova Scotia Department of Natural Resources (Daneshfar et al., 2001). The survey collected surface water samples at a density of 1 per 10 km² from first and second order streams; samples were filtered at 45 micron; cation samples were acidified with 0.4% HNO₃ within 12 hours of collection to stabilise them before shipment; the anion samples were untreated.

The survey denoted the role of bedrock factors in the geochemical patterns elucidated by GIS data reduction techniques (Daneshfar et al., 2001). However, one of the more interesting results concerns the identification of a significant presence of N₂ ions in surface water near to lowland areas primarily used for agriculture (Figure 7). This study illustrates the tremendous application that this type of data reduction and surveying methods have for the extension to fields such as precision agriculture amongst others.

Example 3:

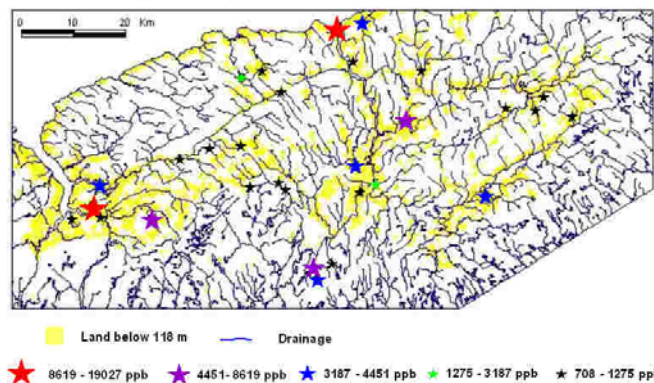


Figure 7. Profile of N distribution, Soldier Lake

Estimating and Modeling Geochemical Baselines Using Lake Sediments

RATIONALE

Grab samples of lake bottom sediment are commonly used for mineral exploration or resource appraisal type geochemical mapping (Hornbrook, 1989) as lake drainage systems cover large parts of the Canadian landmass and present a very convenient means of surveying large areas quickly and cheaply. However, these random grab samples lack the more precise stratigraphic detail needed for environmental studies including baseline mapping, pollution and climate change (Rogers and Ogden, 1992). Small or long cores of lake sediment are very precise mapping tools as they obtain data related to the spatial and temporal aspects of landscape evolution and have been likened to a mass storage device for catchment historical geochemical data (Ogden et al., 1988).

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Focus on: Catchment Pathways and Controls...

continued from page 16



Results

Data from Ontario and Nova Scotia lake cores demonstrate that spatial landscape correlations and temporal markers from lake system to lake system are established by these methods. Temporal correlations across vast areas are obtainable by pollen analysis of these controlled cores. For example, a ragweed (*Ambrosia* spp.) pollen layer in Ontario and a *Plantago* spp. pollen layer in Nova Scotia have both been used extensively to date the chemical stratigraphy of lake sediment cores collected from these areas (Figure 8). This layer is a well known time marker when wooden ships brought this foreign species into Canadian waters during the 17th century and later, its phased arrival denoting the progressive surveying of Canada. Any anthropogenic inputs are therefore easily charted by their appearance above this layer.

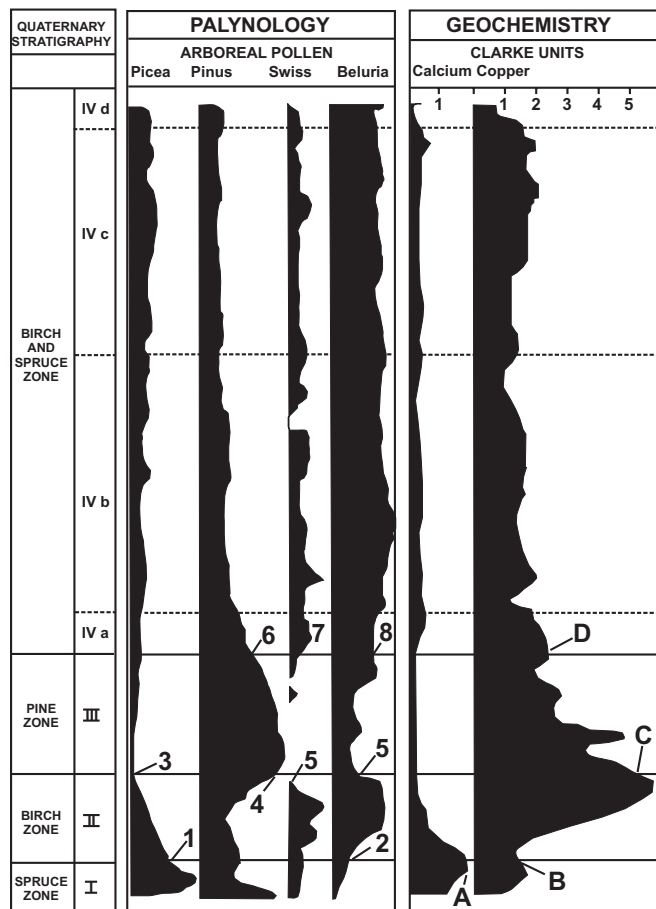


Figure 8. Comparison profile of Ontario lakes, after Fortescue, 1986.

Lake sediment core case histories describe at least four types of Canadian acid lakes. While some lakes are naturally acidic, others have been affected by proton build-up due to acid rain, pollution and/or environmental degradation. The geochemistry of post-Ambrosia environmental disturbances has been noted from lakes near smelters in Ontario (Fortescue 1986) and from the post-Plantago layer at Chocolate Lake, Nova Scotia. Dramatic increases in baseline

metal values (e.g. by Pb due to automobiles, Cu due to modern plumbing, V due to home heating oil, etc.) are observed in most lake sediment cores (Rogers and Ogden, 1992). Cores from some Nova Scotia lakes include a geochemically distinct 'backhoe' horizon caused by accelerated bedrock weathering due to excavation and construction activities in catchment areas about 40 years ago (Ogden et al., 1988). Certain elements can also be used as time and spatial or ballistic markers. For example Ni, Cu, U, Br, As, Sb and Co have been found useful in Ontario and Al and Zn at Soldier Lake in Nova Scotia (Fortescue, 1986; Ogden and Rogers, 1988).

All post-glacial lakes in central and eastern Canada show an increased organic content with time from ca. 10,500 to 9,000 radiocarbon years before present (RYBP). This increase is a consequence of decreased soil erosion and increasing vegetation as post-glacial warming permitted a re-establishment of closed boreal forests. In Nova Scotia, lake sediment cores record a distinct climatic change to a warm, dry maximum at ca. 3500-5500 RYBP, the xenothermal interval. Reduced precipitation and runoff during this time lowered flushing rates and increased organic sedimentation. The possible effects of future global warming can be inferred from such data on previous periods of global warming recorded in long cores.

Studies at Chocolate Lake (Figure 9) have indicated significant anthropogenic input of elements during the past few hundred years when compared to the advent of modern man in lake catchments in Nova Scotia and Ontario. A

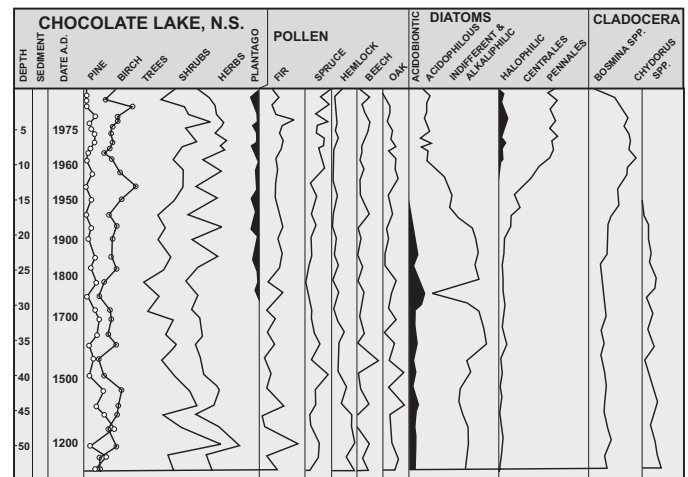



Figure 9. Stratigraphic profile of micro organisms Chocolate Lake.

continued on Page 18



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Focus on: Catchment Pathways and Controls...

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number of significant chemical changes are noted (Figure 9). Increasing bedrock exposure, weathering and additions from human activities have resulted from changing land use within the lake catchment. Increased heavy metal deposition of Al, As, Fe and Mn has resulted from accelerated excavation and construction activities since about 1950. Anthropogenic input of Cr, Pb, V and Zn are noted and use of road salt for increased halophilous diatoms indicate ice control. Deforestation is indicated by changes in the record of tree pollen and diatoms since ca. 1750. Increasing lake water eutrophication from leaching of domestic waste is reflected by increases in the presence of alkaliphilous diatoms, which show pH changes from approximately 4.5 prior to 1900 to near neutral (pH 7) in the 1970s (Ogden et al., 1988).

In the St. Margaret's Bay area, development and construction activities have been primarily limited to the Five Island Lake catchment area, and are mostly residential and seasonal cottage developments. A number of new residential developments are currently under way in this watershed and may be expected to change both runoff and water quality as development pressures continue to affect many of the present hydrogeochemical parameters. With increasing acidification, we infer the development of geochemical deposition domains in these lakes in future, similar to those described for Soldier Lake.

CONCLUDING REMARKS

The adoption of several exploration geochemical techniques including sampling, data analysis and data models offers great promise for the synergy of the two disciplines. This is especially relevant when desktop mapping technologies are used to map and model the spatial variables of the exploration and environmental datasets.

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Update from Chile Regional Council



Brian Townley

As the recently nominated Regional Councilor for Chile I am honored to serve the AAG in our mission of spreading knowledge in the proper use of applied geochemistry. My first task at hand is to join new members to the AAG, this by showing a professional community that geochemistry, as an applied tool, when properly used, is in effect very powerful. After IGES20 (Santiago, 2001), the next major meeting in Chile was the X Chilean Geological Congress (Concepción, 2003). It was great to see that many colleagues, both from

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Announcement

John Steven Cone Memorial Scholarship Fund



A scholarship fund has been established at the Colorado School of Mines in memory of Steve Cone (1941 – 2002) – chemist, trusted advisor, gifted educator and close friend to many in the mining industry. The purpose of the scholarship is to support graduate research in exploration geochemistry and economic geology for students focused on a career in the mining industry.

Donations or inquiries should be directed to:

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THE ASSOCIATION OF APPLIED GEOCHEMISTS presents the 22ND INTERNATIONAL GEOCHEMICAL EXPLORATION SYMPOSIUM incorporating the 1ST INTERNATIONAL APPLIED GEOCHEMISTRY SYMPOSIUM

Important Dates: Submission of Abstracts: Friday 4 February 2005
Notification of Acceptance: Friday 25 March 2005

Introduction

On behalf of the IGES Committee we would like to invite you to participate in the 2005 Symposium and consider submitting an abstract on one of the aspects below.

The Symposium theme reflects the diverse environments in which exploration geochemistry is applied, many of which are found in Western Australia.

The keynote speakers will set the scene for the Symposium and your contribution will be greatly appreciated in making a program that will be relevant and attractive to members and others.

We urge you to submit an abstract for a paper as soon as possible for this exciting event.

Nigel Radford, Paul Morris CO-CHAIRS

Note to Authors

As a commitment to attend and support the Symposium, accepted presenters are expected to pay and register for the full-time program on the day of their presentation.

All costs to attend the Symposium, including the registration fee, must be met by presenters.

Call for Abstracts

The organisers of 2005 IGES (the 1st IAGS) are calling for abstracts of papers covering all aspects of the geochemistry of mineral deposits: their genesis, exploration, exploitation and remediation.

Sessions at the Symposium will be organised along the following lines:

- Regolith — the continuum; from tropics to tundra.
- Discovery case histories and geochemical exploration in tropical, temperate and glacial terrains.
- Geochemical exploration's brave new world. Seeing through transported overburdened, mechanisms of metal mobility.
- Environmental Geochemistry: its interaction with exploration.
- Geochemistry of mineral deposits: isotope and hydrothermal geochemistry.
- Data, our raw materials: analysis, QAQC, data management, data processing.

A series of pre-conference Workshops and Short Courses will be offered.

Detailed instructions for authors can be found at:

www.promaco.com.au/conference/2005/iges

Short Courses

The Short Courses, of half or full day duration, will be presented by an individual or group of presenters. Each will follow a set theme, and include course notes.

At present, the following **Short Courses** are planned — more suggestions are welcome:

- Regolith processes in WA. Useful for participants in the WA Regolith field trip, though attendance is not essential. Presenters CSIRO/CRC LEME.
- Geochemical data interpretation in a regolith context. Presenters Simon Bolster (Regolex) and David Lawie (io Geochemistry).
- Spectroscopy in geology: from remote sensing to grade control. Presenter Bob Agar (Australian Geological and Remote Sensing Services).

Field Excursions

Proposed field trips are as follows:

- Regolith and Mineralisation in the Eastern Goldfields.
- Mines and Wines in the South West of Western Australia.
- Pilbara Mineralisation.
- Mineralisation in New South Wales.
- Epithermal Gold Mineralisation in New Zealand.

Workshops

Workshops will be less formal. Each will be coordinated by a facilitator, and various presenters will contribute on a less formal level than would apply to the main Symposium sessions. Discussions between the participants will be an integral part of each workshop. Wherever possible, informal abstracts of presentations will be available to participants..

Workshops are planned for the following topics:

- Deep penetrating geochemistry mechanisms: cations, currents, critters.
- Laboratory methods, new developments, new applications.
- QAQC: being sure you get it right.
- Data management: databases, novel processing, statistics, presentation.
- Environmental geochemistry: what geochemistry does for the rest of society.
- Forensic geochemistry.

Other ideas for workshops are welcome, as are expressions of interest from contributors.

Contributors to the Symposium may wish to expand on their themes via workshops.

Call for Abstracts

Abstract submission to be sent by 6 February 2005 as a single email attachment, saved as a Microsoft Word 98 or later document, to email address: promaco@promaco.com.au.

For inserted characters use only 'Symbols' type fonts. Name the file **iges** followed by the first four letters of the surname of the presenting author, followed by the author's first initial. For example **igescitij.doc** for an abstract with the presenting author Jane Citizen.

To assist you, an electronic abstract form with style guide may also be downloaded from the website: www.promaco.com.au/conference/2005/iges or may be requested by email from promaco@promaco.com.au. Instructions for email submissions are included in the file.

Symposium Location and Venue

IGES 2005 will be held at the Sheraton Perth Hotel in the beautiful city of Perth, Western Australia. Bounded on the west by the waters of the Indian Ocean and along the north and south banks of the Swan River, Perth is a shopper's paradise, with scenic attractions to delight the visitor.

Trade Exhibition and Sponsorship opportunities

A trade exhibition featuring new and innovative products will be a key feature of the Symposium, and numerous opportunities will be provided to organisations that wish to take advantage of the exposure to Symposium participants.

Travel & Accommodation

Travelling to Perth is more affordable than you may think. Discounted fares within Australia are available. Some conditions apply and a Saturday night or three nights away is usually required. A range of accommodation can be booked in Perth to cater for all budgets.

Further details will be available in the Symposium registration booklet, to be published in 2005.

Social Program

A Symposium is not complete without the opportunity to socialise and network, providing a break from the intensity of the educational program.

A Welcome Reception and Symposium Dinner will be the main social functions and other evening events are planned. You may also like to take advantage of the many facilities in and around Perth and Fremantle. Why not plan to stay a little longer and enjoy the experience of 'taking a break' in Western Australia.

September in Perth is glorious and delegates may like to see the wonderful wildflowers that abound and enjoy the many restaurants and river cruises that are available.

Partners

Partners are 'very important people' and a special program of activities and tours will offer the best of Perth and surrounds.

Further Information

All enquiries should be directed to the Symposium organisers:

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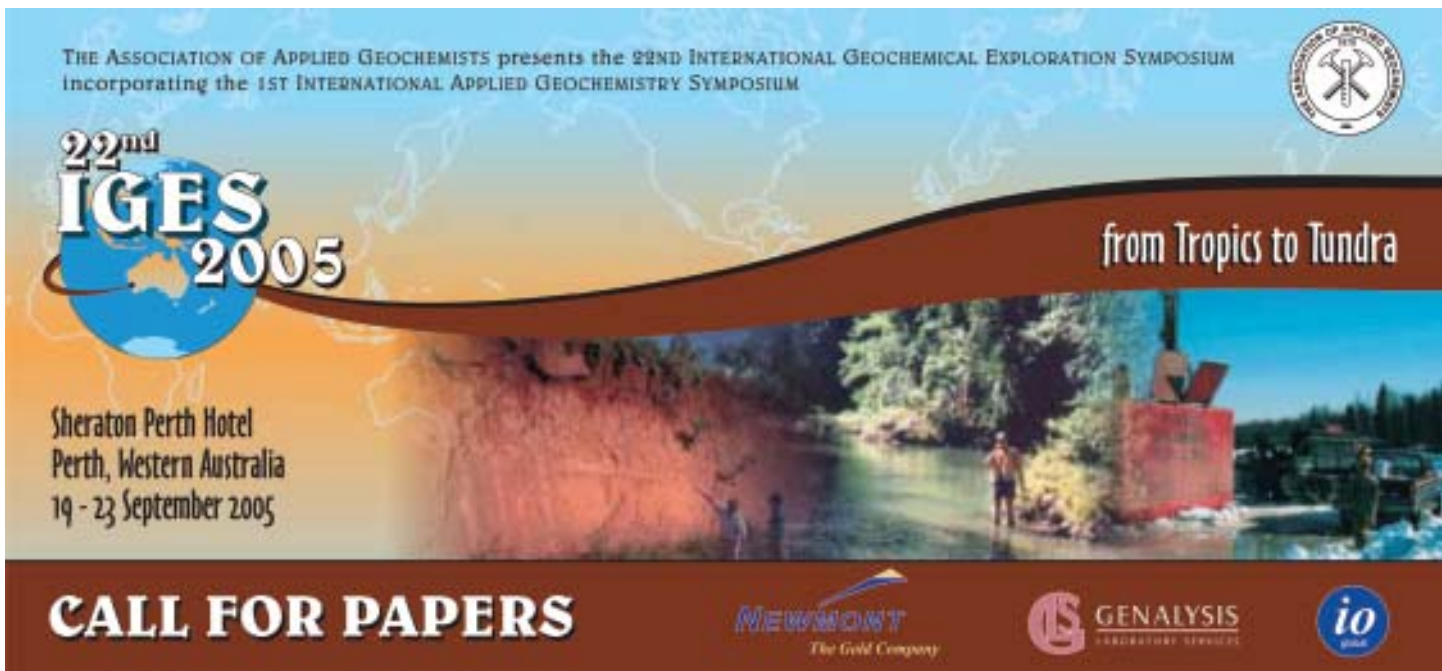
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Abstract Format

Abstract submissions are invited for consideration by the Symposium Technical Committee. Accepted papers will be published in the Symposium Proceedings.

It is expected that presenters will have 20 minute timeslots, plus 10 minutes for discussion. Each paper should support one of the six sessions listed.

Abstract Preparation

The purpose of the abstract to define the precise subject of the presentation. The abstract should not contain acknowledgements, figures or references.

Include the names of all co-authors plus affiliations and addresses for general correspondence (including email address).

To assist the Technical Committee, a brief personal profile (maximum 100 words) is required from the presenter with the abstract.

Abstract Specifications

- Font:** Times New Roman
- Title:** 12 pt **BOLD CAPS**, centered
- Presenter:** 11 pt italics, centered
- Affiliation:** 11 pt italics, centered
- Text Body:** 11 pt regular style, single spaced, justified
- Spacing:** 1 line space under title and between author details and body of text
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Update from Chile Regional Council...

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.....

the private and public sectors, and students, work and publish on topics of applied geochemistry. Subjects on exploration and environmental geochemistry were presented, one particularly good, by Alejandro Kakarieca (Breakwater Resources Ltd.) regarding the application of traditional exploration geochemistry to the discovery of new ore deposits within the El Toqui Zn district, XI region of Chile. His excellent oral presentation made it quite clear that geochemistry applied to exploration, when carried out correctly, can be the leading tool to discovery. Bottom line, do the right thing.

Do the right thing! This motto sounds easy enough, but to actually follow it requires knowledge and proper training. A recent article in Explore number 123, "Who will deliver the last classical exploration geochemistry course" by David Cohen should have us all on our toes. Chile has not fallen behind the international trend. The proportion of university students specializing in economic geology, in particular exploration, has progressively decreased. Exploration geochemistry (nowadays actually applied geochemistry), as a formal term course, is only lectured at the University of Chile. Interest in this course averages around 10 students/year. Not many considering the total local economic geology work force in Chile (~ 1000).

Despite this situation, geochemistry is broadly used in exploration and more recently in environmental studies. Lack of training commonly leads many geologist to miss those little details in sampling, sample handling, processing, analytical procedures, quality control, data processing and interpretation, among other things, providing poor or simply wrong results, that can be extremely damaging both to the outcome of a specific study, be it exploration or environmental, and to the good name of applied geochemistry as a tool. It is obviously necessary to spread knowledge and consciousness of the difficulties behind the proper use of geochemistry. Our AAG, through our **EXPLORE** Bulletin and the GEEA Journal and any other means at hand, bear this responsibility. Keep courses alive at Universities and reach out to industry by means of short courses or seminars. Invite participants to join the AAG. The benefits are well worth the cost. A geologist, qualified in geochemistry has broader work fields of application, something quite desirable in the ever shifting markets of today.

In the same article mentioned above (Focus on: Academic Institutions) I missed my opportunity to include the Department of Geology, University of Chile. Teaching activities related to geochemistry include a basic mandatory course on topics of primary and secondary geochemical environments, fractionation, petrochemistry, isotopic geochemistry, among others, and an elective course on applied geochemistry, originally focused on exploration, with an increasing interest on the environmental application side. Research in the past has seen many large scale projects; from 1993 - 96 starting with a regional exploration program of the XI region of Chile; then in 1996 - 99 with a good

exploration program in central Chile; recently in 2002 - 04 an exploration program in northern coastal Chile with applications of caliche geochemistry to regional undercover deposit exploration; and currently active, a three year US\$300.000 project (FONDEF 1083) on deep penetrating geochemistry, theory and applications. All of these projects have been financed by the Chilean National Science Foundation (CONICYT), in particular FONDEF (applied research funds). These projects require at least one industry sponsor, the currently active project (1083) in collaboration with CODELCO - CHILE. Research collaboration include the Catholic University of the North, Antofagasta, and IRD (France). All of these projects have included many undergraduate and graduate students, probably the best way to provide proper training and experience to those professionals whom will join the market.

Expect more brief notes from Chile, references of local publications and description of activities, both industry and government, and if all goes well, new membership applications. A student chapter is in the line of thought, yet critical mass is still low. Glad to join the Council and looking forward to doing my best at promoting the AAG.

Brian Townley

Email: btownley@cec.uchile.cl



Becquerel Laboratories - termination of neutron activation analysis service in Australia

Becquerel Laboratories, Sydney, Australia will terminate its neutron activation analysis (NAA) service on 30 September 2004.

If you wish to continue using NAA in the future we strongly recommend that you utilise the services of Becquerel Laboratories in Canada. They specialise in NAA, have over twenty years experience in operating a commercial NAA facility, and are accredited under ISO 17025 delivering high quality analyses on a wide range of sample matrices. The analytical options that they offer are very similar to those offered by Becquerel in Australia.

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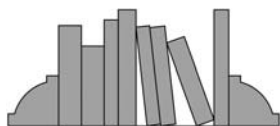
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RECENT PAPERS

This list comprises titles that have appeared in major publications since the compilation in **EXPLORE** Number 123. Journals routinely covered and abbreviations used are as follows: Economic Geology (EG); *Geochimica et Cosmochimica Acta* (GCA); the USGS Circular (USGS Cir); and Open File Report (USGS OFR); Geological Survey of Canada papers (GSC paper) and Open File Report (GSC OFR); Bulletin of the Canadian Institute of Mining and Metallurgy (CIM Bull.); Transactions of Institute of Mining and Metallurgy, Section B: Applied Earth Sciences (Trans. IMM). Publications less frequently cited are identified in full. Compiled by L. Graham Closs, Department of Geology and Geological Engineering, Colorado School of Mines, Golden, CO 80401-1887, Chairman AEG Bibliography Committee. Please send new references to Dr. Closs, not to **EXPLORE**.

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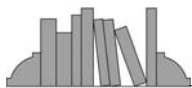
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