EXPLORE
NUMBER 129 DECEMBER 2005
Newsletter for the Association of Applied Geochemists

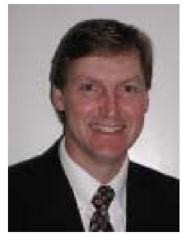
## Focus On: Geochemistry as a Career

This **EXPLORE** has several articles by geochemists describing how they got into the profession and how they see the different parts of the profession developing in the future. The main intention of this "Focus" is to offer some written insight into the real world of applied geochemistry for young geoscientists and students.

The New Membership Committee under the leadership of Robert Jackson has produced an excellent powerpoint presentation that members can use at any time to promote membership in the AAG. There is a slide in this presentation that relates well to many of the experiences described in this **EXPLORE** and is shown below as an introduction to the following contributions

continued on page 4

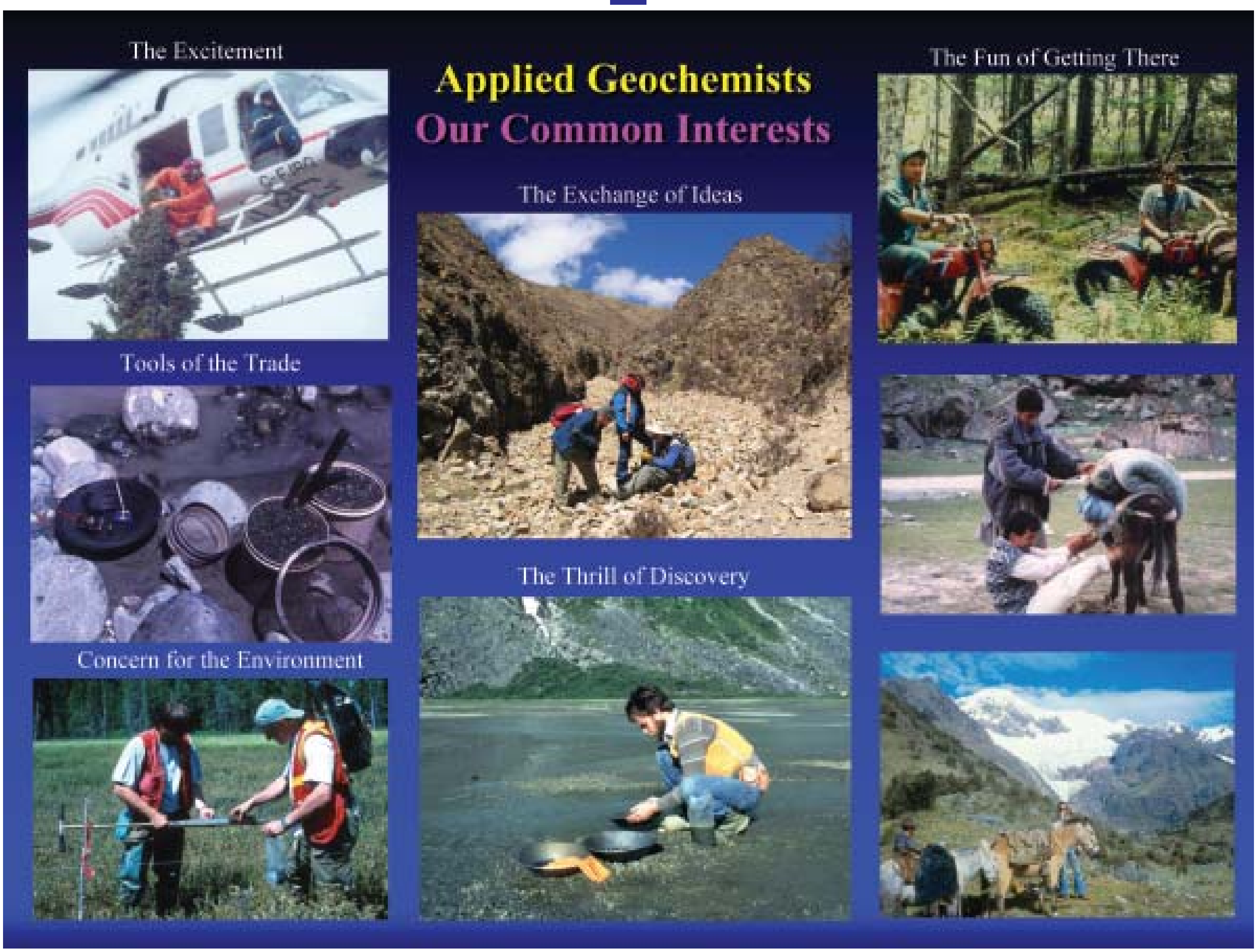
## AAG Presidential Address



*David Kelley*

It was great to see many of you at the IGES/IAGS in Perth. The meeting was a huge success thanks to the hard work of Paul Morris, Nigel Radford, the Local Organizing Committee and conference organizers Promaco. Pulling off a successful international symposium is no easy task and the Association is fortunate to have such dedicated members stepping up to ensure that our most important technical forum continues to promote applied geochemistry to an international audience. We also had the pleasure of presenting Ian Nichol the Honorary Membership in the AAG and the Gold Medal to Gwendy Hall. Bill Coker accepted the Honorary Membership

continued on page 2




EXPLORE NEWSLETTER
wishes to thank our
Corporate Sponsors
GEOSOFT Actlabs SGS ALS Chemex

## President's Message...

continued from page 1

award on behalf of Ian and it was truly impressive to see Ian's legacy when Bill asked all of Ian's past students in the audience to stand up. Gerry Govett's thoughtful citation of Gwendy's Gold Medal was an appropriate tribute to someone who has given so much to the science of applied geochemistry and to the Association. Ian and Gwendy are both highly deserving of these awards. The Student Paper Prize was also deservingly given to Nigel Brand. Well done Nigel. Ian Robertson has looked after this award for many years and is now handing over the reigns to David Cohen. I would like to thank Ian for his many years of service to the Association in looking after this award.

We had a spirited Annual General Meeting at the IGES. I took the opportunity to read a letter from Eion Cameron regarding the financial status of the Association and I expected silence afterwards. But instead, members responded with a plethora of ideas of how we can improve our situation. We agreed that the value that each of us receives from being a member is worth more than the US$70 we pay annually for membership, so we increased dues to US$100. Student fees are still unbelievably low at US$10. We also agreed to aggressively pursue new membership, which is already paying off from the efforts of Robert Jackson, Brian Townley, Dr. Wang and others. From their efforts and new members from the IGES, we already have 100 new members. Other ideas include re-establishing Corporate membership and marketing AAG-sponsored workshops on applied geochemistry.

Our next symposium, the 23rd IAGS, is just 18 months away. Jorge Loredo and his organizers are working on this meeting, which will be held in Oviedo, Spain, in June of 2007. More information on this meeting is coming soon.

The theme of this issue of Explore is "Geochemistry as a Profession." There are several excellent articles on this subject from practicing geochemists. One

continued on page 3

## TABLE OF CONTENTS



New unique techniques for the detection of GOLD and PGE in WATER, ROCK, SOIL, SEDIMENT, HUMUS and VEGETATION


*Quality Analysis . . .*
*Innovative Technologies*

*Activation Laboratories Ltd.*

1-888-228-5227 • www.actlabsint.com • ancaster@actlabsint.com

Paid Advertisement

## President's Message... continued from page 2

commonality that I see in all geochemists is a true love and passion for the profession. Applied geochemistry is not just about the science, but rather how science can be applied to serve society. Regardless of whether your focus is finding a mineral deposit or improving the environment, being successful requires applying the science to achieve a useful result. Another trait of applied geochemists is that they tend to be inquisitive, resourceful, open minded and team players. Our trade can only be successful if we have the support of our colleagues, which requires that we work together. Finally, practicing applied geochemistry is fun. You never know what the result will be, and the places you go and people you meet along the way makes every experience unique and rewarding.

If you have not visited our website www.appliedgeochemists.org lately, please do so. Bob Eppinger and Andrew Ransom have made a number of improvements to the site. We are no longer maintaining the old www.aeg.org address so please update your bookmark if you have not done so already.

Sincerely,

**David Kelley**
*Newmont Mining Corporation*
*Malozemoff Technical Facility*
*10101 East Dry Creek Rd*
*Englewood, Colorado*
*USA 80112*
*dave.kelley@newmont.com*

## AAG Distinguished Lecturer

The Distinguished Lecturer Series for 2005-2006 is being given by Stew Hamilton.

**Details of Lecturers**

**No1** Electrochemical transport, reduced chimneys and "forest rings" – implications for mineral exploration

**No 2** "Forest Rings" and their implications to geochemical exploration for oil, gas and mineral deposits

**No 3** Deep penetrating geochemistry using selective leach methods over mineral deposits

**No 4** The hydrogeology of "forest rings": evidence supporting a completely new groundwater transport mechanism

For further information please contact Stew Hamilton (stew.hamilton@ndm.gov.on.ca). Organizations interested in putting on a lecture should contact Robert Bowell (rbowell@srk.co.uk) for further information

**Tentative Lectures & Tours**

- Beijing China, January 2006. Institute of Geophysical and Geochemical Exploration.
- Western and Central Canada (Vancouver, Calgary, Regina, Toronto, Waterloo), spring, 2006.
- United States (Houston, Denver), spring, 2006.
- Europe and/or Fennoscandinavia, spring or fall 2006.


Paid Advertisement

## Focus on: Geochemistry as a Career ... continued from page 1

**Emily Chastain**
**Environmental Geochemist**

In what is probably a familiar story for a number of geochemists, I enrolled in university ; at the Colorado School of Mines -; with plans of becoming a chemical engineer. After taking the Geology 101 requirement, I promptly switched majors and became a geological engineer. After taking the chemistry requirements, I promptly went to the bar and drank a lot of beer. My interest in chemistry was rekindled when I took part-time work as a research assistant examining the acid buffering capacity of soils downstream from a high sulphidation mine. The work was extremely interesting and provided a first glimpse at applied geochemistry. It was also the first hint that information from all of those university lectures actually made sense and had a place in the real world.

The summer after graduation I was very lucky to work on a stream sediment and soil sampling program. Classic geochemistry field work. I was getting paid to spend all day outside — hiking, sampling and applying skills learned in field school.

My career in geochemistry was cemented when I accepted a master's degree project at the University of British Columbia in Vancouver, Canada. My project was to examine the geochemistry of surface materials at a gold project in South America. Not that I really knew what that meant.

That autumn I moved to Canada and promptly went to Chile and Argentina for 2 months to complete the field work for my thesis. Turns out that examining the surficial geochemistry of a gold deposit starts with taking lots of large (20+ kg) samples. The study area was two stream drainage basins in the high Andes that straddle the Chile and Argentina border. Most of the area was above 4,000 m (13,000 feet). Getting to the Argentinean area meant an 8 hour truck ride and went over a pass more than 5,000 m in elevation (16,000 feet). Because of the deposit style and mineralogy, the streams draining the deposit were naturally acidic with a pH often less than 3.

After finishing graduate school, I spent the next 4 years working as an exploration geochemist for Barrick and BHP Billiton. In four years, I worked in northern Saskatchewan, Baffin Island, northern British Columbia and Whitehouse in Canada, Nevada in the US, northern Sweden and Chile. Additionally, I worked on data that was generated in Africa, Indonesia, Australia and Peru. Relative to most of my co-workers I had an easy travel schedule! Common to both companies was the international make-up of the office. I've met and spent time with co-workers from Canada, US, Australia, South Africa, UK, Germany, Russia, Sweden, Argentina and Chile.

The work at the two mining companies was highly varied and always exciting. In my first job, I was a member of a team comprised of four geologists, a geophysicist and myself. We were the exploration team for base metals (copper, lead, zinc, etc.) in North America and Europe. I was responsible for helping the project geologists design and execute geochemical surveys and interpret the results. At the second company, I began as a contract employee working on an in-house GIS based research project. The project relied heavily on data management and geostatistics to develop geochemical discriminators for a specific style of gold deposit. One of my favorite applications of the GIS analysis for the project used randomly generated subsets of the original data to determine the minimum sampling density that still identified the deposit. After being hired by the company, I became more involved with the project geologists and on-going exploration projects completing interpretation of geochemical surveys. I also became more involved in quality assurance and control; accompanying my manager on inspections and audits of analytical labs and eventually conducting my own audit on an exploration drilling program.

It is worthwhile to note that none of the work as an exploration geochemist is done without input from geologists and geophysicists. Exploration geology, geochemistry and geophysics all generate a lot of data and it's easy to become isolated during interpretation. The maximum value of the data is achieved when the geology, geochemistry and geophysics are examined concurrently. A personal prejudice aside, the most effective exploration is the result of a scientifically integrated program.

continued on Page 5

**Mobile Metal Ion Geochemistry**

***High Resolution, Deep Penetrating***

- Commodity element leaches for ultra-low level analysis.
- MMI-M — Single multi-element leach (choice of 30+ elements).
- Superior anamaly to background definition.
- Premium quality data — robust, repeatable, and globally available.
- Industry proven surface geochemical technique for difficult terrains and complex soils.

Successful global case studies, press releases, and research reports available for precious, base metal, nickel, and diamond exploration.

Mobile Metal Ion mmi TECHNOLOGY

Phone: +61 8 9472 7344
www.mmigeochem.com
mmi@mmigeochem.com

Paid Advertisement

## Focus on: Geochemistry as a Career ...

continued from page 4

After 4 years doing exploration geochemistry, I recently switched professions and am now an environmental geochemist for the mining division of URS, a large consulting firm. The decision to change jobs had little to do with the exploration work and more to do with the lifestyle. I simply wanted to spend less time away from home and fewer hours in airports and airplanes. While geology and geochemistry are the common threads between the two industries the work is very different. In consulting, you have to learn to work with clients, limited budgets, limited sampling programs, limited data and often other people's data. Instead of generating a memorandum or email with a couple of figures, as is often done in exploration, all reports flow though a document quality control process. The composition of the office has less of an international component but encompasses a much greater range of professions including biologists, chemical engineers, civil engineers, geographers, foresters and geologists.

I am currently involved with a project to complete closure and remediation plans for a number of mines in Manitoba and Saskatchewan. In the mining group, we were responsible for reviewing the relevant guidelines and regulations and using them to develop a list of criteria that the mine would have to meet to be considered remediated. The client also required a detailed cost estimate of the work required to meet the criteria. I've had to rely on the engineering skills that I was taught in my undergraduate studies to adapt to these new job demands. Some of the other work has been examining historic mine water geochemistry data for an operating British Columbia mine to predict the final water chemistry after the mine closes. As an environmental geochemist, learning about acid rock drainage and how to remediate sites that have poor quality drainage is a large part of the work. Fortunately, with a background in exploration geochemistry, it was an easy transition to make. The years spent working in exploration also mean that I can speak "mining" to clients and can easily socialize at mining and exploration industry events – both important marketing tools in consulting.

Geochemistry will always exist as a specific focus in the exploration and environmental industries. It is too useful and too interesting a profession to be neglected. Part of our responsibility~~ies~~ as professionals is keeping our work relevant, effective and training others to properly employ geochemical tools. Being able to speak geochemistry with engineers or geologists in a way that makes geochemistry accessible generates more opportunities for the profession.

**Mike Grimley**
**Exploration Geochemist**

Like so many other geologists I have met I initially went to university to study something else (engineering in my case) and after studying a couple of geology courses I was hooked. I also really enjoyed chemistry which happens to fit quite nicely with geology so geochemistry was for me. The more I learnt about the geological profession as a whole the more I enamoured I became — a chance to see the world at someone else's expense and also to see places which simply aren't accessible to the general public. Virtually everyone in the exploration business is in it for the lifestyle as much as for the job itself, and that certainly is the case for me. I have thoroughly enjoyed working for a large company that has provided the opportunity to travel the globe and gain experience exploring in different countries and for a variety of commodities. I have also been brought into contact with many people whom I would never have otherwise met, and as a result travelling has significantly altered my view of the world.

I should note that my perspective of geochemistry as a profession is from being an employee of the mineral exploration group of a major mining company. There are big differences between how junior companies, exploration businesses, mining businesses, consultants and the education sector operate. One of the benefits of the geological profession is that they are diverse in terms of both opportunities offered and demands or pressures created by the multitudes of possible jobs so almost everyone is able to fit in somewhere.

Currently I am a geochemist with BHP Billiton's

exploration group based in Vancouver. For the first seven years I was based in Australia working on a variety of base metal programs, both in Australia and overseas, but

continued on page 6

**Robert G. Jackson**
Consulting Geochemist

**3D Zonation Modeling and Vectoring Methods to discover Blind Deposits**
**Survey Designs and Data Interpretation**

*Seeking new target possibilities through 3D visualization*

3 Leamont Terrace
Dartmouth, N.S., Canada B2Y 1V1
rgjackson@eastlink.ca 902-463-6910

Paid Advertisement

## Focus on: Geochemistry as a Career ... continued from page 5

moved to Canada three and a half years ago. Since then I have been working exclusively on diamond exploration, predominately in the Canadian Arctic but also on projects in Africa, some of which I have had the opportunity to visit. My prime responsibility relates to geochemical aspects of exploration for kimberlites — mostly interpretation of mineral chemistry data (both in-house and external), program management, project generation and mineral title acquisition, but also routine geochemical support functions like interaction with laboratories, quality assurance and data management plus target screening and selection.

Possibly the most important function of my role is to ensure that geochemical techniques are used appropriately and applied so as to create a balanced, multi-disciplinary approach to exploration. A key element of this is educating other explorers about new advances in geochemistry, and then driving the application of these techniques into exploration programs. I have had exposure to, and actively used, various forms of mineral chemistry such as lithogeochemistry, hydrogeochemistry, selective extraction and traditional analytical geochemistry, isotope chemistry, soil gas geochemistry and other geochemical exploration methods. Implementing these into exploration programs has been a real challenge at times, however the successful use of a new or different technique can be very rewarding.

One of the fundamental tasks of being a geochemist is dealing with raw data, manipulating it into a form which can be interpreted to provide a geochemical picture of a particular area and then relate this to other datasets (eg, an airborne EM survey) to extract the maximum value. Ten years after first entering the exploration industry I am always excited to receive new data, knowing that I am the first to review and potentially recognize a new significant opportunity. Eternal optimism is a must in exploration, and geochemists are no exception.

Fieldwork is a key component of geochemistry, and any geochemist will agree is critical in understanding the surficial environment and being able to confidently interpret geochemical data. Apart from visiting some fantastic places and seeing some truly amazing sight, it also presents an opportunity to interact with different cultures, many of which I would have otherwise been unaware.

While each individual has a particular bent (geologists, geochemists and geophysicists), everyone is expected to contribute to and be responsible for all aspects of exploration from generating and managing projects, acquiring mineral title and budgeting to interaction with joint venture partners and negotiations with governments. Although much of my time is spent on matters geochemical and it is this part of a particular project for which I am ultimately responsible, team members do not work in isolation and everyone contributes when required. Learning how to operate in a team environment is key in any successful exploration program. I devote a great amount of time to training people unfamiliar with certain aspects of geochemical exploration but also to disseminating new knowledge to the group as whole.

Modern exploration geochemistry often generates vast amounts of data, which produces a challenge during visualization and interpretation. It is easy to fall into the hole of spending a great deal of time, money and effort generating data, but ultimately extract minimal value by not devoting sufficient time to interpretation. As geochemical techniques become more complex and a greater amount of data becomes available to manipulate it

continued on page 7

ASSAYS AND GEOCHEMICAL ANALYSES
ACME ANALYTICAL LABORATORIES LTD.
ISO 9001:2000
FM 63007
Vancouver 2003
ICP Mass Spec Analysis CDN $15.75 US $12.60
(Aqua regia digest on 1g sample)
37 Elements including:
Au 0.2 ppb, Ag 2 ppb, As 0.1 ppm, Bi 0.02 ppm, Cd 0.01 ppm, Co 0.1 ppm, Cu 0.01 ppm
Hg 5 ppb, Ga 0.1 ppm, Mo 0.02 ppm, Ni 0.1 ppm, Pb 0.01 ppm, S 0.02 %
Sb 0.02 ppm, Sc 0.1 ppm, Se 0.1 ppm, Te 0.02 ppm, Tl 0.02 ppm, W 0.2 ppm, Zn 0.1 ppm
852 East Hastings St.
Vancouver • BC
Canada • V6A 1R6
Tel: 1-604-253-3158
Fax: 1-604-253-1716
Toll Free:
1-800-990-2263
www.acmelab.com
MEXICO
GM LACME Laboratories SA de CV
Leonardo@acmelab.com
SOUTH AMERICA
ACME Analytial Laboratories (Chile) Ltda.
acmechile@123.cl
Paid Advertisement

GENALYSIS LABORATORY SERVICES PTY LTD
"Specialising in quality analyses"
Genalysis, now in it's 30th year of operation, is proud to be a major sponsor of the IGES 2005 conference in Perth, Western Australia.
An invitation to delegates is extended to visit our analytical facility and attend a social function as part of your IGES 2005 experience.
Contact us on:
Telephone +61 8 9459 9011
Email genalysis@genalysis.com.au
15 Davison Street
Maddington 6109
Western Australia
Facsimilie +61 8 9459 5343
Website www.genalysis.com.au
PO Box 144
Gosnells 6990
Western Australia
Paid Advertisement

## Focus on: Geochemistry as a Career ...

continued from page 6

is important that we extract maximum value from this information.

It is important for applied geochemists of all disciplines to become more involved and gain greater influence at higher levels of their respective businesses. Although geochemistry will always remain a core skill it is very important for geochemists to constantly acquire new skills outside of their traditional bounds of technical knowledge, thus allowing us to direct changes within our many varied working environments.

**Mike Whitbread**
**Geochemical Consultant**

It is difficult to pin down what turns a 'geoscientist' into a full-blooded 'geochemist', or when one can safely assume that esteemed/derided title when dealing with work colleagues.

Many geochemists I know started life as geologists. The geological clincher for me was being shown mineral specimens in my first year. I was amazed that anything that forms a rock could look quite as amazing as micas do. So on into a geology major I went. Geochemistry didn't really appeal to me at the time, as 'spreadsheets and graphs' appeared far less glamorous and 'manly' than strutting around the outback armed with a trusty hammer and sporting a robust beard. What probably exacerbated this notion was that I was also majoring in chemistry, and analytical chemistry seemed fairly dry in comparison. Organic chemistry was a hideous form of torture, and while inorganic chemistry practicals were interesting, with pretty coloured solutions, the practical applications seemed abstract.

A few years into the exploration game, I started to find that 'geology' alone was not able to answer my questions about why elements were or were not being concentrated in certain areas. Or why this lump of green altered rock was associated with a barren system and another identical-looking lump of green altered rock was metres from mineralisation. Geology helps you build the framework for targeting ore systems but, in my opinion, geochemistry fills in critical pieces of the puzzle.

So the geochemical clincher for me was being able to start to understand why ore-bodies are found where they are. I could begin to understand and look for the presence and extent of alteration effects, many of which can't be seen with naked eye. I could also see how minerals and chemistry are fundamentally linked. A happy consequence of these aspects, is that I could see why geochemistry is a very practical and rigorous tool in searching for mineralisation. After all, ore-bodies are just atypical concentrations of one or more elements.

So the transition from geologist to geochemist involved a PhD and a few years of consulting. I now find myself being called a geochemist and finally feel comfortable with the term. The consulting role I occupy at ioGlobal is varied, challenging, frustrating and rewarding all at once. I have very rarely woken up and thought "oh god, I have to go to work today"… which happened all too frequently during my brief stint with production geology a long time ago. I get to be involved in a variety of projects and commodities and interact with all sorts of people as well as deal with a massive array of concepts. I also know I am adding value to the exploration process by helping teams carry out appropriate geochemistry for the questions they are trying to answer. 'Fit-for-purpose' geochemistry is an appropriate buzz phrase.

continued on page 8

**Analytical & Sample Preparation Services for Mineral Exploration**
OMAC Laboratories

Geochemical Analysis, Assaying, Fire Assay,Cyanida-tion, ICP-OES, ICP-MS, Environmental, Metallurgical, Consulting, Mobile Preparation, Laboratories. Offices in 52 countries with laboratories in Argentina, Bolivia, Iran, Ireland, Kyrgyzstan, Mongolia, Tanzania, Turkey.

Contact: Steve Walker
Tel: +44 151 548 7777 Fax: +44 151 548 0714
email: steve.walker@alexstewart.com
www.alexstewart.com/exploration.htm

Paid Advertisement

**ROCKLABS**
**REFERENCE MATERIALS FOR GOLD ASSAYING QA/QC**

Quality Reference Materials affordable for use on an every batch basis. Wide range of values.
**Available in sachets for geologists** or 2.5 kg jars for laboratories.
Used in over 30 countries.
Check Certificates and range at **www.rocklabs.com**
ROCKLABS LTD 161 NEILSON STREET, P.O BOX 18-142
AUCKLAND, NEW ZEALAND
Telephone: 64 9 634 7696
Fax: 64 9 634 6896
E-mail: rocklabs@clear.net.nz

Paid Advertisement

## Focus on: Geochemistry as a Career ... continued from page 7

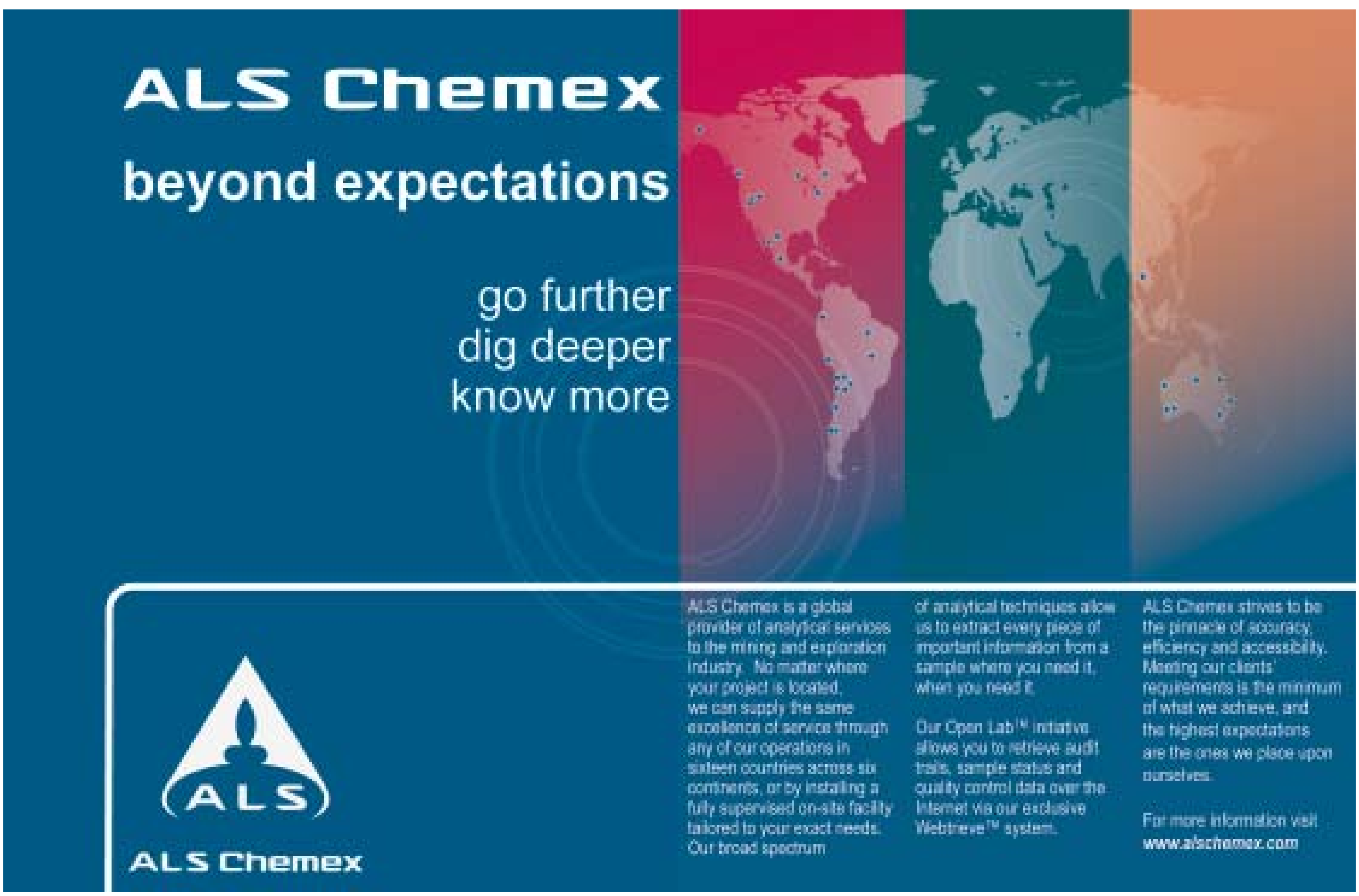
Much of the day to day work involves data cleaning, manipulation and incorporation into sensible formats that will be utilised by others e.g. GIS, graphs, tables, powerpoints. Some time is spent looking at new methods of projecting multivariate information into 2 or 3 dimensions or trying to work out how to apply methods to new or unusual situations. Software evaluation is another important task, as good software is absolutely critical to modern geochemical practise, primarily because we are expected to turnover large volumes of data in relatively short time intervals. Perhaps the most challenging part is helping geologists and managers understand that you can only get so far by looking at commodity elements alone e.g. Cu, Pb, Zn and Au, particularly in well explored areas. However, there is nothing better than being able to hand over a bunch of rigorously defined targets, that were identified using careful examination of the dataset and underlying controls on geochemical variability. People are commonly surprised by what they have missed, even in dirty old data, or how much of an area was really untested due to poor sampling and/or analytical methods. If companies collected more modern high quality data, they would be astounded at what they could see. That's a constant barrow we geochemists need to push to the industry.

However, geochemistry isn't all flowers, fluffy bunnies and warm and fuzzy light. Geochemists are almost always in a service capacity, which means they must convince, educate and cajole those around them into implementing exploration geochemistry in a sensible fashion. Geochemists are almost always striving to strike a balance between competing factors and personalities e.g. expenditure versus sufficient scientific rigour. This can be entertaining and also frustrating, but it is an unavoidable part of the job.

So far, I have no regrets about my occupation. It is rewarding to be able to help geologists out, to improve their prospects of finding another ore-body. I get exposed to new concepts almost daily, and it is a good challenge to work out how to implement practical solutions to a variety of problems. I would encourage anyone looking to pander to their geochemical bent to be sure to polish up on their maths (especially matrix algebra) and their mineralogy. I would also encourage geologists to utilise geochemistry more – especially as many are good mineralogists and should find the intellectual leaps not too difficult.

### Reminder

Just a reminder to all Members and Fellows that the GEEA is available electronically at www.ingentaconnect.com. Issue 4 of volume 5 for November 2005 is available and is a thematic issue on ***Geochemical Mapping***. By signing up on the website it is possible to download the individual papers and also access by RSS.

Paid Advertisement

## Focus on: Geochemistry as a Career ...

**Robert G. Eppinger, U.S. Geological Survey**

### A Serendipitous Journey into Applied Geochemistry with the U.S. Geological Survey

Whitewater river running initially piqued my interest in geology and for me the two are intimately related. I started university study in the early 1970s at the University of Colorado in engineering and quickly realized that I would never become an engineer. At the same time, I began a summertime job guiding whitewater float trips down the Green, Colorado, and Yampa Rivers in Utah and Colorado. Dinosaur National Monument has fascinating geologic exposures of sedimentary rocks and structure, and I wanted to learn about them—in part because my passengers were asking me about them. I picked up a book on the geology of the monument, but I could not understand the language of geology. So I switched my university study to geology, while guiding in summers on the above rivers as well as the Salmon and Middle Fork of the Salmon Rivers in Idaho, which cut through the Idaho batholith, Challis Volcanics, and Proterozoic Belt rocks. I also took time off from school to go to Mexico a couple of times. Again, there was a language problem, so I began taking Spanish as a minor, eventually attending the University of Veracruz in Mexico for a short while. In retrospect, this was a fortuitous and important decision!

After graduating with a B.A. in geology and after many thousands of river miles, I took a 3-month job collecting stream sediment samples in Arizona for the U.S. Geological Survey (USGS). Little did I know that this would lead to a career with the USGS. Despite working for Maggie Hinkle, an early AEG member who did some of the first research on soil gas collection and analysis, I was hired to collect and process stream sediment. During lunch breaks at the USGS Branch of Exploration Research facility, I would practice my Spanish with Rudy Gonzalez, a janitor of Mexican heritage. Fortuitously, this was overheard by Paul Theobald, a founding member and former President of AEG. All that I knew about Paul was that he was a highly regarded geologist of world-class stature and that he had various on-going projects in the U.S. and around the globe. Paul was looking for a young, impressionable "junior geologist" that he could train and mold to become a part of his staff, and I was given the edge because of my Spanish (Paul had a project in Sonora, Mexico)—not because of my infantile understanding of geology and geochemistry! This is how I began my career in geology and geochemistry with the USGS. Paul also encouraged me to join AEG, my first professional organization, in the early 1980s.

I worked with Paul for about four years, learning by doing, covering various aspects of geology, exploration geochemistry, geologic mapping, and the study of mineral deposit, in northern Mexico, southern Arizona, central Idaho, and the high Colorado Rockies. I was commonly in the field for seven months of the year, and absorbed information on geologic and geochemical theory and technique like a sponge. Mentoring by Paul in his forte of stream sediment heavy-mineral concentrate geochemistry and mineralogy was particularly useful to me. Paul also taught me the importance of integrating chemists and analysts in all phases of project work, including fieldwork. I did a lot of computer-based mapping and database work for Paul; these are ever-evolving tools that are essential for applied geochemists. Heavy mineral work with Paul helped me formulate a thesis topic for graduate work, using trace and rare-earth element geochemistry of fluorite as a sampling medium for exploration. This led to an M.S. degree, supervised by Graham Closs, a professor at the Colorado School of Mines and former President of AEG.

Moving from under Paul's wing, I worked through the 1980s and early 1990s as a USGS project geochemist doing exploration and landscape geochemistry for mineral resource assessment studies of Federal and Native American lands in Arizona, Colorado, Idaho, Utah, New Mexico, Oregon, and Alaska. On occasion, the best access for geochemical sampling and mapping was by whitewater raft! Geochemical techniques employed varied with the different geologic and physiographic settings of the areas, from alluvium-covered Basin-and-Range terrain in the southwest to high-energy physical weathering and glaciated alpine environments. I was able to draw upon the broad intellectual resources available in the USGS Branch of Geochemistry to design geochemical programs and bring in specialists appropriate for the various environments. Eventually, the U.S.-honed skills led to international work with colleague Maurice Chaffee, another former President of AEG, on a concealed porphyry W-Mo deposit in southern Poland. Long-standing friendships with geologists/geochemists in the Polish Geological Institute resulted from this multi-year project. Additional geologic fieldtrips to Spain, Portugal, Mexico, the former Yugoslavia, Greece, Scotland, South Africa, and Australia have broadened my understanding of geology, geochemistry, and national geologic institutions worldwide.

In the mid-1990s, following the desires of the public and U.S. Congress, the USGS began to take on a greater role in understanding the environmental aspects of mineral deposits, which evolved into ore deposit life-cycle studies. My work in environmental geochemistry began as

*continued on page 10*

SheaClarkSmith
MINERALS EXPLORATION & ENVIRONMENTAL GEOCHEMISTRY
*Advanced survey, analytical and interpretational methods for exploration through exotic overburden.*
PLANT • SOIL • GAS • ROCK • STANDARDS
SPECIALTY SAMPLE PREPARATION
P.O. Box 18325, Reno, Nevada 89511
Tel: 775-849-2235 • Fax: 775-849-2335
SheaClarkSmith@compuserve.com
Paid Advertisement

## A Seredipitous Journey...

continued from page 9

an outgrowth of a national-scale mineral resource assessment, in which I combined and assessed existing stream sediment geochemical data for some 25 1:250,000-scale quadrangles in northern Alaska. One surprising nugget of information that emerged from this study was a large, previously unrecognized, As anomaly in the Koyukuk National Wildlife Refuge in northwestern Alaska. My derivative paper on the topic brought the exceedingly high As concentrations in sediment to the attention of the refuge managers. However, I still have not had the opportunity of visiting the remote refuge in person to see and sample the As anomaly firsthand.

This study led to an environmental geochemical investigation of historic mining areas in Wrangell-St. Elias National Park and Preserve (WRST) in Alaska in the mid to late 1990s. National park lands in Alaska were expanded dramatically in 1980, resulting in some parks, such as WRST, having a rich legacy of abandoned mines. The study was very fruitful, owing in large part to Park Geologist Danny Rosenkrans' keen interest in the study and logistical support; and in recently-retired USGS chemist Paul Briggs' superb field and analytical expertise. We investigated and published on modern-day environmental effects on the geochemical landscape from mining activities at the stratabound Kennecott Cu, Nabesna Cu-Au skarn (Figure 1), Bremner polymetallic Au vein, and Gold Hill placer Au deposits within WRST. Expanding the study—literally and conceptually—we investigated the *unmined*, but well-exposed Orange Hill and Bond Creek Cu-Mo porphyry deposits, which are incised by low-pH, metalliferous streams. This work led to a similar study of an abandoned epithermal Sb vein deposit in Alaska's Denali National Park and Preserve.

On a different avenue, results from a 1996 mineral resource-related stream-sediment and hydrogeochemical study in central Idaho (which involved whitewater river running!) became pre-burn baseline data when some 70%

*Figure 1. Eppinger collecting water pH from stream below the Nabesna mill tailings pile during spring breakup in April, 1997. Water temperature 0° C, pH 2.8, conductivity 1600 µS/cm. Same site during the summer months had pH 7.2 and conductivity 580 µS/cm, demonstrating importance of snowmelt and seasonality to water composition.*

of the sampled area was consumed by wildfire in 2000. Funded in part by the U.S. Forest Service, the entire area was re-sampled nine months following the wildfires (another whitewater river trip!) to evaluate the effects of wildfire on the drainages. While geochemical differences were found to be minimal, there nevertheless were statistically valid differences for certain elements that likely relate to unwinnowed, post-wildfire, debris flow material entrained in the stream sediment.

My current work involves a fascinating environmental geochemical study of a series of *unmined* Zn-Pb volcanogenic massive sulfide deposits in the Bonnifield district of the Alaska Range (Figure 2), a landscape geochemistry study of the central Colorado mountains

*Figure 2. Red Mountain, an unmined Zn-Pb volcanogenic massive sulfide deposit in the Alaska Range that I am presently investigating. Very low pH (down to 2.4), high metal content, and exceedingly high rare-earth content are found in springs and streams draining the quartz-sericite-pyrite alteration zone. Photograph by Bob Eppinger from a helicopter coming in for a landing along the ridgeline, July, 2003.*

from the New Mexico to Wyoming borders, a study modeling the environmental geochemistry of porphyry and massive sulfide deposits, and a mineral resource assessment of Afghanistan (requiring that I dust off and re-discover my exploration geochemistry skills). Potential mineral resource assessment work on remote continents looms over the horizon for me as the USGS Mineral Resources Program pursues funding sources beyond the traditional Federal monies for in-country work.

Science in the U.S. Federal government for me has been and continues to be a very rewarding experience and has taken me to many diverse geologic environments. Foreign language and even whitewater river-running skills are occasionally utilized. Bureaucratic challenges must be dealt with along the way, but I suspect that similar challenges present themselves in large corporations as well. Declining funds for national geological survey organizations have been and will continue to be difficult obstacles to overcome, requiring retooling of scientists and innovative solutions. I particularly have enjoyed

continued on page 11

## A Seredipitous Journey...

continued from page 10

delving into the environmental geochemistry of unmined mineral deposits. Geochemists with a strong background in ore deposits bring a much clearer understanding of natural geochemical variability to the table when dealing with environmental scientists and engineers who usually do not have a good understanding of naturally high metal accumulations in the crust.

Teamwork, whether in government, industry, or academia is critical for success in modern geoscience projects, where data acquisition commonly ranges from satellite based instrumentation to microanalytical techniques on individual mineral grains. However, there is no substitute for on-the-ground fieldwork. Fieldwork in remote, wild places; working with other geoscience professionals on a team; intellectual stimulation; mentoring young, impressionable students; seeing new geology; ever-changing analytical techniques; travel by foot, helicopter, small fixed-wing bush plane, horse, and sometimes by whitewater raft(!); and exposure to diverse, local cultures are just a few reasons why I continue to enjoy immensely the work that I do in applied geochemistry after some 25 years. There are many problems to identify and solutions to discover for the young, aspiring, future applied geochemist!

On a final note, after four years of working for Paul Theobald, his lovely daughter Cathy asked me out. I never would have asked her, as she was the boss's daughter. Cathy and I have been married for twenty-one years, and we have two wonderful children, Paul and Rosemary. We all miss Grandpa Paul a lot. He was perceptive and keen even in his final days.

Thank you **EXPLORE** for allowing me the opportunity to outline and philosophize on this rather serendipitous journey through applied geochemistry from a Federal geologist's perspective. Requests for private whitewater river running permits are due next month, so I better get busy filling them out!

## Best Talks and Posters at the IGES 2005 in Perth

**Best Student Talk (a tie):**

**LOCATING ORE UNDERCOVER USING A BACTERIAL LEACH AND OTHER GEOCHEMICAL TECHNIQUES**

*Ryan R P Noble, CRC LEME / Curtin University of Technology*

**LITHOGEOCHEMISTRY OF THE COLLAHUASI PORPHYRY CU-MO AND EPITHERMAL CU-AG (-AU) CLUSTER, NORTHERN CHILE: PEARCE ELEMENT RATIO AND STABLE ISOTOPE VECTORS TO ORE**

*Esteban Urqueta[1], Kurt Kyser [1], Alan Clark[1], Cliff Stanley[2], Christopher Oates[3]*
*Department of Geological Sciences and Geological Engineering, Queen's University, Kingston, Ontario, Canada, K7L 3N6.[1]*
*Department of Geology, Acadia University, Wolfville, Nova Scotia, Canada, B4P 2R6.[2]*
*20 Carlton Terrace, London, England, SW1 Y5AN.[3]*

**Best Student Poster:**

**LITHOGEOCHEMICAL CONSTRAINTS ON THE HOST ROCK, HYDROTHERMAL ALTERATION AND WEATHERING OF THE GROUNDRUSH GOLD DEPOSIT**

*D.M.K. Murphy[1], C.R. Stanley[2], S.G. Hagemann[1]*
*[1]Centre for Exploration Targeting, School of Earth and Geographical Sciences, The University of Western Australia, Perth, Western Australia, murphd05@student.uwa.edu.au & shageman@cyllene.uwa.edu.au*
*[2]Dept. of Geology, Acadia University, Wolfville, Nova Scotia, cliff.stanley@acadiau.ca*

**Best Professional Talk:**

**CARBON ISOTOPIC EVIDENCE FOR MICROBIAL INFLUENCE IN EXOTIC-TYPE COPPER ORE DEPOSITS: IMPLICATIONS FOR EXPLORATION WHERE MICROBES ARE INVOLVED**

*Kurt Kyser[1], Alan Clark[1], Mark Nelson[1], Esteban Urqueta[1], Chris Oates[2]*
*Department of Geological Sciences and Geological Engineering, Queen's University, Kingston, Canada[1;] Anglo American plc, London, England[2]*

***Honourable Mentions:***

**DEEP PENETRATING GEOCHEMISTRY, FROM SOURCE TO SURFACE: EXPERIMENTAL AND FIELD RESULTS**

*Brian Townley[1], AlvaroPuig[2], Tomas Vargas[3],Jacobus Le Roux[1], Peter J. Rogers*
*[1] Department of Geology, University of Chile*
*[2] Codelco –Chile*
*[3] Department of Chemical Engineering, University of Chile*

**SOIL AND LAKE SEDIMENT GEOCHEMISTRY IN EXPLORATION FOR KIMBERLITE: NWT, CANADA**

*John Gravel, Acme Analytical Laboratories Ltd.; Ray Hrkac, GGL Diamond Corp. Ltd., Paul Richardson, Geochemical Consultant*

**Best Professional Poster:**

**USING GROUNDWATER TO VECTOR TOWARDS MINERALISATION UNDER COVER: THE CURNAMONA PROVINCE**

*Patrice de Caritat[1] and Dirk Kirste[2]*
*[1]Cooperative Research Centre for Landscape Environments and Mineral Exploration, c/o Geoscience Australia, GPO Box 378, Canberra, ACT 2601, Australia*
*[2]Cooperative Research Centre for Landscape Environments and Mineral Exploration, c/o Department of Earth and Marine Sciences, The Australian National University, Canberra, ACT 0200, Australia*

***Honourable Mentions:***

**SOIL AND BIOGEOCHMICAL SIGNATURES OF THE ARIPUANÃ BASE METAL DEPOSIT – MATO GROSSO, BRAZIL**

*Matthias Cornelius[1], Claudio G. Porto[2], Colin E. Dunn[3], Charles R.M. Butt[1], Christopher Oates[4] & Roque Coelho[5]*
*[1]CSIRO Exploration and Mining / CRC LEME Perth, [2]Departamento de Geologia - UFRJ - Rio de Janeiro, [3]Consulting Geochemist, Sidney BC, Canada, [4]Anglo American plc, London, [5]Anglo Brazil, Cuiaba, Brazil*
*Corresponding author: Matthias.Cornelius@csiro.au*

**MINERAL HOSTS FOR GOLD AND PATHFINDER ELEMENTS AT THE MOUNT GIBSON AND LANCEFIELD GOLD DEPOSITS, WESTERN AUSTRALIA**

*R. M. Hough[1], R. R. Anand[1], M. Norman[2] and C. Phang[1]*
*[1]CRCLEME, CSIRO Exploration and Mining, PO Box 1130, Bentley, WA 6102*
*[2]Research School of Earth Sciences, Australian National University, Canberra, ACT 0200*
*robert.hough@csiro.au*

# Obituary

## Paul Kellogg Theobald

Paul Theobald, one of the pioneers in the field of exploration geochemistry, died at his home in Golden, Colorado on July 16, 2005. He was a graduate of Stanford University and spent almost his entire career with the United States Geological Survey (USGS). He was an acknowledged expert in drainage geochemisty, particularly in arid terrains.

Paul began work with the USGS in 1951, “retired” in 1990, but continued to work as a scientist emeritus for the better part of another decade. His extensive contributions to the USGS were recognized through receipt of the Meritorious Service Award in 1985, and the Distinguished Service Award (the highest honorary award granted by the U.S Department of the Interior) in 1992. He contributed in both scientific and management positions throughout his career: as committee member, committee chairman, coordinator, USGS Branch Chief, and supervisory geologist on numerous technical and planning committees, both internally and externally as a USGS representative.

A brief review of programs that he participated in provides an appreciation of the breadth of his contributions to both the USGS and the international scientific community at large: heavy mineral studies in the southern Appalachians; mineral resource investigations in the Berthoud Pass quadrangle, Colorado project (which contributed to the discovery of the Henderson molybdenum deposit by Climax-Amax), mineral resource and geochemical studies of the Selway-Bitterroot Wilderness, Idaho, the Williams Fork / St. Louis Peak Roadless Area, Colorado, the Ajo quadrangle, Arizona, and the San Carlos Apache Indian Reservation, Arizona; assignment to the USGS Mission in Saudi Arabia; geochemical baseline studies in the National Petroleum Reserve, Alaska; geologic mapping and geochemical studies in the Northern Sonora Mexico Project (a joint USA-Mexico project); and geochemical investigations in the Xinjiang-Uygur Autonomous Region, northwestern China.

He was an active member of the Geochemical Society, the American Association for the Advancement of Science, the Society of Economic Geologists, the Colorado Scientific Society, the Geological Society of America, and the Association of Exploration Geochemists (AEG) / Association of Applied Geochemists (AAG).

Paul was the Chairman of the Organizing Committee for the 7th International Geochemical Exploration Symposium (IGES) in Golden in 1978 and, with John Watterson, edited the proceedings volume. He served the AEG as President in 1979 / 1980. He shared his expertise through organization of and contributions to numerous short courses and workshops sponsored by AEG and other scientific groups. He gave the Keynote address at the 13th IGES in Rio de Janeiro in 1989 and, in typical fashion, shared the authorship with his other colleagues.

Two scientific aspects stand out in my mind when I think of Paul, both related to drainage geochemistry. His 1956 paper entitled “The gold pan as a quantitative tool” forewarned of his contributions in the area of heavy mineral geochemistry. How many of us did he introduce to this art? Yes, exploration geochemistry is still both science and art! His early experience with precipitates of aluminum, iron, and manganese at Deer Creek, Summit County, Colorado, resulting in his paper with T.T. Chao in 1976 on “the significance of secondary iron and manganese oxides in geochemical exploration” demonstrated his leadership in labile drainage geochemistry. This paper bridged the gap between the colorimetric analysis days of the 1950s and the rediscovery of selective extraction analysis in the early 1990s.

Many have commented on Paul’s passion for geology. What was even more to his credit was the infectious manner in which he transferred that passion to others. When demonstrating a technique or discussing a concept, Paul often took the devil’s advocate position just to make sure we were really thinking things through for ourselves. Numerous young scientists, both domestic and international, have benefited from Paul’s supportive and challenging mentoring. I’m proud to say that I’m among that special group. Paul was and is a role model for us all. Other passions that Paul enjoyed include wood turning, making musical instruments (guitar, pipe organ, harpsichord, clavichord, and dulcimer) and fly fishing – particularly for the small, but difficult to catch, brookies found in the Colorado Rockies.

He leaves his wife of 53 years, Jean, daughters Mary Doherty (geochemist – Reno, Nevada) and Catharine Eppinger (Veterinarian – Nederland, Colorado), grandchildren Jonathon, Jessica, Zachary, and Stephanie Doherty, and Paul and Rosemary Eppinger; and sister Martha Peterson (Reno, Nevada).

Memorial contributions may be made to the Distinguished Geochemist Scholarship Fund, Association of Applied Geochemists, P.O. Box 26099, Nepean, Ontario, Canada. K2H 9R0.

December 7, 2005

**Graham Closs**
*Colorado School of Mines*
*Golden Colorado, U.S.A. 80401*
*lcloss@mines.edu*

# Automated Data Exchange Format (ADX)

Computer-based data transfer from a laboratory to a client is now the norm in mineral exploration. Data are immediately interpreted and plotted, taking into consideration what is known about the sample preparation and analytical methods employed. With time, however, databases grow, and individuals come and go. Often, the analytical values become detached from the methods used to generate those numbers and the situation becomes confusing at best or misleading at worst. I suspect most of us have, at some time, received a spreadsheet with column headers Au, Cu, Pb… exhibiting three or more different detection limits for the same elements. So what does that mean?

Individual companies have developed custom report formats which fulfill most of their needs, today. Often these are not sufficiently complete or flexible, particularly in the area of sample prep. As a result, commercial laboratories must supply data in literally hundreds of formats with a constant need to retool and adjust each time a lab, client or method is changed.

The idea of developing a standardized electronic format for reporting analytical data, together with all of the important meta data, has gained acceptance among several groups. With a universal format, software could be developed to import analytical data, including the critical meta data, without human intervention. At any given time, you could trace back an individual number to the sample and procedures employed. Most importantly, that software would remain stable for several years.

A project to define and advance such a format (named ADX) has been on-going over the past few years in fits and starts, and is currently stalled. A group of interested parties met in Vancouver in early November to evaluate the current status and make suggesting for restarting. Representatives from ALS-Chemex, Placer Dome, BHP-Billiton, Kennecott and Newmont were present. Opinions varied, however, in summary:

- The concept of a universal laboratory data exchange format, including the critical meta data, would be of benefit to the individual companies as well as the industry in general.
- The universal laboratory exchange format should be entirely open to the public, with no private ownership, fees or membership requirements.
- The ADX project should be restricted to the requirements of analytical data exchange between laboratories and clients. It should not be burdened with the requirements and restrictions of other functions.
- The logical host of the format is the Association of Applied Geochemists. It is envisaged that this would include:
    + Publication of the format on the AAG web site
    + A committee that would look after administration, updates, and funding, if necessary.
- Given the potential complexity and countless variations possible, particularly in sample preparation, the XML language is probably the only reasonable choice for a universal lab data format.
- After three years and more than $US80,000 we are generally disappointed that we are not closer to a final solution.
- The root cause of the disappointment is largely due to poor project management.
    + Contractors were given money, but inadequate direction, goals, and objectives. As a result, the project drifted from the original objectives.
    + Geochemists, geologists and database experts, did not become actively involved and provide sufficient feedback and review of contractor activities.
- The ADX initiative should be restarted, with more diligent project management.

The following activities have been proposed:

1. Potential users of ADX, including geochemists, geologists and laboratory analysts should define the requirements of ADX files, from a user's standpoint. This would include selection of parameter names, acceptable ranges and level of necessity. It is anticipated that this would require the concentrated effort of a cloistered group for 2-4 days.
2. Database professionals from both the lab and client organizations would need to vet and qualify the "wish list" of the above group. This would probably require another 1-2 days.
3. Recommendations from steps 1 and 2 would be circulated to a wider audience for comment.
4. A "request to bid" would be developed based on the experiences from the first three steps.
5. Provided funding could be secured, the contract would be let and ADX would be completed.

The next meeting, at which we intend to accomplish item 1 listed above, is tentatively schedule to occur around the time of the Roundup in Vancouver, BC. Interested parties are invited to contact owen.lavin@nemont.com

**Owen Lavin**

# Awards Presented at the IGES / IAGS in Perth

## Winner of the Association Gold Medal – 2005 - Gwendy Hall

*Oral citation given by Gerry Govett at the IGES in Perth on September 27th 2005.*

To do justice to Gwendy Hall's achievements would require at least a full session of this Symposium. As this is not possible, we have compiled this brief summary to give you just a taste, a flavour of her achievements.

All of us here have been influenced by our Gold Medal recipient and five Fellows of the Association - Rob Bowell, David Garnett, Barry Smee and me - under the leadership of Eion Cameron (who sadly is not with us tonight) - nominated Gwendy for the award.

We have all read her papers and have used her analytical methods. The journals that she has edited are found on our bookshelves and in our libraries. We have heard her speak at conferences, workshops and company meetings.

Gwendy has spent her career at the Geological Survey of Canada where she established a laboratory to develop analytical methods in exploration and environmental geochemistry. At first her laboratory served mainly the Applied Geochemistry group of the Survey. This work is reflected in the methods used for the National Geochemical Reconnaissance surveys, which have produced geochemical maps for resource and environmental purposes covering more than half of Canada.

Along the way, the GSC suffered substantial budget and staffing cutbacks. Does this sound familiar? But Gwendy went out and forged a series of alliances with mining companies, commercial laboratories, and instrument manufacturers to provide funding to *expand* the activities of the laboratory. This vigorous interaction with other organisations and scientists has been a hallmark of her career.

SUPPORT YOUR ORGANIZATION

ADVERTISE!

Her experience in ICP-Mass Spectrometry is unequalled, having helped test the prototype for the first commercial ICP-MS, manufactured by a Canadian company, Sciex. The ICP-MS formed the basis for a number of innovative developments, notably in selective leaches. A particular problem with these is that the elements, once dissolved, may reabsorb on to the matrix. In a series of papers she has defined this problem and proposed solutions. With commercial partners she has developed "designer" leaches that may be applied in exploration and environmental geochemistry where previous methods were found to be less effective.

The field of hydrogeochemistry has been enhanced by Gwendy's work. She has been particularly influential in developing sampling and preservation protocols that are now accepted internationally by environmental regulators. One of her most significant tasks resulted from an invitation from the Canadian Department of Foreign Affairs to develop geochemical methods to detect underground nuclear test explosions. There was a need to have robust methods to test for violations of the Comprehensive Test Ban Treaty.

The work, carried out in Nevada in collaboration with Barringer Research, was resoundingly successful with high contrast anomalies for volatile elements using selective leaches, whereas previous attempts using total digestions of the soil showed no anomalies.

Her output of publications is prodigious - 130 papers in refereed journals and books, 46 GSC publications and 64 papers in a variety of other publications, including Explore. She has been an editor of important special issues, most notably one on selective leaches in the Journal of Geochemical Exploration.

Gwendy has also given immense service to this Association. After serving as an Editor-in-Chief of the Journal of Geochemical Exploration, she undertook the difficult task of founding a new journal: "Geochemistry: Exploration, Environment, Analysis", now in its fifth year of publication.

Gwendy has also been President and long-time Treasurer of the AAG. Since the AAG office moved to Ottawa in 1995, she has supervised the working of the office.

These achievements were attained not solely by an astute scientific mind and hard work. Her friendly and generous character has permitted her to establish - and retain - strong working relationships with a remarkable range of scientists from many countries and different disciplines. The cooperative nature of her work may be gauged by the statistic that over the past 10 years no less than 120 persons have been co-authors of her papers.

Ladies and gentlemen, I could not introduce a more popular or deserving winner of the Association's gold medal, Gwendy Hall.

## Honorary Membership – Ian Nichol.

Presented at the IGES/IAGS in Perth, September, 2005

A reply from Ian:

I was completely surprised and absolutely delighted to hear in August that I had been awarded an Honorary Membership of the AAG, to be presented at the upcoming Symposium in Perth.. Prior to being advised of this award, I had been very much looking forward to attending the Symposium to meet former students and to get an update on recent exploration geochemistry activities but regrettably my doctor had advised me that such a trip would be unwise. I am most grateful to Bill Coker for expressing my deep appreciation of the award on my behalf at the Symposium.

In short, I am proud of the achievements of the Exploration Geochemistry program at Queen's but consider this to be significantly due to team work and communication which I will try to summarize. With regard to personal experience, following training at Durham, Queen's and Durham Universities for my B.Sc, M.A. and Ph.D respectively, I had the good fortune to serve my "apprenticeship" in geochemical exploration at Imperial College with John Webb and Co. from 1961-1969. During this period I was involved in assisting in the supervision of research programs in Sierra Leone, Zambia, Ireland and the U.K. As you will appreciate, these programs provided me with an exposure to exploration in a broad range of surface exploration environments.

In the late 1960s interest was expressed in Canada for more applied geological research being undertaken at Canadian Universities so Queen's appointed me in 1969 to initiate activities in exploration geochemistry, a contributing factor undoubtedly being field visits to the Sudbury and Bancroft areas and field experience in Quebec and Labrador in the summers of 1957 and 1958 while a graduate student at Queen's. In point of fact, a significant number of graduates of the Imperial College program had got jobs in Canada and the U.S. without any background experience in North America so the plan to initiate a program at Queen's University made sense, notwithstanding the fact of Imperial College graduates fulfilling extremely important roles in exploration geochemistry in North America.

Over the period 1969-1997 graduate students at Queen's undertook research on a broad range of exploration geochemistry projects, mostly in Canada but also in Chile, China, Thailand and the U.S., largely sponsored financially by the private sector and government agencies. I attribute the overall success of the program to active technical communication and feedback from the private sector representatives and from the Geological Survey of Canada and Ontario Geological Survey. In addition to individual research projects, attention was paid to field trips to see the complexity of glacial stratigraphy and appropriate geochemical exploration strategies led by G.S.C. staff and also undertaking orientation surveys to gain familiarity with questions to be addressed in designing appropriate exploration programs in the future. At the same time I sincerely acknowledge the critical analytical guidance by Bob Foster at Queen's and services by various analytical companies (Bondar Clegg, Activation Services, X-Ray Assay Labs and Overburden Drilling Management). The subsequent career achievements of graduates in the private sector, government surveys and universities indicate the overall significance of the Queen's program. Contributing factors to this included:

(a) taking various graduate courses in the broad field of economic geology with a bearing on exploration;

(b) advice from professors of geology and geography within the University on aspects relevant to their research;

(c) recognition that successful exploration geochemistry involves a multi-stage program: Appropriate Design and Planning, Sampling, Sample Preparation, Analyses, Data Presentation and Interpretation;

(d) graduate students bringing very worthwhile background experience to the program.

You may know that I was the first Secretary of the AEG (1970-72) which gave me exposure to a broader range of activities in geochemical exploration, President of the AEG in 1974 and Distinguished Lecturer in 1986. I also gained considerable exposure to world-wide exploration geochemistry activities with the United Nations.

The program in exploration geochemistry at Queen's now run by Kurt Kyser is largely based on isotope analyses and has made very significant contributions to exploration success for uranium, nickel, copper and zinc. Isotope analysis in use as a measure of elements dispersing towards the surface can indicate deposits buried under hundreds of metres of bedrock and overburden. At the recent symposium in Perth, Kurt Kyser won the award for the best professional presentation for a paper describing the influence of microbes in creating responses related to copper deposits. In addition, a Queen's graduate student, Esteban Urqueta, tied for the best student presentation describing the role of vectors as indicators of proximity to porphyry copper. Thus I am very glad to say that significant research in exploration geochemistry continues at Queen's.

Should readers be interested in communicating with Professor Kyser re work underway, future research or potential graduate studies, his E-mail address is kyser@geol.queensu.ca .

# Readers' Forum

## Commercially Motivated/Promotional Talks at the IGES/IAGS, Perth

Sept. 24, 2005
Dear Fellow AAG Members,

I write this letter after returning home from the very successful 22nd International Geochemical Exploration Symposium in Perth, Western Australia in September. The local organizing committee, headed by co-chairs Drs. Paul Morris and Nigel Radford, and assisted by the conference organizing group Promaco, put on an excellent symposium that was very well organized, scientifically informative, and socially enjoyable; in short, it was just about what we would want the biennial meeting of our association to be. However, although I came away from the end-of-symposium social hour with a strong feeling of satisfaction for the conference, I was disappointed with a small proportion of the talks and posters presented. This disappointment stems from the commercially-motivated, promotional orientation of these presentations. These talks and posters, although ostensibly scientific in their aims, unfortunately ended up as rather obvious advertising campaigns for proprietary analytical methods offered by some commercial laboratories. In one case, it wasn't just the contents of the presentation that was 'morphed' into a sales pitch; the actual title of the presentation was changed to include references to the discussed proprietary method.

As an ad hoc contributor to the local organizing committee, I know that the technical program co-chairs made a very significant effort to accept for presentation only new and significant scientific contributions to applied geochemistry. Inclusion of presentations had to be based strictly, and appropriately, on the content of the abstracts submitted. Unfortunately, several abstracts did not meet the required standards because of their overly commercial orientation, and these were not accepted for presentation. However, having attended the talks and having read the abstracts associated with them, it is clear to me that some geochemists submitted abstracts with themes that sounded scientific enough to warrant inclusion in the technical program, but then exploited their time in front of the symposium audience to 'pitch their products' via commercially-oriented presentations. Furthermore, because so many authors submitted abstracts to the IGES for oral presentation, and many of these had to be relegated to poster sessions because of the limited number of time slots for talks, the unintentional inclusion of commercially-oriented talks deprived the oral presentation of a number of worthy scientific research efforts by other geochemists.

I have two significant objections to the presentation of commercially-oriented talks and posters at a professional meeting like the IGES. The first is that the commercially-oriented presentations generally provided inadequate background on the nature of the geochemical results. The proprietary analytical techniques employed were not described, and the results were presented in the form of un-disclosed numerical parameters derived from the measured concentrations, which themselves were not presented. Both of these deficiencies prevented the audience from using their geochemical background to interpret the results. How can a geochemist interpret the data that support an idea when they don't know how the samples were digested or numerically processed? What mineral species were attacked? What were the actual concentrations obtained and how different are these from the detection limit? Without these critical pieces of information regarding the geochemical and mineralogical foundation of the results, any presentation looses it credibility. Essentially, the audience is forced to take the word of the presenter without any way of technically evaluating the validity of the results.

This brings me to my second objection to these commercially-oriented presentations. All of these presentations were given by geochemists with a financial stake in the methods employed. This creates a major problem. How can the audience accept the word of the presenter when such a conflict of interest exists? How can the author be perceived as an objective scientific observer? Are the results compromised by this lack of impartiality? Clearly, when science and marketing overlap, as in these cases, the technical foundation of any presentation is significantly undermined.

I do not believe that commercially-oriented presentations have a place in the technical program of an IGES. Furthermore, I believe that the AAG membership expects IGES presentations to air only dispassionate and objective scientific results that advance our understanding of geochemistry and its application in the exploration and environmental milieus. The presentation of marketing-oriented talks and posters disrespects the symposium audience and represents a self-centred desire to advance the personal financial interests of the authors in a venue that is not designed for that purpose.

To rectify this problem, I call on those geochemists that made such commercially-oriented presentations to voluntarily refrain from continuing this behaviour at future IGES meetings, and at other meetings sponsored by the AAG, so that only truly scientific presentations are included in the technical program. I hope this will be sufficient, as I don't think it would be appropriate to require authors to sign letters acknowledging their independence from financial benefits associated with the procedures employed in their presentations in order to curtail this activity. Other professional associations (mostly in the medical realm) do require such declarations.

This said, the problem of commercially-orientated presentations will not go away unless an alternative solution is identified. As a result, I would suggest that it may be appropriate to include in an IGES, sessions outside of the formal technical program that address commercial geochemical services of whatever ilk. In these

continued on page 17

## Readers' Forum

continued from Page 16

sessions, proprietary analytical procedures, data analysis services, geochemical software, and other commercial geochemical ventures could be described, marketed and discussed. There is a precedent for this, as an extra-curricular evening session involving a proprietary geochemical analysis method was informally held at the 1995 Townsville IGES. I believe that including such commercially-oriented sessions in an IGES will benefit the association's membership, as the marketing and science activities of the conference can be well and truly separated, and commercial presentations would not then be confused with the formal scientific talks and posters. Given that at our Annual General Meeting during the IGES, the AAG membership informally asked council to look into the possibility of holding our IGES meetings every third year, perhaps other format changes to the IGES, such as a commercial session, could also be considered at the same time.

Our association can serve society best by advancing the scientific principles of applied geochemistry, not the specific financial interests of some of the entrepreneurial geochemists in our midsts. Our association's health will largely depend on how well we can address the exploration and environmental problems of today and the future, and this will require that we not derail technical advances by mixing science and marketing, but rather that we be both honest and objective in the presentation of applied geochemistry research.

I encourage others with similar or alternative views on this subject to similarly share their thoughts in a future issue of **EXPLORE**.

Sincerely,

**Cliff Stanley**
*Associate Professor*
*Applied Geochemistry & Economic Geology*
*Department of Geology, Acadia University*
*Wolfville, Nova Scotia, Canada*
*cliff.stanley@acadiau.ca*

• • • • • • • • • • • • • • • • • • • • • • • •

### A New Low?

Dear Fellow AAG Members,

As a sometime reader of the tabloid press I was astonished to receive my recent copy of Explore 128 complete with an obvious advertiser's article sharing the front page with our president's message. I submit that the Association needs to make some clear definition between the need to inform our Members of the latest analytical developments and that of the clear promotion of commercial laboratory products - which are inevitably always portrayed in glowing terms.

In most newspapers this is clearly labeled as an advertisement at the top of the article. In this case our members are clearly receiving far more than an intended update. I would suggest that in cases such as these that the laboratory concerned also publish cases where their technology did not work so well, all too often the real world scenario.

Sincerely

**Peter J. Rogers**
*proger3@attglobal.net*

• • • • • • • • • • • • • • • • • • • • • • • •

### Increasing Membership: The Santiago Example, An Open Letter to Council and Executive.

Dear Fellow AAG members,

I have just left a recent meeting with Brian Townley where he told me of the finalization of the previous plans for the student chapter here in Chile. This is great news and is a permanent testament and legacy to the hard work of the members of the Chile 2001 Santiago IGES LOC. This group had the foresight to set up a student travel bursary program as a permanent tribute to the excellent company financial support for that conference. Apart from basking in some of the reflected praise as joint General Chair of the Santiago IGES it also behooves me to write this letter to indicate that this type of occurrence is perhaps a way for consideration about how to nurture and develop our membership base.

Over the years the Association has seen many attempts to increase membership. Traditionally the IGES always saw a significant boost incrementally which carried over to the next one 2 years later and so on.

Unfortunately with the typical economic cycle of boom and bust in the major recruiting area, the mining industry, this has seen a gradual decline as the industry has reduced staffing levels in exploration. Notable attempts to reverse this trend have been taken, the latest enthusiastically led by Bob Jackson and his committee. Most of these attempts have focused on the use of personal networks to pass on the message as even the IGES recruiting mechanism has foundered due to small or even loss making ventures.

The question is why has the Santiago IGES and follow-on seen a reverse to this trend and how can this be applied to other parts of the world to produce similar results of increased membership and interest?

Firstly the presence of a group of committed volunteers certainly helps along with an active Regional Councilor such as Brian. In Chile one of the key elements has been the preservation of the student travel bursary put in place by myself on behalf of the Santiago IGES LOC. This has served both as a way of both thanking industry contributions that enabled a profit to be made but also to keep the Association profile alive in Santiago and Chile in general. This seems to have worked well as we have seen a winning student go to Dublin and Perth IGES. The Association also kept its agreement with the Santiago IGES LOC by providing a free registration and workshop participation to the IGES.

Another factor here is the widespread interest of

continued on page 18

## Readers' Forum

continued from Page 17

students in environmental issues – the possibility to participate in a wine project I am putting together jointly with the Universidad de Chile also generated a lot of interest. Present plans call for solidifying the local chapter by soliciting financial operating support from the Santiago Exploration and Mining Association (SEMA). This sister organization was key to the fund raising for the Santiago IGES. SEMA have offered to coordinate annual contributions from companies based in Chile to both maintain the chapter and also facilitate professional monthly presentations and lastly but very importantly the on going social activities such as the famous Friday Night Beer in the Geopub.

More news will no doubt be forthcoming from Brain in his Explore updates and from any visitors who are down this way.

Saludos from the Cono Sur

**Peter Rogers**
*November 2005*

## CALENDAR OF EVENTS

These events also appear on the web page at www.appliedgeochemists.org
International, national, and regional meetings of interest to colleagues working in exploration, environmental and other areas of applied geochemistry.

■January 4-6, 2006 **Mineral Deposit Studies Group 29th Annual Winter Meeting,** The Natural History Museum, London. See website www.mdsqconference.org.uk. Email john.chapman@imperial.ac.uk

■January 23-26, 2006 **BCYCM Mineral Exploration Roundup 2006,** Vancouver, BC, Canada "Striving for Excellence in Exploration". Website: www.bc-mining-house.com/roundupoverview.html

■March 5-8th, 2006 **Prospectors and Developers Assocaition 2006Conference** Toronto, Canada. Website www.pdac.ca/pdac/conv/index.html

■March 13-16, 2006. **Alaska Miners Association 20th Fairbanks Biennial Conference** Arctic International Mining Symposium, Westmark Fairbanks Conference Centre – Fairbanks, Alaska.

■March 27-29, 2006 SME Annual Meeting, St.Louis, Missouri. Website: www.smenet.org/AnnualMeeting2006/index.cfm

■April 3-7, 2006 **Backbone of the Americas – Patagonia to Alaska**, Co-sponsored by the Geological Society of America and the Association Geologica Argentina. Mendoza, Argentina. Website www.geosociety.org/meetings/06boa/index.htm

■April 10-12, 2006 **Scientific Conference – Topical Problems of Ore Formation and Metallogeny**. Russian Academy of Sciences, Institute of Geology,. Novosibirsk, Russia. Website: www.uiqqm.nsc.nu/conf/conf100

■April 5-16, 2006. **Modular Course in Exploration for Magmatic Ore Deposits**, Sudbury, Ontario, Canada.. Email: mlesher@laurentian.ca, Website: http://earthsciences.laurentian.ca.

■May 14-16, 2006 **Wealth Creation in the Minerals Industry**, **SEG 2006 Conference** in Keystone, Colorado. Website www.seg2006.or

■May 14-17, 2006 **GAC-MAC Annual Meeting "206 is the International Year of the Planet"**, Montreal, QC, Canada. Website www.er.uquam.ca/nobel/gacmac/welcome.html

■May 14-17, 2006 **CIM's VANCOUVER 2006 –** "Creating Value with Values". Website www.cim.org/vancouver2006

■May 14-18, 2006 International conference on Continental Volcanism, Guangzhou. Website www.iavcei2006.org

■**2006 Precious Metals Symposium**. Hosted by the Society for Mining, Metallurgy and Exploration. See website for details: www.iseg.2006.com/welcome.tm

■July 2-7, 2006 **18th AGC:Australian Earth Science Convention 2006** Melbourne Exhibition and Convention Centre, Melbourne, Australia. Website www.earth2006.org.edu.org

■13-15 September 2006 First International Seminar on Mine Closure, Perth, Western Australia. Website www.acq.uwa.edu.au

■27 August – 1 September 2006 **16th Annual VM Goldschmidt Conference 2006** Melbourne Exhibition and Convention Centre, Melbourne, Australia. Website www.goldschmidt2006.org

■24-29 September **2006 IGCP 486 Au-Ag-telluride-selenide deposits.** Field Workshop, Izmir, Turkey. Email ismet.ozgenc@deu.edu.tr

■Sept 25-30 **7th International Symposium on Environmental Geochemistry (2006)** Beijing, China

■June 2007 23rd **International Applied Geochemistry Symposium, Oveido, Spain**

Please let this column know of your events by sending details to:

**Chris Benn**
*BHP Billiton*
*Suite 800 – Four Bentall Centre*
*1055 Dunsmuir Street*
*Vancouver V7X 1L2 BC Canada*
*TEL: 604 632 1493*
*FAX: 604-683 4125*
*e-mail: Chris.Benn@bhpbilliton.com*

*New Technology*

## Chinese Technology Applied to the Search for Buried Mineral Depositis in South Australia

Electro-geochemical "CHIM" techniques, developed by Chinese researchers, are undergoing trials in South Australia to assist in the search for buried and "blind" mineral deposits. Surveys were recently conducted at Dominion Mining Ltd's Challenger Gold Mine southwest of Coober Pedy in the state's far north, at Havilah Ltd's copper-gold-molybdenum prospect at Kalkaroo, northwest of Cockburn on the SA-NSW border, and at Gould's Dam uranium prospect on tenements held by Southern Cross Resources Inc. These surveys are the first use of the Chinese variation of the CHIM technique under arid conditions, in the Australian outback.

The CHIM (CHastichnoe Izvlechennye Metallov) technique of electro-chemical prospecting was developed by Russian scientists in the early 1970s. Ongoing research and modification by Professor Luo Xianrong of Guilin University of Technology have resulted in several variations on the technique aimed, in part, at simplification to improve mobility for deployment in difficult terrains. Luo has successes acknowledged in China using modified CHIM techniques to locate deep extensions to known ore and outlining new ore systems buried beneath regolith. These include the Jinwozi gold deposits at Hami in the Xinjiang Autonomous Region with extensions located at 160 m depth in bedrock with 10 m of residual and transported regolith cover, and Yangcheng lead-zinc deposit in Hubei province at 200 m in karstic Triassic limestone (Luo et al., 2004).

For the Australian demonstration, a simplified and highly mobile system was used. An electric current, supplied by a 12 v battery, drives mobile ions from the surrounding soil and sub-surface to specially coated carbon electrodes buried in the soil. Electrode couples were placed at 20 m intervals along surveyed lines. After a given time, generally 24 - 48 hours, the electrodes were exhumed and the coating removed and dispatched for analysis. The method relies on the leakage of ions from an ore body to the surface where the applied current collects ions from a much larger volume than would be feasible with more traditional soil sampling methods. The demonstration sites include areas currently being investigated by a variety of geochemical techniques to determine if a geochemical response is detectable at the surface and if so, the likely mechanism for transport of the metal ions from the ore to the near surface.

The demonstration surveys and continuing collaborative research in South Australia is supported by Primary Industries and Resources, South Australia (PIRSA) and is integrated with current activities of the Co-operative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME) in which PIRSA is a core participant. The project has recently received backing from the Australian Government under the Australia-China Special Fund for Scientific & Technological Cooperation. Expenditure of $44,500 over 3 years has been approved from the fund to Dr Baohong Hou, project leader at PIRSA, for travel to China. The Chinese government has agreed to provide a similar amount to meet the travel expenses of Chinese researchers on the project.

**Reference**

Luo, X., Taofa, Z. and Hou, B., 2004: The geoelectrochemical extraction method (CHIM) in exploration for concealed ore deposits. In: I.C. Roach (Editor). *Regolith 2004*. CRC LEME: 230-233.

**John Keeling**
*Assistant Director CRC LEME*
*C/- PIRSA, 101 Grenfell Street, Adelaide SA 5000*
*Email: keeling.john@saugov.sa.gov.au*

*Professors Luo Xianrong (left) and Zeng Nanshi from the Guilin Institute of Technology exhuming buried electrodes at the Gould's Dam uranium prospect*

Coming soon in the
AAG **EXPLORE** newsletter:

Technical articles and letters to the editor are encouraged as submissions for discussion within the newsletter. Each issue of **EXPLORE** contains a series of short discussion papers which provide either an update on a particular geochemical topic, or present current debates about issues of interest. Suggestions for future "Focus" topics may be forwarded to the editor,

Chris Benn (Email: Chris.Benn@BHPBilliton.com)

130 Technical Article—RAB Drilling and Geochemistry—An Australian Perspective

| | |
|---|---|
| **Contributor Deadline** | February, 2006 |
| **Publication Date:** | March/April 2006 |

# New Members and Fellows

The following applications were reviewed by the Admissions Committee and approved by Council.

**FELLOWS**

Mr. Martin J. Davidson
3636 Haynie Avenue
Dallas, TX
USA 75205
Membership #3837

Dr. Patrice de Caritat
Senior Research Scientist
CRC LEME, Geoscience Australia
GPO Box 378
Canberra, ACT
AUSTRALIA, 2601
Membership #3640

Mr. Cary L. Foulk
Senior Geologist/Geochemist
MWH Global
1475 Pine Grove Road, #109
PO Box 774018
Steamboat Springs CO, USA 80477
Membership #2111

Steve Windle
4 Lexia Place
Carseldine
Qld, Australia, QLD 4034
Membership # 3799

Professor David Lentz
University of New Brunswick
Box 4400
Fredericton
NB, Canada EB3 5A3
Membership # 3226

**STUDENT MEMBERSHIPS:**

Mr. Aristeo Nunez Othon
Graduate Student
Posgrado en Ciencias de la Tierra
Universidad Nacional A
Calle Escobedo Num. 157.
Entre Michoacan Y Tabasco
Hermosillo, Sonora
MEXICO, CP 83190
Membership # 3834

Ms Carmina Jorquera Zuniga
Universidad de Chile
Los Diamantes 0554, Villa
Los Herdes, Maipu
Santiago, CHILE
Membership #3874

Ms. Tansy O'Connor-Parsons
MSc. Candidate
Acadia University
10504-127 Street
Edmonton, AB CANADA T5N 1V9
Membership #3880

Ms. Rebecca Schaefe
Student
Acadia University
153 Spring Street
Summerside, PEI CANADA C1N 3G2
Membership #3882

Ms. Karen Hulme
Student
Adelaide University
13 Liverpool Cres.
Salisbury East, SA AUSTRALIA 5109
Membership # 3883

Ms. Anna Petts
Student
University of Adelaide
Dept. of Geology & Geophysics
OP 313 Mawson Labs
Adelaide, SA AUSTRALIA 5005
Membership 3889

Mr. Nathan Reid
Student
University of Adelaide
2/17 Clark Street
Wayville, SA
AUSTRALIA 5034
Membership #3894

Mr. Esteban Urqueta
Student
Queen's University
Dept. Geological Sciences
36 Union Street
Kingston, Ontario
CANADA K7L 3N6
Membership #3895

**NON VOTING MEMBERSHIP:**

Mr. Erik Van Noort
Geochemist, Gleneagle Gold Ltd.
5/33 Churchill Avenue
Subiaco, WA AUSTRALIA 6008
Membership #3831

Mr. Ingar F. Walder
Program Director Kjeoy Research @
Education Center
Kjeoy, Vestbygd, NORWAY N-8581
Membership #3832

Mr. Gordon Southam
Associate Professor & Canada
Research Chair
University of Western Ontario Dept.
of Earth Sciences London, Ontario
Canada N6A 5B7
Membership #3833

Mr. Morton W. Coleman
1780 San Pasqual St.
Pasadena, California USA, 91106
Membership # 3835

Ms. Kylie A. Foster
Research Associate
University of British Columbia
Dept. of Earth & Ocean Sciences
Mineral Deposit Reseach Unit
6339 Stores Rd.
Vancouver, BC CANADA V6T 1Z4
Membership # 3836

Mr. Basil E. Walker
Eagle Exploration Co., Inc.
PO Box 1300
Amarillo, TX USA 79105
AAG Membership #3838

Mr. John L. Clanton
1220 Frost Bank Plaza
802 No. Carancahua St.
Corpus Christi, TX USA 78470
AAG Membership #3839

Mr. Tony M. Preslar
Chairman & CEO
Geosurveys, Inc.
218 S. Leggett Dr.
Abilene, TX USA 79605-1628
Membership # 3840

Mr. Harold R. Beaver
Geologist
Saint Joseph Petroleum, Inc.
7378 Cockrill Bend Blvd.
Nashville, TN USA 37209
Membership # 3841

## New Members... continued from page 20

Katie Silk
Publisher Account Assistant
Swets Information Services
160 E. Ninth Ave.
Runnemede, NJ 08078
Membership #3842 - Ref # 31242319

Prof. Kurt Kyser
Queen's University Canada
Dept. of Geol. Science
Kingston, Ontario K4L 3N6
Membership #3843

Mr. Jose Lattus Sanhueza
Geologist
Los Peumos Oriente 6020
Condominio Altod de la Arboleda
Penalolen Santiago, CHILE
Membership #3870

Mrs. Anna Price
Project Geologist
Placer Dome Australia
223B Hancock Street
Doubleview, WA AUSTRALIA 6018
Membership #3871

Ms. Joanna Pearson
Technical Director
Maxwell GeoServices
PO Box 372
South Fremantle, WA
AUSTRALIA 6162
Membership #3872

Mr. Peter Crowhurst
Senior Projects Geologist
Teck Cominco
PO Box 1677
West Perth, WA AUSTRALIA 6872
Membership #3873

Ms. Karen Kelley
U.S. Geological Survey
Geologist
MS 973 PO Box 25046
Denver, CO USA 80225
Membership #3875

Mr. William R. MacFarlane
Research Associate
Queen's University
96 Toronto Street
Kingston, ON CANADA K7L 4A6
Membership #3876

Dr. Douglas A. Jones
VP, Exploration
Golden Star Resources
38 Berkeley Crescent
Floreat, WA AUSTRALIA
Membership #3877

Mr. Adrian Fabris
Pirsa
101 Grenfell St.
Adelaide, AUSTRALIA
Membership #3878

Mr. Justin Gum
Pirsa, Geologist
4 Old Beach Rd.
Brighton, SA AUSTRALIA
Membership #3879

Prof. Huseyin Yilmaz
Faculty of Engineering
Dokuz Eylul University
Dept. of Geol. Engineering
Bornova/35100 Izmir, TURKEY
Membership #3881

Mr. Tom Marshall
Consulting Geologist
68 Lawler St.
Subiaco, WA AUSTRALIA 6008
Membership #3884

Mr. Alexander Christ
ICP-MS Manager, Ultratrace
20 Harwood Rise
Leeming, Perth WA
AUSTRALIA 6149
Membership #3885

Ms. Vanessa Bocks
Senior Geochemist
Anglo American Research Lab
PO Box 106
Crown Mines, Johannesburg
SOUTH AFRICA 2025
Membership #3886

Ms. Megan Lech
Environmental Geoscientist
c/ Geoscience Australia
GPO Box 378
Canberra, ACT AUSTRALIA 2601
Membership #3887

Mr. Andrew Somers
Sales Manager
JBS Technologies/Niton Mining Tech.
Suite 2, 595 Gardeners Rd.
Mascot, NSW AUSTRALIA 2020
Membership #3888

Ms. Heikki Niskavaara
Laboratory Manager
Geological Survey of Finland
GeoLaboratory
PO Box 77
Rovaniemi, FINLAND
96101
Membership #3890

Mr. Greg Cozens
Senior Exploration Geologist
Peak Gold Mines
23 Kurrajong Circle
Cobar, NSW AUSTRALIA 2835
Membership #3891

Mr. Mark Mitchell
Divisional Geologist
De Beers Australia Expl. Ltd.
9A Fifth Avenue
Mt. Lawley, WA
AUSTRALIA 6050
Membership #3892

Pertti Sarala
Senior System Analyst
Geological Survey of Finland
PO Box 77
96101-Rovaniemi, FINLAND
Membership #3893

Ms Maite Le Gleuher
Australian National University
Dept. of Earth & Marine Sciences
Canberra, ACT AUSTRALIA 0200
Membership #3896

Dr D.C. "Bear" McPhail
Australian National University
Dept. Earth & Marine Sciences
Canberra, ACT AUSTRALIA 2913
Membership #3897

Mr. Ivor Roberts
Manager-Mineral Resources
Geological Survey of Western Aust.
100 Plain Street
East Perth, WA AUSTRALIA 6004
Membership #3898

Dr Steve L. Rogers
Chief Executive Officer
Coop. Research Centre
Landscape Environ & Min. Expl.
CRC Leme, PO Box 1130
Bentley, WA AUSTRALIA 6102
Membership #3899

Mr. Paul Dunbar
Senior Geologist
Redport Ltd.
46 Duncraig Rd.
Applecross, WA AUSTRALIA 6153
Membership #3900
Membership # 3830

# Student Paper Prize

The Association of Applied Geochemists and SGS take pleasure in announcing the winner of the 2004 Student Paper Competition Award. This is for the best paper in a refereed scientific journal by a student, on work performed as a student, published within five years of graduation which addresses an aspect of exploration geochemistry. The student must be the principal author and nominations may be made by anyone familiar with the student's work. Details of this award are on the AAG website under Students.

Entries closed at the end of 2004 for the Association's fifteenth biennial Student Paper Competition. We received three entries from three entrants from Australia and Canada. They were all of a high standard and the choice was close. The winner is Nigel W. Brand, now a Principal Geochemist with ioGeochemistry, ioGlobal, in Perth, Australia. His winning paper is based on research for his Ph.D in Australia.

Nigel completed his undergraduate training at the Derbyshire College of Higher Education in 1986. He went on to the University of Leeds for his MSc in Geochemistry, which he completed 1988, with a thesis on volatile species in fluid inclusions, focusing on their relevance to gold transport and deposition and their possible uses in gold exploration. He was awarded a NERC scholarship.

From 1993-1994 he worked for Western Mining Corporation in the NE Goldfields of Western Australia, evaluating Ni and Au targets with multi-element regolith geochemistry. From 1993-1997 he took study leave from WMC. He complete his Ph.D. at the University of Western Australia on '*Chemical and mineralogical characteristics of weathered komatiitic rocks, Yilgarn Craton, Western Australia: discrimination of nickel sulphide bearing and barren komatiites*' under the supervision of C.R.M. Butt, N. McNaughton and D.J. Gray. He returned to WMC as a Senior Geochemist to provide geochemical support for the WMC Ni and project generation teams, applying his skills in regolith geochemistry, sample preparation, quality control and base-line environmental studies. From early 1998 to late 1999 he moved to WMC's Leinster Nickel Operations. Here, he provided geochemical support to their exploration, in particular evaluating geochemical methods to 'see through' cover and to develop 3D regolith exploration models, being involved in discovering the Harmony Ni sulphide deposit and the Progress shoot.

He then moved to Anglo American Exploration (Australia) as a geochemist for their Zn, Ni and Cu-Au operations in Australia, India and the Philippines. In 2004 he co-founded ioGeochemistry.

He received a $500 cash prize from SGS, a two-year membership of the Association of Exploration Geochemists, together with our journal, *Geochemistry, Exploration, Environment Analysis* and our newsletter, *Explore*, a certificate of recognition and $500 towards expenses to attend the 22nd IGES in Perth, where the award was presented.

His award-winning paper is entitled '*Weathering, element distribution and geochemical dispersion at Mt Keith, Western Australia: implication for nickel sulphide exploration*' which was published in 2001 in our very own *Geochemistry, Exploration, Environment Analysis* Vol. 1 and was co-authored with C.R.M. Butt. The abstract of the paper follows:-

"*The komatiite-dunite-hosted Ni sulphide deposit at MKD5 (Mt Keith) has a complex regolith consisting of a residual profile (>75 m depth), partly collapsed towards the top, overlain by 40 m of exotic sediments. The weathered komatiites are composed predominantly of degraded serpentine, neo-formed hydrated Mg-silicates, carbonates, silica and Fe oxides. Magnesium concentrations decrease upwards through the lower regolith, whereas those of Fe and Si increase, reflecting degradation of Mg-bearing minerals. A sharp decline of Mg within the profile marks the Mg discontinuity, separating Mg saprolite from the overlying Fe saprolite. The Fe saprolite, dominated by Fe oxides and silica, has pseudo-sedimentary structures indicating partial collapse*

continued on page 23


A rock solid reputation for absolute accuracy

Since 1982, Becquerel Laboratories has been meeting the analytical requirements of clients in the geological and mineral exploration sector.

Our company is a world leader in Neutron Activation Analysis (NAA). An ultra-sensitive technique, NAA is an ideal quality control procedure to complement and verify results from other analytical techniques. It provides cost-effective, timely analysis and one simple method can analyze over 30 separate elements.

For absolute accuracy, trust the analytical expertise of Becquerel Laboratories.

**For more information call** 905-826-3080
**or visit www.becquerellabs.com**

*ISO 17025
For Scope of Accreditation No. 422
Pour la portée d'accréditation no. 422

*Accredited to ISO 17025 by the Standards Council of Canada as a testing laboratory for specific tests.

Becquerel LABORATORIES
6790 Kitimat Road, Unit 4
Mississauga, Ontario
Canada L5N 5L9

absolute accuracy

Paid Advertisement

## Student Paper Prize continued from page 22

*of the profile. At the unconformity with the sediments, eluviation, mixing and churning have produced zones with chemical and mineralogical characteristics of the underlying, overlying and adjacent lithologies.*

*Nickel, Co, Mn, Cr and PGE are dominantly hosted by secondary Fe oxides in the regolith, but above the Mg-discontinuity, Ni and Co are locally enriched by co-precipitation with Mn oxides. The oxidation potential, controlled by ferrolysis, ranges from -0.4 to +0.2 volts, and the pH, buffered by bicarbonate ion, irrespective of the presence of sulphides, decreases from 9.5 to 6.0 up through the profile. Copper is not significantly mobile under such conditions and precipitates as inert native metal, commonly spatially associated with Fe oxides. Separation of Ni and Cu occurs in the upper saprolite and pedolith, because metallic Cu (±Pd) is retained and residually concentrated in collapsed Fe saprolite, whereas Ni, adsorbed to goethite, is redissolved and reprecipitated below the Mg-discontinuity.*

*High Ni concentrations in the regolith cannot alone be used to distinguish between Ni sulphide mineralized (NiS) and barren komatiite protoliths. The strong correlation between chalcophile elements evident in mineralized protolith is lost with the oxidation of sulphides, and Ni derived from sulphides is indistinguishable from that derived from silicates. Ultramafic-derived regolith materials having Ni/Cu ratios of 7-19 and >19 may indicate the presence of massive and disseminated sulphides, respectively. The ratio at MKD5 is 60. These relationships may be distorted by preferential leaching, or by the influx of either element from wall-rocks. High concentrations of PGE, especially Pt, Pd and Ru, may also indicate mineralized protolith. However, the very low secondary mobility of PGE and Cu greatly restricts target size. Larger targets are given by Ni/Cr and Cu/Zn ratios which, either singly or multiplied together, can be used to identify mineralized komatiitic sequences and provide vectors towards ore. Their value is diminished if the ore and host sequence are decoupled during emplacement."*

The Association of Exploration Geochemists would like to thank SGS for, once again, supporting this worthy cause, which encourages student geochemists to publish their research in a timely manner.

**I.D.M. Robertson**
*Chairman, Student Paper Competition Committee*

## 22nd IGES and 1st IAGS Perth, Western Australia, September 2005

The last time an International Geochemical Exploration Symposium was held in Australia was in Townsville, in 1995. At that time, apart from the normal range of paper and poster presentations, there was a vigorous debate on the future of the Association and in particular on the role and relevance of environmental geochemistry in an Association such as ours. Ten years later we were back in Australia, on the other side of the continent in Perth, Western Australia, and the consequences of that debate in Townsville were there to see for the first time. We are now the Association of Applied Geochemists and this was not only the 22nd International Geochemical Exploration Symposium (IGES) but also the 1st International Applied Geochemistry Symposium (IAGS) – a practical manifestation of Paul Taufen's claim in Townsville that one man's dispersion train is another man's pollution train and there is essentially no difference between the two. Given that the artificial divide between exploration and environmental geochemistry has now been removed I wonder how long we should continue with this dual IGES/IAGS numbering system for future symposia – a system which seems to entrench the divide between exploration and environmental geochemistry, rather than eliminate it. Would it not be better to adopt a single name that reflects the common ground of all applied geochemists? From a purely historical, if not sentimental, perspective there would seem to be some logic in keeping the 'IGES' sequence going, but with a different word for the 'E'. Any suggestions? In the interests of simplicity, if nothing else, I will stick with 'IGES' for the rest of this review.

Some facts and figures. There were approximately 200 attendees in Perth of which two thirds came equally from the private sector and from various research groups. A further quarter came from service providers and independent consultants with the balance coming largely from government agencies such as state and national geological surveys. This is surely one of the great strengths of these symposia in that they bring together such diverse groups, all united by a common interest in applied geochemistry.

Geographically, two thirds of those attending came from Australia with over two thirds of these coming from the host state of Western Australia. There was a strong Canadian contingent (15% of the total) which was particularly impressive given the long haul required to get to Perth, but in keeping with the tradition established in past meetings the IGES attracted participants from all corners of the globe: from China to Chile, Thailand to Turkey, Fiji to Finland, and many more, reflecting the symposium theme of 'Tropics to Tundra'.

Gwendy Hall ended the abstract for her Keynote Presentation with the suggestion that "by looking back at what we have achieved, perhaps the issues to be addressed on the way forward will become crystal-clear!" I sense that that exclamation mark at the end made the statement as much a challenge as a hope, but it is an interesting exercise to look back to the Townsville IGES and to review what has been achieved since that meeting, as reflected in the papers presented in Perth. Have we moved on?

Regional geochemical surveys were going strong ten years ago and they continue to be at least as popular today: in desert regions in China, in the Yilgarn and Riverina regions in Australia, in Sudan, in British Columbia, and in South Africa, where the Council for Geoscience must surely be able to claim the record for the

continued on page 24

## 22nd IGES and 1st IAGS Perth

continued from page 23

longest running regional survey. From memory it started in 1973 and they are still going strong, and producing some excellent results. Clearly such surveys remain useful, and the challenges continue to be to design them in order to satisfy the needs of the end users, whoever those end users may be. He who pays the piper calls the tune, with the result that choice of sample densities, sample types and analytical procedures will always pose a challenge and will almost inevitably result in compromises. A regional biogeochemical survey across southern Australia could lay fair claim to marking an advance on Townsville on the regional geochemistry front. This reflected part of a general upsurge of interest in biological factors that may influence element mobility and perhaps allow us to see through the regolith. Encouraging results were reported from analysis of mulga leaf litter in Western Australia, and from analysis of eucalypts growing over both gold and lead-zinc deposits. It was also good to hear reports of laboratory experiments quantifying uptake of gold and arsenic by eucalypts. Understanding the underlying processes that control this uptake and subsequent dispersion must lead to greater confidence in interpreting our results.

The traditional biogeochemical approach, with its focus on sampling of higher plants, has been with us for decades but the role of bacteria in generating diagnostic signatures from ores and in identifying them at the surface is only just beginning to come into focus. Results presented in Perth must surely mark one of the greatest advances over the last ten years, all the more so because the best professional talk and one of the equal best student papers both focussed on microbes. It is early days yet but this has to be a fertile field for future research and it was particularly exciting to hear reports of experimental work on this front, and to hear of success in recognising the signature of methanogenic bacteria associated with exotic type ores. Bacterial leaches could also add to our exploration armoury, as could examination of soil organic gas signatures, many of which must have some bacterial input.

Lead isotopes featured in both Townsville and Perth, though aimed at solving very different problems, but with the increase in analytical fire-power over the last ten years the Perth IGES saw an expansion of interest in the use of isotopes (C, H, S, and even N) to understand either original ore depositional processes or subsequent weathering and dispersion processes. There is clearly a move away from simply measuring element concentrations in one of two directions: either focussing more on their isotopes or on the compounds that they form with other elements.

To quote another Keynote Speaker (Rob Bowell), who in turn was quoting someone else, "when attempting to interpret most forms of geochemical data, three rules should always be applied: mineralogy, mineralogy, mineralogy (Day, 1997)." Mineralogy helps to define not only the source of reactants but also the mechanism of that reaction. Support for this approach came from studies on mineral hosts for gold; on geochemical variation of specific minerals (rutile, chromite and tourmaline); and on use of zinc phosphate minerals to constrain the age of non-sulfide mineralisation. It was further reflected in reports on the attempts to map regolith minerals either by PIMA, on borehole samples, or by flying over it and mapping it with airborne hyperspectral techniques. On the environmental side mineralogy can be invaluable in disentangling anthropogenic signals from natural ones.

Partial extraction techniques also attempt to remove specific phases, although some of the continuous leach work reported in Perth certainly suggests that we need to be careful in interpreting the results, since extraction of a particular phase by a particular solvent is often not instantaneous. Many factors can influence that final number and I have to admit to experiencing a touch of concern when reading the claim that a minimum hypergeometric probability method could be used to identify the partial digest that yielded the most non-random results over a known mineral showing. It prompts the question: how many random results are acceptable?

Ten years ago, in Townsville, we were talking about Enzyme Leach and MMI, and they are still with us today, along with many others. There is even a Pink Leach now. But do we understand any more about the processes that generate these subtle anomalies? I'm sure we have advanced, but perhaps not as much as we would have hoped, and there is still a long way to go. There are still many false anomalies and barren holes. Geogas, seismic pumping, nanoparticles and electrochemical models may all help to explain what might be happening, and perhaps there are other mechanisms as well that could be biologically driven, but until we better understand the underlying processes we will continue to make mistakes. To understand the processes we must understand the chemistry that underpins these leaches, and this would seem to be a real challenge where proprietary leaches are used.

Lithogeochemistry is alive and well, with new insights coming from use of such techniques as Pearce Element Ratios. Applications in Australia, New Zealand, Chile and Canada all demonstrated the benefits of this approach. Data processing in general continues to evolve and to become more sophisticated, although it was good to hear of one example where a particular technique did not work.

On the environmental side the very valid point was made that 'acid rock drainage' is often a better term to use than 'acid mine drainage', since acid drainage conditions can often occur naturally without a mine in sight. Inland acid sulphate soils not only pose a potential agricultural problem but may also be useful as a prospecting tool. All the more reason to try to understand them. Geochemical baseline studies are becoming increasingly important for agriculture, forestry, mine management and human and animal health, while specific problems such as As and Hg justifiably continue to attract attention. There was a wide cross-section of environmental papers in Perth, but perhaps surprisingly, no more than Townsville, ten years ago, where thirteen papers were presented in their own environmental geochemistry section.

continued on page 25

## 22nd IGES and 1st IAGS Perth

continued from page 24

We continue to collect a bewildering array of sample types: – just about any part of a laterite is fair game; we still have supporters of good old <80 mesh and heavy minerals; kimberlitic minerals, moss, peat, tree leaves (alive, off the tree, or dead, as leaf litter), gold nuggets (cut open in a brave attempt to understand their origin), kangaroo scats, termite mounds, geogas, ultrafine clays (0.2 – 2 ˜m), acid sulphate soils and groundwaters. You name it, we sample it.

Information is useless unless it is accessible and understandable, and geochemistry is no exception to that, so it was particularly heartening to hear of a number of projects involving collation and synthesis of data: for example, an atlas of geochemical exploration models for mineral deposits in the Canadian cordillera, and the little short of heroic development of a national geochemical database by the USGS from a range of databases produced over time by different administrations, philosophies, laboratories, analytical methods and personnel. Although not yet complete it currently stores almost 2 million sample records and 39 million analytical determinations. CRC LEME also released two impressive and substantial compilations – Regolith Landscape Evolution across Australia and Regolith Expression of Australian Ore Systems and the editors deserve congratulations for their patience, stamina and cajoling powers in successfully completing them in time for the IGES.

Was anything missing from the Perth IGES? I would have liked to have seen more model building / model testing. We still spend too much time taking many samples, making a lot of measurements on them and hoping that if we generate enough numbers 'something' will drop out. In addition it would have been good to hear more on regolith dating techniques and on reference materials, but those are personal wishes and I'm sure that others would have had other priorities.
Overall the meeting was a great success, with an extremely high standard of presentation. The students in particular did exceptionally well. The Organising Committee managed to look serene at all times and deserve congratulations for a job well done.

**David Garnett**

## Regional geochemical surveys: News from Australia

*Patrice de Caritat[1], Megan Lech[2], Subhash Jaireth[2]*
*[1]Cooperative Research Centre for Landscape Environments and Mineral Exploration, c/o Geoscience Australia, GPO Box 378, Canberra, ACT 2601, Australia*
*[2]Geoscience Australia, GPO Box 378, Canberra, ACT 2601, Australia*

**Introduction**

National baseline geochemical surveys have been conducted in most developed countries, but not yet in Australia. In a country as large and diverse as Australia, an initial step in the development of a national low-density geochemical atlas needs to be the pilot testing of geochemical survey metho-dologies in representative regions displaying contrasting topographic, drainage and climatic conditions.

To date, we have conducted—or are conducting—pilot geochemical surveys in four regions of south-eastern Australia: the Riverina, Curnamona, Gawler and Thomson regions (Figure 1). The main focus of the surveys is to sample fine-grained transported regolith (sediments). In all but the Curnamona cases, the sampling strategy adopted consisted of collecting sediment samples at two depths from floodplains near the outlet of (mostly large) large catchments. In the Curnamona, only surface fine-grained soil was collected mostly from depositional plains (Caritat & Reimann 2003). Other sampling media are also being tried in these surveys, including groundwater, plant tissues, and lag. Various sampling densities are being tested (Table 1), and modelling is planned to test what minimum sampling density would be required for a national coverage. The most recent survey, which is still in a preliminary stage, is in the Thomson region, for which only reconnaissance sampling has taken place so far. The most advanced pilot project is the one from the Riverina region, the subject of the remainder of this article.

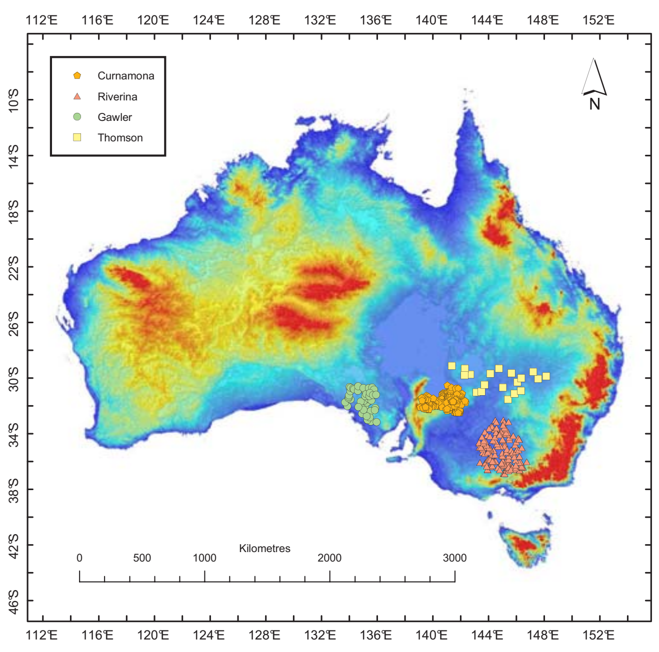



*Figure 1. Location of sampling points for existing pilot regional geochemical surveys in Australia, over digital elevation model.*

**Why geochemical mapping?**

Australia's regolith—the blanket of soils, sediments and weathered rocks covering fresh bedrock—is the natural resource upon which our multimillion dollar agricultural industry is based. It also hosts much of our

continued on page 26

## Regional geochemical surveys:

continued from page 25

**Table 1.** Overview of sizes and sampling densities of pilot geochemical surveys.

| Pilot survey | Distance east-west (km) | Distance north-south (km) | Approximate area (km²) | Number of sampling sites | Average sampling density (1 sample per X km²) |
|---|---|---|---|---|---|
| Riverina | 288 | 427 | 122,976 | 142 | 866 |
| Curnamona | 305 | 203 | 61,915 | 199 | 311 |
| Gawler | 212 | 253 | 53,636 | 48 | 1117 |
| Thomson | 664 | 316 | 209,824 | 19 (preliminary)<br>~200 (target) | 11,043 (preliminary)<br>1049 (target) |

precious groundwater resources and contains or covers ore bodies vital for our economic development. Baseline geochemical surveys provide invaluable information about the natural concentrations of chemical elements in this substrate on which we live, grow crops and raise livestock, and from which we extract water, raw materials and mineral wealth.

Overseas data collated from multi-media and multi-element geochemical surveys carried out over large areas indicates that *natural* concentrations of chemical elements in water, sediment, soil and plants vary spatially *by up to several orders of magnitude* due to geological, climatic, biological and other factors (Reimann & Caritat 1998). It is important to know the *natural* concentrations and distributions of elements in the near-surface environment so that:

- baselines can be established against which future changes (natural or man-made) can be quantified,
- new mineral potential can be recognised and areas for mineral exploration can be selected,
- appropriate and responsible land-use policies and decisions can be formulated,
- localised contamination can be identified and better remediated,
- local salinity stress can be detected and better understood, and
- potential geohealth risks can be identified.

### Low-density geochemical mapping

The concept of low-density sampling for geochemical mapping has been around for a long time (Nichol *et al.* 1966, Garrett & Nichol 1967, Reedman & Gould 1970) and has recently experienced renewed interest in Europe (Reimann *et al.* 1998, 2003), the United States (Gustavsson *et al.* 2001) and China (Li & Wu 1999), for instance. Darnley *et al.* (1995) have suggested a framework for global geochemical mapping, and the sampling media selected include overbank sediments. Sampling densities used for geochemical surveys elsewhere range from high (~1 sample/1 km²) (e.g., Austria: Thalmann *et al.* 1989) to 'ultra low' (~1 sample/1000 to 10,000 km²) (e.g., Europe: Plant *et al.* 2003, Reimann *et al.* 2003).

Based on experience elsewhere (e.g., Reimann *et al.* 1998), a multi-media sampling strategy cost-effectively yields information about sources, sinks and pathways of chemical elements in the near-surface environment. The main sampling medium used for the Riverina survey was overbank (or floodplain) sediments near outlets from large drainage basins or catchments. As this material is mixed and accumulated during widespread erosion related to flooding episodes, it is judged to best represent the average lithological input of whole catchments (Ottesen *et al.* 1989). Deposited outside main drainage channels onto floodplains, this fine-grained sediment has an enhanced propensity to host adsorbed and absorbed chemical species.

We believe this sampling medium is well-suited to Australia's low-relief, regolith-dominated landscapes in tropical to arid climates. It had not previously been used here for low-density geochemical mapping and needed to be tested under local conditions. Other sampling media trialled in the Riverina pilot project were plant leaves and groundwater, which will be discussed in future reports.

### The Riverina region

For the purposes of the pilot project, the Riverina was defined as the 123,000 km² area encompassing catchments that are wholly or partly contained within the Riverina Bioregion (Figure 2; see Lambert *et al.* 1995 for bioregion concept).

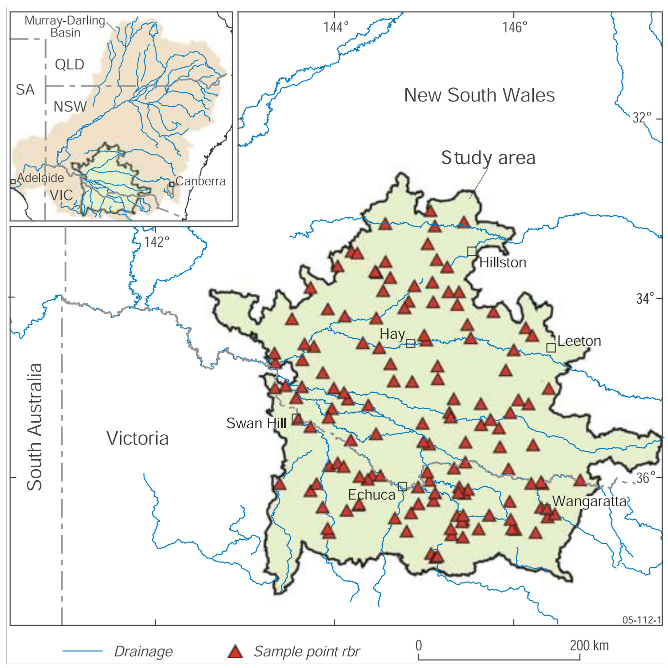



*Figure 2. Location of the Riverina study area and sampling sites.*

The Riverina is part of the Murray-Darling basin, a significant agricultural, social and mineral district in Australia, which:

- covers 1.06 million km², or 14% of the country's total area,
- contains 45% of the Australian crop area and 43% of the total number of farms,
- is Australia's most important agricultural region,

continued on page 27

## Regional geochemical surveys:

continued from page 26

accounting for 41% of the nation's gross value of agricultural production,

- is an important provider of resources such as wheat (34% of national production), cotton (96%), dairy products, rice and grapes, and
- is home to nearly two million people, or 11% of the total Australian population.

**The Riverina pilot project**

Undertaken collaboratively by the Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME) and Geoscience Australia, the first pilot project to be completed is in the Riverina region, a prime agricultural district in~~of~~ southern New South Wales and northern Victoria (Figure 2). The Riverina survey has delivered cost-effective, internally consistent and quality-controlled data on the inorganic chemical composition of surface and subsurface sediments of large catchments in the region.

The resulting geochemical maps show concentrations of 62 elements. This multi-element geochemical data layer will be made available to decision makers, catchment management authorities, farmers, mineral explorers and other stakeholders to guide activities and decisions in a multitude of land-use and resource management applications.

The Riverina survey was designed to prove the value of geochemical mapping and to fine-tune sampling and analytical protocols for a well-drained region with low to modest relief and temperate to semi-arid climate~~.~~

**Sampling and analysis**

The Riverina was the focus of a recent airborne geophysical data acquisition initiative led by the New South Wales Department of Primary Industries, which resulted in new digital elevation model (DEM), airborne gamma-ray and total magnetic intensity data coverages (Hallett *et al*. 2005).

Theoretical sample sites were located by conducting a hydrological analysis of the DEM to determine the lowest point in (mostly large) river catchments (see Caritat *et al.* 2004). The catchments were derived from a combination of DEM and drainage analysis. The sample sites were carefully adjusted in the context of drainage and road/track coverages and field considerations such as land accessibility, landscape position and possible anthropogenic interferences. A total of 142 sample sites were selected near outlets or spill points of large catchments, yielding an average sampling density of one sample per 866 $km^2$.

Two sediment samples were taken at each site:

- a top overbank sediment (TOS) sample from 0-10 cm below the root zone, and
- a bottom overbank sediment (BOS) sample from a ~10 to 15 cm interval between ~65 cm and 95 cm below the root zone.

All samples were subjected to a detailed site description in the field, where measurements of pH, texture and moist and dry Munsell® colours were also taken. In the laboratory, pH 1:5 (solid:water), EC 1:5, moisture content and laser particle size distribution were determined. Sediment splits were dried and sieved to <180 mm then analysed by X-ray fluorescence (XRF), inductively coupled plasma mass spectrometry (ICP-MS), instrumental neutron activation analysis (INAA) and Ion Specific Electrode (ISE) (see Caritat *et al.* 2004).

The concentrations of 62 elements were determined, providing data for maps showing the spatial and statistical distributions in the TOS and BOS samples and of the TOS/BOS ratios (Caritat *et al*. in prep.).

**Results and potential applications**

Sampling at upper and lower levels at each site allows for a more detailed understanding of the potential sources of chemical elements in the environment. TOS samples are susceptible to the influence of human activity (e.g., fertiliser use), while BOS samples from well below tilling depth reflect more closely natural background levels. Median concentrations of most elements were higher in BOS samples, reflecting progressive mineral breakdown during weathering and ensuing mobilisation of soluble products. However, median concentrations of Ag, Pb, Sb, S, Y and most rare earth elements were similar at both depths, while median concentrations of Br, Hf, Mn, P, Si, Zr and organic matter were higher in TOS samples. These variations reflect relative upconcentration of more resistive minerals (quartz, zircon), precipitation of secondary weathering products (Mn oxyhydroxides), greater concentration of organic matter and perhaps fertilisers, and possibly evaporation of irrigation water near the surface.

As a means of independently evaluating the geochemical patterns obtained through this survey, we compared the geochemical map of Th in TOS samples with airborne gamma-ray spectrometry patterns for the same element (Figure 3). The patterns from these two independent datasets coincide well, clearly indicating that

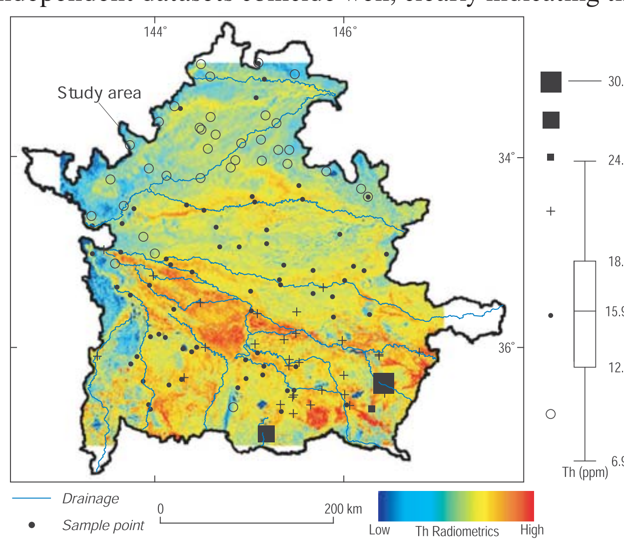



*Figure 3. Geochemical map of total Th (ppm) in top overbank sediment Riverina overbank sediment samples (analysed by INAA), compared to airborne gamma-ray distribution of Th (background image, courtesy of the Department of Primary Industries of New South Wales and Victoria).*

continued on page 28

## Regional geochemical surveys:

continued from page 27

the geochemical patterns that we obtained from the sediments are real. Results for K and U are similarly corroborated by the airborne gamma-ray spectrometry patterns.

*Acidity and salinity*

The survey found obvious patterns of Ca and Cl distribution in overbank sediments which have implications for soil pH and salinity management in agriculture. Ca in BOS samples increased from south to north, reflecting the increasing occurrence of carbonate material observed (Figure 4). Interestingly, the TOS Ca map shows an east-west ridge of values going through the middle of the study area, with lower values to both the south and the north.

*Indicators of gold mineralisation*

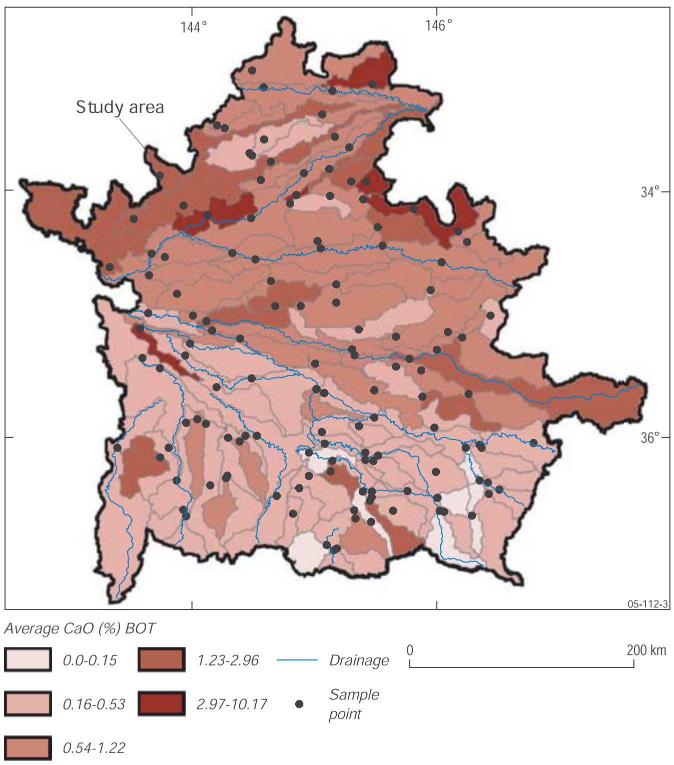



*Figure 4. Geochemical map of total CaO (ppm) in bottom overbank sediment Riverina overbank sediment samples (analysed by XRF).*

As and Sb are well-known pathfinder elements for gold mineralisation. The Victorian goldfields are located immediately to the south of the study area, and the As and Sb distribution maps clearly show a progressive decrease from the southern edge of the area towards the north (Figure 5). We interpret this as a representation of mechanical dispersion trains from the source regions to the south and perhaps also concealed sources below shallow basin sediments.

Sb levels range up to nearly 11 mg/kg, over 20 times the median world soil concentration (Reimann & Caritat 1998). This confirms the anomalous nature of the sediments in the southern part of the study area and highlights the potential for the minerals exploration industry to use such surveys for regional orientation purposes.

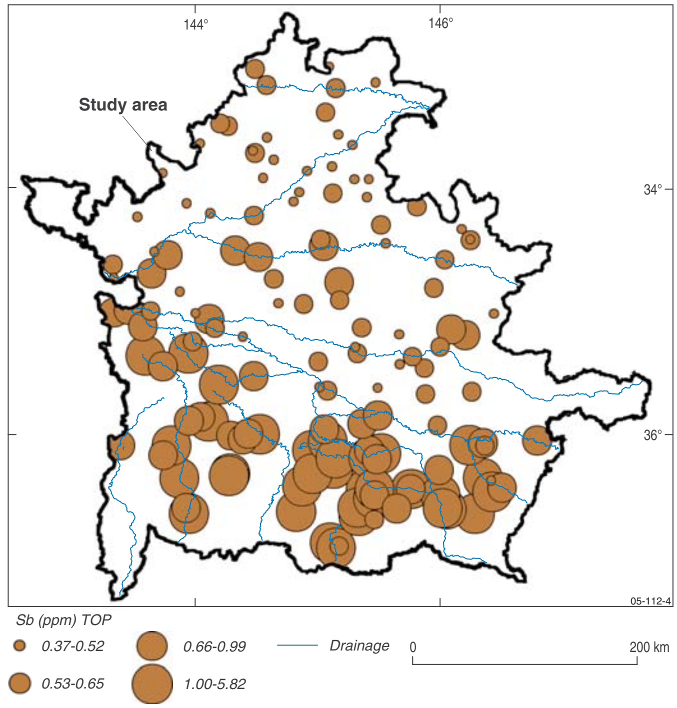



*Figure 5. Geochemical map of total Sb (ppm) in top overbank sediment Riverina overbank sediment samples (analysed by INAA).*

*Trace element enrichments and deficiencies*

Several trace elements were found to be above or below national and international guidelines for maximum allowable concentrations for agricultural soils, soil remediation and biosolids application. Total concentrations of As (0.8-159.8 mg/kg), Ba (189-1263 mg/kg), Br (<1-89.5 mg/kg), Cd (<0.1-2.33 mg/kg), Cr (29-200 mg/kg), F (150-610 mg/kg), Ga (6.3-26.1 mg/kg), Sb (0.37-10.8 mg/kg), U (1.26-8.49 mg/kg) and V (31-145 mg/kg) were locally elevated above these guidelines. Co (2.96-34.2 mg/kg) and Mo (0.5-1.9 mg/kg) were found to be potentially deficient in parts of the region.

Concentrations of Cr increase smoothly towards the southwest with sites in the central southern region amongst the most elevated (Figure 6). Over half of the overbank samples collected contain more than 50 mg/kg Cr, which is the Western Australian ‘ecological investigation limit’ (WA DOE 2003). Ten samples (max = 200 mg/kg) have elevated values above 100 mg/kg, which is the maximum allowable soil contaminant concentration for application of biosolids to agricultural land (NSW EPA 1997). Two of these samples were from the southern central portion of the study area and were elevated in both TOS and BOS samples. These catchments drain a ridge of Cambrian mafic volcanics. Another possible source of elevated Cr is the Quaternary tholeiitic basalts located near the edge of the Riverina region. Whereas high Cr levels may have human health implications (Reimann & Caritat 1998, Adriano 2001), even the maximum total value in the Riverina is unlikely to yield excessive available Cr based on the results of a study in

continued on page 29

## Regional geochemical surveys:

continued from page 28

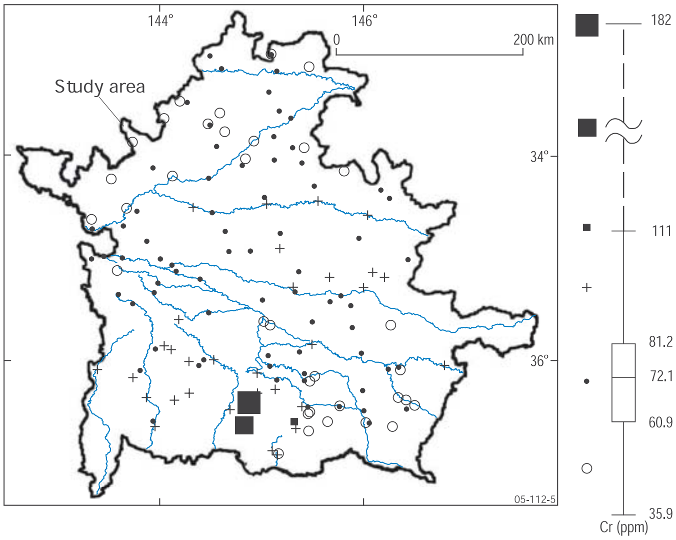



*Figure 6. Geochemical map of total Cr (ppm) in bottom overbank sediment Riverina overbank sediment samples (analysed by INAA).*

Italy, which found that <0.1% of total Cr was bioavailable (Maisto *et al.* 2004). $Cr^{3+}$ is also likely to be the dominant oxidation state and is relatively non toxic and is normally tightly bound in soil (McLaughlin *et al*. 2000).

Mo is an essential nutrient to many crops. The global average concentration of Mo in soil ranges from 0.2-5 mg/kg (Adriano 2001); the median value in the study area was 0.8 mg/kg. Levels at or below 0.5 mg/kg can be considered low, and those with concentrations of 0.1-0.3 mg/kg can be expected to produce Mo deficiencies (Adriano 2001). Six samples from the Riverina survey contained Mo concentrations of 0.5 mg/kg amongst 37 samples with concentrations of 0.6 mg/kg or below. Low Mo concentrations occur mostly in the north and are more common in the TOS samples (Figure 7). Mo has lower bioavailability in acid soils, so those in the southeast are more likely to be prone to deficiencies. This corresponds to observations by farmers that soils in the south of the study area were Mo deficient and that fertiliser applications reversed this problem (C. Simpson, pers. comm., December 2004).

Geohealth implications of the Riverina geochemical survey will be discussed in further detail in an upcoming publication (Lech & Caritat, in prep).

### Conclusions

Australia is one of few developed nations without nationwide baseline geochemical information at the disposal of government, industry, landholders and the general public.

The results of the Riverina survey illustrate how low-density geochemical surveys convey information about regional patterns in soil quality, mineral prospectivity and potential environmental and geohealth risk. Ongoing interpretation of this data will provide information on chemical element residence and mobility in the environment.

Pilot projects such as the Riverina geochemical survey

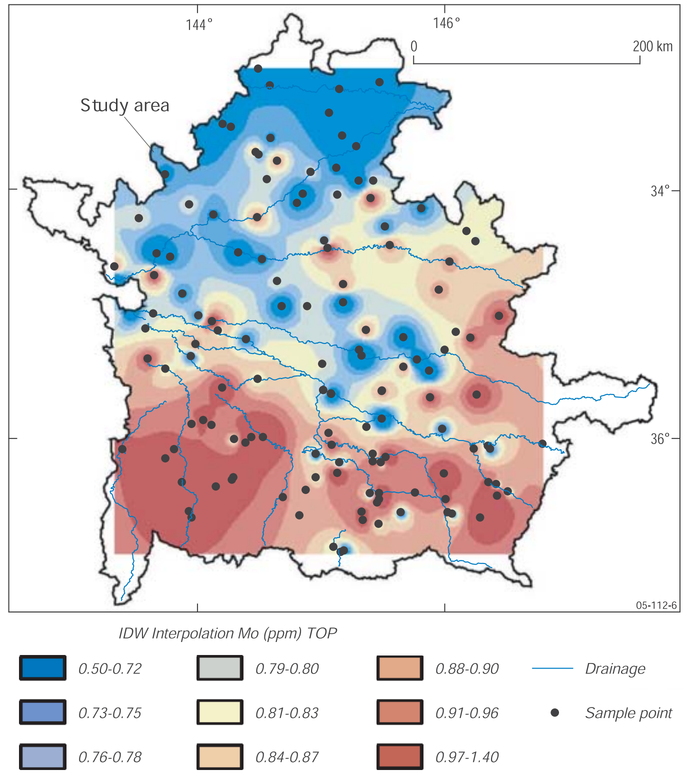



*Figure 7. Geochemical map of total Mo (ppm) in top overbank sediment Riverina overbank sediment samples (analysed by ICP-MS).*

are contributing to establishing and fine-tuning sampling and analytical protocols that can ultimately be applied at the national scale.

### Acknowledgments

This collaborative study was funded by an Australian Government Cooperative Research Centre grant to CRC LEME and by Geoscience Australia. We thank Ben Ackerman, Matt Lenahan, John Pyke, Peter Taylor and Saif Ullah for their assistance in the field and all property owners for permission to collect the samples. Alex Hickey, Marty Young and Yamin Zhou helped with sample preparation, while Bill Papas, John Pyke, Liz Webber and Aleksandra Plazinska provided assistance in the laboratory.

### References

Adriano DC. 2001. Trace Elements in Terrestrial Environments—Biogeochemistry, Bioavailability, and Risks of Metals. Second edition, Springer-Verlag, New York, 867 pp.

Caritat P de, Jaireth S, Lech M & Pyke J. 2004. Regional geochemical surveys: Riverina pilot project—methodology and preliminary results. Cooperative Research Centre for Landscape Environments and Mineral Exploration, Open File Report, 160, 156 pp. + CD-ROM. Available from: http://www.crcleme.org.au/

Caritat P de *et al*. In preparation. Geochemical atlas of the Riverina region.

Caritat P de, Reimann C. 2003. Baseline geochemistry of surficial regolith, Broken Hill region, Australia. In: Roach IC (Ed), Advances in Regolith (Canberra, ACT, 19-21 November 2003). CRC LEME: 53-54.

Darnley AG, Björklund A, Bølviken B, Gustavsson N, Koval PV,

continued on page 30

## Regional geochemical surveys:

continued from page 29

Plant JA, Steenfelt A, Tauchid M, Xuejing X, Garrett RG & Hall GEM. 1995. A Global Geochemical Database for Environmental and Resource Management. Recommendations for International Geochemical Mapping, Final Report of IGCP Project 259. UNESCO Publishing, 122 pp.

Garrett RG & Nichol I. 1967. Regional geochemical reconnaissance in eastern Sierra Leone. Transactions of the Institution of Mining and Metallurgy, B76:97-112.

Gustavsson N, Bølviken B, Smith DB & Severson RC. 2001. Geochemical landscapes of the conterminous United States—new map presentations for 22 elements. U.S. Geological Survey Professional Paper 1648, 38 pp.

Hallett M, Vassallo J, Glen R & Webster S. 2005. Murray-Riverina region: An interpretation of bedrock Palaeozoic geology based on geophysical data. Quarterly Notes, Geological Survey of New South Wales, April 2005, 118, 16 pp.

Lambert JA, Elix JK, Chenowith A & Cole S. 1995. Bioregional planning for biodiversity conservation. Approaches to Bioregional Planning, Part 2. Background Papers to the Conference, 30 October - 1 November 1995, Melbourne. Available from: http://www.deh.gov.au/biodiversity/publications/series/paper10/pubs/elix.pdf

Lech ME & Caritat P de. In preparation. Baseline geochemical survey of the Riverina region of New South Wales and Victoria, Australia: Geohealth implications.

Li J & Wu G (Chief Compilers). 1999. Atlas of the Ecological Environmental Geochemistry of China. Geological Publishing House, Beijing, China, 209 pp.

Maisto G, Alfani A, Baldantoni D, De Marco A & Virzo De Santo A. 2004. Trace metals in the soil and in *Quercus ilex* L. leaves at anthropic and remote sites of the Campania Region of Italy. Geoderma, 122:269-279.

McLaughlin MJ, Hamon RE, McLaren G, Speir TW & Rogers SL. 2000. Review: A bioavailability-based rationale for controlling metal and metalloid contamination of agricultural land in Australia and New Zealand. Australian Journal of Soil Research, 38:1037-1086.

Nichol I, Garrett RG & Webb JS. 1966. Studies in regional geochemistry. Transactions of the Institute of Mining and Metallurgy, B75:106-107.

NSW EPA. 1997. Environmental Management Guidelines—Use and Disposal of Biosolids Products. New South Wales Environment Protection Agency (NSW EPA), 107 pp.

Ottesen RT, Bogen J, Bølviken B & Volden T. 1989. Overbank sediment: a representative sample medium for regional geochemical sampling. Journal of Geochemical Exploration, 32:257-277.

Plant JA, Reeder S, Salminen R, Smith DB, Tarvainen T, De Vivo B & Petterson MG. 2003. The distribution of uranium over Europe: geological and environmental significance. Applied Earth Science, 112:221-238.

Reedman AJ & Gould D. 1970. Low sample-density stream sediment surveys in geochemical prospecting: an example from northeast Uganda. Transactions of the Institution of Mining and Metallurgy, B79:246.

Reimann C & Caritat P de. 1998. Chemical Elements in the Environment—Factsheets for the Geochemist and Environmental Scientist. ISBN 3-540-63670-6. Springer-Verlag, Berlin, Germany, 398 pp.

Reimann C, Äyräs M, Chekushin V, Bogatyrev I, Boyd R, Caritat P de, Dutter R, Finne TE, Halleraker JH, Jæger Ø, Kashulina G, Lehto O, Niskavaara H, Pavlov V, Räisänen ML, Strand T & Volden T. 1998. Environmental Geochemical Atlas of the Central Barents Region. ISBN 82-7385-176-1. NGU-GTK-CKE Special Publication, Geological Survey of Norway, Trondheim, Norway, 745 pp.

Reimann C, Siewers U, Tarvainen T, Bityukova L, Eriksson J, Gilucis A, Gregorauskiene V, Lukashev VK, Matinian NN & Pasieczna A. 2003. Agricultural Soils in Northern Europe: A Geochemical Atlas. Geologisches Jahrbuch Sonderhefte, Reihe D, Heft SD5, 279 pp.

Thalmann F, Schermann O, Schroll E & Hausberger G. 1989. Geochemischer Atlas der Republik Österreich (Textteil and kartenteil). Geologische Bundesanstalt, Rasumofskygasse 23, A-1031 Wien, Österreich.

Velleman PF & Hoaglin DC. 1981. Applications, Basics and Computing of Exploratory Data Analysis. Duxbury Press, Boston, Mass, USA.

WA DOE. 2003. Western Australian Department of the Environment Assessment Levels for Soil, Sediment and Water—Draft for Public Comment. In: Contaminated Sites Management Series, 31 pp. Available at: http://portal.environment.wa.gov.au/pls/portal/docs/PAGE/DOE_ADMIN/GUIDELINE_REPOSITORY/ASSESSMENT LEVELS FOR SOIL%2C SEDIMENT AND WATER.PDF

Several map types are shown here to illustrate various presentation styles, each with advantages and drawbacks. The simplest and most factual maps are the dot-maps (Figures 3, 6), where real concentrations are shown at the exact points where they were obtained.

For easy interpretation, exploratory data analysis (EDA) principles instruct us that boxplot classification with symbology as used here works best (e.g., Velleman & Hoaglin 1981). The resulting maps represent an improvement in the interpretation capability over growing dots maps (Figure 5).

The catchment or 'mosaic' maps (Figure 4) assign the value obtained at the bottom of each catchment to the entire catchment. This is based on the assumption that the overbank sediments analysed are the best possible reflection of the average geochemical composition of near-surface materials in the catchment. Although this assumption is fundamentally valid and faithful to geological understanding, the resulting maps are somewhat difficult to read at first.

Inverse-distance weighted maps (Figure 7) interpolate concentrations to fill in the gaps between real samples (the search radius used here is 50 km). Thus, they are based on mathematical models that may or may not match how the geochemical composition of sediments really varies around known points (i.e. no account is taken of lithology, erosion and transport processes, discontinuities etc.).

These maps, when smooth and "well behaved" are very easy to read and convey their message efficiently, but they reflect a significant, and perhaps unacceptably high, degree interpolation for these low-density surveys.

EXPLORE

Newsletter No. 129 DECEMBER 2005

Editor: Chris Benn (Chris.Benn@BHPBilliton.com)

Associate Editor:
Selwyn Benn

Assistant Editors:
Rob Bowell (rbowell@srk.co.uk/srk003@aol.com)
Richard Carver (RichardCarver@gcxplore.com)
Patrick Highsmith
Barry Smee (bwsmee@attglobal.net)
Neil Adshead (neil_adshead@placerdome.com)

Business Manager:
David Seneshen, (303) 277-1694
(dseneshen@directgeochemical.com)
Back Issues contact: Betty Arseneault
(office@appliedgeochemists.org)

**EXPLORE** is published quarterly by the Association of Applied Geochemists, P.O. Box 150922, Lakewood, CO 80215-0922, USA. **EXPLORE** is a trademark of the Association of Applied Geochemists.

**Type and layout of EXPLORE**: Vivian Heggie, Heggie Enterprises, Thornton, CO (303) 288-6540; <vjmheggie@comcast.net>

## ADVERTISING RATES

| | | | |
|---|---|---|---|
| Full page (Black & White) | 241h x 190w mm | (9.5h x 7.5w in) | US $ 970 |
| Full page (Color) | | | US$1165 |
| Half page (Black & White) | 241h x 89w mm | (9.5h x 3.5w in) | US $ 530 |
| or | 124h x 190w mm | (4-7/8h x 7.5w in) | |
| Half page (Color) | | | US $635 |
| Third page (Black & White) | 241h x 51w mm | (9.5h x 2w in) | US $420 |
| or | 178h x 89w mm | (7h x 3.5w in) | |
| Third page (Color) | | | US $505 |
| Quarter page (B&W) | 124h x 89w mm | (4-7/8h x 3.5w in) | US $300 |
| or | 241h x 41w mm | (9.5h x 1-5/8w in) | |
| Quarter page (Color) | | | US $360 |
| Eighth page (Black & White) | 60h x 89w mm | (2-3/8h x 3.5w in) | US $190 |
| Eighth page (Color) | | | US $230 |
| Business Card (B&W) | 51h x 89w mm | (2h x 3.5w in) | US $ 50 |
| Business Card (Color) | | | US $ 60 |

Please direct advertising inquiries to:
DAVID SENESHEN, DIRECT GEOCHEMICAL
130 CAPITAL DRIVE, SUITE C • GOLDEN, CO 80401 • USA
(303) 277-1694 Fax: (303) 278-0104 (dseneshen@directgeochemical.com)

# LIST OF ADVERTISERS



## THE ASSOCIATION OF APPLIED GEOCHEMISTS

**P.O. Box 26099, 72 Robertson Road, Nepean, Ontario K2H 9R0 CANADA • Telephone (613) 828-0199**
**www.appliedgeochemists.org**

### OFFICERS

January - December 2005

**David Kelley**, *President*
Newmont Mining Corporation
Malozemoff Technical Facility
10101 East Dry Creek Road
Englewood, CO 80112 USA
TEL: +1-303-708-4822
email: dave.kelley@newmont.com

**Robert J. Bowell**, *Vice President*
SRK Consulting
Windsor Court, 1 Windsor Place
Cardiff, Wales CF10 3BX
TEL: 442920348150
FAX: 442920348199
email: rbowell@srk.co.uk

**David B. Smith,** *Secretary*
U.S. Geological Survey
Box 25046, MS 973
Denver, CO 80225, USA
TEL: (303) 236-1849
FAX: (303) 236-3200
email: dsmith@usgs.gov

**Gwendy E.M. Hall,** *Treasurer*
Geological Survey of Canada
601 Booth Street, Room 561
Ottawa, ON K1A 0E8, CANADA
TEL: (613) 992-6425
FAX: (613) 992-6425
email: ghall@nrcan.gc.ca

### COUNCILORS

*Councilor Emeritus*
Sherman Marsh

2004-2005
Chris Benn
William B. Coker
Jeffrey Jaacks
Robert Jackson
Paul Morris

2005-2006
Robert Eppinger
David Seneshen
Phil Baker
Allan Kelly
David Cohen
Stephen Cook
Jorge Loredo
Olle Selinus

*Brazil*
Germano Melo Jr.
*Chile*
Brian Townley
*China*
Xueqiu Wang

*Europe*
J. B. De Smeth
*Northern Countries*
Vacant
*Southeast Asia*
Iftikhar A. Malik

*Southern Africa*
Charles Okujeni
*UK and Republic of Ireland*
Deirdre M. A. Flight

### COMMITTEES

***Australian Geoscience Council Representative***
David Garnett

***Awards and Medals Committee***
*Chair:* William Coker
Robert G. Garrett
Günter Matheis
Barry W. Smee

***Bibliography Committee***
L. Graham Closs, *Chair*
Robert G. Garrett
Richard K. Glanzman
Eric C. Grunsky
Peter J. Rogers

***Distinguished Lecturer Committee***
Jeffrey Jaacks, *Chair*

***Election Official***
Sherman Marsh

***EXPLORE***
Chris Benn, *Editor*
*email: Chris.Benn@BHPBilliton.com*
Rob Bowell, *Assist. Editor*
Barry Smee, *Assist. Editor*
David Seneshen, *Bus. Manager*

***Geochemistry: Exploration, Environment, Analysis***
Gwendy E.M. Hall, *Editor-in-Chief*
*e-mail: Ghall@nrcan.gc.ca*

***Admissions Committee***
Nigel Radford, *Chair*
Paul Morris
Cliff Stanley

***New Membership Committee***
Robert Jackson, Chair

***Publicity Committee***
M. Beth McClenaghan, *Chair*
Sherman P. Marsh
J. Stevens Zuker
R. Steve Friberg

***Regional Councillor Coordinator***
Robert Bowell

***Short Course Committee***
Colin E. Dunn, *Co-Chair*
Vlad Sopuck, *Co-Chair*

***Student Paper Competition***
*Chair: Vacant*
J.B. de Smeth
Paul Morris
Owen Lavin

***Symposium Committee***
Paul Morris, *Co-Chair*
Nigel Radford, *Co-Chair*
Eion Cameron
Mario Desilets
Philippe Freyssinet
Gwendy Hall
Virginia McLemore
Barry W. Smee
Graham F. Taylor

***Web Site Committee***
Robert Eppinger, *Chair*
*Webmaster:* Andrew Ransom

**Betty Arseneault,** *Business Manager*
P.O. Box 26099, 72 Robertson Road, Nepean, ON K2H 9R0 CANADA,
TEL: (613) 828-0199 FAX: (613) 828-9288, e-mail:
office@appliedgeochemists.org

SGS


Exploration geochemistry, check samples, on-site lab operations, mill support.... No matter what your needs, SGS Mineral Services provides a complete range of bankable inorganic and organic analyses on soils, rocks, ores and mine products. Our scope of ISO 17025 testing is at www.sgslakefield.com.

**Geochemical Analysis**

Metallurgical Services
Diamond Exploration Services
Environmental Services
Control Party Umpire Analysis
On-Site and In-Plant Services
Coal Services
Inspection and Sampling

SGS Minerals Services
1 416 445-5755
www.sgslakefield.com
www.sgs.com
pierrette_prince@sgs.com

WHEN YOU NEED TO BE SURE

SGS

Paid Advertisement

EXPLORE

*Newsletter for The Association of Applied Geochemists*
P.O. Box 150922, Lakewood, CO, 80215-0922, USA

Please send changes of address to:
Association of Applied Geochemists
P.O. Box 26099, 72 Robertson Road, Nepean, Ontario, K2H 9R0, Canada · TEL: (613) 828-0199 FAX: (613) 828-9288
e-mail: office@appliedgeochemists.org • http://www.appliedgeochemists.org

PR SRT STD.
U.S. POSTAGE
PAID
DENVER, CO
PERMIT NO. 3550