

Rising to the Challenge – Applications of Cell-Based ICP-MS to the Analysis of Geological Samples

Introduction

Geologists have always relied on quantitative analysis in order to further their understanding of rock petrogenesis, just as other scientists require assays to measure their experimental progress or explorationists require ore grades. Throughout history, from alchemists attempting to transmute metals into gold to modern day analysts using complex instrumentation, assaying the amount of different elements in a sample has been a tried and trusted method of furthering science, although this approach does require a homogenous solution of the sample. Paracelsus, for example, was a sixteenth century doctor and prototypical chemist whose quest throughout his life was to find the alkahest, a mythical liquid that was said to dissolve anything ‘as warm water dissolves ice’ (Ball 2006). Alas, he was ultimately unsuccessful in his search, but inspired many others to follow in his footsteps.

Many reputable analysts would contend that the modern equivalent of Paracelsus’ quest, and just as foolish, is the attempt by geoanalysts to find a single instrument that can measure all the elements in a rock simultaneously! This is effectively the Holy Grail of modern geological analysis, as it would provide fast, accurate analysis at a reasonable cost for the large numbers of samples generated in an exploration program, especially as modern digestion processes have solved many of the dissolution problems. However, most analytical procedures for geological samples have to resort to multiple instruments for a complete elemental analysis. This problem is exacerbated by the range and complexity of today’s exploration targets.

Until recently, exploration programs have typically been aimed at discovering precious and base metal commodities. However, technological innovations such as hybrid car batteries, more powerful magnets and the ubiquitous iPhone®, have increased demand for more exotic elements in the far reaches of the periodic table. This demand has resulted in assays being required for 50-60 elements that can vary widely in concentration. In addition, requests for lower detection limits and isotopic ratios have resulted in the need for new approaches to analysis that must continue to remain practical, both in terms of cost and numbers of different determinations. ICP-MS is ideally situated to meet these demanding expectations, as it combines multi-element capability with detection limits significantly below other widely used analytical instruments. The aim of this article is to show how cell-based ICP-MS instruments are now being utilized to meet the challenging analytical demands of today’s exploration

programs and attempting to provide a single point analysis for the geologist.

Cell-Based ICP-MS Technology

The typical configuration of a commercial quadrupole ICP-MS is shown in Figure 1a. Although each manufacturer has their own approach, the basic tenets of the argon plasma to produce ions, a lens system to focus the ion beam, a quadrupole mass spectrometer to separate individual ions on a mass to charge ratio, and an electron multiplier detector to amplify very small signals, remain the same. This set-up is used successfully in many geological applications, but does have limitations because of interferences. Other drawbacks include the inability of the instrument to measure high concentrations of ions and inherent fluctuations in the plasma prohibiting the precise measurement of individual isotopes needed for isotopic ratio measurements.

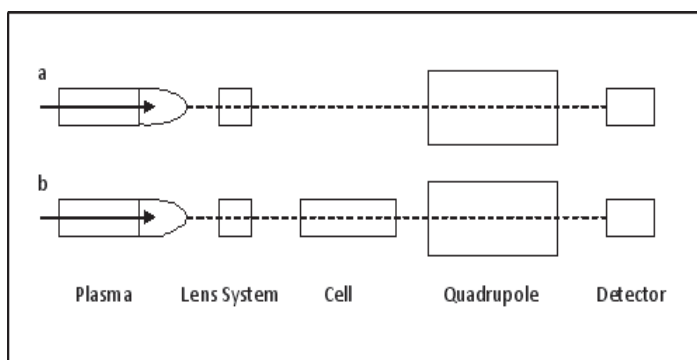


Figure 1. Schematic diagram for a Quadrupole ICP-MS: (a) The sample is aspirated into the plasma (arrowed line) where ions are formed (dotted line). They are focussed using the lens system and then separated into individual masses using the quadrupole mass analyser. Individual ion masses are measured using an electron multiplier detector: (b) The cell is pressurized with a gas to effect interference reduction, either by collisions or chemical reactions before the mass analyser.

When ICP-MS was first developed, it was thought that it would be mostly interference-free as only single masses were being measured and it did not have the complex spectra of emission spectroscopy. How hard could that be? Well, for many high mass elements it is not hard at all, but at masses below 80 there are many polyatomic ions formed in the intense heat of the plasma that can cause interferences. These include staples such as oxygen that interferes with sulphur, to more esoteric argon-based interferences on elements like

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chromium (e.g. $^{40}\text{Ar}^{12}\text{C}^+ = ^{52}\text{Cr}^+$), resulting in higher detection limits.

To overcome these interferences, a cell can be placed between the lens system and the quadrupole (Fig. 1b). This cell can be filled with either an inert or reactive gas. The gas collides or reacts with the ions in the system and breaks up polyatomic interferences. An ion guide is used to push the analyte ions through the cell in order to minimize losses through collisions with the gas molecules (Tanner et al. 2002). Cell-based systems have been used successfully in many areas of chemical analysis over the past decade or so, and are now being applied to the complexities of geological analyses.

SGS Minerals Services uses PerkinElmer instruments that employ a quadrupole as the ion guide in the cell. This cell is known as a Dynamic Reaction Cell (DRC) and works by performing reactions to break down polyatomic interferences, rather than the collision approach of other systems (Baranov & Tanner 1999). Figure 2 shows an illustration of how the DRC works. A mixture of the analyte and the interference enter the cell, pressurized with a reactive gas such as ammonia. The gas reacts with the interference, breaking it apart through charge transfer reactions. The parameters of the quadrupole inside the DRC are adjusted to prevent interferences from re-forming, allowing

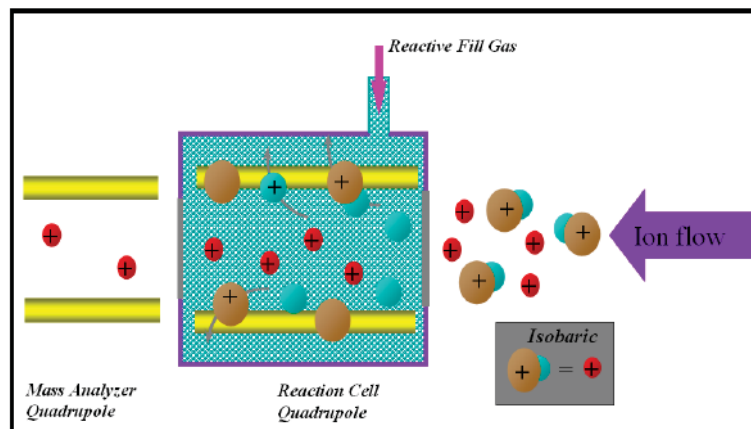


Figure 2. Interference removal using the Dynamic Reaction Cell (DRC). Polyatomic Interferences (brown and blue) of the same mass (isobaric) as the analyte (red) enter the cell, pressurized with a reactive gas. The gas molecules react with the interference, breaking them apart. The parameters of the quadrupole inside the reaction cell are adjusted to only allow the analyte ion through. (© PerkinElmer Inc., used with permission).

Notes from the Editor

The June 2011 issue of **EXPLORE** contains one article by Nick Turner describing the applications of cell-based ICP-MS to the analysis of geological samples. Other contributors to this issue include: Steve Amor, Betty Arsenault, Neil Beward, Graham Closs, Bob, Eppinger, Gwendy Hall, Paul Morris, Scott Robinson and Dave Smith. Scientific and technical editing assistance for this **EXPLORE** issue was provided by Gwendy Hall, Emeritus Scientist, Geological Survey of Canada, and Steve Amor, Geological Survey of Newfoundland & Labrador.

Beth McClenaghan

Editor



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only the analyte ion to exit the cell (Tanner & Baranov 1999). This filtering, or bandpass tuning, allows for a number of different applications, including:

- Electronic signal control to measure both high and low concentrations of elements in a single pass (extended dynamic range, or EDR);
- Detection limit improvement by either interference removal or reaction with the analyte to measure at a non-interfered higher mass;
- Use of a non-reactive gas to improve measurement precision in isotopic ratios.

These applications can lead to exciting new methodologies that stretch the boundaries of typical geological applications, as described in the examples below.

Determination of High Concentrations of Rare Earth Elements (REE) using EDR

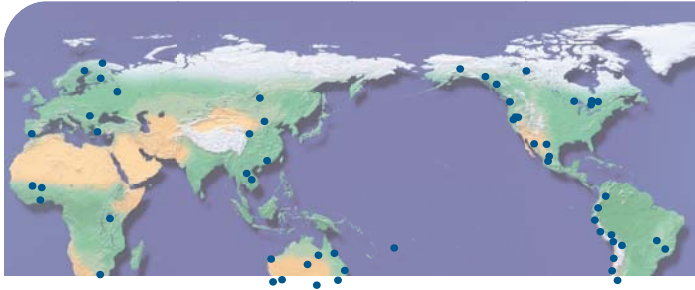
Interest in the determination of high concentrations of REE has spiked recently because of their extensive use in batteries, magnets and electronic technologies. The REE are listed in Table 1, along with typical ranges detected in geological materials. They are determined using a variety of instrumental techniques, including: neutron activation analysis (NAA); X-ray fluorescence (XRF); and both ICP-AES and ICP-MS. Most methodologies were developed to measure low-levels (parts per million) of REE found in most rocks, and for these types of material ICP-MS is ideal, because it has the ability to measure all of the rare earth series to low (sub ppm) concentrations. In comparison to XRF or ICP-AES, there are fewer interferences for the REE elements using ICP-MS, while NAA is not able to measure all of the REE in a single run.

Higher concentrations of REE (>5000 ppm total REE) found in ore bodies are harder to measure by a single process because of the large differences in concentration, from percentage levels of light REE to single parts per million for the



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heavy REE. To achieve this analysis, a new method has been developed by SGS Minerals Services that involves the use of a specific digestion procedure, followed by ICP-MS analysis using extended dynamic range (EDR). This is an attenuation process based on the characteristics of the quadrupole inside the reaction cell. No cell gas is used here, but the conditions in the cell are changed to allow fewer ions through, culminating in a drop in signal and consequently the ability to measure very high concentrations of specific REE, whilst retaining detection limit capabilities for others.

The extraction consists of sintering the sample with a sodium peroxide flux, followed by digestion in dilute nitric acid. The resultant solution is measured by ICP-MS to determine all of the REE in a single pass. EDR is used to measure the high concentrations of light REE, in conjunction with the heavy REE to produce detection limits and measurement ranges listed in Table 1. Cerium, for example,

can be measured at concentrations in excess of 15%, whilst still maintaining <1 ppm detection limit for elements such as holmium and thulium. Furthermore, additional elements can be added to the analysis to increase the range of applications as required by exploration geologists.


Detection Limit Improvements for Mobile Metal Ion (MMI™) Weak Leach Extractions using Cell-Based ICP-MS


Mobile Metal Ion (MMI™) Technology is one of several commercially available weak leaches that are used for a variety of resource identification and lithological mapping projects (e.g., Mann et al. 1998). The principle of MMI™ is that mobile ions associated with an ore body migrate to the surface over a period of time. These mobile ions adhere to soil particles at the surface and can be selectively extracted by mixing the sample with MMI™ solution. The resultant extract is measured for a variety of elements using ICP-MS

Element	DL	Typical Range*	Element	DL	Typical Range*		
Lanthanum	La	50	1000ppm - 10%	Terblum	Tb	1	20 - 500ppm
Cerium	Ce	50	1000ppm - 20%	Dysprosium	Dy	1	100 - 5000ppm
Praesodymium	Pr	10	1000ppm - 5%	Holmium	Ho	0.1	20 - 500ppm
Neodymium	Nd	50	1000ppm - 10%	Erbium	Er	0.5	50 - 1000ppm
Samarium	Sm	10	100 - 5000ppm	Thulium	Tm	0.1	10 - 50ppm
Europium	Eu	1	100ppm - 1%	Ytterbium	Yb	1	50 - 500ppm
Gadolinium	Gd	5	100 - 5000ppm	Lutetium	Lu	0.2	5 - 50ppm

Table 1: List of Rare Earth Elements in ascending atomic number, including detection limits using the cell-based method and typical ranges seen in the laboratory. La to Eu are referred to as the light REE and Gd to Lu as the heavy REE. * Ranges are given to show approximate levels seen in typical high concentration REE samples only.


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in order to detect a buried ore body through identification of anomalies over background levels. This has proven valuable for many target elements, but some critical elements cannot be measured at low levels because of matrix and sample interferences (Table 2).

Analyte	Mass	Major Interference	Reaction Gas	Det. Lt. (ppm)
Vanadium	51	ClO ⁺	Ammonia	0.001
Chromium	52	ArC ⁺	Ammonia	0.001
Selenium	78	Ar ₂ ⁺	Ammonia	0.002
Sulphur	34*	O ₂ ⁺	Oxygen	0.1

*Table 2: Enhanced MMI™ elements measured using cell-based ICP-MS. Ammonia reacts with the interferences, allowing lower detection limits for V, Cr and Se. Detection limit for Cr is 0.1 ppm for standard ICP-MS analysis, while the other elements are not determined. For Sulphur, the excess oxygen is used to move the sulphur ion to a higher mass, enabling a lower detection limit to be achieved. * Sulphur is actually measured as the oxide, SO⁺, at mass 50.*

Chromium is an important element in the discovery and identification of kimberlites for diamond exploration and for other ultramafic lithologies for nickel exploration. Vanadium has potential uses in uranium exploration and selenium is a useful pathfinder element for several types of mineral deposits including various polymetallic ores and ores containing gold and uranium. All three elements suffer from interferences in quadrupole ICP-MS (Table 2). To overcome these limitations, a cell-based method has been developed using ammonia gas. Ammonia reacts with the interfering polyatomic ions and removes them from the ion beam, resulting in low detection limits required for exploration work. All other elements are measurable in the same analysis to provide a comprehensive sample analysis required for target resource identification.

Sulphur is key element for nickel or oil and gas exploration, but is notoriously difficult to measure by ICP-MS because of oxygen interferences. However, a new cell-based method has been developed that utilizes the ability of the reaction cell to move an analyte away from interferences. In this case, oxygen gas is used in excess to react with the sulphur ions to produce SO⁺ ions that are measured at a higher mass away from interferences. Again, the parameters of the quadrupole in the cell are optimized to remove other potential interferences and all other elements can be measured in the same analysis.

Precise Isotopic Ratios of Copper using DRC-ICP-MS

Copper consists of two isotopes, mass 63 (with nominally 69.17% abundance) and mass 65 (30.83% abundance). Studies of copper isotopic ratios have shown that there are small differences in copper from various sources. The difference in isotopic ratios is given as the delta value ($\delta^{65}\text{Cu}\text{‰}$), defined as the difference in the $^{65}\text{Cu}/^{63}\text{Cu}$ ratio relative to the NBS976 isotopic standard, expressed in parts per thousand (‰) (Maréchal et al. 1999). It is this delta value that

can potentially be used in exploration geology to distinguish copper from various reservoirs. For example, it has been shown using a specialized technique that Cu oxides rimming a vein of chalcocite from El Salvador, Chile, had significantly lighter isotopic signatures (by approximately +1 $\delta^{65}\text{Cu}\text{‰}$). These were then used to evaluate the extent of veining of copper mineralization (Mathur et al. 2009). Additionally, the leach cap minerals have lower delta values than the primary mineralization and potentially this tool can be used to vector into blind mineralization.

ICP-MS has been utilized for the measurement of isotopic ratios in a variety of matrices, but the precision is typically limited to ca. 0.5% R.S.D., mainly because of fluctuations of the ion density in the extracted beam. By the time you move from measuring one isotope to the next, there is a small difference in the counts. Considering that a $\delta^{65}\text{Cu}\text{‰}$ difference of 1 is equivalent to a 0.1% difference in the isotopic ratio, the difficulty of measuring these values using conventional ICP-MS is apparent. Currently, precise isotopic ratios are typically determined using multi-collector or thermal ionization mass spectrometric techniques that are expensive, time-consuming and, thus, not easily applicable to geological exploration surveys.

In order to determine precise isotopic ratios using ICP-MS, the cell-based system is pressurized with a non-reactive gas. This pressurization effectively homogenizes the ion beam by increasing the residence time of the ions in the cell due to collisions with the gas, thus eliminating most of the fluctuations from the plasma source (Bandura et al. 2000). Copper determinations carried out using neon gas produced isotopic ratio results with precisions of $\pm 0.5 \delta^{65}\text{Cu}\text{‰}$. This precision is illustrated in Figure 3, where the small differences in delta values required for exploration purposes were measured by spiking the NBS976 standard with differing levels of enriched copper to simulate changes in the delta value.

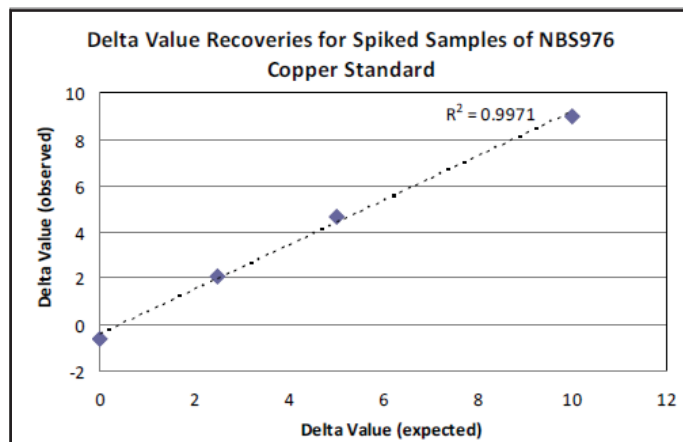


Figure 3: Plot of delta ($\delta^{65}\text{Cu}\text{‰}$) values for copper isotopic ratios measured using cell-based ICP-MS. NBS976 (nominal $\delta^{65}\text{Cu}\text{‰} = 0$) was spiked at +2, +5 and +10 $\delta^{65}\text{Cu}\text{‰}$ equivalents using an enriched ^{65}Cu standard solution to show that the method was capable of distinguishing between delta values of 1 unit.

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A similar approach is available for the determination of lead isotopic ratios that are important in uranium exploration. A multi-elemental scan (from an aqua regia digest or MMI™ extraction, for example) is used to screen samples for potential lead isotopic anomalies. Samples of interest are then measured precisely using a cell-based isotopic ratio method. This is particularly effective with uranium exploration, because there is a significant shift in isotopic signature that can be detected using the quadrupole ICP-MS and refined using the cell-based approach to provide high quality isotopic data for target resource identification.

Conclusions

Cell-based ICP-MS has allowed the expansion of analysis into various areas of recent interest, in order to respond to the ever-increasing demands of geological analysis. The examples given above are now routinely measured and are effectively 'tip of the iceberg' applications of this exciting technology, as we strive for a simplified approach to geological analysis. Whilst there is still considerable work to be done, the use of digestion processes such as fusions and selective weak leaches, combined with cell-based ICP-MS technology have succeeded in pushing us closer towards the end of the quest for a single dissolution and measurement process for specific target commodities.

But what of the alkahest, the ultimate solvent that Paracelsus strived in vain for? Alchemists kept looking for it well into the eighteenth century, even after the German chemist

Kunckel correctly noted in 1702 that if anyone actually discovered the alkahest, there would not be anything to contain it!

Acknowledgement

This article benefited from a review by Gwendy Hall.

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Nicholas Turner

*Global ICP/ICP-MS Technical Manager
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Erratum

Regarding subsidized membership for members in developing countries, on page 12 of **EXPLORE** issue No. 150, a four-column list of countries was shown. Only the first two columns (Least Developed Countries and Other Low Income Countries) should have been shown, in agreement with the list that is posted on the AAG website.



Paul Morris

President's Message

By the time you receive this edition of **EXPLORE**, many AAG members will be finalising travel plans to attend the 25th IAGS in Finland. In addition to the comprehensive technical and social program compiled by

the local organising committee, the Symposium will also provide the opportunity to present Eion Cameron with the Association's Gold Medal, awarded for outstanding scientific achievement in exploration geochemistry. Eion's long relationship with AEG and AAG means that most members will know of him and his achievements, and I am sure everyone will agree that this award is richly deserved.

As you will be aware, AAG has been pursuing charitable status, in order to make the Association a financially more attractive recipient of donations from individuals and companies. Following a rather protracted process, the desired outcome has not been achieved, and after consultation amongst Executive Council, it has been decided that the benefits of pursuing this change in status could not be justified by further expenditure. Although the closure of this door is disappointing, it opens another, in that the Association is now free to take an active role related to recruitment, starting off by offering space on the website to advertisers who seek to recruit geochemists etc. AAG's involvement in recruitment was precluded in the quest for charitable status. I am also hopeful that those who seek

employment in geochemistry will make available relevant information (experience, contact details) for the website, and advertisements related to recruitment will soon appear in **EXPLORE**.

At the March 2011 Council Meeting of the AAG, Erick Weiland presented a report on the progress of the Education Committee, which aims to generate support for students of applied geochemistry. The committee is making great progress in this area, and I feel sure that there will be benefits not only to students but also to the Association.

The activities of the Association are looked after by a small group of volunteers elected to Council. Duties of Councillors are not onerous, but all fulfil an important role in ensuring the proper running of the Association. I would be grateful if all Fellows of the Association would consider a stint on Council (two year period) – I know that Dave Smith would be greatly pleased if he was inundated with applicants.

The next **EXPLORE** will post-date the Rovaniemi meeting, so I take this opportunity to wish those of you who will attend the meeting in August a safe trip, and I hope to catch up with you at the meeting.

Paul Morris
President



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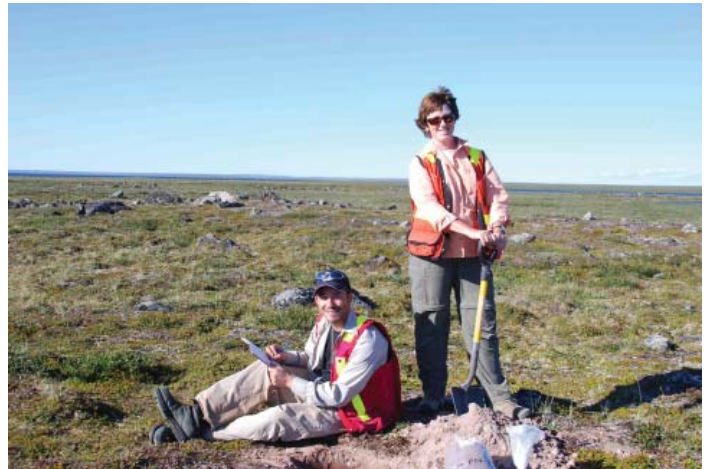
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Characterization of Indicator Mineral and Till Geochemical Signatures of the Kiggavik Uranium Deposit, Nunavut, Canada

The vast wilderness, the endless daylight and the ratio of caribou to humans of 1000:1, are what truly make the Canadian North an adventure that everyone should experience. Throw in a beautiful treeless landscape, snow in July, sparkling lakes and world class geology; I think we found paradise. This past summer I was fortunate enough to undertake a M.Sc. project along the Northeast margin of the Thelon Basin at the Kiggavik uranium deposit located ~80 km west of Baker Lake, Nunavut. The project is a collaborative effort between the Geological Survey of Canada (GSC), Queen's University, Overburden Drilling Management Ltd. and AREVA Resources Canada under the supervision of Dan Layton-Matthews (Queen's U.), and Roger Paulen, Beth McClenaghan and Charlie Jefferson (GSC). The purpose of this project is to investigate the indicator mineral and till matrix geochemical signatures of the Kiggavik deposit as a proof of concept as to the application of drift prospecting for uranium targets in glaciated terrain.

Field work took place over the months of July and August (2010), where we first conducted ice-flow mapping to document the dominant ice-flow patterns of the region. It was soon discovered that the highly polished and well exposed Paleoproterozoic quartzites to the north of camp were excellent sources of glacial striations and chattermarks, documenting four different ice flow orientations. With this evidence, a predominant NW-W ice flow orientation was determined and the bedrock and till sampling program to follow was carried out with this in mind.

Till and bedrock samples collected will be subjected to detailed mineralogical and petrographic analyses on polished thin sections/mounts to characterize mineral species and abundances, and size ranges to determine the key (unique) minerals indicative of uranium mineralization and spatially and temporally related hydrothermal alteration zones. This will include relative abundance, size range and compositional range for metallic, oxide and silicate minerals. Further geochemical analyses will be conducted in the <math><0.063\text{ mm}</math> (silt + clay) and the <math><0.002\text{ mm}</math> (clay) fractions of till to examine the potential dispersal of mineralization from the deposit. The winter months will be spent cozying up in the laboratory dreaming of returning to the great north for more excellent geology.



Here I am (left) on the Arctic tundra taking field notes, while Beth McClenaghan (GSC) uncovers some till for sampling.



Caribou herds were a common occurrence near the Kiggavik deposit. I am sure they also came to look at the geology.

Scott Robinson, M.Sc. Student
 Queen's University, Department of
 Geological Sciences & Geological Engineering
 Kingston, ON CANADA K7L 3N6
 E-mail: Robinson@geol.queensu.ca



Symposium on the Release of the Geochemical Atlas of Cyprus

5-7 September, 2011
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AAG speakers include Clement Reimann, Patrice de Caritat, Neil Rutherford, Iain Dalrymple, Olle Selinus, David Cohen.

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AAG Distinguished Lecturers 2011-2012

In 2011 and 2012, Rob Bowell and Scott Long will travel around the world delivering the AAG Distinguished Lectures. For more information about their travel schedules, contact the speakers directly.

Rob Bowell has a PhD in Geochemistry from Southampton University and has worked as a geochemist in academic research and in the mining industry for Goldfields, Ashanti and BHP. Since 1995, he has worked for SRK Consulting where he is Corporate Consultant in Geochemistry. Rob has represented AAG as Councillor for Europe, EXPLORE manager, general member of Council, Vice President and President for 2006 to 2007. He is on the editorial board of GEEA. Rob's main areas of expertise in SRK are applied geochemistry studies on uranium, exploration geochemistry (especially for uranium), environmental geochemistry of mine waste and waters and geometallurgy.

Rob's tentative lecture titles are:

1. Geochemical exploration for uranium; deconvolution, disequilibrium and details
2. Occurrence of uranium in Africa and implications for finding new uranium deposits
3. Role of mineralogy in interpreting applied geochemistry data
4. Applied geochemistry in the mine life cycle
5. Predicting quality of water: use and abuse of geochemical predictive calculations in the prediction of mine water chemistry
6. Close relationship between elephants, bat guano and zeolites

Rob may be contacted at:

SRK Consulting
17 Churchill House, Churchill Way
Cardiff CF10 2HH, Wales, UK
E-mail: rbowell@srk.co.uk

Scott Long has more than 20 years of geological and geochemical experience on mining projects in North and South America, Asia, Australia and Africa. He is a specialist in analytical chemistry, geochemical/geologic fieldwork and computer-based analyses, forensic database investigations and assay quality control, and has conducted numerous workshops in quality control of geologic and assay data. His career as an industry geochemist includes a long period for Newmont, as a consultant, and, since 1994 to the present, as the chief geochemist for AMEC. Scott has an MS in geochemistry from the New Mexico Institute of Mining and Technology, and is a long-time member of AAG.

Scott's tentative lecture titles are:

1. Customizing metallic (screen) fire gold assay procedures for coarse gold projects
2. Assay techniques for estimating Ni sulphides and Ni in silicates in ultramafic Ni deposits
3. How to use duplicate results to guide improvements in precision of the sampling-preparation-assaying process
4. Graphical presentation of quality control data: how to

communicate the essential and direct attention to areas in need of improvement

5. Approaches to evaluating the integrity of assay databases when doing an audit of due diligence

Scott may be contacted at:

AMEC
Mining & Metals: Mining Consulting Group (formerly MRDI)
4435 E. Holmes Avenue, Mesa, Arizona 85206-3372 USA
E-mail: scott.long@amec.com



The AAG Needs You as a Councillor

Each year the Association of Applied Geochemists needs motivated and energetic AAG Fellows to stand for election to the position of "Ordinary Councillor". Fortunately, each year some of our most outstanding Fellows are ready, willing, and able to meet this challenge. This is the annual article in EXPLORE summarizing the job and describing how one goes about getting on the ballot. It is our sincere hope that this might entice more Fellows to step forward for election to this most important position.

Job Description

The AAG By Laws state that "the affairs of the Association shall be managed by its board of directors, to be known as its Council". The affairs managed by Council vary from reviewing and ranking proposals to host our biennial Symposium to approving application for new membership to developing marketing strategies for sustaining and growing our membership. These affairs are discussed and decisions made at Council teleconferences usually held 3-4 times per year. Each teleconference lasts about 90 minutes. In addition, there is often a running email discussion about a selected issue or two between each teleconference. So for a commitment of about 8 hours of your time per year, you can

continued on page 10



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AEG needs you ... *continued from page 9*

help influence the future of your Association. If you want to spend more than the minimum time required, there is plenty of opportunity to do so through committee assignments and voluntary efforts that greatly benefit the Association.

Qualifications and length of term

The only qualification for serving as Councilor is to be a Fellow in good standing with the Association. Please note the difference between being a Member of AAG and being a Fellow. A Fellow is required to have more training and professional experience than a Member. Consult the AAG web site, Membership section, for further details. If you are not currently a Fellow and have an interest in serving on Council, please go through the relatively painless process of converting to Fellowship status in AAG.

Each Councilor serves a term of two years and can then stand for election to a second two-year term. The By Laws forbid serving more than two consecutive terms, although someone who has served two consecutive terms can stand for election again after sitting out for at least one year. Elections are usually held in the fall of the year for a term covering the following two years. Our next election will be in the fall of 2011 for the term of 2012-2013.

How to get on the ballot

If you are interested in placing your name into consideration for election to AAG Council, simply express your interest to the AAG Secretary (Dave Smith, dsmith@usgs.gov) by August 31, 2011 and include a short (no more than 250 words) summary of your career experience. All that is asked is that you bring energy and ideas to Council and are willing to share in making decisions that will carry the Association forward into a successful future. We look forward to hearing from you.

David B. Smith

Secretary, Association of Applied Geochemists



AAG Regional Councillor's Report: Progress in Applied Geochemistry in the United Kingdom and Republic of Ireland

Last year (2010) saw the 175th Anniversary of the British Geological Survey, which was celebrated in some style with a seminar at the venerable Royal Institution in London on 28th September, and was attended by many high-profile personalities from the Earth Sciences community, notably Sir David Attenborough, Prof. Ian Stewart, Marcia McNutt (USGS Director), and several hundred others including representatives from government, industry, academia, international geological surveys, students, earth science professionals and science journalists. The day was hailed as a great success, with excellent press coverage, and also saw the launch of a Geological Map 'App' for the iPhone and iPad – possibly the ultimate in portable geological maps!

BGS geochemists have also been closely involved in several European projects, notably the GEMAS survey of agricultural soils, the geochemistry of European bottled waters, and in the production of the forthcoming book on Urban Geochemistry (Johnson *et al.* 2011). With the change of direction of the BGS's main geochemical survey project G-BASE (Geochemical Baseline Survey of the Environment) away from systematic regional surveying towards more focussed multidisciplinary projects, the last year has seen the completion of a major urban geochemical survey of Greater London. This epic undertaking has involved the collection and analysis of soils from some 6600 sample sites from an area of 1594.7 km². Work has now been completed, and the dataset will be officially launched at a special meeting to be held at the Institute of Physics in London on May 13th. See <http://www.bgs.ac.uk/news/conferences/FTLEseminar/home.html?src=sfb>. For more details please contact Cathy Scheib at BGS (Cemery@bgs.ac.uk).

The other major G-BASE activity has been a re-survey of the River Clyde catchment in Scotland, collecting regional soil and stream water data to complement an earlier stream-sediment survey carried out in the early 1980s. This new dataset also includes high-order stream sediment sampling on the Clyde and its major tributaries, something of a novelty for G-BASE which normally collects stream sediment from 1st and 2nd order streams. The collection of this new data provides a comprehensive integrated geochemical dataset for the Clyde catchment including regional, urban, river and estuarine data with stream sediment, stream water, regional, peri-urban and urban soil for the Glasgow, and estuarine sediment.

Major urban geochemical surveys seems to be a popular current feature, with the Geological Survey of Ireland (GSI) being heavily involved in the SURGE project (<http://www.gsi.ie/Surge.htm>), a high-density urban soil geochemistry survey of Dublin, carried out in association with the Geological Survey of Norway. In Northern Ireland, the Tellus Project's integrated geochemical and geophysical survey carried out by

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www.stewartgroupglobal.com

AAG Regional Councillor's Report — *continued from page 10*

the GSNI (Geological Survey of Northern Ireland) and BGS under the auspices of the Northern Ireland government's department of Enterprise, Trade and Investment (DETI) was completed and has already stimulated much MinEx interest in the province, especially for gold. Recently, it was announced that for 2011-13, a new survey, Tellus Border, funded under the INTERREG IVA inter-regional cooperation programme of the European Regional Development Fund, will make soil and stream surveys of the six northern counties of the Republic of Ireland. The survey will follow G-BASE standard protocols but at a sampling density of only one site per 4 km². Project partners include: GSNI, GSI, Queens University of Belfast and the Dundalk Institute of Technology.

Elsewhere, and more generally, the recent rise in the price of some major commodities, despite the recession, has led to renewed interest in metal deposits in the UK, notably for tungsten and other rare elements such as uranium, niobium-

tantalum and Rare Earth Elements in SW England. It remains to be seen whether this interest is transient or more sustained.

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Dr Neil Breward

AAG Regional Councillor for the UK and the Republic of Ireland

British Geological Survey

Keyworth,

Nottingham UK NG12 5GG

Email: nbr@bgs.ac.uk

BGS website: www.bgs.ac.uk



New Members of AAG

Fellow (voting member)

Joao H. Larizzatti
Rua Mario Portela
161 - Apt. 2003A
Rio de Janeiro
RJ BRAZIL 22241-000
Membership # 3443

Regular (non-voting) Members

Andrey Tairov
Technical Manager
OMAC Laboratories Ltd.
Athenry Road
Loughrea, Co.
Galway IRELAND
Membership # 4049

Daniel E. Rickleman
Senior Geologist
Manas Resources
15 Benjamin Rd.
Mt. Kembla,
NSW AUSTRALIA 2526
Membership # 4051

Mansour Edraki
Senior Research Fellow
CMLR,
The University of Queensland
St Lucia, Brisbane,
QLD, AUSTRALIA 4072
Membership # 4052

Mr. Bob P. Patey
Research Geologist
Altius Minerals Corp.
P.O. Box 8263 Station «A»
St. John's, NL
CANADA A1C 1R2
Membership # 4053

Bjorn B. Jeune
Senior Project Geologist
Sacre-Coeur Minerals
2920 Well Road North
Ruimveldt Park, Georgetown,
Guyana SOUTH AMERICA
00592 Membership # 4056

Ignacio Gonzalez-Alvarez
Research Projects Officer
CSIRO
26 Dick Perry Av.
Kensington, Perth
WA AUSTRALIA 6151
Membership # 4057

Andreas J. Scheib
Geochemist
British Geological Survey
Nickerhill, Keyworth
Nottingham,
UK, NG125GG
Membership # 4058

Erin Bluemel Geochemist
ioGlobal Solutions Inc
300-1055 W. Hastings Street
Vancouver, BC
CANADA V6E 2E9
Membership # 4060

Susan L. Drieberg
Senior Geochemist
Rio Tinto
7 Whitfeld Street Floreat
WA AUSTRALIA 6014
Membership # 4063

Joanna Nissenbaum
Intermediate Geochemist
Klohn Crippen Berger
1928 Old Huntingdon Pike
Huntingdon Valley, PA,
USA 19006
Membership # 4064

Student Members

Shuang Zhang
China University
of Geosciences
Faculty of Earth Sciences
388 Lumo Road Wuhan,
HuBei CHINA 430074
Membership # 4050

Charlotte A. Mitchell
The University of Adelaide
35 Neuville Court
Wynn Vale, Adelaide,
SA AUSTRALIA 5127
Membership # 4054

Stephanie M. McLennan
University of Adelaide
29 Johns Road Prospect,
SA AUSTRALIA 5082
Membership # 4055

Gregory McKenzie
University of British Columbia
PO Box 99
Garibaldi Highlands BC,
CANADA V0N 1T0
Membership # 4061

Trenton T. Newkirk
University of British Columbia
1525 Allen Street
Reno, NV
USA 89509
Membership # 4062





CALENDAR OF EVENTS

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

2011

20-24 June 2011. Frontiers in Environmental Geoscience 2011, Aberystwyth Wales UK. Website: <http://tinyurl.com/yhyxllj>

28 June-7 July 2011. XXV IUGG General Assembly: Earth on the Edge: Science for a Sustainable Planet, Melbourne Australia. Website: www.iugg2011.com

3-7 July 2011. 11th International Conference on the Biogeochemistry of Trace Elements. Florence, Italy. Website: <http://www.icobte2011.com/>

4- 9 July 2011. Seventh Hutton Symposium on Granites and Related Rocks, Avila Spain. Website: www.seventh-hutton.org

10-15 July 2011. Catchment Science: Interactions of Hydrology, Biology & Geochemistry. Lewiston ME USA. Website: <http://tinyurl.com/35vxvuy>

20-27 July 2011. International Union for Quaternary Research (INQUA) XXVIII Congress, Bern Switzerland. Website: www.inqua.tcd.ie/congress.html

24-29 July 2011. 10th International Conference on Mercury as a Global Pollutant, Halifax NS. Canada. Website: <http://mercury2011.org>

25-27 July 2011. 6th International Conference on the Impact of Environmental Factors on Health, Riga Latvia. Website: <http://tinyurl.com/2ayqw2j>

31 July-4 August 2011. The Society for Organic Petrology (TSOP) Annual Meeting, Halifax NS Canada. Website: <http://tinyurl.com/4rgy4pj>

1-5 August 2011. 10th ICAM International Congress for Applied Mineralogy, Trondheim Norway. Website: www.icam2011.org

6-9 August 2011. 9th International Eclogite Conference, Tepla Czech Republic. Website: <http://tinyurl.com/29oaxrk>

7- 10 August 2011. Teaching Mineralogy, Petrology and Geochemistry in the 21st Century. Minneapolis MN USA. Website: <http://serc.carleton.edu/NAGTWorkshops/mpg/workshop2011>

9-11 August 2011. 21st Biennial Conference, European Current Research on Fluid Inclusions. Leoben Austria. Website: <http://tinyurl.com/3tt2sxn>

14-19 August 2011. Goldschmidt 2011, Prague Czech Republic. Website: www.goldschmidt2011.org

21- 23 August 2011. Short Course: Sulfur in Magmas and Melts and its Importance for Natural and Technical Processes. Goslar, Germany. Website: <http://msasulfurinmelts.org/>

21- 24 August 2011. 2nd International Workshop on Antimony in the Environment. Jena Germany. Website: www1.uni-jena.de/Antimony2011/

22-26 August 2011. 25th International Applied Geochemistry Symposium, Rovaniemi Finland. Website: www.iags2011.fi

4-7 September 2011. 7th European Conference on Mineralogy and Spectroscopy. Potsdam Germany. Website: <http://www.physchemgeo.com/ECMS/>

4-7 September 2011. Fragile Earth: Geological Processes From Global to Local Scales, Associated Hazards & Resources. Munich Germany. Website: <http://geosociety.org/meetings/2011munich/>

5- 9 September 2011. Annual Conference of the International Association for Mathematical Geosciences. Salzburg, Austria. Website: www.iamg2011.at/

7- 8 September 2011. Fermor Meeting 2011: Ore Deposits in an Evolving Earth. London UK. Website: www.fermor2011.org.uk/

20-24 September 2011. GEOMED2011 - 4th Hemispheric Conference on Medical Geology, Bari Italy. Website: www.geomed2011.it

26- 29 September 2011. 11th Biennial Society for Geology Applied to Mineral Deposits (SGA) Meeting. Antofagasta Chile. Website: www.sga2011.ucn.cl/

27-30 September 2011. 20th International Symposium on Environmental Biogeochemistry, Istanbul Turkey. Website: <http://tinyurl.com/4gyu2pz>

27-30 September 2011. International GNM-GABeC School on Minerals and Biosphere. Campiglia Marittima, Italy. Website: <http://tinyurl.com/3wylxyo>

9-12 October 2011. GSA 2011 Annual Meeting, Minneapolis MN USA. Website: www.geosociety.org/meetings/2011/index.htm



CALENDAR OF EVENTS

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24- 28 October 2011. Cathodoluminescence 2011: A MAS Topical Conference. Gaithersburg, MD USA. Website: tinyurl.com/3p7nqhd

1-3 November 2011. 8th Fennoscandian Exploration and Mining, Levi Finland. Website: <http://fem.lappi.fi/en>

14-17 November 2011. Conference on Arsenic in Groundwater in Southern Asia, Hanoi Vietnam. Website: www.as-hanoi.org/

Northwest Mining Association: Annual Meeting, Exposition and Short Courses

28 November 2011 - December 2011. Sparks NV USA. Website: www.nwma.org/convention.asp

2012

9-14 January 2012. 2012 Winter Conference on Plasma Spectrochemistry. Tucson AZ USA. Website: <http://tinyurl.com/4xm wz24>

23-26 January 2012. Mineral Exploration Roundup 2012. Vancouver BC Canada. Website: <http://tinyurl.com/3k9tqgb>

6-11 February 2012. 10th International Kimberlite Conference, Bangalore India. Website: <http://10ikbangalore.com>

4-7 March 2012. Prospectors and Developers Association of Canada Annual Convention. Toronto ON Canada. Website: www.pdac.ca/pdac/conv/

11-15 March 2012. The Minerals Metals & Materials Society 2012: Linking Science and Technology for Global Solutions, Orlando FL USA. Website: <http://tinyurl.com/4q388lq>

27-29 May 2012. GAC/MAC Annual Meeting, St. Johns NL Canada. Website: www.stjohns2012.ca

31 May-10 June 2012. Present and Future Methods for Biomolecular Crystallography, Erice, Italy. Website: <http://tinyurl.com/4vqxw7s>

2-8 June 2012. 11th International & 2nd North American Symposium on Landslides. Banff AB Canada. Website: www.isl-nasl2012.ca/

15- 22 July 2012. 9th International Symposium of Environmental Geochemistry. Aveiro Portugal. Website: <http://9iseg.web.ua.pt>

24-29 June 2012. Goldschmidt 2012. Montréal QC Canada. www.goldschmidt2012.org/

5-15 August 2012. 34th International Geological Congress, Brisbane Australia. Website: www.34igc.org

9- 13 September 2012. Planet Earth-from Core to Surface: First European Mineralogical Conference . Frankfurt Germany. Website: <http://emc2012.uni-frankfurt.de/>

17- 20 September 2012. Geoanalysis 2012, Buzios Brazil. Website: www.ige.unicamp.br/geoanalysis2012

9-13 September 2012. First European Mineralogical Conference. Frankfurt Germany. Website: <http://emc2012.uni-frankfurt.de/>

4-7 November 2012. GSA 2012 Annual Meeting, Charlotte NC USA. Website: www.geosociety.org/meetings/2012/

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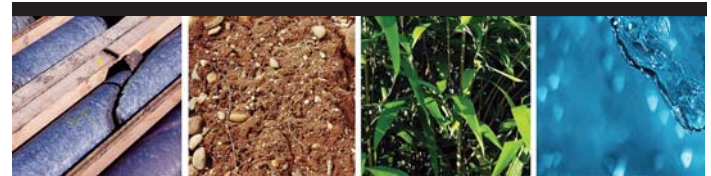
Steve Amor

Geological Survey of Newfoundland and Labrador

P.O. Box 8700, St. John's NL Canada. A1B 4J6

Email: StephenAmor@gov.nl.ca

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This list comprises titles that have appeared in major publications since the compilation in **EXPLORE** Number 150. Journals routinely covered and abbreviations used are as follows: Economic Geology (EG); *Geochimica et Cosmochimica Acta* (GCA); the USGS Circular (USGS Cir); and Open File Report (USGS OFR); Geological Survey of Canada papers (GSC paper) and Open File Report (GSC OFR); Bulletin of the Canadian Institute of Mining and Metallurgy (CIM Bull.); Transactions of Institute of Mining and Metallurgy, Section B: Applied Earth Sciences (Trans. IMM). Publications less frequently cited are identified in full. Compiled by L. Graham Closs, Department of Geology and Geological Engineering, Colorado School of Mines, Golden, CO 80401-1887, Chairman AEG Bibliography Committee. Please send new references to Dr. Closs, not to **EXPLORE**.

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Thank you Eion Cameron



Eion is an Honorary Member of AAG, winner of the AAG's Past President's Medal in 1993, past Treasurer of the AAG, and past editor and founder of the *Journal of Geochemical Exploration*. Since 1996, Eion has been contributing to the AAG in yet another important role - as the investment manager for AAG funds. In 2011, Eion retired from this role, leaving the AAG funds in an extremely healthy state. AAG would like to thank Eion Cameron for his significant contributions to the financial well being of the Association.

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David Lawie, John Gravel



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Sarah Lincoln, 1 (720) 881-6980 (SARAH.LINCOLN@MMG.COM)

Back Issues contact: Betty Arseneault (office@appliedgeochemists.org)

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U.S. Geological Survey
Box 25046, MS 973
Denver, CO 80225, USA
TEL: (303) 236-1849
FAX: (303) 236-3200
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Gwendy E.M. Hall, Treasurer

Geological Survey of Canada
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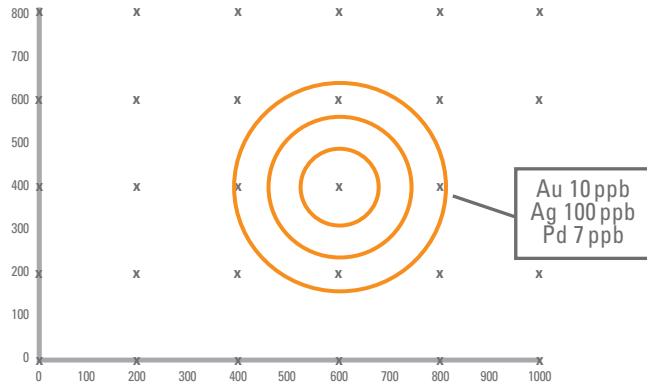
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