

The Evolution of the Geological Survey of Canada's Regional Reconnaissance Geochemical Drainage Sediment and Water Surveys

Introduction

As a result of the 1973 international energy crisis, the Canadian government introduced the Federal-Provincial Uranium Reconnaissance (URP) Program in 1974. The objectives of this program included establishing and maintaining high-quality databases of field observations and geochemical data for stream and lake sediments and waters, and airborne gamma-ray survey data, to aid uranium exploration. Technological advances in analytical methods and computing since then have led to improvements in efficiency, presentation, and the amount of information derived from each site. Counterbalancing these improvements have been steady decreases in funding and staff. Large-scale regional surveys managed by the Geological Survey of Canada (GSC) and carried out by contractors as stand-alone projects for mineral exploration, ceased in 2004. Since then, regional geochemical surveys have been undertaken within larger projects with multiple objectives including environmental evaluation and surficial and bedrock mapping, in addition to supporting mineral exploration.

A Brief Summary of Past Work

The exposed Canadian Shield (Fig. 1), with an area of 4.4 million km² and rich in mineral resources, occupies a little less than half of Canada's surface area of 10.0 million km² (Bostock 1967). Prior to 1970 conventional methods of geochemical exploration (stream sediments), soils and bedrock were employed mostly in the Canadian Cordillera and the Appalachian Mountains physiographic

regions (Fig. 1) (Brunner *et al.* 1987). Attempts to transfer sediment and soil methods and techniques to the Canadian Shield generally had poor success, and by 1970 exploration geochemistry on the Shield had acquired an unflattering reputation (Hansuld 1971). The problems facing exploration companies were and still are daunting: the area is vast and for the most part remote, bedrock is overlain by a variety of glacial sediments, and as a result of low relief and relatively recent de-glaciation, swamp, muskeg and indefinite and disorganized drainages are common (Coker & Nichol 1975). However, one notable feature of the Shield is a multitude of lakes. Beginning in 1970, research at the GSC began to focus on near-shore lake sediments, including inflow stream deltas and shoreline sediment deposits, as a sample medium for mineral exploration (Allan 1971). This led to the first large-scale reconnaissance survey of near-shore, predominantly clastic, lake sediments, including submerged frost/mud boils, carried out in 1972. Investigations by Hornbrook and Gleeson in 1971-1972 in the Abitibi Greenstone Belt (Hornbrook 1972) into the utility of centre-bottom lake sediments did not lead to encouraging results due to the presence of thick cover of glaciolacustrine clay. Studies continued in 1972 in Newfoundland with encouraging results (Hornbrook *et al.* 1975), and as a result organic-rich centre-lake bottom sediment sampling was adopted by the GSC as a regional reconnaissance tool in 1974. Research at Queen's University by Coker (1974) indicated that the best place to sample true 'lake sediments' was in the centre of the lake where the most organic-rich *gyttja* was found. This material has the highest and most homogeneous organic carbon content, and hence maximum metal levels for the lake most indicative of the average metal levels within the lake catchment basin. Near-shore materials, heterogeneous mixtures of materials from cobble to clay in size, are subaqueous equivalents of glacial and postglacial sediments and are not produced by the normal processes of lacustrine sedimentation (Coker *et al.* 1979).

In 1974, the Canadian government announced the initiation of the Uranium Reconnaissance Program (URP), a national program of mineral exploration for uranium (Darnley *et al.* 1975) which included regional reconnaissance surveys of organic-rich centre-lake bottom sediments as a major component. The term 'National Geochemical Reconnaissance' (NGR) program was first coined by Cameron (1976) in a paper that outlined the importance of having consistent protocols for sample

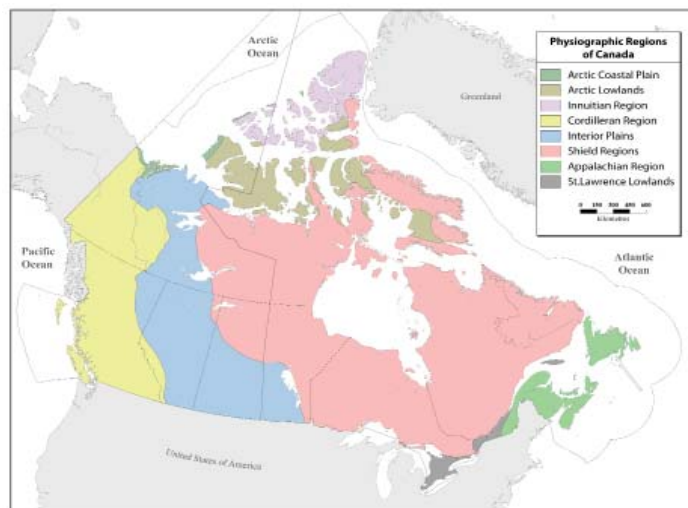


Figure 1. Physiographic regions of Canada.

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President's Message



The 27th International Applied Geochemical Symposium (IAGS) is already less than a year away – only six months after the last one! The symposium website is fully active now (www.27iags.com), and includes a call for abstracts, and information about field trips (6 field trips, highlighted by an 8-day trip on the geology of the Grand Canyon, by boat), short courses, and sessions. Registration was activated on May 15th, so register early (and often). There are 6 short courses offered, including courses on acid rock drainage, indicator minerals in mineral exploration, metal mobility in hydrothermal and supergene environments, utility of isotopes in mineral exploration, regolith and terrain mapping, and application of field portable XRF in exploration. There are numerous planned social events including: Sunday Ice-Breaker, Lunch provided in a common area each day of the symposium (MTTF), Tuesday evening Distinguished Lecturer, Wednesday (all day) social programs and short field trips (designed for attendees and accompanying persons), Thursday evening AAG Awards / IAGS Dinner, plus partner events throughout the week. Unlike the last IAGS, the meeting will have a rest day in the middle of the symposium (Wednesday). The meeting and accommodations are at the Hilton El Conquistador Hotel Resort and Spa in Tucson.

In this issue of **EXPLORE** you will notice an advertisement for a new Editor-in-Chief for our Association's journal *Geochemistry: Exploration, Environment, Analysis*. Gwendy Hall is stepping down in 2015. The Association will be hard pressed to find an Editor-in-Chief as organized, dedicated, and successful as Gwendy has been. Gwendy has taken GEEA from its beginnings 14 years ago to being the strongest journal in the field of exploration geochemistry, along with increasing

strength in analytical and environmental geochemistry. Thank you Gwendy for your outstanding leadership in this role. On a related note, I am working on an issue that affects journals like GEEA. I am sure that many if not all of us receive, at least weekly, emails asking for submissions to new journals, typically described as “open-access”. This is an important issue for a number of reasons: 1) these open-access journals are typically not real journals in the sense that they do not appear to have rigorous peer-review processes in place; several scientists and journalists have shown this over the last year by submitting, and having accepted for publication, manuscripts deliberately designed to be garbage; 2) the notion of “open access” is, as a result, becoming conflated with bad science. Open access from reputable journals simply means that non-subscribers do not have to pay for access to the article; 3) these “journals” are making a mockery of the peer-review process. Peer-review is not without its flaws, but strong peer-review, combined with strong editorial leadership, is the best mechanism we have to ensure that good science is promoted and published. As a result, I encourage reviewers to reveal their identities to authors (this is optional for GEEA), and for authors to make the effort to acknowledge their reviewers in their manuscripts (even where anonymous).

If you have not done so, please make sure that you have renewed your 2014 AAG membership via the AAG website (www.appliedgeochemists.org). Finally, nominations for the Gold and Silver medals of the AAG are due soon. Please refer the medals section of the AAG website for nomination instructions.

Matt Leybourne
President



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Notes from the Editor

The June 2014 issue of **EXPLORE** features one technical article by Martin McCurdy, Wendy Spirito, Eric Grunsky, Steve Day, Rick McNeil, and Bill Coker that describes the Geological Survey of Canada's regional reconnaissance geochemical drainage sediment and water surveys. **EXPLORE** thanks all contributors and reviewers for this second issue of 2014: including Steve Amor, David Cohen, Patrice de Caritat, Bob Garrett, Gwendy Hall, Matt Leybourne, Jesse Rice, and Erick Weiland.

Beth McClenaghan
Editor



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collection, preparation and analysis as well as effective quality control procedures so that data can be compared from year to year. Hornbrook & Garrett (1976) described the first centre-lake bottom regional reconnaissance survey undertaken in 1974 in east-central Saskatchewan. This survey was to serve as the template for all future regional reconnaissance lake and stream sediment surveys managed by the GSC.

The first regional stream sediment and water surveys under the federal URP program were carried out in 1976 in British Columbia and Yukon Territory. The URP was terminated in 1978, but NGR surveys continued to be carried out most years under two Mineral Development Agreements (1984-1990 and 1990-1995) between the federal, provincial, and territorial governments.

In 1978, the Geological Survey of Canada and partner provincial surveys collected 9,969 stream sediment and water samples and 9,976 lake sediment and water samples across Canada (Fig. 2). This marked the high point of regional government drainage sediment and water surveys in Canada using a model that incorporated federal funding, and federal ownership of data and standard methods of collection and analysis. The introduction of personal computers, Geographic Information Systems (GIS), and Global Positioning Systems (GPS) into the production of

geochemical maps and reports for publication gradually reduced or eliminated most of the manual cartographic and data entry tasks, so that despite reductions in staff, output was maintained.

Present State of Affairs

Regional geochemical surveys carried out by the GSC, many in partnership with Provinces and Territories, now extend over approximately 20% of the Canadian landmass (Fig. 3). In addition, Quebec has made available lake or stream sediment survey geochemical data for the entire province, and the province of Newfoundland and Labrador has published lake sediment geochemical data for the Island of Newfoundland and most of Labrador. Although no new regional lake sediment surveys have been carried out by the GSC since 1993, stream sediment and water surveys continue to play an important role in larger GSC regional mapping projects. The integration of current technologies and the new uses for geochemical data described below have combined to make regional geochemical surveys even more relevant for resource assessment, environmental applications, and land-use planning.

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Reanalysis

One of the unique characteristics of the NGR program has been the commitment of resources to maintaining an archive of dried sediment samples for future reanalysis (water samples are discarded after one year). In Ottawa, over 200,000 dried sediment samples are organized and stored in fire-resistant cabinets or on industrial metal shelving. An additional 22,000 samples collected by the province of British Columbia are part of the GSC's archive.

Reanalysis of existing samples, at around 5% of the cost of new surveys, has become the first option for both the mineral exploration industry and government scientists currently working in areas previously covered during the NGR program. The availability of low-cost, multi-element analytical packages and constantly changing international markets for different metals has resulted in demand for new data for up to 60 or more elements in lake and stream sediments from areas with high mineral potential. Under the Geo-Mapping for Energy and Minerals (GEM-1) Program, a 5-year (2009-2013) investment by the Government of Canada in geoscience information to help discover new energy and mineral resources in Canada, most lake sediment samples collected from sites in Nunavut and Northwest Territories between 1974 and 1979 were re-analyzed. Access to archive samples can be arranged

by contacting Ann Therriault (Ann.Therriault@NRCan-RNCan.gc.ca). All published data NGR data are available at no cost at <http://geochem.nrcan.gc.ca>.

Partnerships

Funding for new surveys has traditionally been provided to stimulate mineral exploration activity, however, an increasing proportion of monies are being provided to carry out NGR-style surveys to generate a layer of geochemical data critical in evaluating the mineral potential of an area. Regardless of the objectives of the funding sources for the survey, the resulting data are published in a timely manner to be used by the public and other government agencies.

In 2002, after nearly two decades of no new large government drainage geochemical surveys in the Northwest Territories, the Northwest Territories Geoscience Office (NTGO) requested the expertise of NGR geochemists to co-operatively manage what would become a series of new stream sediment and water surveys along the western margins of the Territory. The majority of the funding was provided by NTGO, and GSC involvement has helped to establish and maintain high quality data, which are compatible with existing NGR and other provincial/territorial drainage geochemical datasets. An increase in mineral exploration, claims staked, prospecting permits and

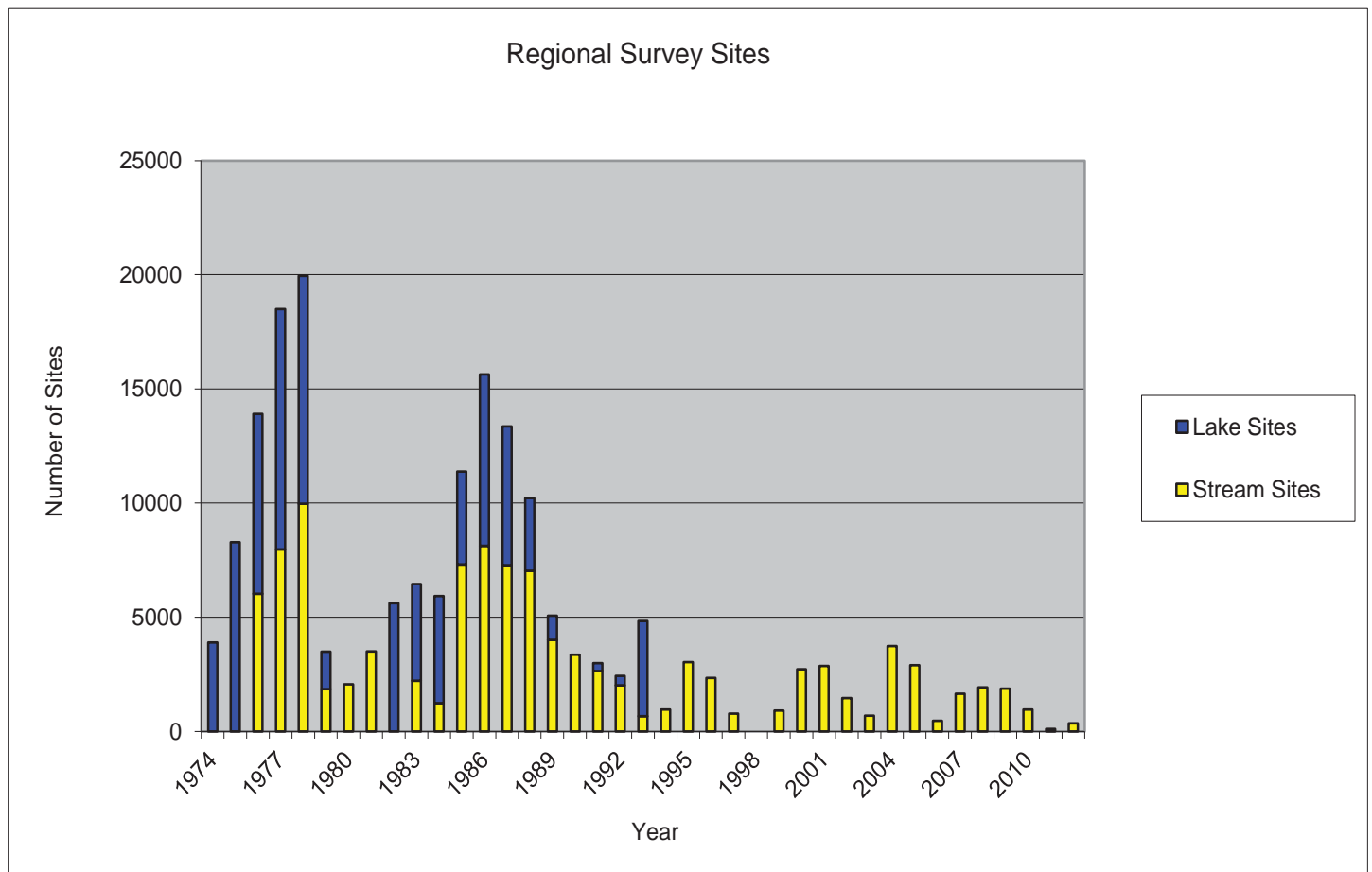


Figure 2. Total number of lake and stream sediment sites for the years 1974-2012.



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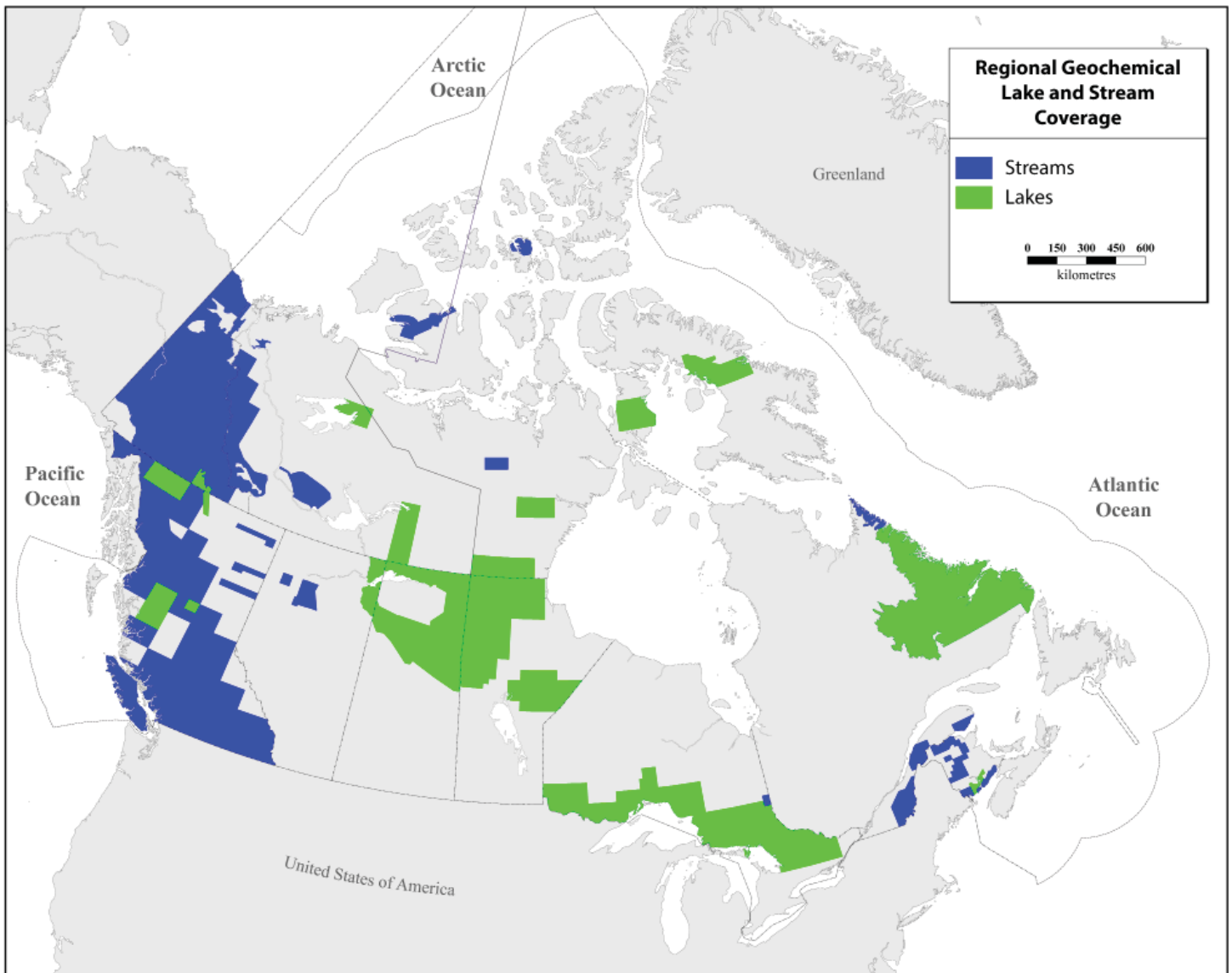


Figure 3. Regional drainage surveys to NGR standards in Canada.

informed land use planning decisions have resulted from this partnership.

Survey Design

The standard procedure developed at the GSC, and employed for recent stream sediment and water surveys carried out by the NTGO, is to select an area (usually a National Topographic System map sheet) and systematically sample one stream or lake within a 13 km² (5 mile²) grid. On average, approximately one thousand samples are collected from centre-lake basins or first or second order streams using helicopters. This model is efficient, thorough and expensive, with helicopter time accounting for 50-60% of the budget. Reduced funding at the GSC brought the need to reduce costs, where possible, for regional surveys. For streams, a strategy that incorporates the collection of indicator minerals from larger streams draining greater areas, in addition to silts

and waters, has been developed. The overall sampling density can be reduced to approximately two silt and water samples and one heavy mineral sample per 100 km², significantly reducing helicopter hours. Rather than sampling on a grid, sites are selected in order to effectively capture the geochemistry of sediments and waters by focussing on watersheds and the rock type underlying them.

Sample Media

Indicator Minerals

Although the cost of processing and analyzing heavy mineral concentrates is significant, identifying indicator minerals and interpreting their morphological characteristics provides a wealth of information about potential economic mineralization. Research at the GSC

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continues to expand the knowledge about indicator mineral methods that can be applied to stream sediments as well as glacial sediments for: gold and platinum group elements (McClenaghan & Cabri 2011); magmatic Ni-Cu-PGE (McClenaghan *et al.* 2013a); kimberlites (McClenaghan & Kjarsgaard 2007); W-Mo (McClenaghan *et al.* 2013b), volcanogenic massive sulphides (McClenaghan *et al.* 2012a,b; Hicken *et al.* 2013); Mississippi Valley Type Pb-Zn (McClenaghan *et al.* 2012c; Oviatt *et al.* 2013); and iron oxide copper gold deposits (McMartin *et al.* 2011).

Waters

Until the year 2000, only uranium, fluoride, and pH were routinely determined in stream and lake waters. After 2000, up to 60 or more elements were determined in filtered and acidified waters from every fifth site by a combination of ICP-MS and ICP-AES methods. At present, water samples from all sites are filtered and acidified in the field and later analyzed.

Stream and Lake Sediments

Lake sediments collected in 1974 for the URP were analyzed for 11 elements by several different methods, including atomic absorption spectrometry, colourimetry, and fluorimetry. Results were accurate and precise, but the process was time-consuming and expensive. The commercial development of rapid and economical INAA and ICP-MS analytical methods for lake and stream sediments has resulted in the ability to determine up to 65 elements, from sample aliquots as small as 0.5 g for ICP-MS.

Targeted/Integrated Surveys

Drainage sediment surveys are now smaller, more focussed and integrated within larger projects, instead of being large stand-alone projects. GSC exploration geochemists adapted quickly to the changes and have played important roles in a number of projects. Recent surveys (since 2005) include stream sediments, waters and heavy minerals on Baffin Island, Nunavut (Utting *et al.* 2008), Victoria Island, Northwest Territories (McCurdy *et al.* 2012), Pine Point Pb-Zn MVT District, Northwest Territories (McClenaghan *et al.* 2012c), and the Sisson W-Mo deposit (McClenaghan *et al.* 2013b).

Resource Assessment and Environmental Applications

A new federal government policy was established in 1980 to guide the process of creating National Parks and under this policy it was mandated that an assessment of the non-renewable resources of an area be conducted prior to formal establishment of a National Park north of latitude 60° (Falck *et al.* 2007). Regional stream sediment surveys were an integral part of two park assessments, 1) northern Bathurst Island (Anglin & Harrison 1999), and 2) a proposed expansion of Nahanni National Park Reserve to include the Greater Nahanni Ecosystem (Wright *et al.* 2007). The Bathurst Island geochemical survey marked

the NGR's first significant use of heavy minerals in stream sediments to evaluate mineral potential.

Predictive Geochemical Mapping

The GSC is taking a leading role in the development of predictive geochemical mapping of Canada's North. Mapping with geochemical data involves a rigorous approach to validating the quality of the analytical data followed by a sequential investigation of process discovery and subsequent process validation. Through the application of data adjustment procedures, compositional data analysis, and the application of statistically-based classification procedures, geochemical data can be successfully used to predict lithology and estimate potential mineralization (Grunsky *et al.* 2012). Lake sediment samples collected up to 27 years ago have been reanalyzed for up to 60 elements and multivariate statistical procedures used to classify and predict lithologic variability, the location of mineral ore alteration zones, and zones of mineralization. These methods in combination with remote predictive mapping can be used to evaluate mineral potential over large areas of northern Canada.

Canadian Database of Geochemistry (CDoGS)

Geochemical data and metadata for NGR and other surveys are being stored in a sophisticated, general-purpose database, the Canadian Database of Geochemical Surveys (CDoGS) (Adcock *et al.* 2013). The public inter-face to CDoGS can be found at <http://geochem.nrcan.gc.ca> (Fig. 4). This web site provides high-level metadata for each catalogued survey and its associated publications. Links to raw data in their original published format are included where possible. Currently, there are over 1200 surveys stored in the database and 221 of them are NGR and NGR-style surveys. Links to published data for NGR surveys are available on the website and raw data in a standardized format are available for approximately 10% of them. Adding more surveys and standardizing the raw data for viewing in Google Earth™ is on-going, with the focus on loading raw data, in particular for NGR surveys. More details about how to use the CDoGS site are found in Spirito & Adcock (2010).

The Future of Regional Geochemical Surveys at the GSC

In August 2013, the Canadian government announced that \$100 million will be provided over seven years (2013-2020) to support increased exploration for natural resources in Canada's North, as a second phase of the GSC's GEM Program. Renewal of the GEM program was due in no small part to the output of high-quality maps and reports (over 700) produced during the first phase of the program. Over the previous five years much effort at the GSC has gone into developing new methods for collection, analysis, interpretation and dissemination of drainage sediment and water geochemistry. There is considerable scope for continued participation with the NTGO in lake sediment

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and water surveys in northern Canada. In areas of the Northwest Territories underlain by the Canadian Shield, over 400,000 km² are suitable for lake sediment and water sampling. Vast areas of Nunavut remain to be evaluated for mineral potential using geochemical surveys. Financial resources and expertise provided by the GSC will play a major role in collecting new data.

The development of ICP-MS techniques has had a far-reaching effect on all areas of geochemistry, including exploration geochemistry. Analytical data for dozens of elements in sediments and waters not previously available continue to provide research opportunities for geochemists. Modern micro-analytical techniques such as high-resolution ion microprobe and laser ablation ICP-MS available at the GSC provide rapid analysis of isotopic distributions within individual grains of ore minerals, and the subsequent development of databases can be used to identify individual deposits. Piercey (2010) noted that techniques such as laser ablation ICP-MS and laser

ablation multi-collector ICP-MS are providing geochemical and isotopic signatures of resistate minerals in rocks that could in the future be applied to exploration. An obvious application of these new technologies would be to examine indicator minerals collected from stream sediments.

Resource assessments will continue to be a major focus for the GSC and the systematic collection and analysis of lake and stream sediments and waters remain one of the best methods for quickly providing data for large areas at reasonable cost. Predictive geochemical mapping will become an increasingly important means of identifying rock types in unexplored regions. Finally, geochemical databases developed at the GSC for public use will continue to grow and evolve as new information is added and new applications are developed for these data.

Acknowledgements

The authors wish to thank Bob Garrett, GSC Emeritus Scientist, for reviewing this article and providing additional

The screenshot shows the CDoGS website interface. On the left, there are search filters: 'Survey count' (188), 'Province' (All), 'Organisation' (All), 'Survey Type' (All), 'Year' (= All), 'Title' (NGR), and 'Abstract'. Below these is a 'Location' section with 'Longitude', 'Latitude', and 'NTS' fields, and a 'Raw data surveys only' checkbox. A 'Limit selection' button and a 'Reset' button are also present. The main area contains a map of Canada with green grid overlays. Above the map are navigation tools for 'mouse navigation' and 'keyboard navigation'. Below the map are 'NTS' (Default, 250K, 50K), 'Map Limits' (N: 88.22200, S: 32.24151, W: -188.19157, E: -0.56250), and 'Scale' (1: 39,591,283, 5,573 km) settings. 'Redraw' and 'Submit' buttons are at the bottom right, along with a 'High Res' checkbox.

Figure 4. Index map query interface from the CDoGS website.

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historical information. We thank Beth McClenaghan for many valuable suggestions offered during a preliminary review of this article.

* Author's Note: Co-author Bill Coker passed away in January, 2014. He was an important contributor to the GSC's National Geochemical Reconnaissance program and this article. Those interested, may read Bill's obituary in **EXPLORE** 162.

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**M.W. McCurdy, W.A. Spirito, E.C. Grunsky,
S.J.A. Day, R.J. McNeil, and W.B. Coker***
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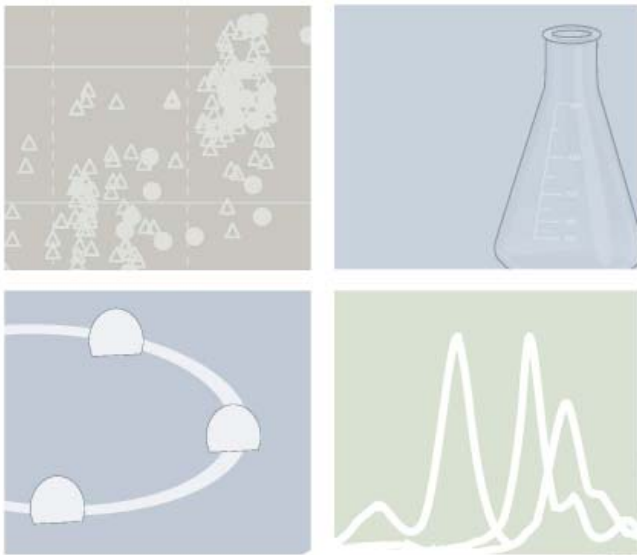
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MDRU

Mineral Deposit Research Unit

Exploration Geochemistry Initiative



The MDRU Exploration Geochemistry Initiative will provide the leadership and financial support to implement a five year program that will significantly increase the amount and quality of research and training in the discipline of mineral exploration geochemistry.

This initiative will be undertaken by the MDRU-Mineral Deposit Research Unit, based at the Department of Earth, Ocean and Atmospheric Sciences at The University of British Columbia. Funding for this initiative will be acquired through industry contributions and project sponsorships that will be leveraged to engage government support. This initiative already benefits from generous funding supplied by Acme Analytical Laboratories Ltd.



MDRU is an internationally recognized, collaborative research venture between the minerals industry and The University of British Columbia dedicated to solving exploration problems and training the next generation of exploration geologists.

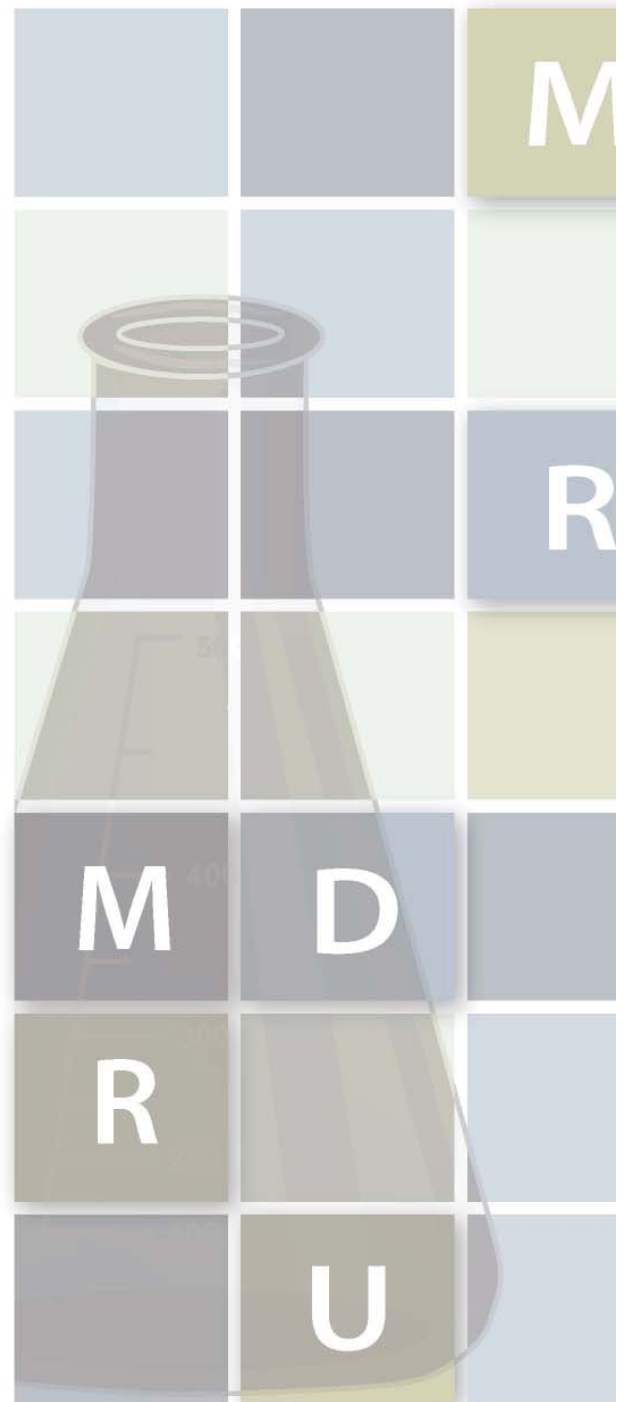
The MDRU Exploration Geochemistry Initiative operates within three modules

- 1 A **Research Chair in Exploration Geochemistry** has been established at UBC. The Chair will provide the leadership and innovation required to establish a robust research foundation in the field of Exploration Geochemistry. This role places an emphasis on project design, graduate student supervision, interaction with industry, and contributions to undergraduate and graduate teaching.
- 2 A **robust research program** will be established to understand element mobility and transport through the surficial environment, specifically from buried and blind deposits; and to develop new mineral exploration techniques and strategies. This will be accomplished by establishing a well-funded and dynamic research group consisting of Post-Doctoral Fellows, Doctoral and Masters level graduate students.
- 3 Emphasis will be placed on the provision of **education, training and professional development opportunities** in the field of exploration geochemistry. An Exploration Geochemistry Field School will be established to emphasize the teaching of practical field skills, as well as short courses and workshops for students and industry, using the appropriate tools and instrumentation.

Peter Winterburn

MDRU is pleased to announce the hiring of Dr. Peter Winterburn as the **Acme Industrial Research Chair in Exploration Geochemistry**. With expertise in regional geochemistry and exploration methodologies, Peter has previously served as Chief Chemist for Anglo Research and Chief Geochemist – Global Exploration for Vale. His research interests centre on innovation of cost-effective, robust geochemical exploration methods for concealed deposits.

At MDRU, Dr. Winterburn will establish a fully funded research team comprising Post Doctoral Fellows, PhD and MSc students to undertake collaborative industry relevant research to develop a deeper understanding of the formation of inorganic and organic geochemical anomalies over concealed mineralisation. This research is intended to lead to the development of industry appropriate geochemical tools and applications with a clear understanding of their geological and environmental constraints.



MDRU Rises to Meet Exploration Challenges

Societal demands for mineral resources continue to spur high metal prices and billions of dollars in resource investment, but are coupled with skill shortages and restrictive policy changes. The discovery of new mineral resources requires increasing risk, increasing costs, and increasingly effective exploration techniques. As a result, exploration activity has been accelerated in difficult localities such as those that lack outcrop, are covered by transported surficial materials, or reside at greater depth. The demand to develop innovative geochemical exploration techniques and strategies is higher than ever, as is the demand for highly-qualified individuals to play a role in this effort.

Canadian contributions are significant to the development of exploration geochemistry geoscience and generated internationally renowned scientists and practitioners. However, government geological surveys and universities alike have not maintained expertise to contribute to the science

and there has been a steady decrease in research and technical developments in this field. Diminished mentorship and training over the past two decades resulted in a missing generation of exploration geochemists. This significantly impacted Canada's ability to compete internationally, in both research and in the capacity to provide a trained workforce.

Vancouver has long been a global leader in exploration geochemistry. The world's largest and most innovative commercial laboratories are based in Vancouver. Vancouver has amongst the greatest congregation of exploration geochemists, either as key representatives of exploration and mining companies, or as consultants.

Recognizing the challenges faced by this discipline and the mineral exploration industry, the MDRU Board of Directors took the lead in developing the Exploration Geochemistry Initiative.

Exploration Geochemistry at UBC

UBC had been a leader in exploration geochemistry with a rich history for more than 60 years.

UBC **Prof. Harry Warren** (Emeritus 1974) was a pioneer in the development of the discipline, researching analytical techniques and strategies since the 1930s. He established interdisciplinary geochemical studies by linking biology, geology and chemistry, and by evaluated soils, plants and animals as geochemical representatives of the earth and it's underlying resources. He was also amongst the first to recognize the relationships between trace elements in soil and the

health of people living on it. These achievements were recognized by the Order of Canada, the Royal Society and the Canadian Mining Hall of Fame.

UBC **Prof. Alistair Sinclair** (Emeritus 1999) contributed significantly to the development of numerical and statistical applications of exploration geochemistry data.

UBC **Prof. Kay Fletcher** (Emeritus 2003) provided an understanding of stream silt geochemistry in various climates and ore environments that now provides a foundation for most regional exploration programs.

UBC's leadership in exploration geochemistry research and training is widely recognized as contributing to the foundations of the exploration geochemistry profession.

MDRU continues to progress in the field of exploration geochemistry by developing new exploration geochemical strategies and analytical tools. Research in this discipline is further strengthened by associations with other departmental expertise in geochemistry such as the **PCIGR**-Pacific Centre of Isotopic and Geochemical Research and **MAGNET**-Multidisciplinary Applied Geochemistry Network.

Funding for this initiative will be obtained and is sought from contributions from industry. These funds will be leveraged through the Natural Sciences and Engineering Research Council of Canada (NSERC) to secure additional funds.

A significant foundation contribution from Acme Analytical Laboratories Ltd. has provided this initiative with funding to hire the Acme Industrial Research Chair in Exploration Geochemistry.

Engage. Additional contributions and research project proposals are welcome.



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MDRU
Mineral Deposit Research Unit

To learn more about MDRU, this initiative, or membership benefits:

<http://www.mdru.ubc.ca>

MDRU Director Craig Hart at chart@eos.ubc.ca

Acme Industrial Research Chair Peter Winterburn at pwinterburn@eos.ubc.ca

Students supported by AAG to attend the 26th IAGS, Rotorua, NZ

The AAG traditionally provides financial support to students to attend the biennial IAGS. Most recently, AAG was able to provide financial support to 16 students to attend the 26th IAGS in Rotorua, New Zealand in November, 2013. Student names, affiliations, and their research topics are listed below.

Britt Bluemel, MSc student, Department of Earth, Ocean and Atmospheric Sciences, MDRU, University of British Columbia, Canada

Topic: Biogeochemical Expressions of Buried Rare Earth Element Mineralization at the Norra Korr Alkaline Complex, southern Sweden

Dane Burkett, PhD student, School of BEES, University of New South Wales, Australia

Topic: Use of fpXRF in chemostratigraphy and litho-geochemistry vectoring towards mineralization, Kulumadai epithermal gold deposit, Woodlark Island, PNG

Lauren Greenlaw, MSc student, Department of Earth, Ocean and Atmospheric Sciences, MDRU, University of British Columbia, Canada

Topic: Litho-geochemical footprint of the Relincho Cu-Mo porphyry deposit, Atacama Desert, Chile

Sarah Hashmi, MSc student, Department of Earth Sciences, Simon Fraser University, Canada

Topic: Drift geochemistry, Mt Polly porphyry Cu Mine

Gemma Kerr, PhD student, Department of Geology, University of Otago, New Zealand

Topic: Experimental mobilisation and secondary mineralisation of antimony and arsenic from gold ore, Reefton New Zealand

Margaux Le Vaillant, PhD student, The University of Western Australia (UWA), Centre for Exploration Targeting (CET), Australia

Topic: Hydrothermal footprints around magmatic nickel-sulfide deposits: a case study at the Miitel deposit, Yilgarn craton, Western Australia

Xuemini Liu, PhD student, Institute of Geophysical and Geochemical Exploration, Chinese Academy of Geological Sciences, China

Topic: Comparison of catchment/floodplain sediment geochemical data obtained by global-scale projects in Australia, China and Europe

Caitlin Morris, BSc student, School of Earth Sciences, James Cook University, Australia

Topic: Petrology, geochemistry and ore genesis of the alkaline REE Toongi deposit, Dubbo, NSW

Nayeem Mullungal, PhD student, University of Otago, Department of Chemistry, New Zealand

Topic: Unraveling the nitrous oxide bio-geochemistry in the southwest Pacific Ocean using stable isotopes

Markham Phillips, PhD student, Department of Geology, University of Otago, New Zealand

Topic: Geochemical variations in the Sams Creek Gold Prospect, northwest Nelson, New Zealand

Greg Poole, BSc student, School of BEES, University of New South Wales, Australia

Topic: Modeling hydrothermal alteration facies of Earth's oldest hydrothermal setting: the 3.5 Ga North Pole Dome, Western Australia, Australia

Ksenia Sormaz, MPhil student, School of BEES, University of New South Wales, Australia

Topic: In-situ measurements of soil helium to detect leakage patterns through transported regolith

Benjamin Uster, PhD student, University of Canterbury, Department of Civil and Natural Resource Engineering, New Zealand

Topic: Performance of Sulfate-Reducing Bioreactors Treating Mine Influenced Waters Using Waste Mussel Shells

Rocío Vargas, MSc student, Departamento de Geología, Universidad de Chile

Topic: Integration of geochemical data from fpXRF analyzer, ICP-OES and AAS with mineralogical techniques to characterize a porphyry Cu-Mo deposit, Chile

Diego Venegas, MSc student, Departamento de Geología, Universidad de Atacama, Chile

Topic: Geochemical exploration in carbonatitic and felsic xenoliths associated to pegmatites NW of Sierra El Roble, Chile

Qichao Zhao, PhD student, Institute of Geophysical and Geochemical Exploration, Chinese Academy of Geological Sciences, China

Topic: Spatial-temporal distribution of elements in clastic sedimentary rocks in a transect across south China: implications for the W, Sn metallogenic province

Dr. David Cohen

School of Biological, Earth and Environmental Sciences, University of New South Wales



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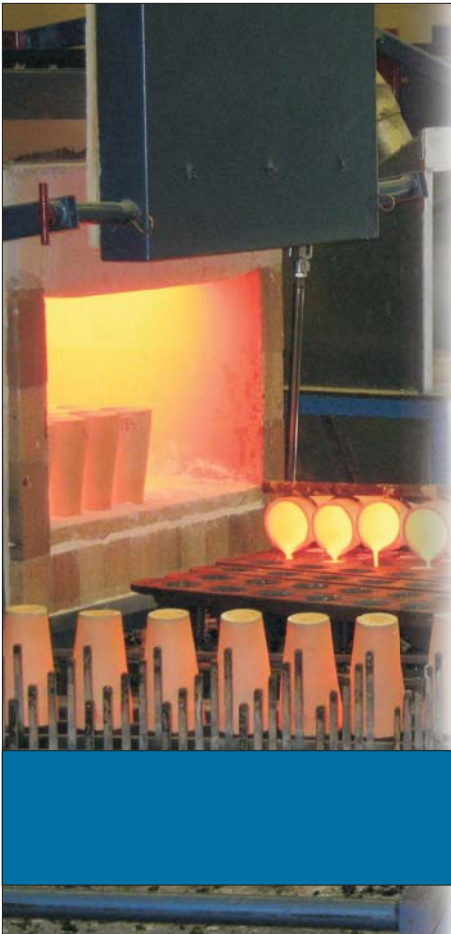
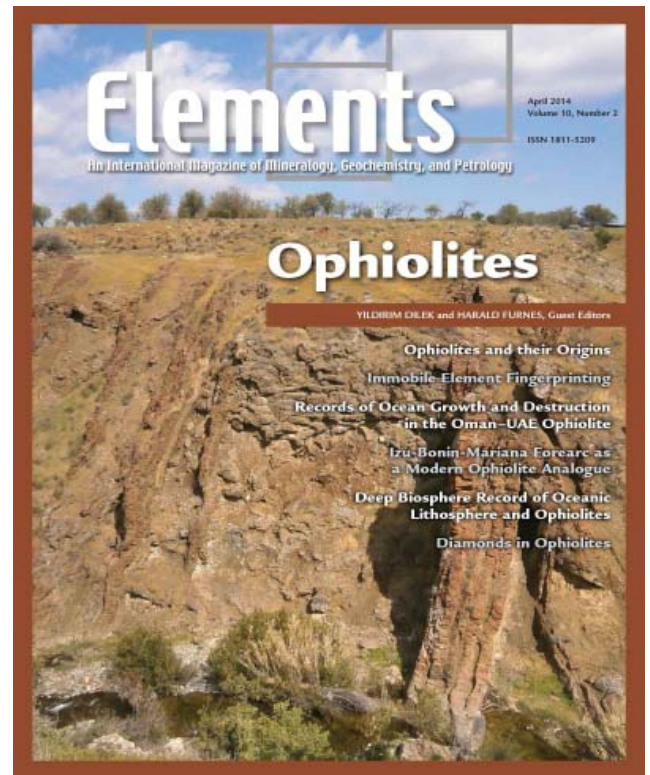
Upcoming Elements issue

“The next issue of *Elements* is dedicated to ophiolites. How do these rocks form and where do we find them? What tectonic secrets do they reveal? Much has been learned since the first Penrose definition of an ophiolite. Multiple tectonic settings are now recognized and are summarized in this issue, and a geochemical basis is presented for their identification.

The classic localities of Oman and the Izu-Bonin-Mariana arc are described in detail. This issue also reports on the discovery of diamonds and an amazing array of reduced and exotic minerals in chromitites from several ophiolites.

The alteration of basaltic glass in ophiolites may even lead to the recognition of primitive life-forms on the seafloor of the early Earth.

The study of ophiolites and their mineralogy, petrology, and geochemistry, has never been more fascinating or relevant to mankind.” Excerpt from John Valley’s editorial **Playthings versus the Killer Rock?**



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AAG Office Manager Betty Arseneault Honored for 20 years of service

About 20 years ago, the AAG moved its core of operations from Vancouver to Ottawa, Canada and established a business office. Betty Arseneault, a friend and neighbour who happened to be running a day-care which my daughter attended, accepted the challenge of setting up that office in her house. This was no small task as there were many boxes of paperwork from Vancouver to sort through, a well functioning data-base to establish, and relationships to build with AAG members, publishing houses, bank staff, etc. She and my husband, Graeme Bonham-Carter, a geomathematician, spent many evenings setting up the Alpha 4 data-base.

Betty's enjoyment in and enthusiasm for the work were obvious, not just to those close by but to our Association members whom she would eagerly help, always with her very cheery disposition. The office became a well-run entity. Betty's husband, Al, gradually took over the accounting tasks and recently has taken over for Betty because her day-care business now demands so much of her time. A small gift of thanks from the AAG - a very



'Canadian' painted scene - was presented to Betty during a delicious restaurant dinner recently and will remind Betty of our heartfelt appreciation.

Gwendy Hall
Ottawa



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

Please let us know of your events by sending details to: Steve Amor, Geological Survey of Newfoundland and Labrador, P.O. Box 8700, St. John's, NL, Canada, A1B 4J6
Email: StephenAmor@gov.nl.ca

15-19 June 2014. 2nd International Symposium on Ethics of Environmental Health. Ceske Budejovice, Czech Republic. Website: www.iseeh2014.org

17-20 June 2014. 38th International Symposium on Environmental Analytical Chemistry. Lausanne Switzerland. Website: tinyurl.com/p4q2qgd

21-26 June 2014. Euroscience Open Forum. Copenhagen Denmark. Website: esof2014.org

29 June - 2 July 2014. 2nd International Conference on 3D Materials Science. Annecy France. Website: www.tms.org/Meetings/2014/3DMS2014

30 June - 4 July 2014. International Conference of the Society for Environmental Geochemistry and Health.

Newcastle-upon-Tyne UK. Website: www.segh.net/events/segh-conference/

7-10 July 2014. Australian Earth Sciences Convention, Newcastle NSW Australia Website: www.aesc2014.gsa.org.au

14-19 July 2014. Earth Sciences and Climate Change: Challenges to Development in Africa. Nairobi Kenya. Website: www.aawg.org

29-30 July 2014. Sampling 2014 (AusIMM). Perth WA Australia. Website: www.ausimm.com.au/sampling2014

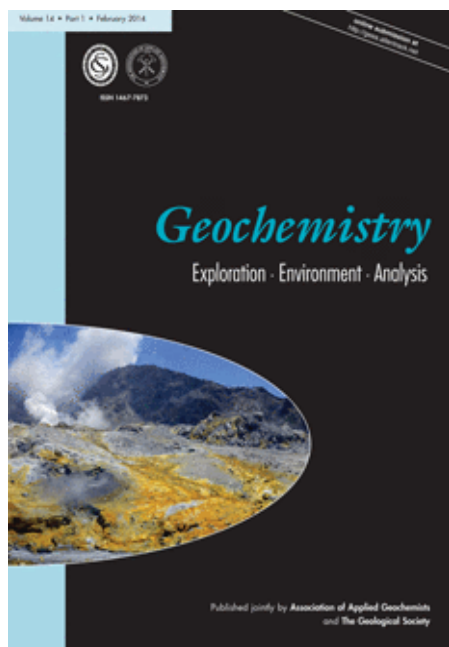
2-3 August 2014. Organic Geochemistry — Gordon Research Seminar/New Advances for Organic Geochemists. Holderness NH USA. Website: www.grc.org/meetings.aspx?year=2014

3-8 August 2014. Organic Geochemistry — Common Connections: The Processes That Link Past and Recent Systems. Holderness NH USA. Website: www.grc.org/meetings.aspx?year=2014

3-7 August 2014. Microscopy & Microanalysis 2014. Hartford CT USA. Website: tinyurl.com/mrtf48v

5-7 August 2014. Urban Geochemistry Working Group Meeting. Columbus OH USA. Website: www.iagc-society.org/queries/IAGC/UG/index.html

5-12 August 2014. 23rd Congress and General Assembly of the International Union of Crystallography. Montreal QC Canada. Website: www.iucr2014.org



Editor-in-Chief

Geochemistry: Exploration, Environment, Analysis

The Association of Applied Geochemists (AAG) and the Geological Society of London (GSL) are seeking to fill the position of Editor-in-Chief of their co-owned journal, *Geochemistry: Exploration, Environment, Analysis (GEEA)*. There would be a period of overlap with the current Editor early in 2015, with the new Editor taking full management in the later months of the year. GEEA is available online through GSL's Lyell Collection, GeoScienceWorld or the AAG; it was established in 2001 and is published quarterly (<http://www.geolsoc.org.uk/geea>). The Journal covers all aspects of the application of geochemistry relating to exploration for mineral deposits. Topics include: new and improved methods of geochemical exploration; geochemical mapping; sampling and analytical

techniques; processes of dispersion of elements in rocks, soils, vegetation, water and the atmosphere; differentiation of geogenic and anthropogenic sources; statistical methods applied to interpretation; and related environmental aspects.

The position requires a strong background in research in this field together with a substantial publication record. The Editor will be a good communicator and have a high degree of organizational skills and leadership ability. Building a network with geochemists in academia, industry and government is vital. The Editor is free to build their editorial team and to develop the optimal arrangement of associate Editors and board members to carry out a balanced and efficient procedure for reviewing, editing and general processing of papers. The Editor will be in frequent email communication with the journal's Production Editor in Bath, UK and will interact with the Director of Publishing of GSL and also with other journal Editors within the GSL to aid in the establishment of an integrated policy and publishing system.

This is an exciting, evolving time in publishing globally and you can make your mark! The rewards are many, such as the opportunities to: create your vision of GEEA and take the journal in new directions; produce special thematic issues on emerging technologies/methods; develop an extensive network and new relationships within the broad community of geoscientists; and foster integration of related disciplines.

Please send expressions of interest to Gwendy Hall (gwendyhall@gmail.com) for eventual review by a selection committee.



CALENDAR OF EVENTS

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11-13 August 2014. 4th International Conference on Environmental Pollution and Remediation. Prague Czech Republic. Website: icepr.org

11-14 August 2014. XII International Platinum Symposium Yekaterinburg Russia Website: tinyurl.com/qyle4lp

19-22 August 2014. 14th Quadrennial IAGOD Symposium Urumqi China. Website: www.14iagod.org/en

24-27 August 2014. 8th International Conference on Environmental Catalysis. Asheville NC USA. Website: www.icec2014.us/

25 August – 3 September 2014. EMU School 2014: Planetary Mineralogy. Glasgow UK. www.eurominunion.org

1-5 September 2014. 21st General Meeting of the International Mineralogical Association (IMA2014). Johannesburg South Africa. www.ima2014.co.za

4-7 September 2014. ERES-European Rare Earth Resources Meeting. Milos Island Greece. Website: <http://eres2014.conferences.gr/>

17-19 September 2014. ERA12: An International Symposium on Nuclear & Environmental Radiochemical Analysis. Bath UK. Website: tinyurl.com/on9vn9p

20-28 November 2014. Association of Environmental & Engineering Geologists 57th Annual Meeting. Scottsdale AZ USA. Website: <http://tinyurl.com/pv29nw8>

21-25 September 2014. Uranium Mining and Hydrogeology 2014 International Conference. Freiberg Germany. Website: tu-freiberg.de/umh-vii-2014

21-26 September 2014. IWA World Water Congress and Exhibition. Lisbon Portugal. Website: www.iwa2014lisbon.org

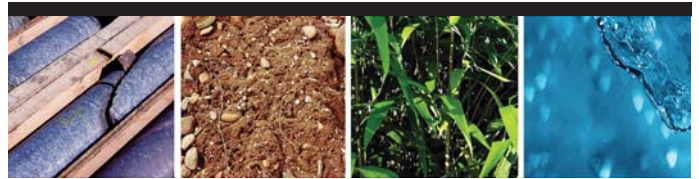
24-27 August 2014. 7th International Conference on Environmental Catalysis. Asheville NC USA. Website: www.efrc.lsu.edu/ICEC

1-5 September 2014. 21st General Meeting of the International Mineralogical Association (IMA2014). Johannesburg South Africa. Website: www.ima2014.co.za

24-26 September 2014. XX Congress of Carpathian Balkan Geological Association. Tirana Albania. tinyurl.com/kxegtd8 (Facebook)

27-30 September 2014. SEG 2014: Building Exploration Capability for the 21st Century. Keystone CO USA. Website www.seg2014.org

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17-20 October 2014. 16th Annual Conference of the International Association for Mathematical Geosciences. New Delhi India. Website: www.jnu.ac.in/Conference/IAMG2014/

19-22 October 2014. GSA 2014 Annual Meeting. Vancouver BC Canada. Website: www.geosociety.org/meetings/2014

20-24 October 2014. Introduction to Secondary Ion Mass Spectrometry in the Earth Sciences. Potsdam Germany. Website: <http://tinyurl.com/pfnj3qj>

17-22 November 2014 5th International Maar Conference. Queretaro Mexico. Website: <http://maar2014.geociencias.unam.mx/>

1-5 December 2014. American Exploration and Mining Association (formerly NWMA) Annual Meeting. Sparks NV USA. Website: www.miningamerica.org/annual-meeting-exposition/brochure/

20-24 April 2015. 27th International Applied Geochemistry Symposium. Tucson AZ USA. Website: <http://www.27iags.com>

27 July -2 August 2015. 19th INQUA Congress (Quaternary Perspectives on Climate Change, Natural Hazards and Civilization). Nagoya, Japan. Website: inqua2015.jp

2-6 August 2015. Microscopy & Microanalysis 2015. Portland OR USA. Website: www.microprobe.org/events/microscopy-microanalysis-2015

8-14 August 2015. Geoanalysis 2015. Leoben, Austria. Website: geoanalysis.info

16-21 August 2015. Goldschmidt 2015. Prague Czech Republic. Website: www.geochemsoc.org/programs/goldschmidtconference

20-25 September 2015. 8th Hutton Symposium on Granites and Related Rocks. Florianopolis Brazil. Website: www.hutton8.com.br

1-5 November 2015. GSA 2014 Annual Meeting. Baltimore MD USA. Website: www.geosociety.org/meetings/2015

26 June-1 July 2016. Goldschmidt 2016. Yokohama Japan. Website: www.geochemsoc.org/programs/goldschmidtconference

27 August – 4 September 2016. 35th International Geological Congress. Cape Town South Africa. Website: www.35igc.org



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M4P 1Y4 Canada
Membership No. 4117

Fiona Eddison
171 Fitzgerald Street,
West Perth, WA
6005 Australia
Membership No. 4146





Association of Applied Geochemists 27th INTERNATIONAL APPLIED GEOCHEMISTRY SYMPOSIUM

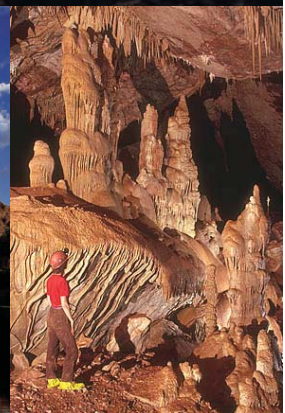


Registration begins May 2014

Pre-symposium field trips and short courses, keynote and technical presentations, plus an active social program will make this an IAGS to remember.



The Venue – Hilton El Conquistador



**Visit the IAGS website
www.27IAGS.com
for detailed information.**



AAG Student Support Initiative Analytical Support for BSc (Hons), MSc and PhD Students in Applied Geochemistry

In 2011, AAG implemented a coordinated program with analytical laboratories to provide In-Kind Student Support for applied geochemical research projects. We are off to an exciting start with several students currently being assisted, multiple laboratories participating, and the first student paper published in EXPLORE #157: "Particle size fractionation and chemical speciation of REE in a lateritic weathering profile in Western Australia". Ms. Xin Du is from University of Western Australia with Genalysis Laboratory Services (Intertek) sponsoring the analyses. The latest Student/Laboratory match-up is Markham Phillips from the University of Otago in New Zealand who is being supported by ALS Geochemistry in Vancouver, Canada on his research into "*Granite host and it's alteration suites as well as geochronology of gold bearing sulphide minerals*" in New Zealand.

Investment in Applied Geochemistry

The AAG Council believes that securing both the future of the Association and that of applied geochemistry requires attracting more students to the science. As an investment in the future, the AAG wishes to encourage and support students whose area of study is Applied Geochemistry. For students of applied geochemistry, a major cost component in any research is the geochemical analyses. AAG believes that by identifying appropriate students, using a set of simple criteria, and coordinating with analytical laboratories that are willing to offer support in terms of geochemical analyses, high quality research and training in fundamental geochemical principles can result. The research is then published through the AAG journal (*Geochemistry: Exploration, Environment, Analysis*) or the *EXPLORE* newsletter.

Laboratories Participating in the In-Kind Student Support Initiative

Four laboratories generously signed on to provide the analytical support to students during 2012; committing over \$35,000 in terms of analytical support:

- Becquerel Laboratories Inc., Mississauga, Ontario, Canada
- ALS Geochemistry, North Vancouver, BC, Canada
- Genalysis / Intertek, Gosnells, Western Australia
- Ultratrace / Bureau Veritas, Canning Vale, Western Australia

If your laboratory or student is interested in being a part of this program, please contact the chair of AAG's Education Committee, Erick Weiland (education@appliedgeochemists.org), who can provide you with details of this program. Student applications and instructions may also be found on the AAG web site: <http://www.appliedgeochemists.org/> student's page under the Student Support link.

Education Committee

Eric Grunsky, Ray Lett, Ryan Noble, Nigel Radford, Erick Weiland (Chair)



EXPLORE

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Formats for headings, abbreviations, scientific notations, references and figures must follow the Guide to Authors for *Geochemistry: Exploration, Environment, Analysis* (GEEA) that are posted on the GEEA website at: http://www.geolosc.org.uk/template.cfm?name=geea_instructions_for_authors

Submissions should be sent to:

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