



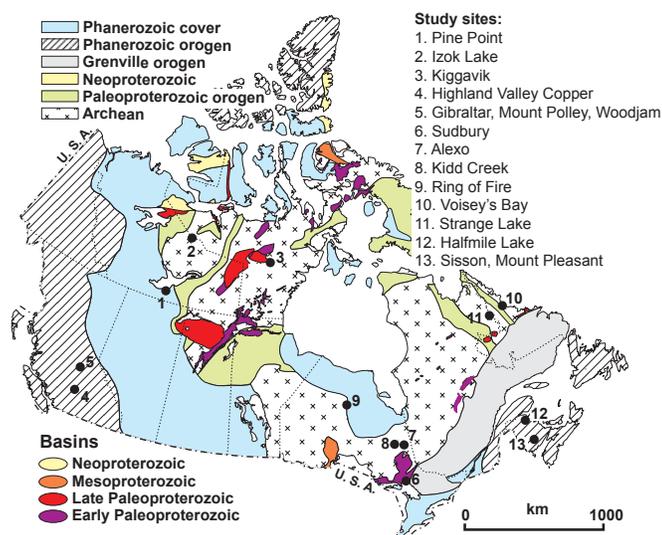
Overview of Indicator Mineral Research at the Geological Survey of Canada - An Update

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INTRODUCTION

This article provides an update on indicator mineral methods research conducted by the Geological Survey of Canada (GSC) since the last report in EXPLORE (McClenaghan et al. 2008). In the glaciated terrain of Canada, indicator mineral methods have been successfully applied to gold and diamond exploration for more than 30 years. The GSC's ongoing indicator mineral research program is focussed on other deposit types: porphyry Cu, magmatic Ni-Cu-PGE, intrusion hosted Sn and W, volcanogenic massive sulphides, Mississippi Valley-Type Pb-Zn, basement-hosted U, and rare metals. This research has been funded by the GSC's Targeted Geoscience Initiative (TGI) 3 Program (2005-2010) in partnership with Canadian Mining Industry Research Organization (CAMIRO, 2005-2008) and the British Columbia Mountain Pine Beetle Project (2007-2009), the TGI-4 Program (2010-2015), and the Geo-mapping for Energy and Minerals (GEM) Program (Phase 1 in 2008-2013; Phase 2 in 2013-2020). All GSC

Figure 1. Location of GSC indicator mineral test sites across Canada that are discussed in this article (base map modified from Potter & Wright 2015).



publications cited in this article can be downloaded free from the Natural Resources Canada website: <http://geoscan.nrcan.gc.ca>

METHODS

GSC's indicator mineral research has focused on both surficial (till, stream) sediments and bedrock samples collected around known mineral deposits. For the surficial studies, ore and host rocks (~1 kg) and till and stream sediment samples (15 kg) at varying distances up- and down-ice of known deposits were collected at various test sites across Canada (Fig. 1). Samples were processed at a commercial heavy mineral laboratory (Overburden Drilling Management Ltd.) in Ottawa to recover heavy (specific gravity >3.2), and in some cases mid-density (specific gravity 2.8-3.2), mineral concentrates for the identification, counting and analysis of potential indicator minerals. Concentrates were prepared using a combination of tabling and heavy liquids (Averill & Huneault 2006; McClenaghan 2011). Selected grains were photographed, examined using a scanning electron microscope (SEM) and Mineral Liberation Analysis (MLA), and analyzed by electron microprobe (EMP) to confirm the visual identifications and document their major and trace element signatures. In some cases, grains were further analyzed by laser ablation-ICP-MS to characterize their trace element signatures.

Protocols for the collection of till samples and for the processing of unconsolidated sediments for the recovery of indicator minerals were developed at the GSC to ensure quality assurance and quality control on all reported indicator mineral data (McClenaghan et al. 2013a; Plouffe et al. 2013a). These protocols include the use of field duplicate samples, blank samples (e.g. pure quartz) and base material (background till) spiked with known numbers, morphologies, species, and sizes of indicator minerals. Field duplicate samples are used to estimate sediment heterogeneity and/or variability at sampling site. Blank samples serve to detect potential carry-over contamination.

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Manuscripts should be double-spaced and submitted in digital format using Microsoft® WORD. Do NOT embed figures or tables in the text document. Each photo and/or figure (colour or black and white) should be submitted as separate high resolution tiff, jpeg or PDF (2400 resolution or better) file. Each table should be submitted as separate digital file in Microsoft® EXCEL format. All scientific/technical articles will be reviewed. All contributions may be edited for clarity or brevity.

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

In addition to the technical article, authors are asked to submit a separate 250 word abstract that summarizes the content of their article. This abstract will be published in the journal **ELEMENTS** on the 'AAG News' page.

Submissions should be sent to the Editor of **EXPLORE**:

Beth McClenaghan

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Notes from the Editor

The March 2016 issue of **EXPLORE** features a technical article about indicator mineral research at the Geological Survey of Canada and a second article about exploration geochemistry research at the University of British Columbia, Canada.

EXPLORE thanks all contributors to this first issue of 2016: Steve Amor, Dennis Arne, Al Arseneault, Pim van Geffen, Michel Houlié, Simon Jackson, Ryan Noble, Roger Paulen, Jan Peter, Alain Plouffe, Jamil Sader, and Peter Winterburn.

Beth McClenaghan, Editor

2016 AAG Dues Reminder

Reminder that AAG membership fees for 2016 are now due.

Membership fees can be paid on AAG's website (www.appliedgeochemists.org).



President's Message

For those members I have yet to meet, I am a Principal Research Scientist with CSIRO based in Perth, and have spent the past decade or so working on regolith and groundwater chemistry principally for mineral exploration. More recently I have also worked in geosequestration monitoring and experimental work (with gases and microbes); jack of all trades, master of none. At least I can say my research life is never boring.

Without fact checking and asking a number of my colleagues a personal question about their age, I believe I start my two year tenure as the AAG President as the youngest to hold this position (I just squeak in below 40). I am honoured to do this and whilst this may appear to be bragging, my actual motivation is to highlight the inclusive nature of the AAG.

It's really only been a bit more than 10 years from my initial contact with some prominent researchers within the AAG. These senior geochemists took the time to talk with me and really engage in "our" research field. The AAG is small enough for a "newbie" not to get lost or feel overwhelmed, the Association is relatively student focused, and the numerous informal mentors is something that makes the AAG stand apart from others, in my view. I'm not that far removed from those student years and I still recall being nervous going up to speak with these top researchers in their field. Time moves on and I now feel very comfortable talking to all our members and call many of those initial contacts friends, something that was enabled through the Association and its membership. I would encourage all student and junior members to be brave

and just go up and introduce yourself to those people that you have been recently citing in your thesis introduction or the like.

I would like to welcome and thank our new Councillors for 2016-2017 (Dave Cohen, Ray Lett, Tom Molyneux, Juan Carlos Ordóñez, Peter Rogers, and Peter Winterburn) and the new Vice President, Steve Cook. As many previous Presidents have written before, I am thankful for the support of our members and particularly those that put in a bit more time for the benefit of all. You have seen those names before, so I won't list them – our current Executive and Councillors, as well as those that serve on various AAG committees and our publications (**EXPLORE**, **GEEA**). While these people have sustained the AAG for many years we really must look to get more new faces into our membership and, importantly, involved in the Association. The work we do now will hopefully be for the benefit of the next generations of geochemists, so having our Gen X and more importantly our Gen Y/Millennials being part of this is critical, and will help shape an AAG that fits with the future needs of our younger geochemists.

So, if you are a student member or someone with only a couple of years experience, as depicted in the style of an Uncle Sam poster "I want you!"... to be a part of the AAG. Encourage your peers to join the AAG, attend our next IAGS and let me know if you want to be part of future AAG committees, action groups, social media, etc. Getting involved is easier than might be expected and is a great mechanism to build a solid network in a relatively short period, enhance career opportunities and to assist the greater science community.

This coming year should be an exciting one for the AAG. One where we look to revise our vision for the future of the AAG. Times change, people change and, importantly our society is changing to reflect this. Part of this evolution of the AAG will be to seek more feedback from our members on how we can improve our association and ensure its longevity. I would hope that many of you have seen and responded to the AAG survey that was sent around earlier this year. Your responses will form the base of the AAG's updated strategic direction, business plan and hopefully some new initiatives to improve the number and retention of members, and the value you gain from being part of the AAG.

If you missed your opportunity to provide feedback, my door (in Perth is not that close to many of you) or email is always open, so just let me know.

Finally, I would like to draw attention to the new **EXPLORE** feature "Geochemical Nuggets". This is the brainchild of Ray Lett and Dennis Arne to provide useful advice - particularly for the younger geochemists. If you or your colleagues have a "nugget" to contribute in 2016 it would be much appreciated and please contact Dennis, Ray, or the **EXPLORE** Editor to contribute to a future edition. We hope to make this a regular feature of each issue. I hope 2016 is a safe and prosperous year for you. An increase in commodity prices would surely be one way to assist many of our members to achieve this. Fingers crossed.

Ryan Noble, AAG President
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Overview of Indicator Mineral Research... *continued from page 1*

Spiked samples are used to monitor the accuracy of the sample processing and mineral identification methods for recovering specific minerals. See Plouffe et al. (2013a) for additional details.

TEST SITES

Porphyry Cu-Mo-Au Deposits

Orientation surveys were completed in British Columbia around two calc-alkaline Cu-Mo porphyry deposits (Gibraltar and Highland Valley Cu mines), one alkalic Cu-Au porphyry deposit (Mount Polley Mine) and one mixed calc-alkaline and alkaline Cu-Mo-Au porphyry prospect (Woodjam). The primary objective of these surveys was to define the mineralogical and geochemical signatures of Cu porphyry mineralization in till. These case studies were a collaborative effort between the GSC and the British Columbia Geological Survey, in cooperation with Taseko Mines Limited (Gibraltar), Imperial Metals Corporation (Mount Polley), Teck Resources Limited (Highland Valley Copper), and Gold Fields Limited with Consolidated Woodjam Copper Corporation (Woodjam).

Porphyry Cu indicator minerals in till at these study sites include the ore minerals chalcopyrite and gold, as well as alteration minerals epidote group (Fig. 2), andradite garnet, and apatite. Jarosite, a sulphate mineral typically associated to supergene alteration (Averill 2011; Kelley et al. 2011), was identified in till in the Mount Polley region

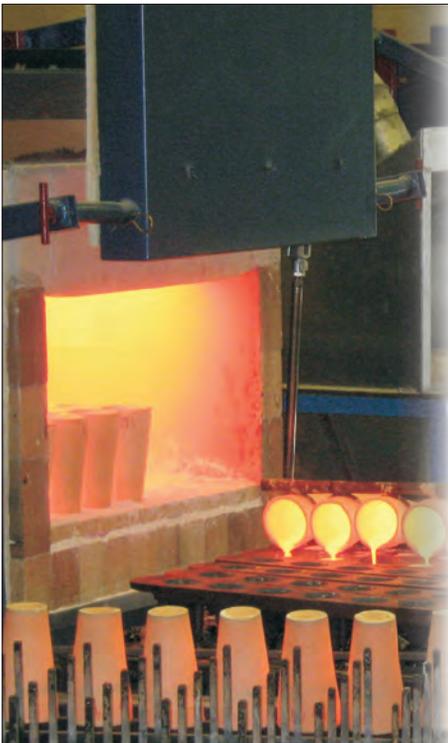
(Hashmi et al. 2015). Their distributions in till define glacial dispersal trains that extend up to several kilometres (i.e. > 2 km) down ice from mineralized bedrock. In some cases, dispersal trains extend in more than one direction and were formed by multiple phases of ice flow. Preliminary interpretations of the indicator mineral results are presented in Plouffe et al. (2013b; 2015) and Plouffe & Ferbey (2015a). Plouffe & Ferbey (2015b) provide a more detailed overview of the project highlights.

As part of this project, research on indicator mineral composition was completed for: magnetite (Grondahl, 2014; Piziak et al. 2015; Canil et al. 2016), tourmaline (Chapman et al. 2015a, b), and apatite (Rukhlov et al. 2016). Detailed study of epidote group minerals, titanite, and rutile is ongoing by C. Kobylinski at the University of Ottawa under the supervision of K. Hattori.

Intrusion-hosted Sn-W Deposits

Indicator minerals methods for Sn and W intrusion-hosted deposits were tested at the Sisson W-Mo and Mount Pleasant Sn-W-Mo-Bi-In deposits in eastern Canada. These case studies were a collaborative effort between the GSC, the New Brunswick Department of Energy and Mines, and the holders of the Sisson (Northcliff Resources Limited, Hunter Dickinson Inc.) and the Mount Pleasant (Adex Mining Inc.) deposits, and Laurentian University.

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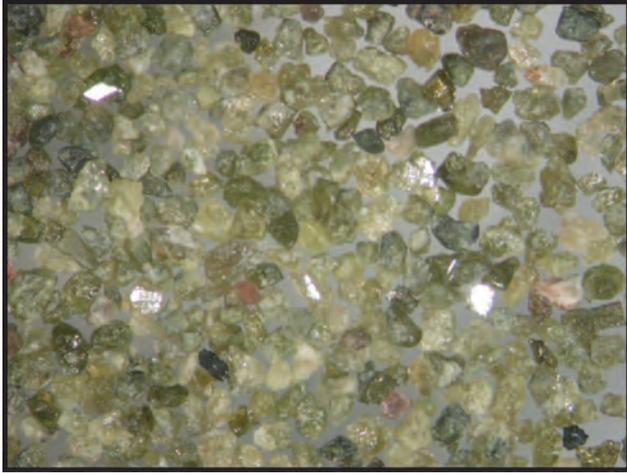
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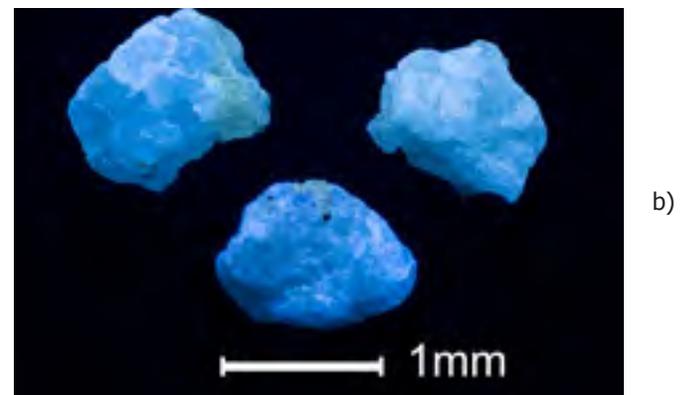
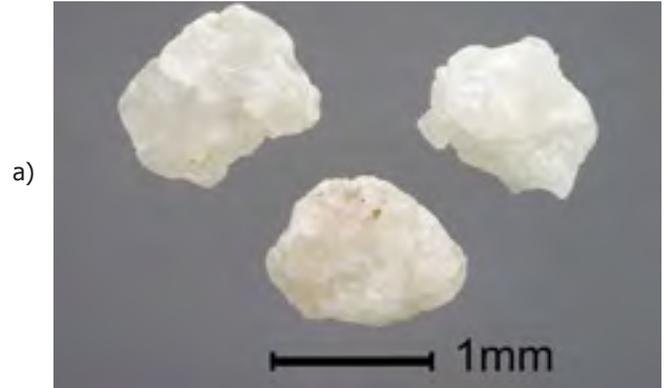
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Figure 2. Colour photograph of the 0.25-0.5 mm non-ferromagnetic heavy mineral (>3.2 SG) fraction of a till sample from the Woodjam occurrence in western Canada. Epidote group minerals make up about 80% of this concentrate (modal, +/- 10%). The width of view is 5 mm.



Indicator minerals of the Sisson deposit identified in mineralized bedrock, till, and stream sediments include scheelite (Fig. 3), wolframite, molybdenite, chalcopyrite, Bi minerals (joseite, native Bi, bismutite, bismuthinite), galena, sphalerite, arsenopyrite, spessartine, pyrrhotite, and pyrite. Indicator minerals of the Mount Pleasant deposit identified in mineralized bedrock and till include cassiterite, wolframite, molybdenite, topaz, fluorite, galena, sphalerite, chalcopyrite, galena, arsenopyrite, pyrite, and loellingite.

Figure 3. Colour photographs of scheelite grains recovered from till overlying the Sisson W-Mo deposit in eastern Canada: a) visible light; b) short wave ultraviolet light. Photographs by Michael Bainbridge.



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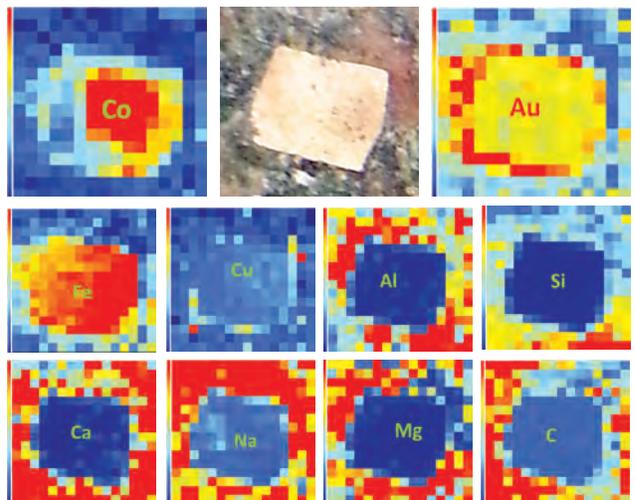
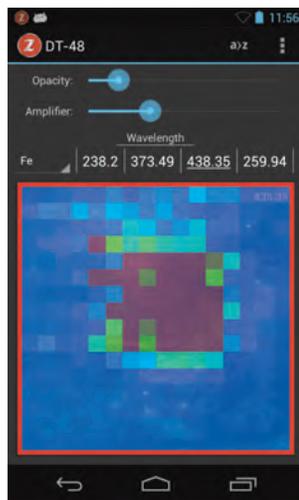
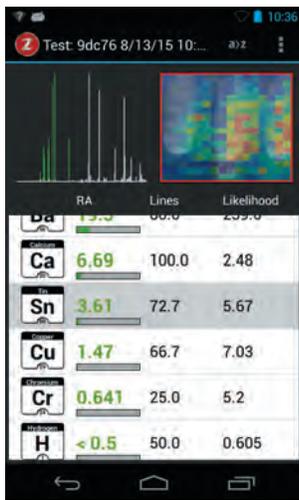
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Rare secondary indicator minerals in till include beudantite, anglesite, and plumbogummite which formed by oxidation and weathering of the galena. The extensive suites of indicator minerals for each deposit reflect their polymetallic natures and the ability of modern indicator mineral methods to recover these minerals. Detailed results of the Sisson study are reported in McClenaghan et al. (2013b,c; 2014a; 2015a,b) and Thorne et al. (2014) and the Mount Pleasant study in McClenaghan et al. (2014b,c; 2015a,c,d) as well as the TGI-4 Intrusion-hosted Deposits summary volume (Rogers 2015).

The relationship between scheelite mineral chemistry and its cathode luminescence (CL) response was investigated to develop criteria for discriminating scheelite from different deposit types (e.g. porphyry related greisens, skarn, orogenic Au, VMS). These criteria can help identify potential bedrock sources of scheelite grains that are recovered as part of standard stream sediment and till indicator mineral surveys. Results will be reported by Poulin et al. (in press).

Volcanogenic Massive Sulphide Deposits

Indicator minerals methods were tested at the Izok Lake Zn-Cu-Pb-Ag volcanogenic massive sulphide (VMS) deposit, one of the largest undeveloped Zn-Cu VMS resources in North America. This case study was a collaborative effort between the GSC, Queen's University, Université Laval, the property holder, MMG, and Overburden Drilling Management Ltd. At the same time, GSC research continued on indicator mineral signatures of the Halfmile Lake VMS deposit in the Bathurst Mining Camp of New Brunswick.

Till samples down ice of the Izok Lake deposit contain chalcopyrite, sphalerite, galena, and pyrite as well as gahnite (ZnAl_2O_4). Gahnite is an ideal VMS indicator mineral in till because of its occurrence in highly metamorphosed VMS deposits such as Izok Lake. It has a visually distinctive bluish green colour (Fig. 4), a high specific gravity (4-4.6) (ideal for recovery using density-based separation methods), moderate hardness (physical durability during glacial transport), and chemical stability in oxidizing surficial environments (resistance to post glacial weathering). Glacial dispersal of gahnite can be traced at least 40 km down ice of the deposit. Detailed results of the Izok Lake study are reported in McClenaghan et al. (2012a; 2013d;

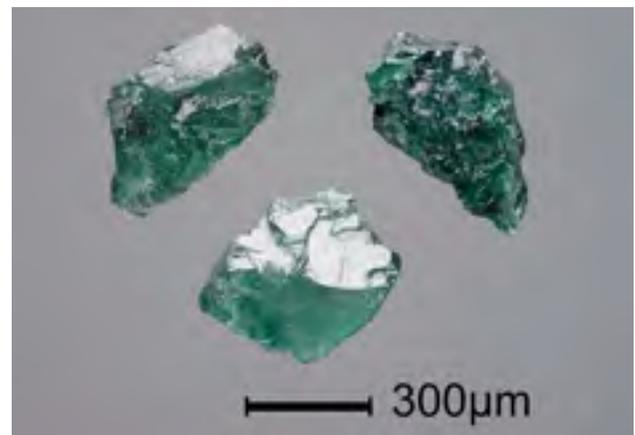
2014d; 2015e), Hicken et al. (2013a,b) and Paulen et al. (2013).

Till down ice of the Halfmile Lake VMS deposit contains chalcopyrite, pyrite, gold, cinnabar and gahnite. The presence of a preglacial gossan overlying the deposit is reflected in the recovery of secondary minerals in the till down ice: beudantite, jarosite, and goethite, (Budulan et al. 2015; McClenaghan et al. 2012b).

The GSC also contributed to the investigation of magnetite chemistry in VMS deposits and in till down ice. The study focused on bedrock and till samples from the Izok Lake and Halfmile Lake deposits. Results are reported in Makvandi et al. (2015, 2016) and highlight the different chemical compositions of magnetite in massive sulphide ore, alteration zones, and pre-glacial gossans.

The application of laser-ablation ICP-MS analyses was tested as a potential vectoring tool, using pyrite from metalliferous black shales of the Kidd-Munro assemblage proximal and distal to the 2.7 Ga Kidd Creek VMS deposit (Chapman et al. 2009, 2010, 2011) under the GSC's TGI-3 Program. Multiple generations of this pyrite range from syn-ore through diagenetic to metamorphic. Trace elements of hydrothermal origin (as determined by LA-ICP-MS) in the syn-ore pyrite are Ag, Au, As, Bi, Cu, Pb, Sb, Sn, Tl, and Zn; these element enrichments are generally greater than in the diagenetic and metamorphic pyrites. The element enrichment suite Co, Ni, Mo, Se, Pt, and Te is attributed to seawater (hydrogenous). Hydrothermal element enrichments as determined by LA-ICP-MS provide much more localized, specific exploration targets than whole-rock analyses of drill core or portable XRF analyses of ≈ 1 cm diameter pyrite grains or aggregate grains. The much more precise LA-ICP-MS analyses target syn-ore pyrite and thus avoid the diagenetic and metamorphic pyrite that generally has lower trace element contents which dilute the whole-rock and portable XRF analyses.

Figure 4. Colour photograph of gahnite grains recovered from the 0.25-0.5 mm non ferromagnetic heavy mineral fraction of till samples down ice of the Izok Lake VMS deposit, northern Canada. Photograph by Michael Bainbridge.





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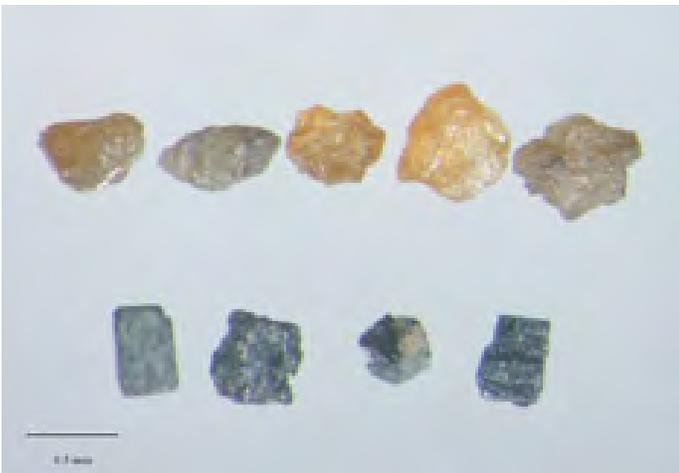
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Mississippi Valley-Type Deposits

The Pine Point Pb-Zn Mining District in northern Canada was used to test indicator minerals methods for Mississippi Valley-Type Pb-Zn deposits. This research was a collaborative effort between the GSC, University of Alberta, Teck Resources Ltd., Tamerlane Ventures Ltd., and Overburden Drilling Management Ltd.

Till derived from these deposits has a carbonate-rich matrix that buffers the till while it oxidizes and allows the ore minerals galena and sphalerite (Fig. 5) to survive post glacial weathering. Lead isotopic studies of individual galena and sphalerite grains in bedrock and till demonstrated that isotopic analyses can help identify the up ice presence of a buried MVT deposit. Detailed results of this study are reported in McClenaghan et al. (2012c) and Oviatt et al. (2013; 2015).

Figure 5. Honey sphalerite (top row) and black cubic galena grains (bottom row) recovered from till down ice of the N-41 deposit in the Pine Point Mining District, northern Canada. Photograph by Overburden Drilling Management Ltd.

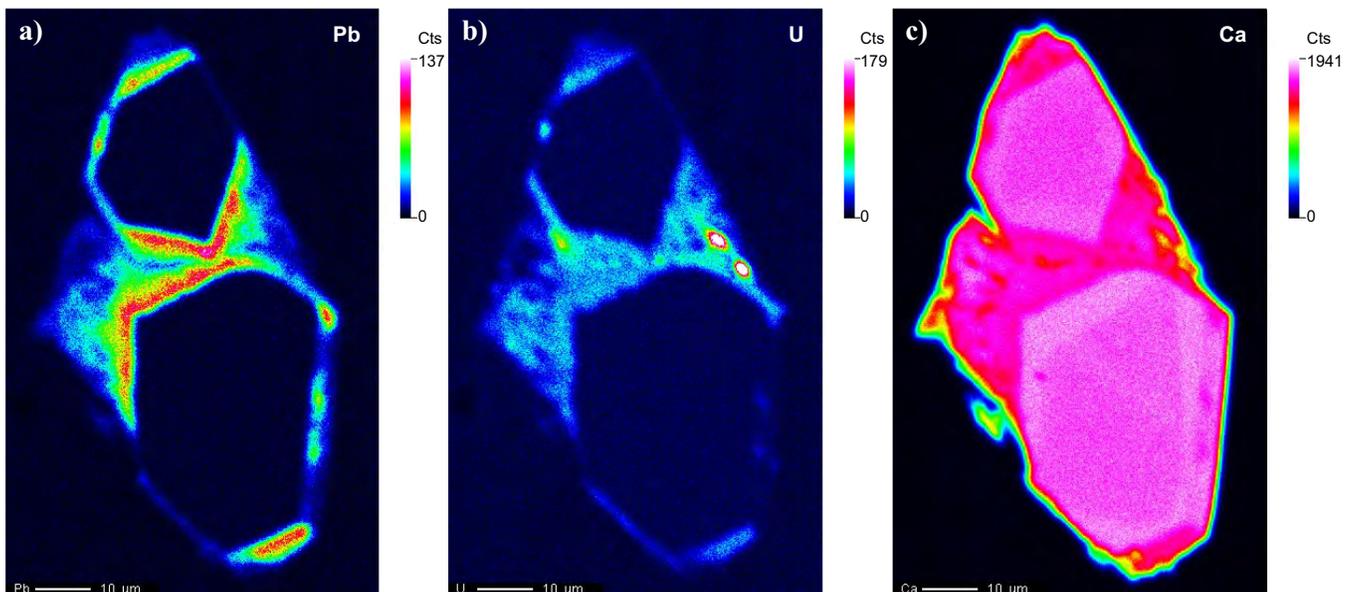


Uranium deposits

The Kiggavik U deposits beside the late Paleoproterozoic Thelon Basin of northern Canada were the focus of a study on indicator mineral and till geochemistry of basement-hosted U deposits in the Canadian Arctic. This research was a collaborative effort between the GSC, Queen's University, AREVA Resources Canada and Overburden Drilling Management Limited. Uraninite is the main ore mineral at Kiggavik, along with less abundant U minerals such as coffinite and uranophane.

GSC results show that uraninite is poorly suited to be an indicator mineral in till for the Kiggavik style of unconformity U deposits because it is too easily oxidized and too fine grained (>250 µm) to be recovered by traditional heavy mineral processing methods (Robinson et al. 2014, 2016). The discovery of Pb+U-rich fluorapatite (Fig. 6) in the Kiggavik Main Zone however, is intriguing because it has not previously been reported as a component of basement-hosted unconformity-related U deposits. Such fluorapatite has significant potential for improving geochronological constraints on the timing of U mineralization; it may be unique to such deposits and, as a stable, durable, moderately heavy mineral, it could be used as an indicator mineral in till derived from the highly altered, weakly mineralized bedrock halo around basement-hosted unconformity-associated U deposits. Challenges for using the Pb+U-rich fluorapatite as an indicator mineral are mainly its small (silt) size and its density, which is the usual density threshold for routine heavy liquid separation (SG 3.2) (McClenaghan 2011).

Figure 6. X-ray map of a single composite fluorapatite grain in bedrock illustrating two euhedral cores that are connected by overgrowths into a single larger euhedral crystal with compositional zonation of (a) Pb, (b) U, and (c) Ca. The sharply-defined outer portions of the grain correspond to the fibrous textured zones rich in Pb and U, and are depleted in Ca. The cores show subtle Ca zonation and an absence of Pb and U (from Robinson et al., 2016).



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Ni-Cu-PGE-Chromium Ore Systems

A decade ago, the GSC initiated numerous studies to characterize indicator mineral signatures in surficial sediments for several types of mineral deposits including magmatic Ni-Cu-PGE deposits in the Thompson Ni Belt (McClenaghan et al. 2012e, 2013d; Dupuis et al. 2012) and Sudbury (Ames et al. 2013; McClenaghan & Ames 2013). These studies identified several suites of indicator minerals in surficial sediments that are useful exploration tools.

In the course of the recently completed TGI-4 Program, new exploration techniques to detect fertility of mafic and ultramafic systems using advanced microanalytical mineral chemistry techniques were developed for oxide phases (chromite, magnetite, ilmenite) in barren and fertile intrusions through examination of Canada's well known Ni-Cu-PGE districts (Sudbury Igneous Complex, Ontario; Voisey's Bay, Labrador and Newfoundland) and Archean komatiite (Alexo, Abitibi-Ontario; McFaulds Lake—"Ring of Fire", Ontario). Oxide phases are quite common in mafic and ultramafic systems, host almost all Ni-Cu-PGE deposits, are extremely resistant and survive post-magmatic processes. For example, Pagé et al. (2015) have proposed binary diagrams such Ni/Mn versus Ni/Cr ratios of the chromite composition that can be used to discriminate processes such as sulphide segregation prior to chromite crystallization vs. superimposed alteration (Fig. 7A).

A large chromite anomaly identified in stream sediments of the McFaulds Lake region («Ring of Fire») of northern Ontario (Crabtree, 2003) reflects heavy mineral contributions from large mafic intrusive complexes. More recently, the re-investigation of these chromite compositions by Burnham et al. (2012) led them to suggest at least nine compositional groups that show spatial associations with the bedrock geology. These chromite compositional associations could better identify fertile mafic and ultramafic intrusions and improve targeting for Cr, Ni-Cu-PGE, and V exploration. Magnetite and ilmenite can also record sulphide saturation through Ni and Cu depletion in Fe-oxides (magnetite, ilmenite), thus distinguishing fertile from barren intrusions (Dare et al. 2015) (Fig. 8). Also, new research highlights apatite, biotite, and epidote-actinolite and their distinctive trace element compositions that can assist with vectoring toward buried Ni-Cu-PGE and Cu-PGE deposits in magmatic mafic and ultramafic systems (i.e. apatite: Shahabi Far et al. 2015; biotite: Hanley et al. 2015; Warren et al. 2015; chlorite: Brzozowski et al. 2015; epidote-actinolite: Ames & Tuba 2015). More exhaustive results on these studies are summarized in a TGI-4 project synthesis volume (Ames & Houlié 2015).

Figure 7. Plot of Ni/Mn versus Ni/Cr for chromite from komatiite near the Alexo Mine and the Hart deposit (from Pagé et al., 2015). Abbreviations: Oc = olivine cumulate; OPc = olivine + pyroxene cumulate; O spinifex = olivine spinifex; diss sulph = disseminated sulphide; P spinifex = pyroxene spinifex; sulph = sulphide.

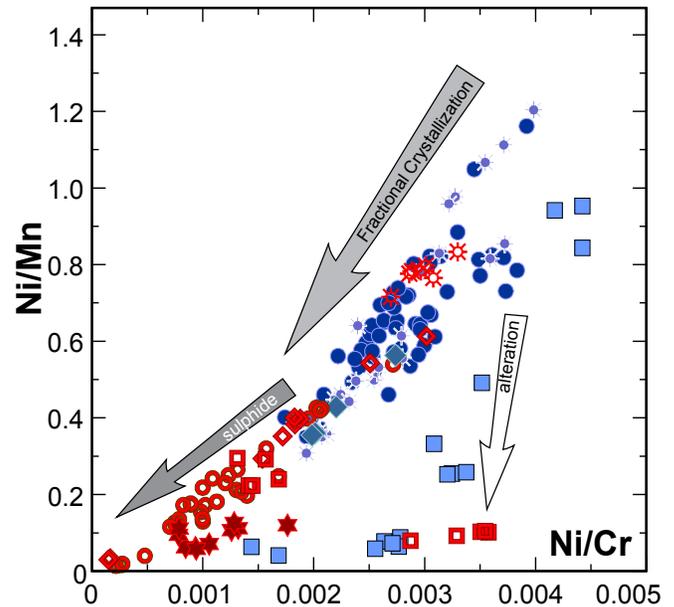
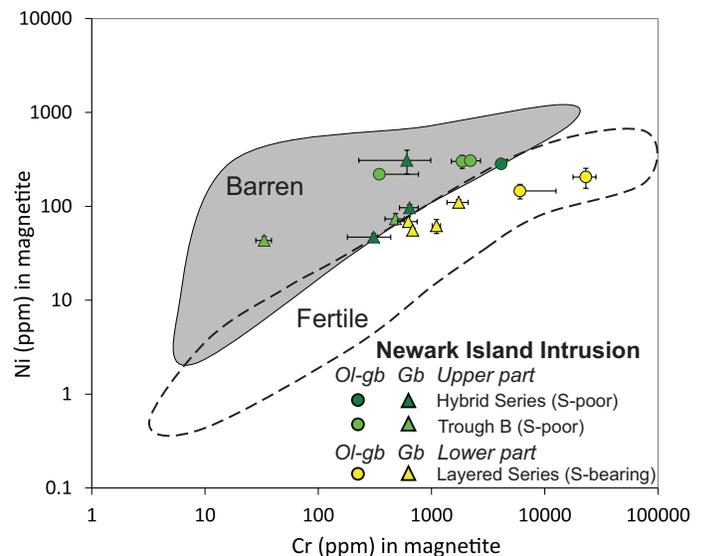


Figure 8. Ni versus Cr in magnetite from the supposedly barren Newark Island intrusion (from Dare et al. 2015). The barren field is based on mafic igneous complexes that lack significant Ni sulphide concentrations whereas the fertile field is from the Sudbury Igneous Complex.



Rare Metal deposits

The Strange Lake rare earth element (REE) deposit in northeastern Canada is the current focus of GSC GEM-2 indicator mineral studies to further develop methods for REE exploration in northern Quebec and Labrador. This research is collaborative between the GSC, and Laurentian

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University in collaboration with Quest Rare Minerals Ltd. GSC collected till samples along the length of the deposit's known 40 km glacial dispersal train defined by Batterson (1989). These samples are currently being examined to determine the indicator mineral suite in till that best reflects the deposit.

Analytical Method Developments

The Inorganic Geochemistry Research Laboratory at the GSC has developed a variety of *in situ* elemental and isotopic measurement techniques for common resistate indicator minerals using laser ablation (LA) sampling coupled with ICP-MS and MC-ICP-MS detection. Development and application projects have included apatite, chromite, epidote (Tuba & Ames 2015), gahnite (O'Brien et al. 2015a,b), garnet (Riches et al. in press), magnetite, pyrite (Jackson et al. 2013; Gao et al. 2015), tourmaline (Chapman et al. 2015a,b) and zircon (Jackson & Chapman 2012; Chapman et al. 2012; Shen et al. 2015). Particular emphasis has been placed on development of procedures for, and applications of, process-sensitive minerals (e.g., zircon), elements (e.g., REE), isotopes (e.g., Fe in magnetite) and other parameters (magma oxidation state and emplacement age). Unique, high-resolution, quantitative 2-D element mapping techniques have also been developed that provide a wealth of information on complex geochemical histories of the target minerals (e.g., Jackson et al. 2012, 2013; Gao et al. 2015).

An excellent example of the power of combining analytical approaches (elemental, isotopic and 2-D mapping) in indicator mineral analysis is provided by a recent study of the potential of zircon trace element data to determine the Ce^{4+}/Ce^{3+} ratio of zircon. Zircon Ce^{4+}/Ce^{3+} ratio is a proxy for the oxidation state of the host magma, which in turn controls its prospectivity for porphyry Cu deposits. Techniques for *in situ* trace determination and 2-D mapping of trace element, U-Pb age and Ce^{4+}/Ce^{3+} ratios in zircon were developed (Jackson & Chapman 2012; Chapman et al. 2012) and applied to a number of Cretaceous and Jurassic intrusions in the southwest Yukon. These studies demonstrated that zircon Ce^{4+}/Ce^{3+} ratios successfully fingerprint the mineralised intrusion that hosts the Cretaceous Casino deposit, clearly distinguishing it from barren intrusions in the same area. The application of Ce^{4+}/Ce^{3+} ratios to the exploration of Jurassic plutons is more complicated. However, element mapping has revealed a strong sector zoning control of REE substitution in zircon, which affects the calculated Ce^{4+}/Ce^{3+} ratio and demonstrates that ubiquitously high Ce^{4+}/Ce^{3+} ratios are apparently related to an early magma oxidation event.

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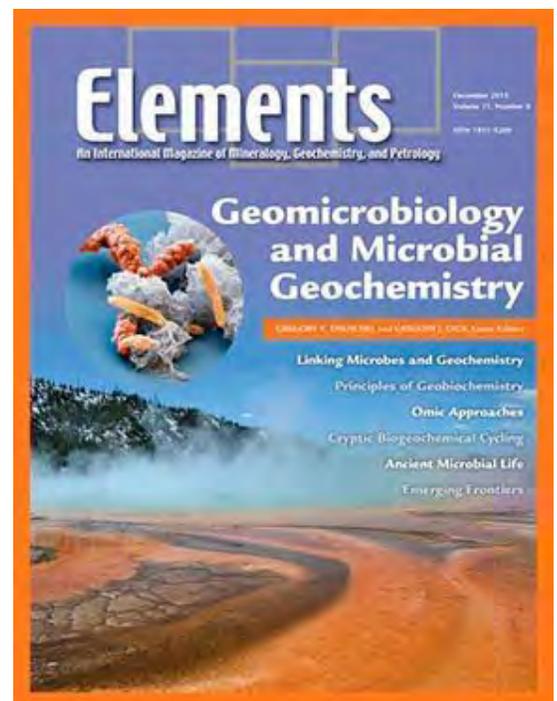
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Recently Published in Elements

Volume 11, no. 6, Geomicrobiology and Microbial Geochemistry

The December edition of *Elements* focuses on geomicrobiology and role of microbes in geochemistry. It starts with an overview of geomicrobiology and microbial geochemistry (Druschel & Kappler). Shock & Boyd provide the principals of geobiogeochemistry, followed by a discussion of omic approaches to microbial geochemistry (Dick & Lam; note omics refers to “Omics aims at the collective characterization and quantification of pools of biological molecules that translate into the structure, function, and dynamics of an organism or organisms.” Wikipedia, January 31, 2016). Hansel, Ferdelman and Tebo review cryptic cross-linkages among biogeochemical cycles, with a discussion of novel insights from reactive intermediates. Emerging biogeochemical views of Earth’s ancient microbial worlds are discussed by Lyons, Fike & Zerkle. The issue finishes with a review of emerging frontiers in geomicrobiology (Templeton & Benzerara). This is a rapidly evolving area of research with implications for the way we few geochemical processes from both an exploration and environmental perspective. There is no AAG Society News in this issue of *Elements* due to an overabundance of material. Instead, we will have a double spread in the first issue of Volume 12, due out in February.



Exploration Geochemistry Initiative at the Mineral Deposit Research Unit, University of British Columbia, Canada.

Peter A. Winterburn, NSERC-Bureau Veritas Minerals Industrial Research Chair in Exploration Geochemistry, Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Earth Sciences Building 2020 - 2207 Main Mall, Vancouver, BC, Canada, V6T 1Z4, Email: pwinterburn@eos.ubc.ca

The University of British Columbia (UBC) had been a leader in exploration geochemistry with a rich history for more than 60 years. Professor Harry Warren (Emeritus 1974) was a pioneer in the development of the discipline, in particular analytical techniques and exploration strategies since the 1930s. He established interdisciplinary geochemical studies by linking biology, geology and chemistry, and evaluated soils, plants and animals as geochemical representatives of the earth and its underlying resources. Professor Alistair Sinclair (Emeritus 1999) contributed significantly to the development of numerical and statistical applications of Exploration Geochemistry data. Professor 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.

Representation of Exploration Geochemistry on the faculty at UBC was a casualty of retrenchments and evolving research priorities. UBC, however, remains a global leader in analytical environmental and solid earth geochemistry. Recognizing the challenges faced by this discipline and the mineral exploration industry, the industry-led MDRU Board of Directors took an active leadership role to develop and implement the MDRU Exploration Geochemistry Initiative.

Significant funding for the initiative was obtained through generous support of Dean Toye, founder of ACME Analytical Laboratories and has been consolidated through continuing financial support from Bureau Veritas Minerals, who acquired ACME in 2013; along with John Gravel and Newmont Mining. Additional funding for the initiative was received from NSERC in 2015 in support of the program as the NSERC/Bureau Veritas Minerals Industrial Research Chair in Exploration Geochemistry.

The initiative has three key objectives:

- Provision of leadership and innovation to establish a world-class research foundation in the field of exploration geochemistry including project design, graduate student supervision, interaction with industry and contributions to undergraduate and graduate teaching within the university.
- Establishment of a robust research program to understand element mobility and transport through the surficial environment, specifically from buried and blind deposits, and to develop foundations for new mineral exploration techniques and strategies.
- Provision of education, training and professional development opportunities through mentoring, lectures, labs, short courses and workshops.

This research program under the initiative is directed at the fundamental questions of:

- How do anomalous responses form directly above mineralisation in young transported till cover?
- What are optimal methodologies that can be applied to their detection?
- How can we filter out the ambient environmental background variability to ensure robust identification of anomalies?

The research program formally commenced in November 2013 with the arrival of Dr. Winterburn as the program leader at UBC. Dr. Winterburn came to the position with over 25 years of experience in senior positions within the minerals industry, with a strong focus on mineral exploration. He most recently served as Chief Geochemist with Vale; and in various roles ranging from Regional Geochemist in Africa and South America, Chief Chemist (mine and Metallurgical auditing) and Manager: Exploration Geochemical Laboratory during 18 years with Anglo American. The combination of experience within the mining industry and research expertise provides a valuable perspective for the initiative.

A robust research program, which formed the backbone of the successful NSERC application, is in progress. The Research Chair currently funds three M.Sc. student projects with an additional 2 M.Sc. students funded through the industry sponsored CMIC-Footprints Project and the MDRU Atacama Desert Project (Fig. 1). In 2016, it is intended to expand the core program further through the NSERC/Bureau Veritas Minerals funding with an additional M.Sc. stu-



Figure 1. Exploration Geochemistry Research Group undergoing in-field training at the Lara Deposit, Vancouver Island, BC, Canada in mid 2015. From left to right: Rachel Chouinard (Highland Valley Copper, BC); Ally Brown (Atacama Desert, Chile); Peter Winterburn (Research Chair); Shane Rich (Deerhorn Porphyry, BC); Erika Cayer (DO-18 Kimberlite, NWT); Matthew Bodner (Lara VMS, BC) and Tim Armitage (Field Assistant).

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Exploration Geochemistry Initiative... *continued from page 16*

dent, 2 additional students at the Ph.D. level and a portion of a Post Doctoral Fellowship (PDF). The initial program commenced with 3 students at the M.Sc. level evaluating geochemical responses in till covered areas from underlying massive sulphide (VMS), disseminated sulphide (porphyry), and non-sulphide (kimberlite) mineralization. At each site, “regolith mapping”, pH, Eh and profile mapping was undertaken along with careful grid based geochemical sampling of selected horizons and a Spontaneous Potential survey. In addition an Amplified Geochemical Imaging Survey (previously Gore-Sorber) was undertaken at each site to detect and characterize hydrocarbon responses.

Matt Bodner (M.Sc. Candidate) is currently working on soil geochemistry of relatively thin tills (5-10 m) above the Lara-Coronation polymetallic VMS deposit on Vancouver Island (Fig. 2). Examination of geochemical data taken in a grid over the mineralisation extending into background has



Figure 2. Matthew Bodner with a carefully prepared field kit and sampling hole undertaking direct and slurry measurements at the Lara Project, Vancouver Island, BC.

identified a clear, though subtle multi-element anomalous response. The field area is densely forested and a variety of potential routes have been identified for the generation of the anomalous response including cycling through vegetation, transportation of material in the till and ion migration directly from mineralization. A variety of methods are currently being applied such as vegetation sampling, detailed soil profiling and Cu and Pb isotopes to identify the source of the response. This area is expected to be deforested later this year, which will provide the opportunity to document

the effects on surface geochemistry of the deforestation process.

Shane Rich (M.Sc. Candidate) is tasked with seeing a porphyry system through 40-60 m of till at the Deerhorn Porphyry, part of the Woodjam Porphyry Cluster (Fig. 3).



Figure 3. Shane Rich (right) presenting initial results of the influence of geomorphology, till materials and soil organic carbon on the surface geochemistry at the 27th Goldschmidt Conference in Prague, 2015.

Use of a detailed regolith map has enabled clear delineation of anomalous responses caused by other actions such as accumulation of organic debris in swamps. Normalisation of the geochemical data against organic carbon provides an effective means of removing some of the false-positive results. Research to date has indicated a large alkali halo in the surface around the porphyry as well as a spotty multi-element response. Pb and Cu- isotopes will be applied to clarify the source of the response and distinguish the response from clastic material derived from other porphyries within the cluster. Here in particular, the multi-element grid sampling approach has generated a much more robust response that a single orientation line survey would have provided.

Erika Cayer (M.Sc. Candidate) spent a busy 3 weeks at the DO-18 Kimberlite (Peregrine Diamonds) in the Northwest Territories (Fig. 4), with considerable logistical support provided by the Northwest Territories Geological Survey as part of their Slave Province Surficial Materials and Permafrost Study. Combining the geochemical data with surface landscape and materials has delineated a clear geochemical anomaly in typical kimberlite indicator elements such as Ni, Nb, Cr and Mg, extending down ice from directly over the buried kimberlite. Two clearly distinct surface regimes separated by an escarpment occur over the kimberlite with only one of these regimes at higher elevations showing a strong anomalous response. Research is currently focusing on clarifying the differences between the two regimes and determining whether a more subtle anomalous response

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Exploration Geochemistry Initiative... *continued from page 17*



Fig 4. Erika Cayar and Rachel Gavin (field assistant) collecting samples at the DO-18 Kimberlite, Slave Province, NWT, Canada.

can be extracted from the subdued area. Subject to a phase II initiation of the Slave Province Surficial Materials Project, it is intended to commence a 2nd M.Sc. student to both extend the research grid at DO-18 to fully document the geochemical dispersion as well as test a range of other concealed kimberlites with differing surface conditions and materials.

Through a Canadian Mitacs Scholarship, Ana Christina Lopez Lopez, a chemical engineer from the Universidad De Guanajuato, Mexico, joined the research group for 3 months in summer 2015 with a B.Sc. project to better understand the variability of various soil geochemical parameters at a local scale in addition to the variability of the actual measurement process themselves. The results from her research are currently being compiled for publication.

This research program is to be extended through a Ph.D. student undertaking a detailed assessment of the deportment of trace metals in the sample suites from a mineralogical, speciation and theoretical perspective and a Ph.D research student investigating the relationship between organic compounds at the surface and non-petroleum mineral deposits.

In conjunction with Thomas Bissig of MDRU and industry sponsorship, a 3 year project is being undertaken on novel exploration geochemical techniques for the discovery of porphyry copper and related exotic copper deposits in the Atacama desert of Northern Chile. To date, M.Sc. student, Ally Brown has completed a geomorphological assessment coupled with sampling at the Atlantida porphyry Project close to Copiapo (Fig. 5), whilst Thomas has been undertaking some innovative sampling above an exotic copper deposit.

As part of the Canadian Mining Innovation Council (CMIC) footprints project, Rachel Chouinard is evaluating geochemical responses to mineralization at the Teck Resources Ltd., Highland Valley Copper Mine in Central BC. Two concealed targets are being study, one buried below 5-10 m of till and the other below >150 m of pre-glacial and glacial sediments. Both targets present interesting challenges, not only because of the depth of one of the targets,



Fig. 5. Peter Winterburn, Ally Brown (left) and Samantha Scher – QPX Ltda. (right) examining surface profiles in the Atacama Desert, N. Chile.

but also because of the proximity of both to historical and existing mine operations.

A research proposal is currently in preparation to evaluate the application of Genomics in mineral exploration for concealed deposits. Whilst Genomics as a science has progressed rapidly over the last decade, there has to date been little attempt to evaluate its applicability to exploration in areas where robust geochemical anomalies are absent. This research program, to be initiated through a PDF, will also review the relationship between Genomics and hydrocarbon signatures to consolidate the relationship between inorganic and organic geochemical processes, physical processes and microbiological processes.

Several other initiatives are currently at the conceptual stage and are being prepared for grant application with a direct industry input. As with all MDRU activities, the Exploration Geochemistry Initiative has strong links with industry, having been initiated, funded and supported directly by industry. The group has regular technical meetings with all facets of the minerals exploration industry including service groups, mining and exploration companies and exploration consultants. As an industry driven initiative with ongoing collaborative support, the research is aimed to directly provide answers and solutions to the problems of discovery through cover.

The EGI research group acknowledges support from the Natural Sciences and Engineering Research Council of Canada (NSERC), Bureau Veritas Minerals, Dean Toye, John Gravel, Newmont, Peter Bradshaw, First Point Minerals, Anglo American, Vale, Olympus Innov-X, Heberline Geoconsulting, Smee and Associates Consulting Ltd., and Chris Benn Consultants. Peregrine Diamonds, Treasury Metals Inc. and Consolidated Woodjam are acknowledged for technical support and access to the research targets at DO-18, Lara and Woodjam.

Contact with the EGI group can be made through Dr. Peter Winterburn at pwinterburn@eos.ubc.ca.



Geochemical Nuggets

New Feature



Treat your bulk reference materials with care... (and a healthy scepticism)!

It's tempting to purchase certified reference materials (CRMs) in bulk in order to save money. However, this should only be done if the use of the material is sufficient to turn it over at a high frequency. This is particularly important for sulphide CRMs which may undergo oxidation during storage.

Figure 1 illustrates an example where a laboratory was using a bulk Ni CRM in a large jar that they had had for several years. Coincidentally, the client was also submitting the same CRM for analysis, but these were purchased in small aliquots in sealed packets.

It can be seen from Figure 1 that the analysis of the laboratory CRM was coming in about 17% below the manufacturer's certified value, whereas the client values for the same CRM were spot on. This led to a frustrating period where the laboratory wouldn't release the final data because they were failing internal quality assurance standards, and the geochemist acting on behalf of the client was asking that the data be released because the data for their CRMs were all reporting as good. The issue was finally sorted out when the laboratory ordered in fresh CRM, re-ran the samples and found that the new CRM reported values close to the certified value. So what went wrong?

The original bulk CRM at the laboratory was old, probably slightly oxidized and possibly hydrated. However, this is unlikely to be responsible for the large negative bias that was observed in the data.

The bulk CRM had been transported from another location immediately prior to its use, and it's possible that it was not re-mixed upon arrival. Sulphides in the sample may have settled under gravity during transport, such that material taken from the top of the jar may have been depleted in Ni sulphides. This is a particular danger when transport-

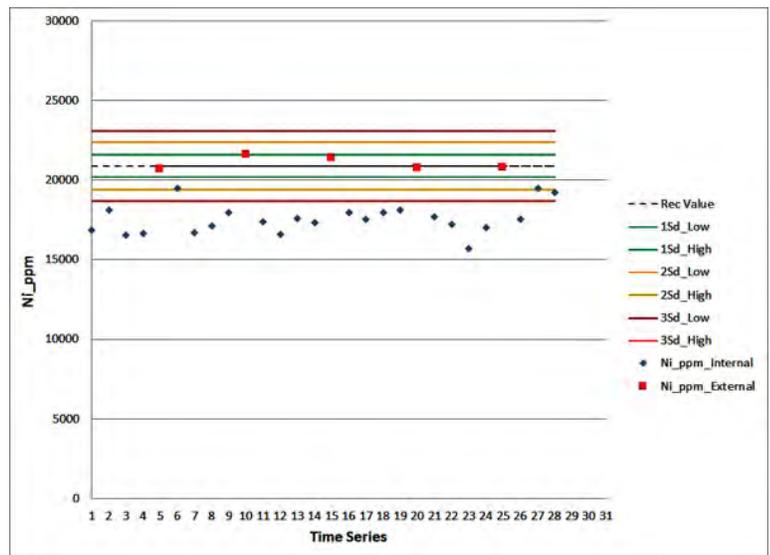


Figure 1. Analyses of the same Ni certified reference material used by a laboratory (internal – blue) and submitted with the samples (external – red).

ing pulps for Au check assaying, particularly by vehicle over long distances. If the check laboratory comes back with a negative bias compared to the primary laboratory, is it a real bias, or had gravity settling affected the transported pulps? Any fresh CRMs submitted to the check laboratory could well come out fine and show no evidence of a systematic bias. The only way to ensure this doesn't happen is to have the transported pulps properly re-mixed upon arrival and before analysis.

Dennis Arne
CSA Global Canada Geosciences Ltd



Join us for Exploration '17

October 21-25, 2017, Toronto, Ontario, Canada

Exploration '17 is the sixth of the very successful series of Decennial Mineral Exploration Conferences which have been held in the seventh year of every decade starting in 1967. The theme of the Exploration '17 conference is "Integrating the Geosciences: The Challenge of Discovery", featuring a multi-national, multi-disciplinary technical programme, exhibition, workshops and field schools.

Decennial Conference Proceedings from the past five conferences (1967, 1977, 1987, 1997, 2007) are available for download on the web site under the 'Resources' header.

Web site: <http://www.exploration17.com>

AAG Members News

John Gravel has retired as Global Technical VP from Bureau Veritas Minerals analytical laboratory (formerly ACME Analytical Laboratories), Vancouver, Canada. He will consult to clients regarding laboratories and analytical methods

Jamil Sader has joined Bureau Veritas Minerals Vancouver office as Corporate Geochemist. Jamil may be contacted at: Bureau Veritas Commodities Canada Ltd. www.bureau-veritas.com/um; 9050 Shaughnessy Street, Vancouver, BC, Canada, V6P 6E5 Email: jamil.sader@acmelab.com

Brenda Caughlin has retired from ALS Minerals, Vancouver. **Bill MacFarlane** has joined ALS Minerals, Vancouver, as Vice President, Analytical Technology. Email: bill.macfarlane@ALSGlobal.com

Dave Smith has recently retired from US Geological Survey where he was a Research Geochemist. Dave is the AAG's Secretary and he will continue to volunteer in this role on Council.

Heather Campbell has joined the Geochemistry, Geophysics and Terrain Sciences Section of the Geological Survey of Newfoundland and Labrador, in eastern Canada, as a Project Geologist. She will be conducting surficial mapping and working with regional geochemical data sets. Email: heathercampbell@gov.nl.ca



New AAG Members

Members (Non-voting)

Tony Goddard
Principal, Intellex Geoscience
15 Fifth Avenue
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Membership # 4313

Bree Morgan
Assistant Lecturer/Researcher
Monash University
15 Collins Street Mentone,
VIC AUSTRALIA 3194
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Membership # 4312

Behnam Sadeghi
James Cook University
James Cook Drive
Rotary International House
Townsville, QLD
AUSTRALIA 4811
Membership # 4314



Past AEG/AAG Events

Abstracts and/or proceedings from past Association of Exploration Geochemists (AEG) and AAG events and other AEG/AAG related events are now available on the AAG web site -just click on the Events header on the home page. The files are searchable pdf files. More events will be added over the course of 2016.

1st International Geochemical Exploration Symposium (IGES 1966)

Date: April 20-22, 1966
Where: Ottawa, Canada
Program and Abstracts

2nd International Geochemical Exploration Symposium (IGES 1968)

Date: April 17-20, 1968
Where: Golden, USA
Program and Abstracts

3rd International Geochemical Exploration Symposium (IGES 1970)

Date: April 16-18, 1970
Where: Toronto, Canada
Program with Abstracts

4th International Geochemical Exploration Symposium (IGES 1972)

Date: April 17-20, 1972
Where: London, England
Program with Abstracts

5th International Geochemical Exploration Symposium (IGES 1974)

Date: April 1-4, 1974
Where: Vancouver, Canada
Program with Abstracts

6th International Geochemical Exploration Symposium (IGES 1976)

Date: 1976
Where: Sydney, Australia
<http://www.sciencedirect.com/science/journal/03756742/8/1-2>
<http://www.sciencedirect.com/science/article/pii/B9780444416537500044>

Exploration Geochemistry in the Appalachians 1976

Date: April 22-23, 1976
Where: Fredericton, Canada
Program and Abstracts

7th International Geochemical Exploration Symposium (IGES 1978)

Date: April 17-19, 1978
Where: Golden, USA
Program and Abstracts

Past AEG/AAG Events... *continued from page 20*

8th International Geochemical Exploration Symposium

(IGES 1980)
Date: 1980
Where: Hanover, Germany
Abstracts Volume

Precious Metals in the Northern Cordillera 1981

Date: April 13-15, 1981
Where: Vancouver, Canada
Programme and Abstracts

9th International Geochemical Exploration Symposium

(IGES 1982)
Date: May 12-14, 1982
Where: Saskatoon, Canada
Program and Abstracts

10th International Geochemical Exploration Symposium

(IGES 1983)
Date: August 29-September 2, 1983
Where: Helsinki, Finland
Program and Abstracts

Exploration for Ore Deposits of the North American Cordillera 1984

Date: March 25-28, 1984
Where: Reno, USA
Program and Abstracts

11th International Geochemical Exploration Symposium

(IGES 1985)
Date: April 28-May 2, 1985
Where: Toronto, Canada
Program and Abstracts

12th International Geochemical Exploration Symposium

(IGES 1987)
Date: April 23-26, 1987
Where: Orléans, France
Program and Abstracts

14th International Geochemical Exploration Symposium

(IGES 1990)
Date: April 23-26, 1990
Where: Prague, Czechoslovakia
Extended Abstracts
Abstract Volume

16th International Geochemical Exploration Symposium

(IGES 1993)
Date: September 1-6, 1993
Where: Beijing, China
Program and Abstracts

19th International Geochemical Exploration Symposium

(IGES 1999)
Date: April 10-16, 1999
Where: Vancouver, Canada
Program and Abstracts

21st International Geochemical Exploration Symposium

(IGES 2003)
Date: May 6-10, 2003
Where: Dublin, Ireland
Abstracts

22nd International Geochemical Exploration Symposium

(IGES 2005)
Date: September 19-23, 2005
Where: Perth, Australia
Abstracts

23rd International Geochemical Exploration Symposium

(IGES 2007)
Date: June 14-19, 2007
Where: Oviedo, Spain
Abstracts

Exploration '07

Date: September 9-12, 2007
Where: Toronto, Canada
Workshops 2 and 3 course notes

24th International Geochemical Exploration Symposium

(IGES 2009)
Date: June 1-4, 2009
Where: Fredericton, Canada
Abstracts and proceedings

25th International Geochemical Exploration Symposium

(IGES 2011)
Date: August 22-26, 2011
Where: Rovaniemi, Finland
Abstracts and proceedings

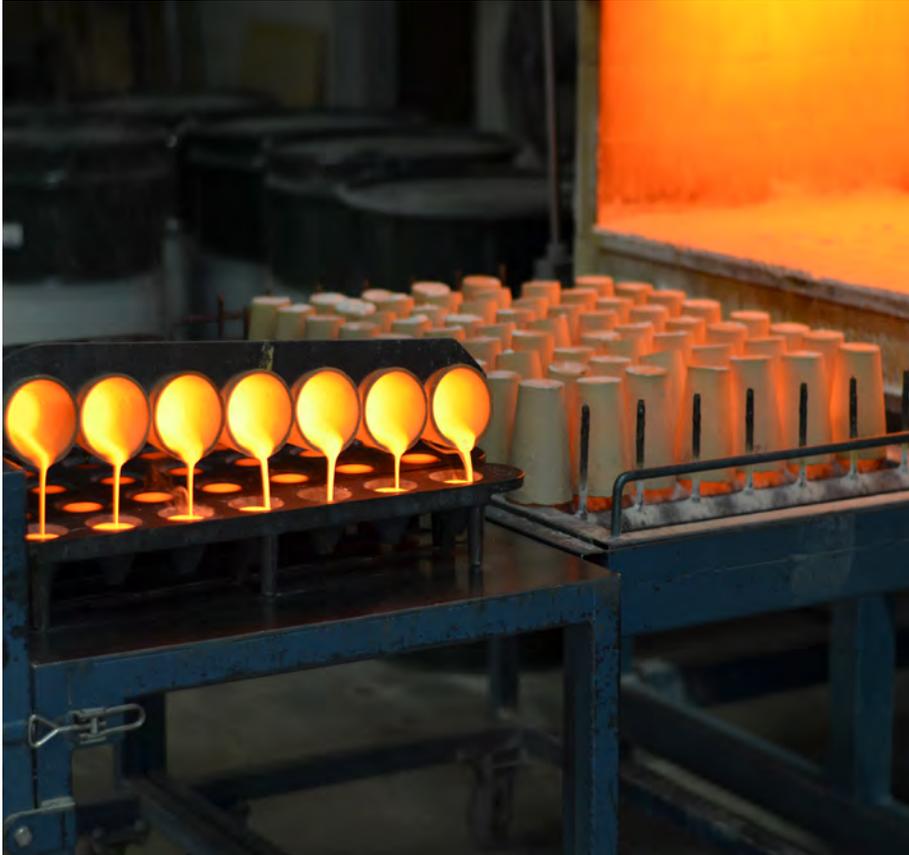
26th International Geochemical Exploration Symposium

(IGES 2013)
Date: November 17-21, 2013
Where: Rotorua, New Zealand
Abstracts

27th International Geochemical Exploration Symposium

(IGES 2015)
Date: April 20-24, 2015
Where: Tucson, Arizona, USA
Abstracts





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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 Tel: +1-709-729-1161

2016

21-23 MARCH	North Atlantic Craton Meeting Edinburgh UK. Website: www.bgs.ac.uk/nac2016	23-27 JULY	Euroscience Open Forum 2016. Manchester UK. Website: www.esof.eu
17-22 APRIL	European Geosciences Union General Assembly 2016. Vienna Austria. Website: www.egu2016.eu/	24-28 JULY	Microscopy & Microanalysis 2016. Columbus OH USA. Website: tinyurl.com/pdyxkpz
1-4 MAY	Canadian Institute of Mining, Metallurgy, and Petroleum Convention. Vancouver BC Canada. Website: tinyurl.com/zzc55rx	24-29 JULY	Organic Geochemistry (Gordon Research Conference). Holderness NH USA. Website: tinyurl.com/jrmsafs
16-18 MAY	7th Geochemistry Symposium with International Participation. Side Turkey. Website: jeokimya.ankara.edu.tr/en	25-27 JULY	5th International Conference on Earth Science & Climate Change. Bangkok Thailand. Website: earthscience.conferenceseries.com
22-25 MAY	10th South American Symposium on Isotope Geology. Puerto Vallarta Mexico. Website: www.ssagi10.geofisica.unam.mx/	27-28 JULY	8th International Congress of Environmental Research. Lübeck Germany. Website: www.icer16.jerad.org
30-31 MAY	Workshop and Special Session on indicator minerals in exploration geology. Whitehorse YT Canada. Website: http://whitehorse2016.ca/program/short-courses-workshops	7-12 AUGUST	Annual Meeting of the Meteoritical Society. Berlin Germany. Website: www.meteoriticalsociety.org
1-3 JUNE	GAC/MAC Annual Meeting. Whitehorse YT Canada. Website: whitehorse2016.ca/	14-18 AUGUST	11th International Conference on the Environmental Effects of Nanoparticles and Nanomaterials. Golden CO USA. Website: tinyurl.com/qa5kzyl
13-17 JUNE	8th International Siberian Early Career GeoScientists Conference. Novosibirsk Russia. Website: conf.ict.nsc.ru/sibconf2016	14-20 AUGUST	Joint International Conference on Environment, Health, GIS and Agriculture. Galway Ireland. Website: www.nuigalway.ie/iseh2016
19-23 JUNE	6th International Congress on Arsenic in the Environment. Stockholm Sweden. Website: www.as2016.se	20-21 AUGUST	6th International Conference on Environmental Pollution and Remediation. Budapest Hungary. Website: icepr.org
19-24 JUNE	Geochemistry of Mineral Deposits. Les Diablerets, Switzerland. Website: tinyurl.com/h7xvh2b	21-25 AUGUST	33rd International Geographical Congress. Beijing China Website: www.igc2016.org
26-30 JUNE	Australian Earth Sciences Convention. Adelaide SA Australia. Website: aesc2016.gsa.org.au	27 AUGUST - 4 SEPTEMBER	35th International Geological Congress CapeTown South Africa. Website: www.35igc.org
26 JUNE-1 JULY	Goldschmidt 2016. Yokohama Japan. Website: www.geochemsoc.org/programs/goldschmidtconference/	28-31 AUGUST	3rd International Symposium on Ethics of Environmental Health. Budweis Czech Republic. Website: iseeh.org
10-13 JULY	3rd International Conference on 3D Materials Science. St. Charles IL USA. Website: tinyurl.com/psr55at	4-7 SEPTEMBER	IAP 2016: Interfaces Against Pollution. Lleida Spain. Website: www.iap2016.org
10-13 JULY	9th International Conference on Environmental Catalysis. Newcastle Australia. Website: tinyurl.com/pts5mtv	4-7 SEPTEMBER	15th Workshop on Progress in Trace Metal Speciation for Environmental Analytical Chemistry. Gdansk Poland. Website: chem.pg.edu.pl/tracespec
11-15 JULY	4th International Workshop on Highly Siderophile Element Geochemistry. Durham UK. Website: community.dur.ac.uk/hse.ws	5-9 SEPTEMBER	13th International Nickel-Copper-PGE Symposium. Fremantle WA Australia. Website: www.iagod.org/node/58
17-22 JULY	Eurosoil 2016. Istanbul Turkey. Website: www.eurosoil2016istanbul.org	11-15 SEPTEMBER	2nd European Mineralogical Conference. Rimini Italy. Website: emc2016.socminpet.it/
19-21 JULY	39th International Symposium on Environmental Analytical Chemistry. Hamburg Germany Website: tinyurl.com/pnaswjw	25-28 SEPTEMBER	SEG 2016 Conference: Tethyan Tectonics and Metallogeny. Çeşme Turkey. Website: www.seg2016.org



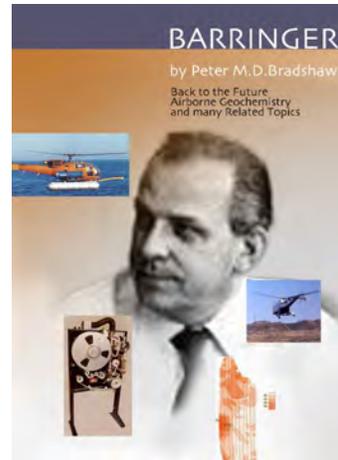
CALENDAR OF EVENTS

continued from page 23

- 25-28 SEPTEMBER Geological Society of America Annual Meeting, Denver CO USA.
Website: www.geosociety.org/meetings/2016
- 9-13 OCTOBER World Water Congress & Exhibition, Brisbane QLD Australia.
Website: tinyurl.com/pgbrkwu
- 10-11 OCTOBER Annual International Conference on Geological & Earth Sciences (GEOS 2016), Singapore. Website: www.geoearth.org
- 16-21 OCTOBER Water Rock Interaction 15, Évora Portugal. Website (pdf): tinyurl.com/lch75x8
- 5-9 DECEMBER American Exploration and Mining Association Annual Meeting, Sparks NV USA. Website: www.miningamerica.org



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The 1960's and 70's were marked by an explosion in mineral exploration and remote sensing technology. A leader throughout this period was Dr. Anthony (Tony) Barringer and his team at Barringer Research Ltd. (BRL). The highly successful airborne geophysical methods created at BRL are well known while the contributions to exploration geochemistry and many other fields are not. This book documents the many advances in geochemical theory, as well as the ground, airborne and remote sensing techniques plus analytical methods that were conceived and developed under the leadership of Tony Barringer. Innovative concepts backed by pioneering research funded by BRL on the movement of metals in rock, soil and vegetation remain important areas of investigation. Tony Barringer's ability to bring together a diverse team including geologists, geochemists and physicists with electrical, optical and aeronautical engineers under one roof, provide leadership, a highly stimulating environment and financial support, was truly remarkable. This led to ground breaking advances in a number of different fields, including: exploration geochemistry for minerals and oil and gas; environmental monitoring from the ground, aircraft and space; and civilian and armed forces security. The underlying scientific principles for many of the inventions, now upgraded with modern electronics, are still considered state of the art. One of the many inventions from the BRL "incubator" described in this book is lonscan, the drug and explosive screening device used in most airports today, which was conceived and developed by BRL in conjunction with technology for the detection of mineral deposits.

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