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Responses in Lake Sediments and Waters to Occurrences of Rare Earths and Rare Metals in the Canadian Shield

Introduction

In this article, 25 documented occurrences of rare earth element/rare metal (REE/RM) mineralization, or of current exploration activity for these commodities, in Canada (Fig. 1) are examined. These occurrences, all hosted in rocks of the Precambrian Canadian Shield, are compared in terms of their geochemical response in lake sediments and, where applicable, lake waters. The article was inspired during research of companies active worldwide in REE/RM exploration, and is based on research directed towards discovery of new deposits of these elements in Newfoundland and Labrador in eastern Canada.

The geochemical responses to REE/RM mineralization are described empirically, with limited reference to the host geology of the deposit, even if known. This approach is not meant to imply that such information is not relevant in the full evaluation of a geochemical anomaly in any element. The scope is further constrained by the overlap, or lack thereof, between documented REE/RM deposits and exploration plays on the one hand, and available lake sediment and water geochemical data on the other. For example, no lake geochemical data are readily available for Quebec's Kipawa REE camp or Lacorne pegmatite district (where there are numerous Li plays, as well as a former and probable future Li producer); for the Clay Howells carbonatite and Separation Rapids pegmatite in Ontario; or the Tanco mine in Manitoba.

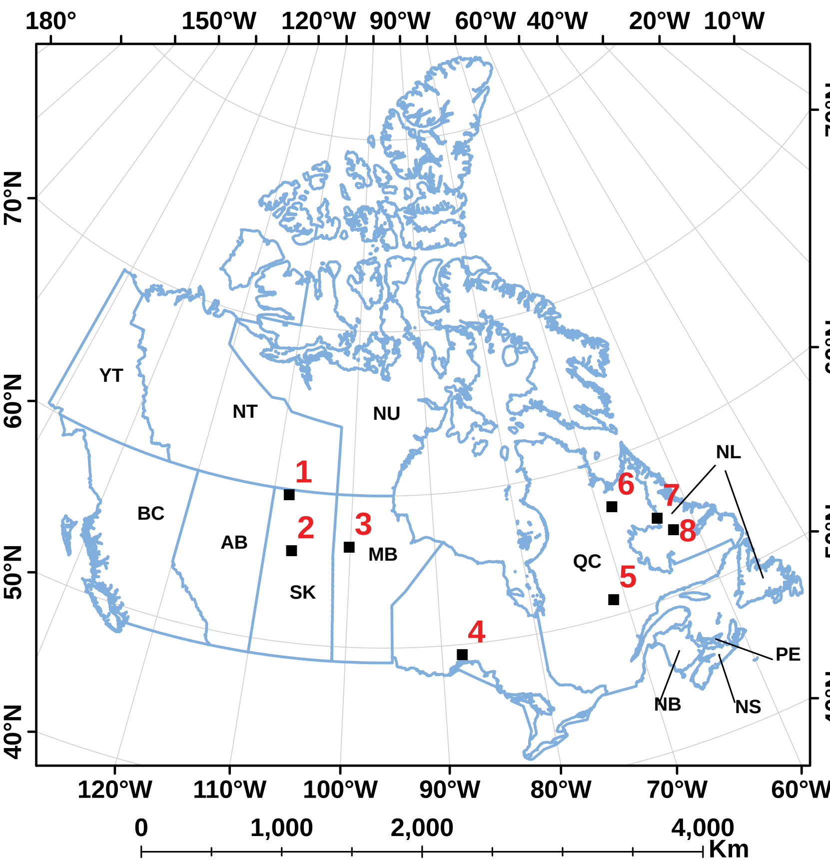

Figure 1: Locations of REE/RM occurrences from Figures 2 to 9. 1: Northwestern Saskatchewan (Hoidas Lake, Hazleton Lake, Alces, Archie); 2: Central Saskatchewan (Sunlite); 3: Eden Lake, Manitoba; 4: Georgia Lake, Ontario; 5: Kwyjibo, Quebec; 6: Erlandson, Quebec; 7: Misery Lake/Ytterby, Quebec/Labrador; 8: Red Wine Mountains, Labrador.

Examples are drawn from the western (NW Saskatchewan) to the eastern (Labrador) extremities of the Canadian Shield. It has not been possible to document dispersion from every known occurrence or group of occurrences, and it is acknowledged that the examples cited may not be entirely representative. Furthermore, some of the data sets from Ontario and Quebec include in excess of 60 analytical parameters and the behaviour of each parameter has not been studied exhaustively.

Since the article comprises a description of the response to known mineralization, speculation about the significance of anomalies not known to be related to REE/RM mineralization is kept to a minimum, although it is hoped that the signatures described in this article will have utility in the identification and evaluation of anomalies of hitherto-unknown provenance.

Definitions of REE and RM

REE/RM are defined as the lanthanide rare earths (plus Y, which is commonly listed separately for both chemical and economic reasons), Li, Nb, Ta, Cs, Rb, Be, Zr, Sc and Hf (although occurrences of the last two elements are rarely documented). The study does not concern itself with four other elements that are occasionally described as rare metals: Sn, In, Ge and Ga.

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Data Sources

The lake geochemical data were derived from three sources:

- The Geological Survey of Canada's National Geochemical Reconnaissance (NGR) lake-sampling program (Hornbrook, 1989) sampled parts of Alberta, Saskatchewan, Northwest Territories, Nunavut, Manitoba, Ontario and Labrador (as well as Nova Scotia and New Brunswick, which are not considered here as they are not underlain by Canadian Shield) at a density of approximately one sample per 16 km2. Sediment samples were originally analyzed for up to 15 elements by various methods, whose details may be found at http://gdr.nrcan.gc.ca/geochem_ngr/format_lake_sediment_e.php, whereas waters were analyzed for U and F-, plus pH (http://gdr.nrcan.gc.ca/geochem_ngr/format_lake_water_e.php).

- Subsequently, and subject to agreements between the Canadian federal government and individual provinces and territories, some archived samples were analyzed by neutron activation for a 27-element package that included the REE/RM elements Ce, Cs, Eu, Hf, La, Lu, Rb, Sc, Ta, Tb, and Yb. This reanalysis is continuing, with the recent (McCurdy et al. 2010) and upcoming (McCurdy pers. comm.) release of additional data for selected samples from northern Manitoba.

- Lake sediments have also been collected by the geological surveys of Ontario and Quebec in a number of programs since the 1970s, at a variety of densities, and analyzed for various packages ranging from a limited suite of AAS analyses to multielement INA, ICP-ES and ICP-MS packages. A number of programs in Ontario also involved the collection of water samples; no water analyses are available from the Quebec surveys. The current study has made use of certain web-accessible lake-sediment geochemical data downloaded from the websites of both provincial governments: http://www.mndmf.gov.on.ca/mines/ogs/ims/pub/digcat/mrd_e.asp in Ontario, and http://sigeom.mrnf.gouv.qc.ca/signet/classes/I1102_indexAccueil?l=a in Quebec.

Mineral-occurrence data are derived from web-accessible mineral deposit databases for the provinces and territories, as specified in Table 1 *(see page 4)*. The data are probably not all-encompassing, because mineral occurrences tend not to be documented as soon as they are discovered. Information regarding foci of REE/RM exploration activity was sourced from the most recently available Canadian and American Mines Handbook (CMH; Giancola 2010). Identification of active projects was followed up with visits to company websites, where they exist. The latter do not conform to any recognized standard of clarity, and information regarding property and mineral-occurrence location varies in its precision and usefulness.

The sources of all of the geochemical and mineral-deposit data are listed in Table 1. For each of the web pages listed in the table, a certain amount of experimentation, on the part of the user, will still be necessary in order to locate the data because the design of the pages is being constantly improved, and also because certain pages are generated by servlet and have no direct URL that can be specified here.

In every case, it is advisable to make the approach in designing the initial query as broad as possible, particularly in selecting commodity types. For example, in searching for rare-earth deposits it is prudent to specify REE as a group, as well as individual elements (Y, La, Ce etc.) if they are offered as search criteria. It is also to be expected that the definitions of REE and RM will vary from database to database.

Definition of an Anomalous Value

Any exercise in the identification of geochemical anomalies requires a definition of what constitutes an anomaly. As a regional first-pass method, the author has found the following definitions useful (although it is not intended to advocate their universal application, applicability, or statistical validity) and they will be applied here.

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Notes from the Editor

By the time you read this issue of **EXPLORE**, the 25th IAGS in Finland will have just ended. I hope you all had an enjoyable time meeting with old friends and making new contacts. The September 2011 issue of **EXPLORE** contains one article by Steve Amor and describes REE and rare metal responses in lake sediments and waters using Canadian examples. Other contributors to this issue include: Graham Closs, Paul Morris, Eric Grunsky and Dave Smith. Scientific and technical editing assistance for this **EXPLORE** issue was provided by Matt Leybourne, GNS Science, and Steve Amor, Geological Survey of Newfoundland and Labrador.

Beth McClenaghan
Editor

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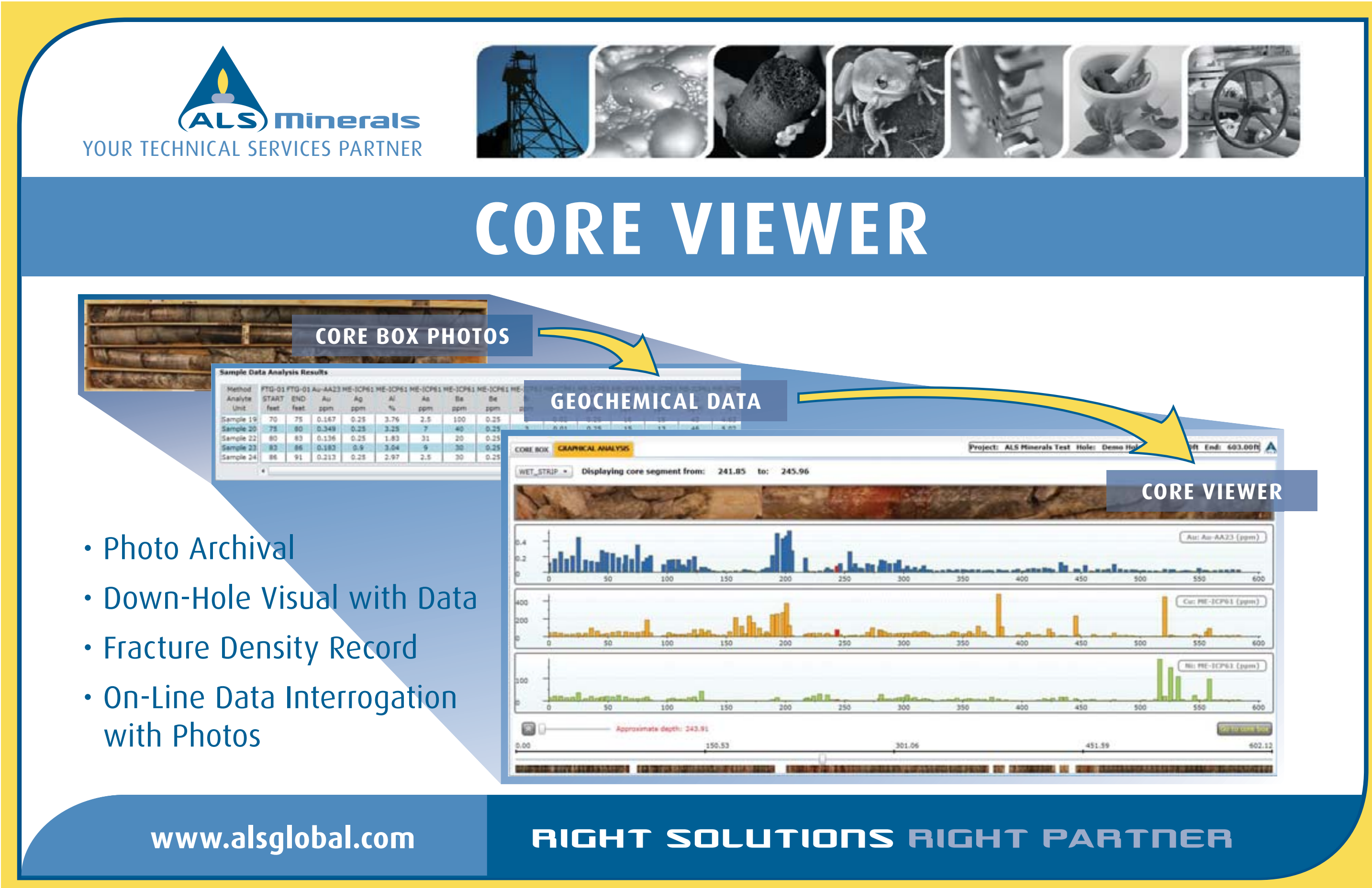
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Table 1. Location of online mineral deposit and lake geochemical databases

Province/ territory	Database	URL	Access via	Output format	Notes
Alberta	Mineral Deposits	www.ags.gov.ab.ca/publications/pubs.aspx?series=dig	Links page	Zipped SHP	
	Lake sediment/ water geochemistry	http://gdrdap.agg.nrcan.gc.ca/geodap/home/ Default.aspx?lang=e	Queryable database	Zipped SHP	1,2
Saskatchewan	Mineral Deposits	www.infomaps.gov.sk.ca/website/SIR_Geological_Atlas/ viewer.htm	Interactive GIS map	Zipped SHP	
	Lake sediment/ water geochemistry	www.infomaps.gov.sk.ca/website/SIR_Geological_Atlas/ viewer.htm	Interactive GIS map	Zipped SHP	1,3
Northwest Teritories	Mineral Deposits	http://www.nwtgeoscience.ca/	Interactive GIS map	Zipped SHP	4
	Lake sediment/ water geochemistry	http://gdrdap.agg.nrcan.gc.ca/geodap/home/ Default.aspx?lang=e	Queryable database	Zipped SHP	1,5
Nunavut	Mineral Deposits	http://nunavutgeoscience.ca/apps/showing/ showQuery.php	Queryable database	CSV	4
	Lake sediment/ water geochemistry	http://gdrdap.agg.nrcan.gc.ca/geodap/home/ Default.aspx?lang=e	Queryable database	Zipped SHP	1,5
Manitoba	Mineral Deposits	http://geoapp2.gov.mb.ca/website/geo1m/viewer.htm	Interactive GIS map	Zipped SHP	
	Lake sediment/ water geochemistry	http://gdrdap.agg.nrcan.gc.ca/geodap/home/ Default.aspx?lang=e	Interactive GIS map	Zipped SHP	1,6
Ontario	Mineral Deposits	www.geologyontario.mndmf.gov.on.ca/	Queryable database	HTML	
	Lake sediment/ water geochemistry	http://gdrdap.agg.nrcan.gc.ca/geodap/home/ Default.aspx?lang=e	Queryable database	Zipped SHP	1,7
	Lake sediment/ water geochemistry	http://gdrdap.agg.nrcan.gc.ca/geodap/home/ Default.aspx?lang=e	Links page	Zipped files in various formats	8
Quebec	Mineral Deposits	http://sigeom.mrnf.gouv.qc.ca/signet/classes/ I1102_indexAccueil?l=a	Queryable database	HTML, KMZ	
	Lake sediment/ water geochemistry	http://sigeom.mrnf.gouv.qc.ca/signet/classes/ I1102_indexAccueil?l=a	Queryable database	Zipped SHP	9
(Newfoundland and) Labrador	Mineral Deposits	http://gis.geosurv.gov.nl.ca/resourceatlas/viewer.htm	Interactive GIS map	Zipped SHP	
	Lake sediment/ water geochemistry	http://gis.geosurv.gov.nl.ca/resourceatlas/viewer.htm	Interactive GIS map	Zipped SHP	10

Notes
1. NGR data
2. Coverage restricted to area of northeastern Alberta underlain by the Canadian Shield: NTS map sheets 74D, 74E and 74M
3. Two high-density surveys conducted by provincial government at Cluff Lake and McLean Lake
4. Requires user ID
5. Coverage << 100%
6. Shield-underlain areas north of 53º30' N. Very few samples analyzed for INAA; no water analyses north of 58 º00N
7. Complete coverage between 44º30' and 48º00N'; almost complete coverage west of 84º00'W and south of 49º30'N. Almost no coverage north of 49º30'N.
8. Data files from 40 Ontario government high-density lake surveys over selected areas between 46 º30'N and 52º 00'N. Considerable overlap with NGR coverage though certain areas of NW Ontario are covered which were unsampled by NGR program.
9. C$0.02 per sample
10. Also available from http://gdrdap.agg.nrcan.gc.ca/geodap/home/Default.aspx?lang=e

• Anomalous indicates that the sample's content exceeds the 97.5-percentile, in a particular population of samples, of the element in question. This threshold is close to the proportion of samples in a normal distribution that exceed the mean plus two standard deviations; the latter statistic was chosen as a means of deriving the threshold for this very reason (Hawkes & Webb 1962; Garrett 1989).

- Elevated indicates that the sample's content is less than or equal to the 97.5-percentile, but exceeds the 90-percentile, in a particular population of samples, of the element in question.
- Background refers to all values less than or equal to the 90-percentile, in a particular population of samples, of the element in question.

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In any geochemical population whose frequency distribution approximates some permutation of the normal distribution, there will always be values that are defined as “anomalous” or “elevated” in this way, whether or not they are either statistically or geochemically anomalous, and whether or not they have any spatial or genetic relationship with enrichment of that element in bedrock. Nevertheless, this method has the advantage of rapid map generation, and once they are plotted, the significance of samples that appear to be anomalous in an element of interest can be assessed by examining their relationship to the behaviour of other elements, or their spatial relationship to known geology, or to one another.

The population of analytical values from which the percentiles are derived is also a judgment call. In the present investigation, 90- and 97.5-percentiles were calculated for each preparation- and finish-specific analytical parameter from three data sets:

- The entire NGR Canadian Shield database, for samples from Alberta, Saskatchewan, NWT, Nunavut, Manitoba, Ontario and Labrador
- A database for all samples collected by the Ontario Geological Survey and compiled from 40 separate data sets
- Four Quebec databases for selected samples, representing each of the Superior, Grenville and Churchill Provinces, and the New Quebec Orogen (Labrador Trough).

Because web-accessible geochemical data posted by the Province of Quebec are unique in Canada in not being free, to derive summary statistics from the entire Quebec database would have incurred an unsustainable expense; hence the use of selected data, some of which were kindly provided by Charles Maurice, here.

Results

The responses to the REE/RM occurrences are listed in Table 2 *(see pages 6 and 7)*. Responses are categorized and coded as follows:

1. Elevated and/or anomalous values localized over, around or down-ice of occurrence(s); strong contrast with surrounding background samples, even when not numerous
2. Many elevated and anomalous values in occurrences' vicinity and possibly elsewhere, not associated with known mineralization; possible application as regional pathfinder
3. A few elevated and anomalous values in occurrence's vicinity; probably inapplicable as pathfinder

The absence of a particular element from an anomalous association may be due to analyses of that element not being available for samples from the region in question, rather than an absence of signature. For example, no REE/RM analyses are available for lake sediment samples collected over the

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Table 2: Lake-sediment and water responses to REE/RM mineralization

Occurrence	Approx location	Host	Deposit type	Metal Associations in Occurrence	Analyses	Strength of Response			Source
						1	2	3	
Hoidas Lake (SK)	59.9° N 107.8° W	Tonalite gneisses, amphibolite, granitic mylonites, and diorites (Churchill Province: Ena Domains)	Late-magmatic to hydrothermal vein	REE, Ba, Sr, Ti	NGR NGR INAA NGR U_w, F_w		Ce, La, Mo, Sm, Th	F_w	1, 2, 3
Alces (SK)	59.7° N 108.0° W	Granite & gneiss (Churchill Province: Beaverlodge Domain)	Pegmatite	REE, Th	NGR NGR INAA NGR U_w, F_w		Ce, F_w, La, Mo, Sm, Th,		2
Hazleton Lake (SK)	59.8° N 109.9° W	Granite & gneiss (Churchill Province: Zemlak Domain)	Pegmatite	REE, Nb, Ta	NGR NGR INAA NGR U_w, F_w	Yb	Ce, F_w, Mo, Sm, Tb, Th, U		2
Archie (SK)	59.5° N 107.7° W	Metasediment (Churchill Province: Beaverlodge Domain)	Placer and Paleoplacer	REE, Th, Ti, Sr	NGR NGR INAA NGR U_w, F_w				2
Sunlite (SK)	56.1° N 106.8° W	Churchill Province (Mudjatik [South] Domain)	Pegmatite	REE, Nb, Ta	NGR NGR INAA NGR U_w, F_w	Cs, Rb, Ta, U, Yb	Ce, F_w, La, Mo, Sm, Tb, Th		2
Nueltin Lake (NU)	60.3° N 99.8° W	Churchill Province Mudjatik (South) Domain	Metamorphic	REE, Th	NGR NGR U_w, F_w		F_w, Mo, U		2
Eden Lake (MB)	56.0° N 100.2° W	Churchill Province (Chipewyan Domain)	Carbonatite	REE	NGR NGR U_w, F_w	F_w, Mo, U, U_w			1, 4
Georgia Lake (ON)	49.4° N 87.9° W	Superior Province (Quetico Subrovince)	Pegmatite	Li, Be, Cs, Nb, Rb, Ta	NGR NGR INAA NGR U_w, F_w OGS (MRD243)		Cs	Li	1
Seymour-ZigZag Lakes (ON)	50.5° N 88.1° W	Superior Province (Wabigoon / English River Subprovinces)	Pegmatite	Be, Li, Ta, Nb	W: OGS (MRD56) E: NGR NGR INAA NGR U_w, F_w	Ce, Eu, La, Lu, Mo, Nd, Sm, Tb, Y, Yb	Cs, Nb, Th		1
Coldwell Complex (ON)	48.8° N 86.5° W	Superior Province (Wawa Subprovince)	Alkalic Complex	Nb, Zr, REE	NGR NGR INAA NGR U_w, F_w	Ce, Eu, F_w, La, Lu, Sm, Ta, Tb, Yb			1
Prairie Lake (ON)	49.0° N, 86.7° W	Superior Province (Wawa Subprovince)	Carbonatite	Nb, P, Ta,U, REE	NGR NGR INAA NGR U_w, F_w				1
Lac Walker Region (QC)	50.5° N, 67.1° W	Grenville Province (Migmatite)	Unknown	Nb-Ta-Zr-REE	AA U (fluor)		Mo,U		2
Lac Manitou Region (QC)	50.9° N 65.3° W	Grenville Province (Paragneiss)	IOCG	Cu, REE, Nb, Mo, Ag, Fe, Th, Zr, Ti	ICP-MS		Cd, Cr, Cs, Cu, Hf, Mg, Nb, Rb, Th, Ti	Ba, Be, Ca, Ce, La, Li, Y	2
Kwyjibo (QC)	51.1° N 71.3° W	Grenville Province (Grey gneiss)	IOCG	Fe, Cu, REE, Au	ICP-MS		Ce, La, Nb		1
Crevier (QC)	49.5° N 72.8° W	Grenville Province (syenite, monzonite)	Carbonatite	Nb, Ta, U, Ti	AA U (fluor)	Nb, Sc, Sr, U			1, 2

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Occurrence	Approx location	Host	Deposit type	Metal Associations in Occurrence	Analyses	Strength of Response 1	2	3	Source
Moblan (QC)	50.7° N 75.2° W	Superior Province (Granite-greenstone)	Pegmatite	Li, Be	ICP-MS		Be, Ce, La, Y	Al, Fe, Nb, P	1, 2
Eastmain (QC)	52.1° N 76.8° W	Superior Province (Late tectonic tonalitic rocks)	Pegmatite	Li, Be, Mo	ICP-MS			Mo	1, 2
Eldor (QC)	56.9° N 68.4° W	Churchill Province (New Québec Orogen)	Carbonatite	Ta, Nb	ICP-MS		Ce, La, Mo, Y		1, 2
Lac Brisson (QC) / Strange Lake (NL)	56.4° N 64.0° W	Churchill Province	Alkalic Complex	Zr, Y, REE, Nb, Ta, Be	(QC) ICP-MS (NL) NGR NGR INAA NGR U_w, F_w	(QC) Be, Cs, Th, U, (NL) Ce, Cs, Hf, La, Lu, Rb, Ta, Th, U, Yb, Fw	(QC) Sn		
Misery Lake (QC)	55.3° N 63.9° W	Churchill Province	Alkalic Complex	REE	(QC) ICP-MS (NL) NGR NGR INAA NGR U_w, F_w	(QC) Be, La, Mo, Th, Y (NL) Ce, Hf, La, Mo, Sm. Ta, Th, U, Tb,Yb, Fw	(QC) Nb		1
Ytterby 2 & 3 (QC/NL)	55.6° N 63.5° W	Churchill Province	Alkalic Complex	REE	(QC) ICP-MS (NL) NGR NGR INAA NGR U_w, F_w	(QC) Ce, La, Mo, Y (NL) Ce, La, Mo, Sm, Th,	(NL) Lu		1, 2
Red Wine Mountains (NL)	54.2° N 62.5° W	Churchill Province	Alkalic Complex	REE, Zr, Be, Nb	NGR NGR INAA NGR U_w, F_w	Ce, La, Lu, Sm, Tb, Yb F_w	Cs, Mo,		1, 2
Flowers River (NL)	55.6° N 61.1° W	Grenville/Nain Provinces	Alkalic Complex	REE, Zr, Nb	NGR NGR INAA NGR U_w, F_w	Ce, Eu, Hf, La, Lu, Mo, Sm, Tb, Yb, F_w	Pb, Zn	F	2
Port Hope Simpson (NL)	52.5° N 56.5° W	Grenville Province	Pegmatite, Alkalic Complex	REE, Zr, Nb, U	NGR NGR INAA NGR U_w, F_w		Ce, Eu, La, Lu, Sm, Tb, Yb	Ta, Th	1
Michikamats (NL)	54.6° N 64.4° W	Churchill Province	Alkalic Complex	REE	NGR NGR INAA NGR U_w, F_w	Mo, F_w			1
Pope's Hill (NL)	53.0° N 61.5° W	Grenville Province	Gneiss	REE	NGR NGR INAA NGR U_w, F_w			Ba	1

1 Elevated and/or anomalous values localized over, around or down-ice of occurrence(s); strong contrast with surrounding background samples
2 Many elevated and anomalous values in occurrences' vicinity and possibly elsewhere, not associated with known mineralization; possible application as regional pathfinder
3 A few elevated and anomalous values in occurrence's vicinity; probably inapplicable as regional pathfinder
Source codes: 1 Canadian Mines Handbook (Giancola, 2010); 2 Provincial online mineral deposit database; 3 Halpin et al. (2008); 4 Mumin (2002)

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Eden Lake or Crevier carbonatites in Manitoba and Quebec, respectively; and analyses of fluoride in lake water (Fw) are only available for the former.

Eight examples of dispersion from REE/RM occurrences are depicted in Figures 2 to 9. The surficial geochemical signature of the Strange Lake REE/RM deposit in Labrador has been described elsewhere (McConnell & Batterson 1987).

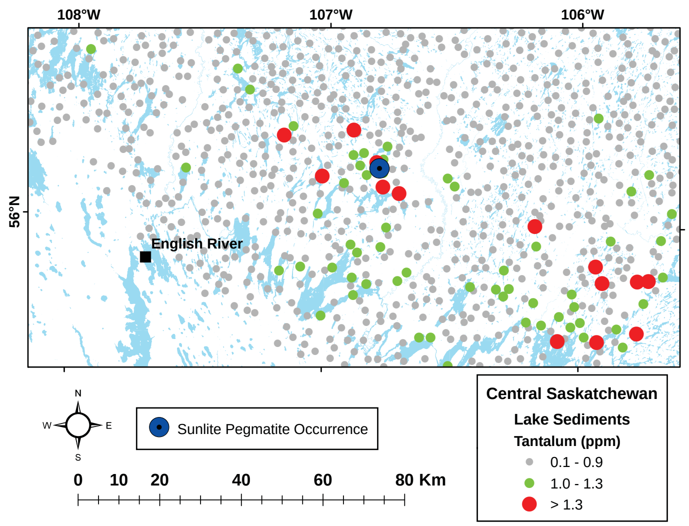

Figure 2: Distribution of Ta in lake sediments around the Sunlite Ta-Nb pegmatite, central Saskatchewan. NGR Data, INA analysis. The direct association of the deposit with the Ta anomaly is accompanied by similar responses in Cs (subdued), Rb (subdued), and there is an outer annulus of lake sediments anomalous and elevated in REE, Mo and Th and about 100 km in diameter. Ice flow directions are predominantly from NE to SW (source of data www.infomaps.gov.sk.ca/website/SIR_Geological_Atlas/viewer.htm).

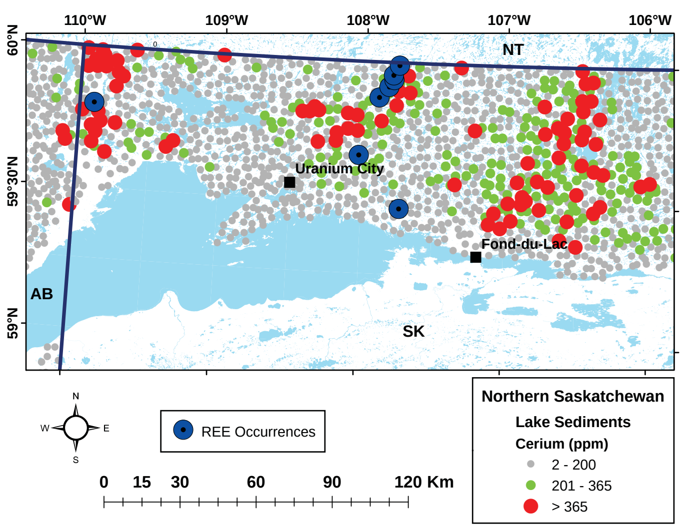

Figure 3: Distribution of Ce in lake sediments, northern Saskatchewan. NGR data, INA analysis. The Hoidas Lake REE discovery and associated occurrences, and the Hazelton Lake pegmatite occurrences are associated with regional REE anomalies but lake sediments in the immediate vicinity of the occurrences are not anomalous. Ice flow directions are predominantly from northeast to southwest (source of data www.infomaps.gov.sk.ca/website/SIR_Geological_Atlas/viewer.htm).

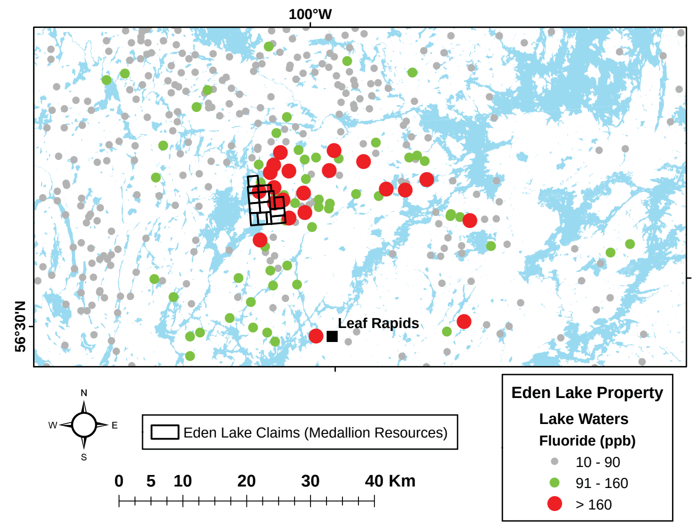

Figure 4: Distribution of fluoride in lake waters (Fw) around the Eden Lake carbonatite, northern Manitoba. NGR data, ISE (ion-specific electrode) analysis. Lake sediments from this region have not been analyzed for REE/RM. There is an anomalous U response in both lake sediments and waters, but none in Mo. Ice flow directions are predominantly from NNW to SSE and NNE to SSW (Kasczycki & Way Nee 1990).

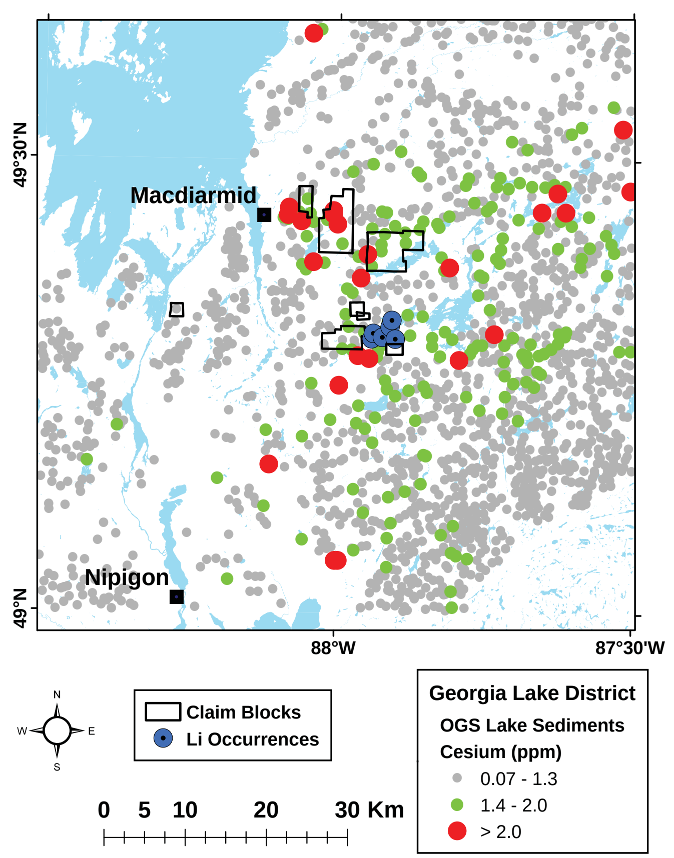

Figure 5: Distribution of Cs in lake sediments, Georgia Lake district, northwest Ontario. Ontario MNDM data, ICP-MS analysis. Cs (and to a much lesser extent, Li itself) show a spatial association with the Li-bearing pegmatites, although there are anomalies of these, and other REE/RM elements, elsewhere in the district. Ice flow directions are predominantly from NNE to SSW (Simms & Baldwin 1991).

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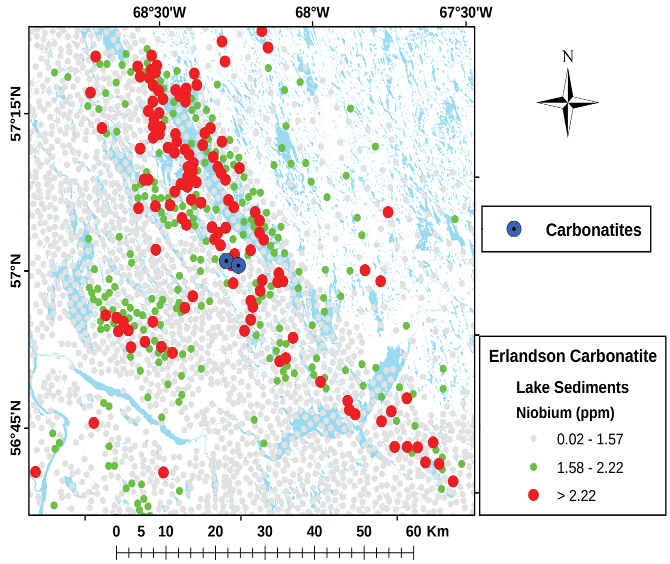

Figure 6: Distribution of Nb in lake sediments around the Erlandson carbonatites, northern Quebec. Quebec MRNF data, Labrador Trough / New Quebec Orogen subset, ICP-MS analysis. Nb shows the strongest response at both local and regional scale but the vicinity of the carbonatites is also marked by Ce, La, Mg, Mo, Sc, Sr, U and Y. There are several other strong REE/RM anomalies in the vicinity. Ice flow directions are predominantly from west to east (source of data http://sigeom.mrnf.gouv.qc.ca/signet/classes/I1102_indexAccueil?l=a)

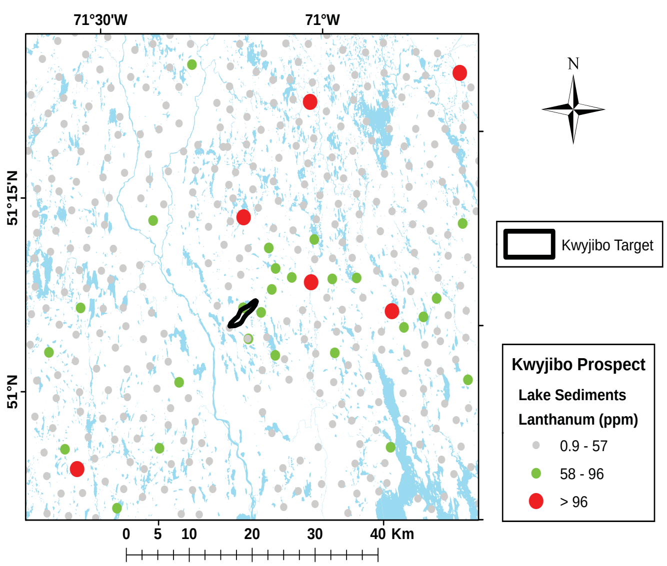

Figure 7: Distribution of La in lake sediments around Kwyjibo prospect, Quebec. Quebec MRNF data, Grenville subset, ICP-MS analysis. The anomalous response to this IOCG deposit, is also shown by Ce and very locally by Nb, although there are other REE/RM anomalies elsewhere in the vicinity. Ice-movement directions are predominantly from west to east (source of data http://sigeom.mrnf.gouv.qc.ca/signet/classes/I1102_indexAccueil?l=a)

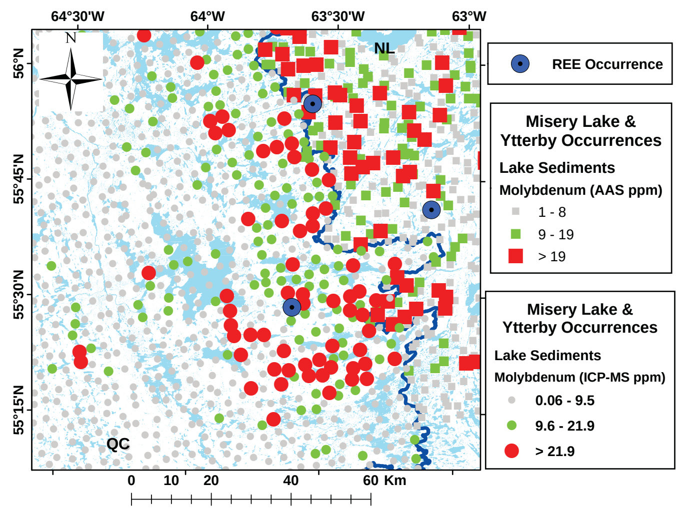

Figure 8: Distribution of Mo in lake sediments around Misery Lake (Quebec), Ytterby 2 (on Quebec-Labrador border) and Ytterby 3 (Labrador) prospects. Quebec: MRNF data, South-east Churchill Province subset, ICP-MS analysis (circles); Labrador: NGR data, AAS analysis (squares). The strong regional Mo anomaly is accompanied by anomalous responses in REE, Be, fluoride in lake waters, Hf, Nb, Ta, Th, U and Y, although not all elements were analyzed, or showed strong responses, in both datasets. Ice flow directions are predominantly from west to east (source of data http://sigeom.mrnf.gouv.qc.ca/signet/classes/I1102_indexAccueil?l=a)

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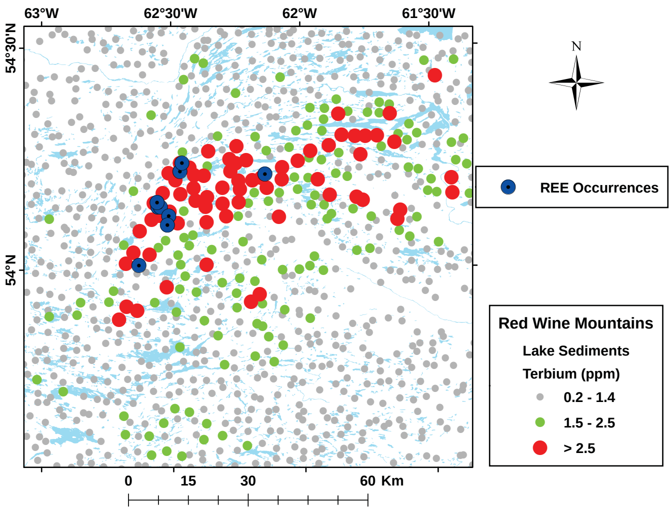

Figure 9: Distribution of Lu in lake sediments over Red Wine Mountains, Labrador. NGR data, INA analysis. Response is generally stronger, more extensive and more homogeneous, in heavy than in light REE. Fluoride in water response is localized over occurrences and to the west, but not to the east. Ice flow direction is from WSW to ENE (Klassen et al. 1992).

Conclusions

A review of the geochemical signatures, in lake sediments and waters, of REE/RM occurrences in the Canadian Shield has led to the following general conclusions:

1. Response to REE/RM occurrences varies from strong and highly focused (e.g. Eden Lake MB, Fig. 3; Red Wine Mountains NL, Fig. 8) through regional and not directly associated with known deposits (Hoidas Lake SK, Fig. 1) to no response at all (Prairie Lake ON, Popes Hill NL; not shown here).
2. Anomalous and elevated values of fluoride in lake water (Fw) are frequently associated with REE occurrences. Most sites in the NGR lake database, even those without REE/RM analyses, have Fw analyses and therefore this parameter appears to constitute a useful pathfinder.
3. Elevated and anomalous values of Mo are commonly associated with REE occurrences (of which an example can be seen at Misery Lake, QC; Fig. 7), and less commonly with RM occurrences. Therefore, in the absence of both Fw in lake water and REE analyses in lake sediment, Mo may be used as a pathfinder element.
4. Li occurrences show a poor response in lake sediments, particularly in Li itself. In Ontario, at the Georgia Lake Li pegmatite district, there is only a weak Li response. The mineralization appears to be associated there, and at the Seymour-ZigZag Lakes district, with anomalous and elevated levels of certain other elements (Cs at Georgia Lake and REE, Mo, Nb and Th at Seymour-ZigZag), but even these are lacking in the Eastmain and Moblan pegmatite districts of Quebec.
5. There are many examples of anomalous and elevated concentrations of REE/RM and pathfinder elements that are not associated with known mineralization, as identified in the source material for this investigation.

In summary, the presence of a lake-sediment anomaly in REE, or a lake water anomaly in fluoride ion, are more than sufficient justification for a search for REE mineralization to be conducted. Molybdenum also appears to have potential as a pathfinder for such mineralization. There are many such untested anomalies in the Canadian Shield, in publicly-available data, in northeastern Saskatchewan, northern Manitoba, southeastern Nunavut and Labrador, and some of these anomalies are situated in ground that is currently unstaked.

The results of past exploration programs, often conducted in pursuit of other mineral commodities but comprising high-quality data, can often be retrieved from assessment files and used to identify targets more precisely within the geochemical anomalies (e.g. Amor 2011).

The geochemistry of lake sediments and waters appears to be less effective in the search for deposits of rare metals, and the absence of an anomaly in lake sediments and waters is not a reason, in isolation, to write off an area's REE or RM prospectivity.

Acknowledgments
Detailed reviews by Matthew Leybourne and Beth McClenaghan resulted in numerous improvements to the manuscript.

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Symposium on the Release of the Geochemical Atlas of Cyprus

5-7 September, 2011 • Lefkosia (Nicosia) Cyprus

AAG speakers include Clemens Reimann, Patrice de Caritat, Neil Rutherford, Iain Dalrymple, Olle Selinus, David Cohen.

Details at www.moa.gov.cy/GeochemicalAtlasCyprus <http://www.moa.gov.cy/GeochemicalAtlasCyprus>
or contact Andreas Zissimos (AZissimos@gsd.moa.gov.cy) <mailto:AZissimos@gsd.moa.gov.cy>.

Paul Morris

President's Message

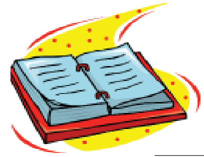
As mentioned in EXPLORE No. 150, the Association of Applied Geochemists draws its membership from a number of countries and a variety of disciplines, with most members involved in the application of geochemistry to mineralization, in terms of exploration or remediation. The promotion and use of applied geochemistry, which is a fundamental aim of AAG, does not usually attract controversy, but when it does, the question arises whether AAG should adopt a position, such as the use of applied geochemistry in the exploration for uranium. Regardless of what news medium you follow, it's hard to ignore the ongoing problems of the Fukushima nuclear power plant disaster in northeast Japan, caused by the catastrophic 8.9-magnitude earthquake and associated and tsunami of March 11, 2011. The damage to the reactors and the possible long-term effects on the surrounding area has reinvigorated the debate about the safety of generating electricity by nuclear means. In Australia, the accident came at a time when there was intense debate about alternatives to fossil fuels, with nuclear a contender, especially as Australia is well endowed with uranium resources. The Fukushima disaster provided those opposed to nuclear energy with a ready-made example of the adverse short- and long-term effects of nuclear power generation; exploration companies with uranium portfolios took a hit in the stock market, and the wisdom of both Federal and State governments who had loosened the earlier restrictive policies on uranium mining was questioned. Of direct relevance to some geologists (some of whom are AAG members) is that the downstream effect of the disaster can impact directly on jobs, and in these instances, taking an objective view of the issue may be compromised.

The position that geoscientific organisations should take on contentious issues can be problematic, especially when the membership represents a wide occupational range and a correspondingly wide range of opinions. When the Geological Society of Australia took a stance on climate change, some members took exception to not being consulted, and a few resigned in protest.

I do not believe that, as an association, AAG should have an 'association point of view' on such matters, but its members should continue to promote good applied geochemical science by testing of hypotheses using well-constrained data, and encourage members to develop their own science-based views. Perhaps this is a topic that could be aired via some letters to **EXPLORE**.

I have recently received a comprehensive email from Pertti Sarala in Finland about the status of the 25th International Applied Geochemistry Symposium, and I am sure that we will have an enjoyable and rewarding meeting. By all accounts, the field trips will be well patronised, and a plethora of papers have been submitted for oral and poster presentation. See you soon.

Paul Morris,
President, AAG



CALENDAR OF EVENTS

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

2011

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

20-24 September 2011. Joint Meeting of the German Crystallographic Society, the German Mineralogical Society and the Austrian Mineralogical Society. Salzburg Austria. Website: www.salzburg2011.org

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

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

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

30 September-2 Oct 2011. 103rd Meeting of the New England Inter-Collegiate Geological Conference. Middlebury VT US. Website: http://tinyurl.com/3cl2em7

2- 5 October 2011. COM 2011 – 50th Anniversary of the Conference of Metallurgists. Montreal QC Canada. Website: www.metsoc.org/com2011

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

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CALENDAR OF EVENTS

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

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

2- 6 November 2011. International Union of Crystallography: Commission on Mathematical and Theoretical Crystallography. Manila, Philippines. http://tinyurl.com/4xgkv82

7- 10 November 2011. Network for the Detection of Atmospheric Composition Change Symposium. Saint Paul, Reunion Island, France. Website: ndacc2011.univ-reunion.fr

11-13 November 2011. 9th Swiss Geoscience Meeting. Zürich, Switzerland. Website: http://tinyurl.com/4y8ovmn

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

28 November-2 December 2011. Northwest Mining Association: Annual Meeting, Exposition and Short Courses. Sparks NV USA. Website: www.nwma.org/convention.asp

5- 9 December 2011. 2011 AGU Fall Meeting. San Francisco CA USA. Website: www.agu.org/meetings/

2012

9-14 January 2012. 2012 Winter Conference on Plasma Spectrochemistry. Tucson AZ USA. Website: http://tinyurl.com/4xmwz24

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

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

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

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

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

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

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

9- 23 June 2012. 6th International Siberian Early Career GeoScientists Conference. Novosibirsk, Russia. Website: http://tinyurl.com/3vlo8xq

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

28 July-2 August 2012. American Crystallographic Association (ACA) Annual Meeting. Boston MA USA. Website: http://tinyurl.com/3dfn8lu

29 July-2 August 2012. Microscopy and Microanalysis 2012. Phoenix AZ USA. Website: http://tinyurl.com/428tyv6

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

26-30 August 2012. 32nd International Geographical Congress: "Down to Earth". Cologne, Germany. Website: www.igc2012.org

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

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

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

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

Please let us know of your events by sending details to:
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709-729-1161

34th International Geological Congress

Brisbane, Australia,
5-10 August, 2012

This meeting will be co-hosted by several societies including the AAG. The sessions listed below may be of interest to AAG members. Abstracts should be submitted via the IGC web site (http://www.34igc.org/) by February 17, 2012.

Symposia 4.3 Advances in the evaluation and interpretation of geochemical data at the continental scale.

Patrice de Caritat (Geoscience Australia) and Eric Grunsky (Geological Survey of Canada) are hosting a session that will focus on the evaluation and interpretation of geochemical data at the continental scale. Geochemical survey data are typically derived from multiple government surveys using a range of analytical methods and sampling media. The integration, evaluation and interpretation of large scale regional geochemical surveys can be challenging given the diversity of sample media, sample preparation, analytical methods and the compositional nature (closure problem) of the data. This session will highlight the advances in the application of statistical methods, including the compositional nature of the data and spatial analysis to provide meaningful interpretation for both geological mapping and environmental monitoring at regional/ continental scales. Those who have been involved in the integration and interpretation of large scale geochemical surveys are encouraged to present their work at this session.

Symposia 4.2 Global Geochemical Mapping: Understanding Chemical Earth (the 2nd Arthur Darnley Symposium).

Dave Smith (AAG Secretary), Xueqiu Wang (AAG Regional Councilor for China), and Patrice de Caritat (AAG Councilor) are convening a technical session that will focus on recently completed, or ongoing, geochemical mapping studies conducted at national or international scales. Although the emphasis is on broad-scale studies, the session also welcomes contributions from studies conducted at a more local or regional scale. The session is being convened under IGC Theme 4: Environmental Geoscience.

Symposia 8.4 Advances in geochemical exploration

David Cohen (Past President AAG), Ravi Anand, Ryan Noble (AAG Councillor), David Lawie, Graham Closs (AAG Bibliography), Andrew Rate and Mark Arundall (AAG Councillor) are convening a session will cover recent advances in exploration geochemistry, including; methods for exploring in regions with transported or deeply weathered cover; development of analytical and data processing methods linked to new models for geochemical dispersion in such terranes; alternate sampling media or sample processing methods to conventional methods; isotope applications. Case studies from various geochemical landscapes from the deeply weathered to the glaciated are invited.

RECENT PAPERS

This list comprises titles that have appeared in major publications since the compilation in **EXPLORE** Number 151. Journals routinely covered and abbreviations used are as follows: Economic Geology (EG); Geochimica et Cosmochimica Acta (GCA); the USGS Circular (USGS Cir); and Open File Report (USGS OFR); Geological Survey of Canada papers (GSC paper) and Open File Report (GSC OFR); Bulletin of the Canadian Institute of Mining and Metallurgy (CIM Bull.): Transactions of Institute of Mining and Metallurgy, Section B: Applied Earth Sciences (Trans. IMM). Publications less frequently cited are identified in full. Compiled by L. Graham Closs, Department of Geology and Geological Engineering, Colorado School of Mines, Golden, CO 80401-1887, Chairman AAG Bibliography Committee. Please send new references to Dr. Closs, not to **EXPLORE**.

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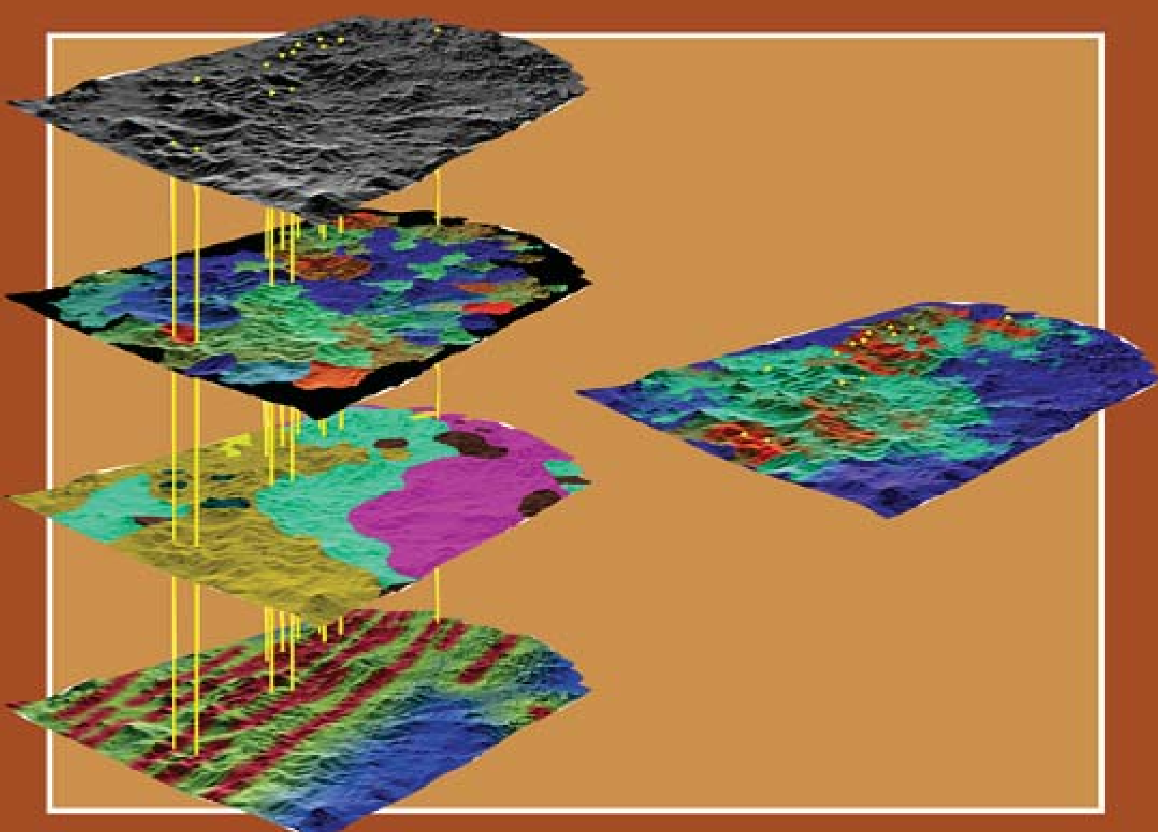
ELSEVIER

HANDBOOK OF **EXPLORATION**
AND ENVIRONMENTAL GEOCHEMISTRY 11
M. HALE (SERIES EDITOR)

GEOCHEMICAL ANOMALY AND MINERAL PROSPECTIVITY MAPPING IN GIS

EMMANUEL JOHN M. CARRANZA



ioStipend

In-kind Analytical Research Fund for BSc(Hons), MSc and PhD students

Much has been said and written about the broadening gulf between the demand for qualified explorationists and the supply coming out of our colleges, technical institutes and universities. One merely has to attend any geo-conference and gaze out over the sea of grey to fully grasp the situation our industry faces. This is all the more evident in the field of exploration geochemistry whose members have always been in short supply.

As consultants and service industries, we owe our livelihood to mining and exploration and thus have a vested interest in its development. We believe that any aid to promote fresh faces into our sector is helping to secure our future.

Acme Analytical Laboratories Ltd. and **ioGlobal** are taking the bold initiative of directly aiding students in the geosciences via the **ioStipend**. The **ioStipend** is a grant available to students conducting exploration-related geochemical studies at a recognized educational institution. The grant is in the form of analytical services using any package provided by Acme Analytical Laboratories Ltd. Students and/or their teachers/advisors can apply for the grant by submitting the application to ioGlobal who will vet the proposals.

The grant is intended to promote the collection of high quality, base-line data for comparison with more "esoteric data" (eg, isotopic data, partial digests, non-standard sample media) generated during the course of research, and to promote broad training in fundamental geochemical principals across the geosciences.

The **ioStipend** allows for amounts of approximately $5,000 (AUD, CAD or equivalent) for in-kind analytical work. Successful applicants will also be provided with 3 academic licences of **ioGAS**, the new exploratory data analysis software package available from ioGlobal.

The application form is available at www.ioglobal.net.

It is envisaged that three or four of these awards will be made each year.

Applications are reviewed by an expert group of ioGlobal's geochemists

Eligibility Criteria

Preference will be given to:

- students with no other source of funding
- students working on exploration geochemistry projects
- projects no or very minimal confidentiality requirements

The ioStipend is international. Applications are welcome from qualified institutions globally.

Some technical input may be provided by ioGlobal on request.

Requirements for receiving the ioStipend

Firstly, there are minimal strings attached. Recipients would have to agree to

1. Have their project promoted on the ioGlobal web site in an area devoted to R&D carried out under the program (couple of passport photo shots, brief description)
2. Acknowledge ACME Labs and ioGlobal for support in technical and public presentations of results
3. Write a short article for Explore describing the project outcomes, and allow this to be published on the ioGlobal web site.

David Lawie, John Gravel

EXPLORE

Newsletter No. 152 SEPTEMBER 2011

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