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Amalgamated lake-sediment data from Quebec and Labrador, Canada

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Merging of geochemical datasets from neighbouring regions, compiled during differently administered programs, in order to create seamless geochemical maps is complicated due to factors such as differences in sampling methodologies and analytical protocols, and sample densities. In this study, a suite of 5,510 lake-sediment samples from western and northern Labrador has been re-analyzed by ICP-MS after *aqua-regia* digestion, in order to merge the results with a suite of 26,727 lake-sediment samples collected in an adjacent area of the province of Quebec, analyzed by the same method. This merging of datasets has enabled the creation of regional geochemical maps of a contiguous area in northeastern Canada of almost 300,000 km^2. This activity is one of several surficial geochemistry and mapping activities in northern Quebec and Labrador that form part of the Geological Survey of Canada's Geo-mapping for Energy and Minerals (GEM-2) Program (2013-2020) (McClenaghan *et al*. 2016). The purpose of this article is to report on the old and new lake-sediment datasets and about the ongoing production of new lake-sediment geochemical maps for the Quebec-Labrador region that will be published in the first half of 2017.

Samples

The Quebec lake-sediment samples were collected during six separate campaigns and have also been analyzed by various methods (Beaumier 1982; 1983; 1984a,b; 1985; 1986a-c; 1987a,b). Of those samples, however, it is only the 24,261 samples analyzed by ICP-MS after *Aqua-Regia* digestion by Acme Analytical Laboratories in Vancouver that were used for the data amalgamation (Maurice & Labbé, 2009). The Labrador samples were re-analyzed in 2015 by Bureau Veritas Mineral Laboratories (the successor company to Acme) and reported by McCurdy (2016) and McCurdy *et al*. (2016). These new data are for a subset of samples that are part of a total of 19,433 samples, which were collected over most of the territory as part of the National Geochemical Reconnaissance (NGR) program of the Geological Survey of Canada (Boyle *et al*. 1981; Hornbrook *et al*. 1983; Friske and Hornbrook 1991; Friske *et al*. 1993a-d, 1994). These lake-sediment samples were previously analyzed for a variety of elements by various methods and after various digestion methods, as well as by INAA (Table 1 - *See page 5*). Only the recent re-analyses by *Aqua Regia*/ICP-MS are considered here. There is general correspondence, between the Quebec and Labrador programs, in the analyzed elements and their lower detection limits (Table 2 - *See page 5*), although the detection limits for Au and Pt in the Quebec dataset are both 1 ppb, compared to 0.2 ppb and 2 ppb in the new Labrador dataset. Also, the Labrador samples were analyzed additionally for Dy, Er, Eu, Gd, Ho, Lu, Nd, Pr, Sm, Tb, Tm and Yb which are omitted from this study since there are no corresponding data for the Quebec samples.

While the sample coverage over Labrador and most of Quebec was fairly even at 6 to 8 samples/100 km^2, coverage over the southern part of the Labrador Trough (Fig. 1 - *See page 6*) in Quebec was at least four times as dense (Amor 2015). In order to provide even coverage over the study area, a random sub-selection of 25% of the samples was taken from the total collected in this higher-density area. Sub-selection was done independently within each NTS 1:50,000 map sheet, to avoid regions of over- or under-selection, or 'clumping', but the resulting coverage is still somewhat uneven compared to the remainder of the study area.

Geology

The area covered by the lake-sediment sampling is entirely underlain by Precambrian rocks of the Canadian Shield (Hoffman 1990; Wardle & Van Kranendonk 1996). It consists of a major zone of diachronous accretion and collision between three Archean-age crustal blocks: i) the Superior Craton (Archean), ii) the Core Zone (mostly Archean with earliest-Paleoproterozoic crust) and iii) the North Atlantic Craton (Archean), and intervening Paleoproterozoic-age supracrustal sequences and magmatic arcs (Fig. 1). The boundary between the Core Zone and North Atlantic Craton is the Torngat Orogen, a zone of high metamorphic grade and ductile, mostly dextral transcurrent shear formed at ca. 1.87-1.84 Ga (Wardle *et al*. 2002). The Torngat Orogen preserves an accretionary prism dominated by metapelites (Tasiuyak Gneiss) and the tectonically exhumed deep root of a ca. 1.87-1.86 Ga magmatic arc (Lac Lomier Complex). The Burwell Domain, exposed on the northern tip of Labrador, consists of ca. 1.89 Ga tonalites and charnockites emplaced in Archean-age crust (Scott & Machado 1995). On its western side, the Core Zone is

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Information for Contributors

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Formats for headings, abbreviations, scientific notations, references and figures must follow the Guide to Authors for Geochemistry: Exploration, Environment, Analysis (GEEA) that are posted on the GEEA website at: http://www.geolsoc.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
Email: beth.mcclenaghan@canada.ca

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Notes from the Editor

EXPLORE issue 173 includes one technical article that describes a new series of lake sediments geochemistry maps for eastern Canada, written by Steve Amor, Martin McCurdy, Bob Garrett, David Corrigan, and Fabien Solgadi. **EXPLORE** thanks all those who contributed to the writing and/or editing of this issue: Steve Amor, Dennis Arne, Al Arseneault, Nigel Brand, Ben Cooke, David Corrigan, Bob Garrett, David Leng, Ray Lett, Matt Leybourne, Martin McCurdy, Paul Morris, Ryan Noble, Roger Paulen, and Fabien Solgadi. In this last issue of 2016, **EXPLORE** gratefully acknowledges our three corporate sponsors for the year, ALS Minerals, SciAps, and Olympus, as well as our advertisers, for their continuing financial support.

Below is the team that has provided readers with 4 excellent issues this year. Our team wishes all AAG members and other readers of **EXPLORE** a successful 2017.

Beth McClenaghan, *Editor*
Pim van Geffen, *Business Manager*
Steve Amor, *Calendar of Events*
Al Arsenault, *New Members list/AAG business office news*
Ryan Noble, *President's Letter*
Dennis Arne, *Elements content*
Dave Smith, *AGM Minutes, Council Elections, and AAG business*
David Leng, *editing assistance*
Dennis Arne, Ray Lett, *Geochemical Nuggets*
Vivian Heggie, *Page layout and mailing*

Beth McClenaghan
Editor

President's Message

It has been a solid year for the AAG, our membership and finances remain stable, our journal (GEEA) impact factor has improved at a better rate than our competitors and we are well underway with the organisation of the next IAGS in Vancouver, Canada in 2018.

Again, like previous years, we've had a great series of articles published in **EXPLORE** in 2016 and I want to encourage our members to consider publishing an article in **EXPLORE**. Some of our readers are concerned about the impact of their research, and in most cases this relates to impact factors for journals. Impact factors may be important, but it is not the only measure of impact. While **EXPLORE** does not have an impact factor, the actual impact of what is published here may far outweigh that numerical value. A lot of the **EXPLORE** readers are linked to industry or active in applying research. In essence, if it is seen in EXPLORE it has a chance to be acted upon and creating real impact. I have not overheard an explorationist or someone working in environmental remediation state "I read this paper in Nature and I think we should try it here." I can, however, attest to people doing this with respect to **EXPLORE** articles. One of my own publications on groundwater sampling and analysis was regularly handed out to local project geologists to try to obtain some regional groundwater samples for exploration. Some of this groundwater sampling lead to further exploration and generation of targets, some results actually identified a future economic ore body (although it wasn't drilled for a few years until coincident EM and structure matched up). As applied geochemists, this is what we are aiming for, so please consider publishing synopsis of your applied research here.

Also, my personal opinion is that more people read the **EXPLORE** articles more fully than even GEEA articles, and certainly a lot more AAG members read both GEEA and **EXPLORE** than the latest articles in our competitor journals. A case in point was the recent **EXPLORE** article by Leybourne *et al.* on mercury (July 2016, Issue No. 171). Just this week I was discussing this article in the hallway with another geochemist. The topic is not something either of us were actively working on, and hence we both would not have read about it had it been published in another journal, The accessibility of the article in **EXPLORE** meant that we had both at least taken some time to relate to this work.

Finally, another big benefit of publishing in **EXPLORE** is that the format, colour printing and a lot of little nit-picking annoyances that are associated with journals are not a problem. The articles are reviewed, but the turnaround is pretty quick and Beth McClenaghan (Editor) and her team certainly have a fast and efficient publication timeline if the science and the presentation are of good quality.

As always at this time of year many of us are getting ready for a break from work. I thank you all for your support of the AAG through 2016 and trust you will continue to renew your membership for 2017 and beyond. I hope you get a good break and switch off from your geochemistry day jobs. I wish you a safe and relaxing start to 2017.

Warm regards,

Ryan Noble
AAG President
ryan.noble@csiro.au

Amalgamated lake-sediment data… *continued from page 1*

Table 1: Summary of lake-sediment analyses for samples collected in Quebec and Labrador databases that were reported prior to current study.

Dataset	Digestion	Finish/Method	Number of Samples	Elements
Quebec	*Aqua regia*	ICP-ES	26497	Ag, Al, As, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cu, Eu, Fe, Ga, Ge, In, K, La, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Sc, Sm, Sr, Th, Ti, V, Y, Zn, Zr
	Aqua regia	ICP-MS	24261	Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Ge, Hf, Hg, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Pd, Pt, Rb, Re, Sc, Sb, Sc, Se, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, W, Y, Zn, Zr
	Multiacid (HNO_3-HCl-HF-$HClO_4$	ICP-MS	1869	Ag, Al, As, Au, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Hf, Ho, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pr, Rb, Sb, Sc, Sm, Sn, Sr, Ta, Tb, Th, Ti, Tm, U, V, W, Y, Yb, Zn, Zr
	Aqua regia	AAS	17169 268 18116 12132	As Cr Hg Sn
		INAA	15393 - 15881	As, Au, Br, Cs, Sb, Se, Tm, U, W
		Gravimetry	26489	Loss on Ignition (L.O.I.)
Labrador	Multiacid (HNO_3-HCl HF-$HClO_4$)	ICP-ES	18357	Al, Ba, Be, Ca, Ce, Co, Cr, Cu, Dy, Fe, Ga, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Sc, Sr, Th, Ti, V, Y, Zn, Zr
	Aqua regia	AAS	19419 10364 19419 10364	Co, Cu, Fe, Mn, Ni, Pb, Zn Cd Mo V
	Aqua regia	Cold-vapour AAS	19296	Hg
	Aqua regia	Hydride AAS	18946 2449	As Sb
	Aqua regia	Colorimetry	4636	As
	K_2CO_3-KNO_3 fusion	Ion-specific electrode (ISE)	19259	Fluoride
		INAA	19196	As, Au, Ba, Br, Ce, Co, Cr, Cs, Eu, Fe, Hf, La, Lu, Mo, Na, Ni, Rb, Sb, Sc, Sm, Ta, Tb, Th, U, W, Yb
		Delayed neutron) counting (DNC	18763	U
		Gravimetry	19410	Loss on Ignition (L.O.I.)

Table 2: Lower Detection Limits (LDL) for aqua regia/ICP-MS determinations in this study. Analyses of Labrador samples also included Dy, Er, Eu, Gd, Ho, Lu, Nd, Pr, Sm, Tb, Tm and Yb. Detection limits for the Quebec and Labrador samples were 1 and 0.2 ppb respectively for Au, and 1 and 2 ppb for Pt.

		LDL				LDL				LDL	
Element	Units	Quebec	Labrador	Element	Units	Quebec	Labrador	Element	Units	Quebec	Labrador
Ag	ppm	0.002	0.002	Hf	ppm	0.02	0.02	S	pct	0.02	0.02
Al	ppm	100	100	Hg	ppb	5	5	Sb	ppm	0.02	0.02
As	ppm	0.1	0.1	In	ppm	0.02	0.02	Sc	ppm	0.1	0.1
Au	ppb	1	0.2	K	ppm	100	100	Se	ppm	0.1	0.1
B	ppm	20	20	La	ppm	0.5	0.5	Sn	ppm	0.1	0.1
Ba	ppm	0.5	0.5	Li	ppm	0.1	0.1	Sr	ppm	0.5	0.5
Be	ppm	0.1	0.1	Mg	ppm	100	100	Ta	ppm	0.05	0.05
Bi	ppm	0.02	0.02	Mn	ppm	1	1	Te	ppm	0.02	0.02
Ca	ppm	100	100	Mo	ppm	0.01	0.01	Th	ppm	0.1	0.1
Cd	ppm	0.01	0.01	Na	ppm	10	10	Ti	ppm	10	10
Ce	ppm	0.1	0.1	Nb	ppm	0.02	0.02	Tl	ppm	0.02	0.02
Co	ppm	0.1	0.1	Ni	ppm	0.1	0.1	U	ppm	0.1	0.1
Cr	ppm	0.5	0.5	P	ppm	10	10	V	ppm	2	2
Cs	ppm	0.02	0.02	Pb	ppm	0.01	0.01	W	ppm	0.1	0.1
Cu	ppm	0.01	0.01	Pd	ppb	10	10	Y	ppm	0.01	0.01
Fe	ppm	100	100	Pt	ppb	1	2	Zn	ppm	0.1	0.1
Ga	ppm	0.1	0.1	Rb	ppm	0.1	0.1	Zr	ppm	0.1	0.1
Ge	ppm	0.1	0.1	Re	ppb	1	1				

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Amalgamated lake-sediment data...

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separated from the Superior Craton by the ca. 1.83-1.79 Ga New Quebec Orogen (Clark & Wares 2005). This predominantly transpressional orogen consists of greenschist- to lower-amphibolite facies clastic and chemical sedimentary rocks representing i) autochthonous rift-to-drift sequences, as well tectonically overlying flysch, banded iron-formation and molasse sediments interlayered with minor volcanic rocks (Kaniapiscau Supergroup), ii) belts composed predominantly of mafic volcanic rocks and sills interlayered with sediments comprised mostly of meta-siltstone and black shale (Baby-Howse and Doublet domains) with the Doublet interpreted as remnant of a back-arc basin (Rohon *et al.* 1993), and iii) Mid- to upper-amphibolite facies, Paleoproterozoic-age clastic metasedimentary and minor mafic metavolcanic rocks that are in thrust contact with the Baby-Howse and Doublet zones in basement-involved thick-skinned tectonics (Rachel-Laporte zone). Rocks of the Baby-Howse and Doublet zones are intruded by voluminous, ca. 1.88 Ga metagabbro sills of the Montagnais suite. Based on continuity of regional aeromagnetic patterns, Archean crust occurring in basement windows and east of the Labrador Trough is interpreted to have Superior Craton affinity; that hypothesis, however, remains to be tested. The Core Zone is also host to a ca. 1.84-1.81 Ga continental magmatic arc, the De Pas Batholith (Dunphy & Skulski 1996).

The southeastern portion of the map presented in Figure 1 is intruded by voluminous Mesoproterozoic-age plutons, including the Nain Plutonic Suite, emplaced between ca. 1.46 and 1.29 Ga (Emslie & Stirling 1993; Amelin *et al.* 1999). The latter are economically important, being host to the Voisey's Bay magmatic Ni-Cu deposit as well as the Strange Lake REE deposit. The southernmost extent of the lake sediment survey, east of the Smallwood Reservoir, covers the Seal Lake Group, a set of ca. 1.25 Ga volcano-sedimentary sequences with low-grade metamorphic overprint that contains numerous copper occurrences (van Nostrand & Corcoran 2013). The study area is bounded to the south by the Grenville Orogen.

Comparison of Quebec and Labrador Analyses

The application of the same methods of digestion and analysis to both suites of samples greatly facilitates the merging of data from the two jurisdictions, despite their having been collected and analyzed at different times, and as part of two separately administered programs. There are no paired analyses (from the Quebec and Labrador programs) of the same samples, with which to establish rigorously the relationship between the two programs. Instead, to verify the closeness of the correspondence, analyses of samples from the Quebec dataset, collected close to the border between the two jurisdictions, have been paired with their 'nearest neighbours' on the Labrador side. In all cases, the paired samples were separated by a distance of 2 km or less; they have been separated into high-loss on ignition (LOI) and low-LOI datasets, using a threshold of 18.4%. This threshold was arrived at by examining the behaviour

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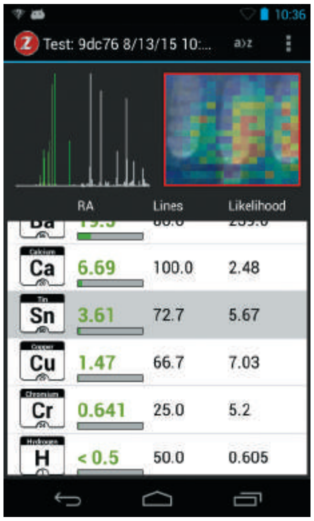

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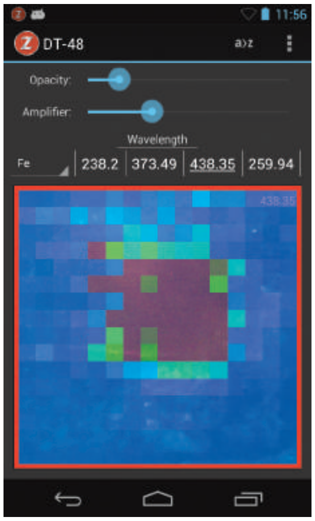
	RA	Lines	Likelihood
Ca	6.69	100.0	2.48
Sn	3.61	72.7	5.67
Cu	1.47	66.7	7.03
Cr	0.641	25.0	5.2
H	< 0.5	50.0	0.605



DT-48

Opacity:
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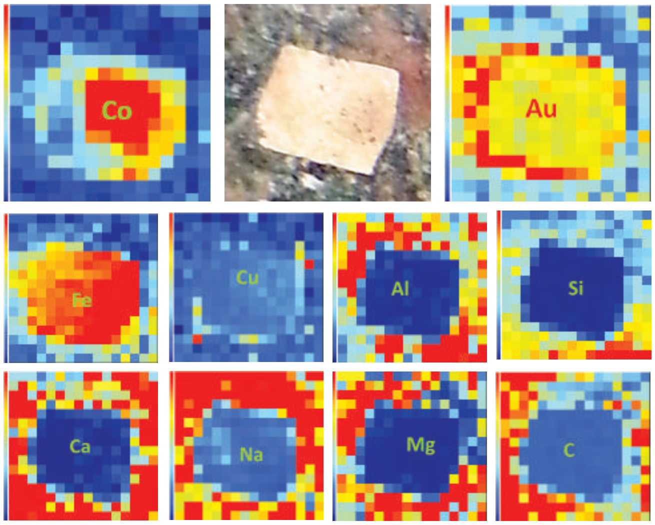
Fe	238.2	373.49	438.35	259.94



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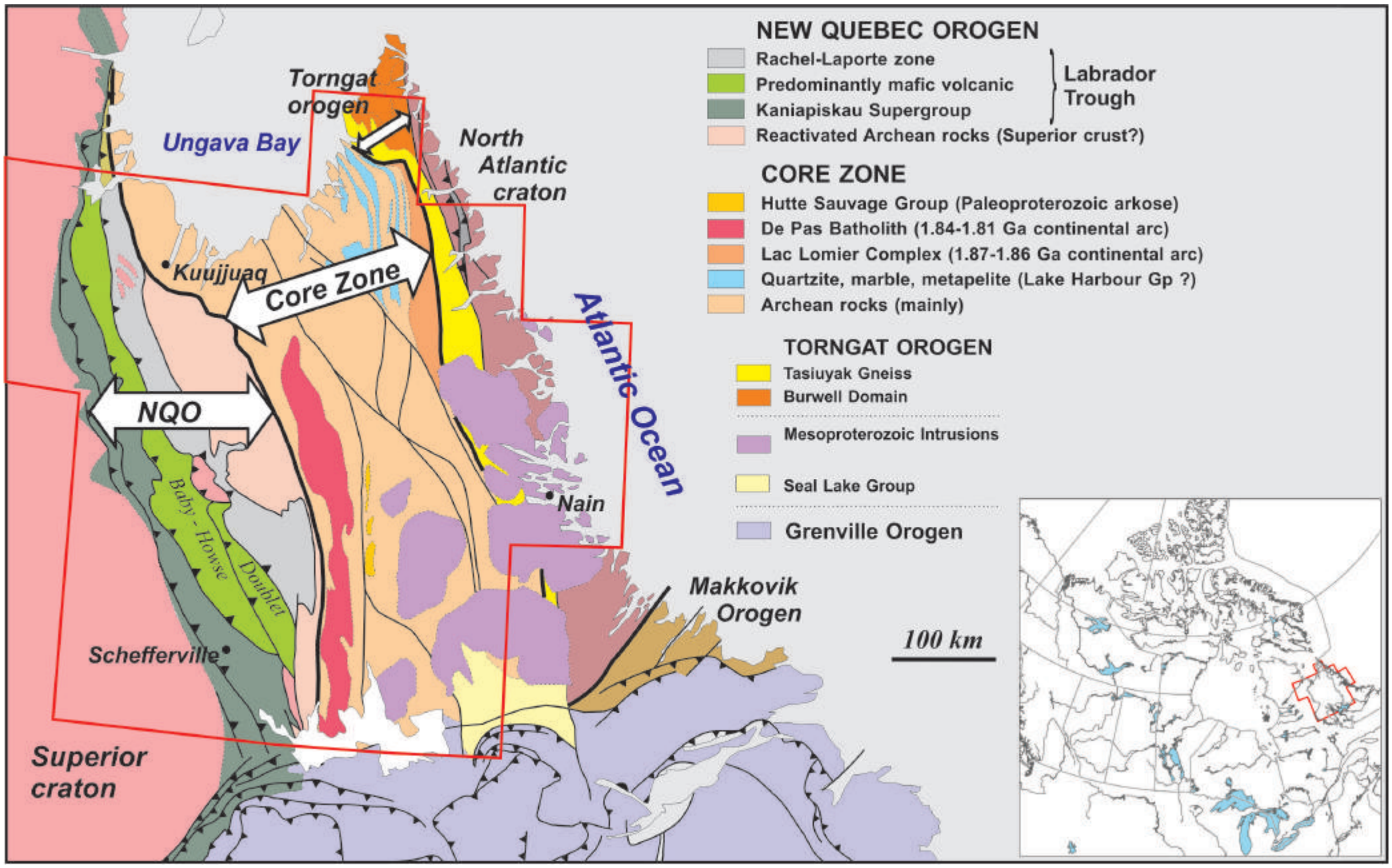

Figure 1: Simplified geological map of the Precambrian Shield in Quebec and Labrador. Modified after James et al. (2003). Study area outlined by red box.

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of a variety of elements with increasing LOI content in the Quebec and Labrador samples (Fig. 2), and corresponds closely to a cutoff arrived at similarly by Trépanier (2007).

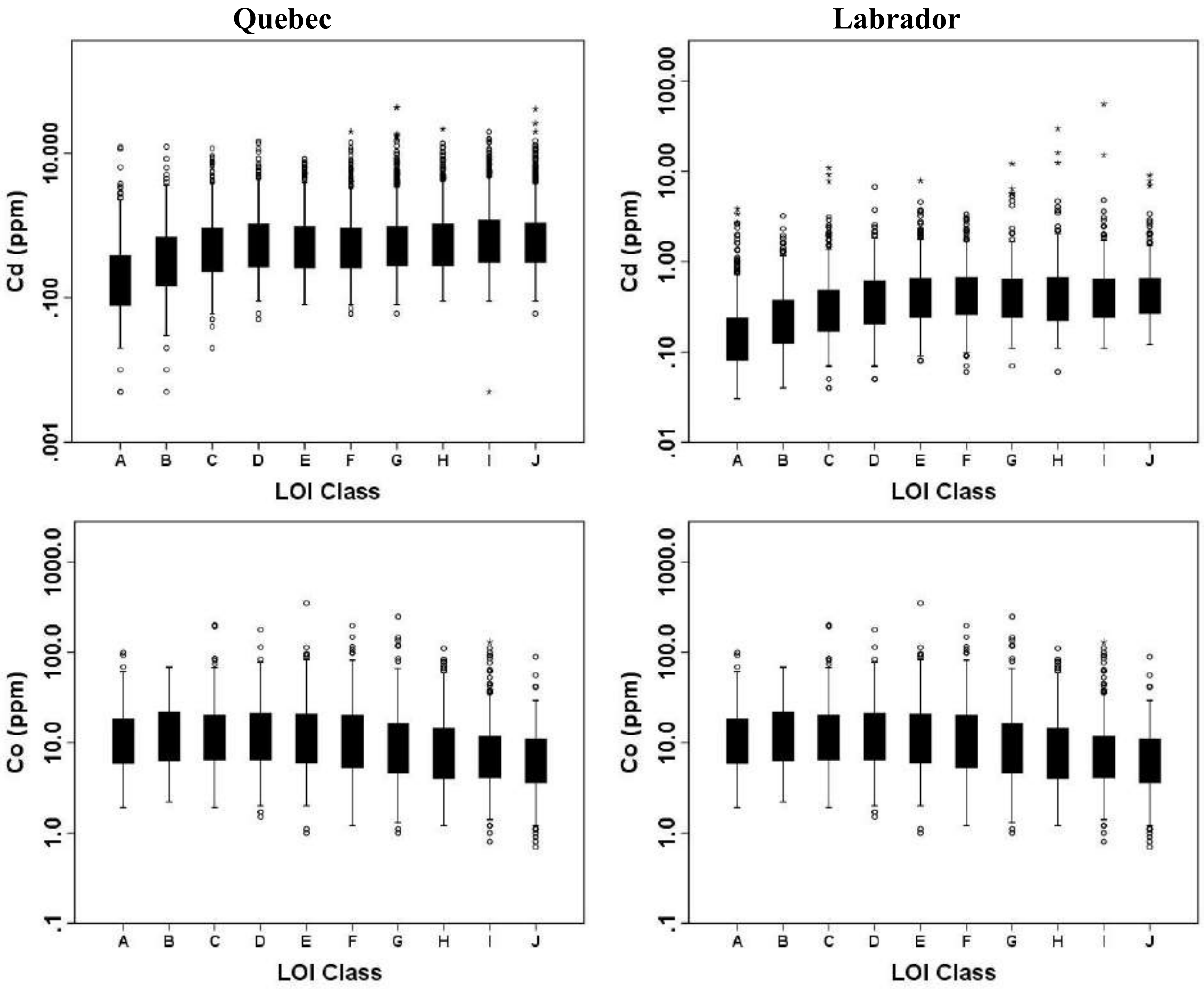

Figure 2: Relationship between loss-on-ignition (LOI) and Cd and Co content of lake sediment in NE Quebec and Labrador. LOI classes: A: ≤ 6.2%; B: 6.3-10.4%; C: 10.5-14.4%; D: 14.5-18.4%; E: 18.5-22.6%; F: 22.7-26.4%; G: 26.5-29.8%; H: 29.9-33.8% I: 33.9-54%;J: >54%. Many (though not all) elements show a similar inflection point between 18 and 22% LOI.

Application of paired t-tests (R-Project, 2016), following $\log_{10}$ transformations, to these high and low-LOI subsets, and both subsets combined, led to the conclusion that if attention was restricted to sample pairs separated by distances of 2 km or less, there was no significant difference (indicating a 'background shift') between analyses of Al, Ba, Cd, Co, Cr, Cu, Fe, Hg, K, La, Li, Mg, Mo, Ni, Pb, Rb, S, Sr, Th, Ti, U or V in the Labrador and Quebec datasets at the 95% confidence level. In the case of Be, Ca, Ce, Cs, Ga, Mn, Nb, P, Sc, Se, Sn, Tl, V, Zn and Zr, at least one (but not all three) of the paired t-tests showed no significant differences. Only Ag showed significant differences in all three tests. More than 10% of the analyses of As, Au, Ge, Hf, In, Re, Sb, Te and W were less than the lower detection limit in all six datasets and are not amenable to statistical calculations of this kind; nevertheless, map plots of some of these elements are instructive.

An alternate procedure used the average difference between the pairs in $\log_{10}$ units; this was then anti-logged and the difference from unity (equivalent to zero difference between the logarithms) was expressed as a percentage. Where the difference was ≤10%, the element was deemed acceptable for mapping, and where >10% and ≤15% the element was deemed acceptable with caveats. Based on the ≤10% criterion the following elements would be 'mappable': Al, Ba, Be, Cd, Cu, Hg, Mg, Ni, Pb, S, Sr, Th, Ti, and U. Relaxing the criterion to ≤15% allowed for these additional elements to be mappable: Ca, Cr, Fe, Ga, Hf, K, La, Li and, Y.

Geochemical Plots

Figures 3 to 7 show the aerial distribution of values of K, U, Pb, S and Cu in the combined datasets. These elements were chosen because they are each loaded significantly in different principal components extracted from each of the four datasets (Quebec / Labrador / high LOI / low LOI) and are therefore probably representative of the dominant processes affecting the distribution of the elements over the

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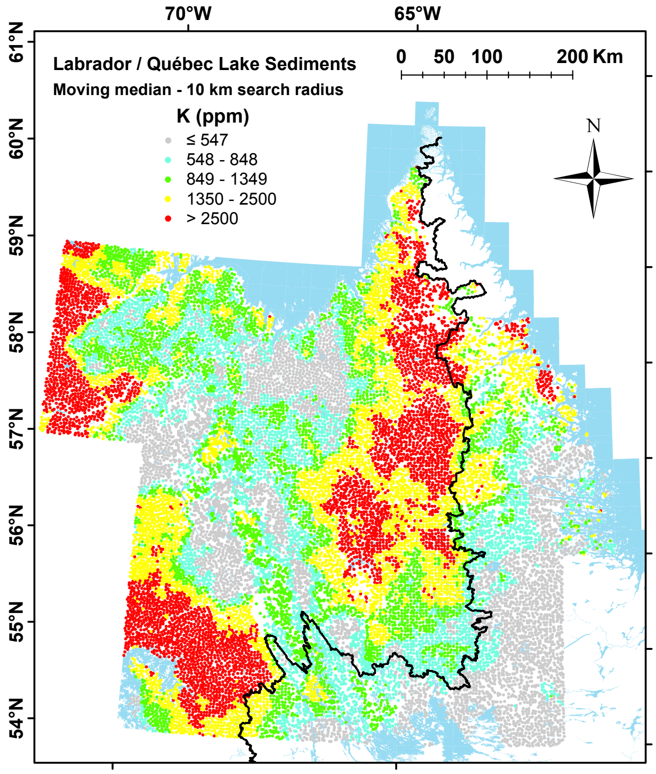

Figure 3: Distribution of K (unweighted moving medians) in Labrador and NE Quebec lake sediments.

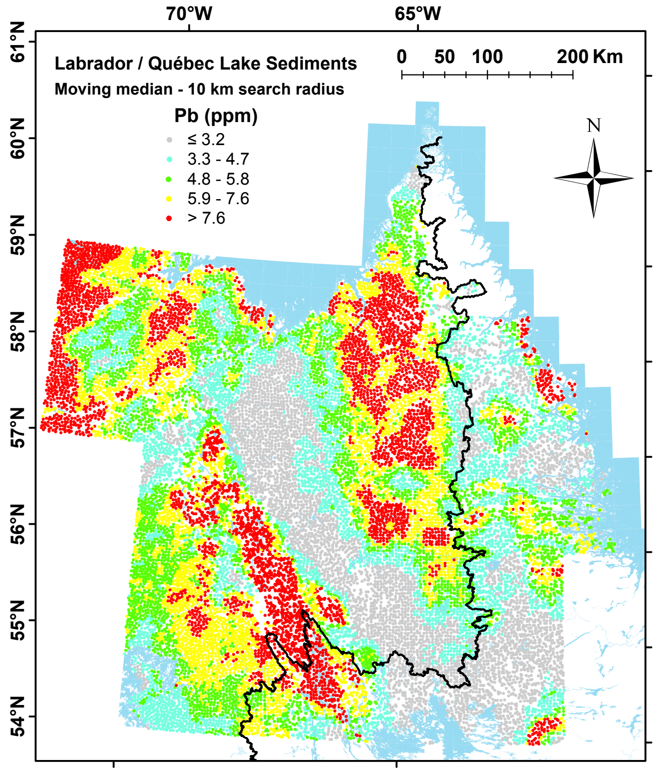

Figure 5: Distribution of Pb (unweighted moving medians) in Labrador and NE Quebec lake sediments.

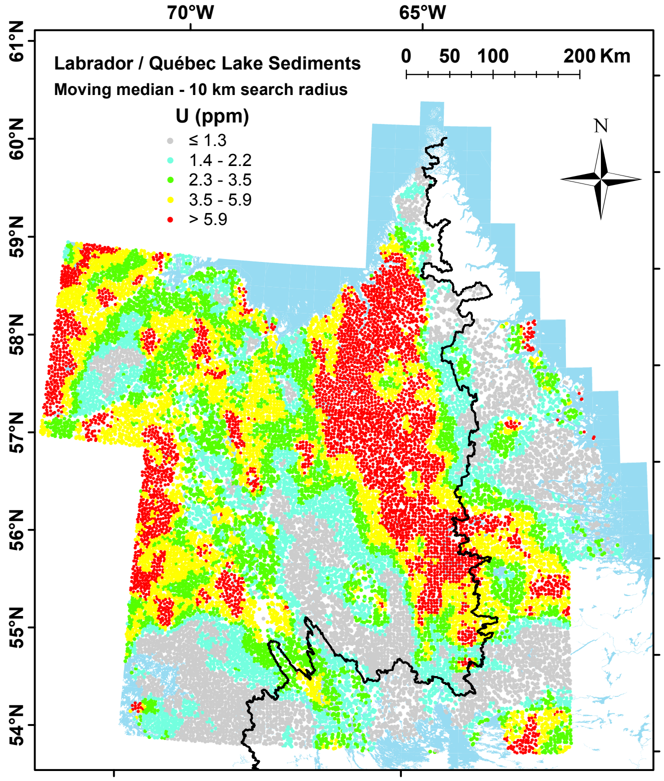

Figure 4: Distribution of U (unweighted moving medians) in Labrador and NE Quebec lake sediments.

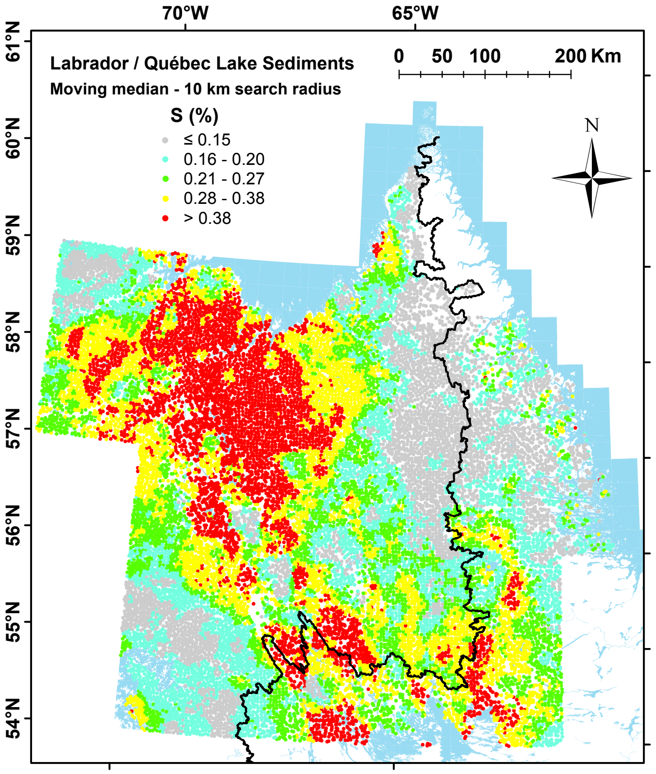

Figure 6: Distribution of S (unweighted moving medians) in Labrador and NE Quebec lake sediments.

entire region. The plotted value assigned to each sample is a moving unweighted median (Gustavsson *et al*. 2001) of all values of samples falling within a 10-km radius; this has the effect of smoothing the data while preserving the sample locations. In all cases the data are divided into five quintile class intervals; that is to say, the samples assigned to each colour make up 20% of

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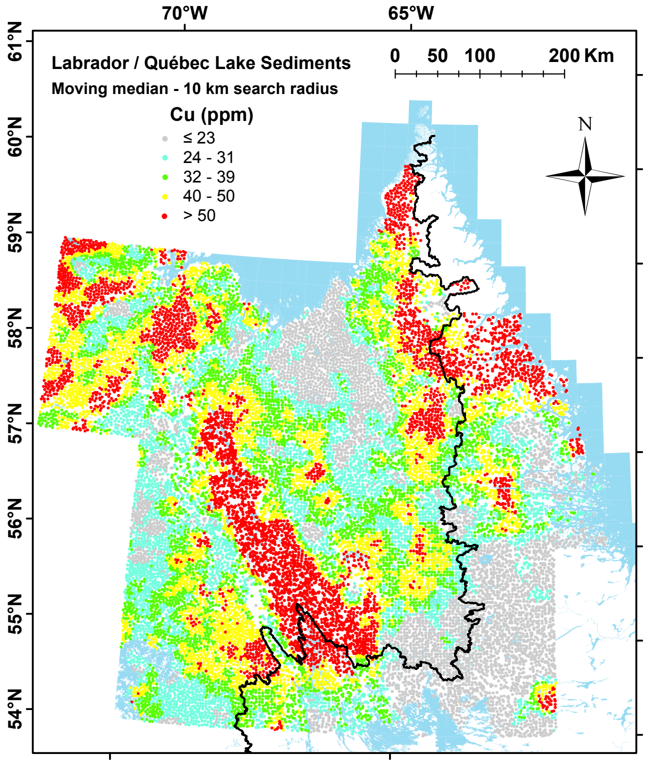

Figure 7: Distribution of Cu (unweighted moving medians) in Labrador and NE Quebec lake sediments.

the total. Figures 8 and 9 show the distribution of Sb and Sn, whose areal distributions display a number of interesting features.

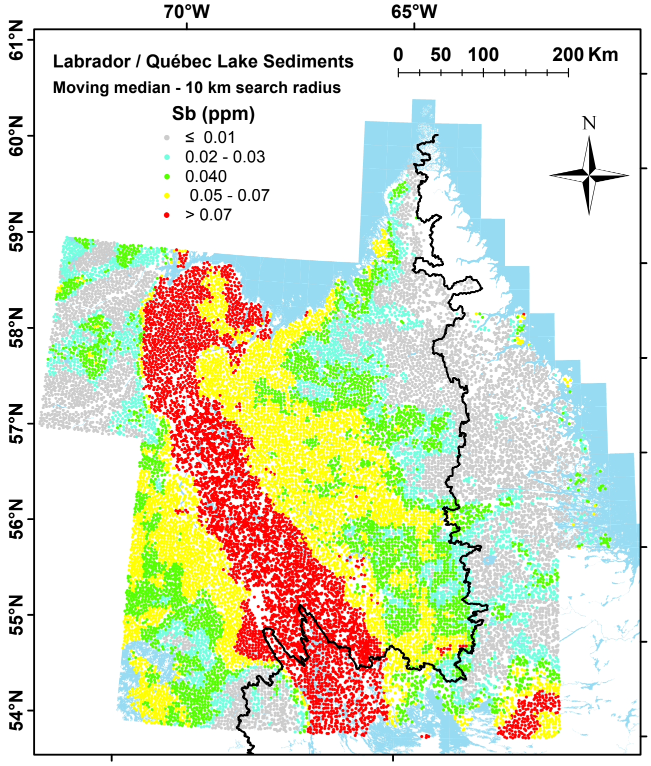

Figure 8: Distribution of Sb (unweighted moving medians) in Labrador and NE Quebec lake sediments.

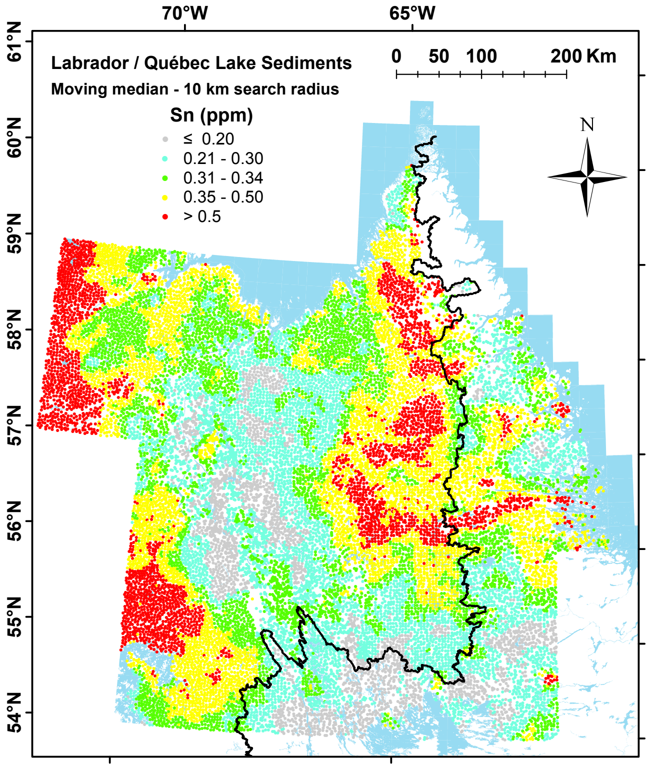

Figure 9: Distribution of Sn (unweighted moving medians) in Labrador and NE Quebec lake sediments.

Levelling between Quebec and Labrador datasets

Results of the paired t-tests described above suggest that there is very little need for levelling of the two datasets. Therefore, the datasets can be combined without a serious discontinuity appearing at the provincial border (e.g., Amor 2015). One exception to this generalization is Ag; therefore the data from Labrador for this element have been levelled using regression equations derived for nearest-neighbour pairs, separated into high-LOI (>18.4%) and low-LOI groups. Results are shown in Figures 10a and 10b.

In the dataset from Quebec, an internal levelling issue is apparent for Cd and Hg, with samples from project 1997520 showing significantly higher values of the first element, and lower values of the second, than in samples from projects 1983050, 1983055 and 1984059. This results in a linear discontinuity along the east-west boundary of project 1997520's area of coverage (Figs. 11a, b). A nearest-neighbour regression exercise was carried out on these data and the results are shown in Figures 12a and 12b.

Conclusion

Multi-element (ICP-MS) analyses of lake sediments from adjacent parts of northeastern Quebec and Labrador, that were collected over an area of approximately 300,000 km^2, were merged to create geochemical maps of this large area. Though the analyses were carried out under different programs at different times, there were no levelling issues between the two datasets for most elements, although levelling was necessary for Cd and Hg within the Quebec

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Amalgamated lake-sediment data...

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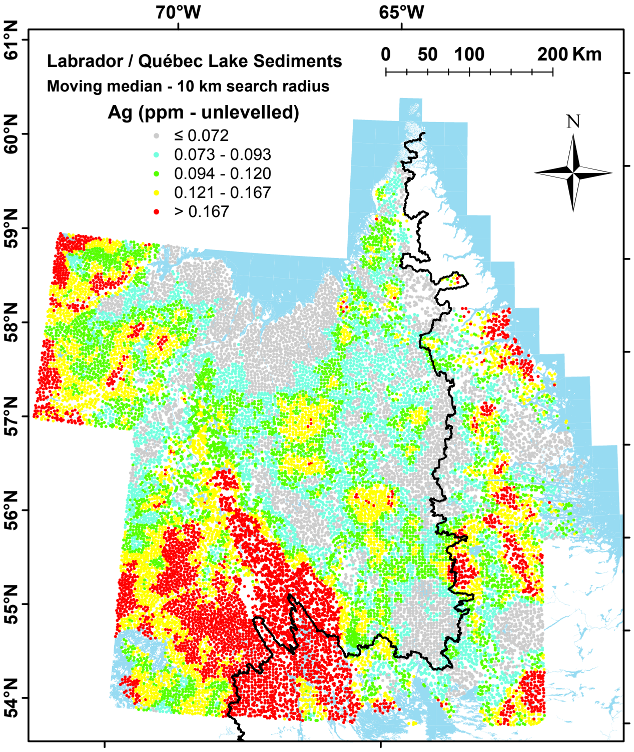

Figure 10a: Distribution of unadjusted Ag (unweighted moving medians) in Labrador and NE Quebec lake sediments.

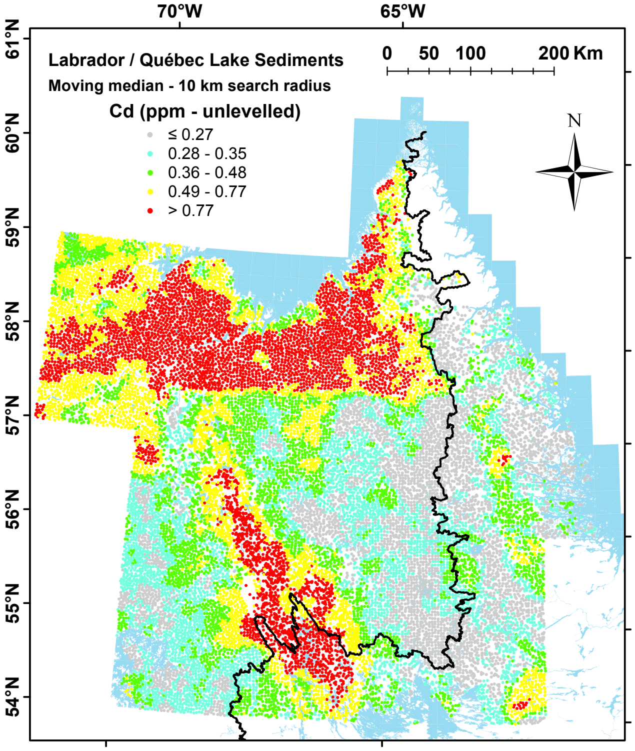

Figure 11a: Distribution of unadjusted Cd (unweighted moving medians) in Labrador and NE Quebec lake sediments.

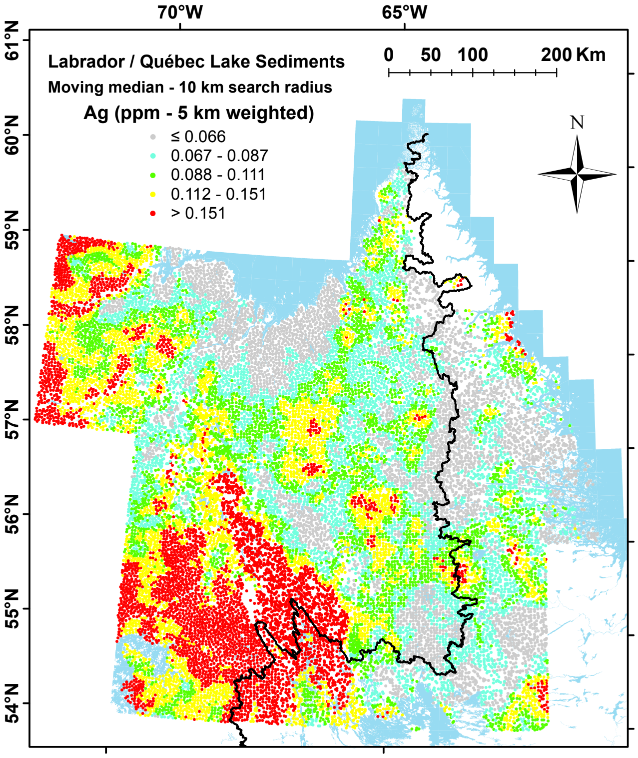

Figure 10b: Distribution of levelled Ag (unweighted moving medians) in Labrador and NE Quebec lake sediments.

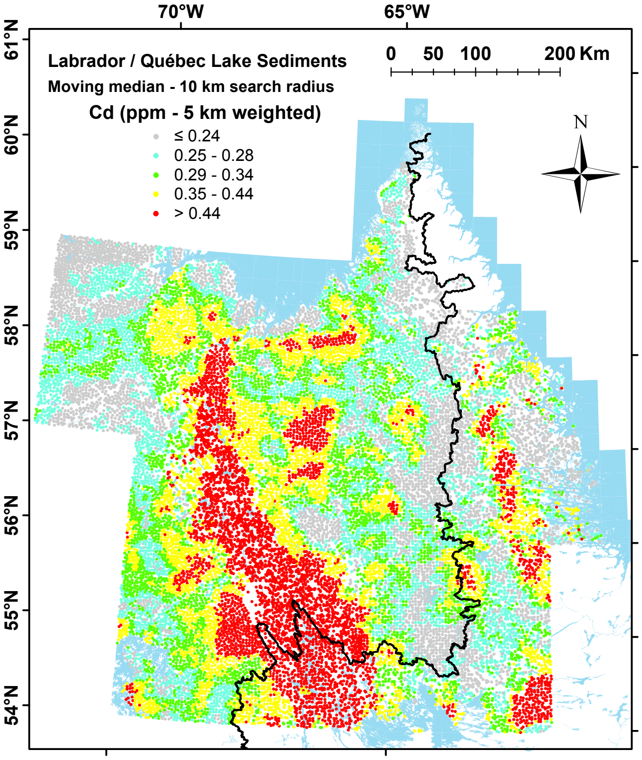

Figure 11b: Distribution of levelled Cd (unweighted moving medians) in Labrador and NE Quebec lake sediments.

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Amalgamated lake-sediment data...

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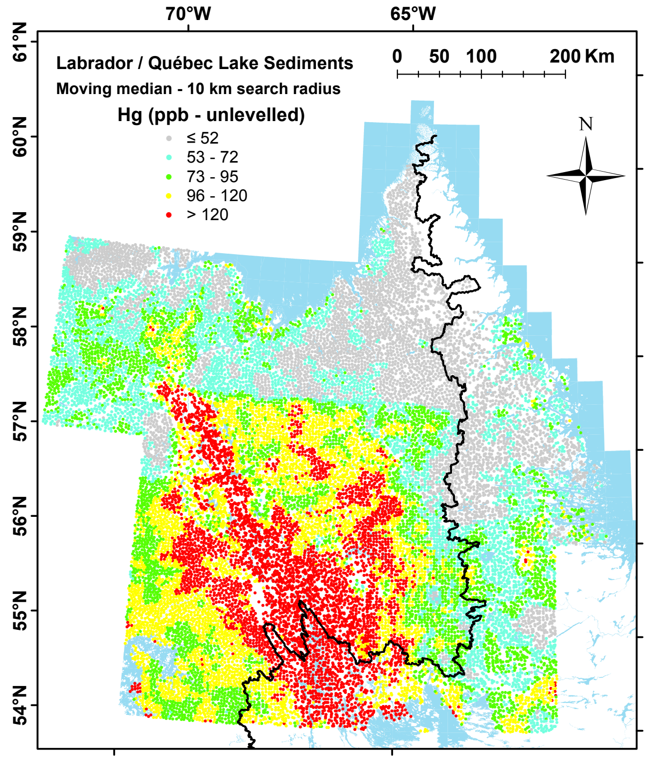

Figure 12a: Distribution of unadjusted Hg (unweighted moving medians) in Labrador and NE Quebec lake sediments.

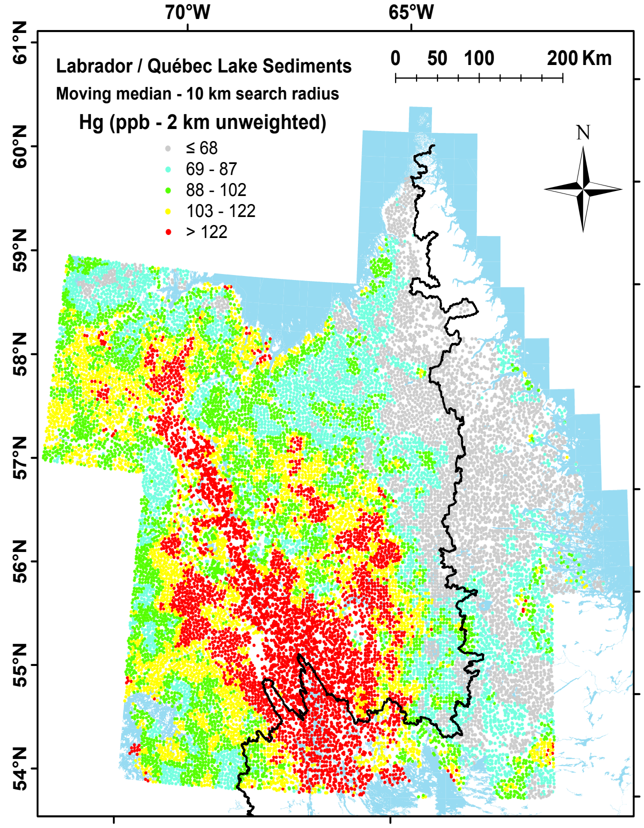

Figure 12b: Distribution of levelled Hg (unweighted moving medians) in Labrador and NE Quebec lake sediments.

dataset. Application of unweighted moving medians, and 5-colour quintile class intervals, has resulted in maps clearly showing a variety of broad geochemical features.

The most distinctive geochemical feature is related to the 1,100 km long, iron-ore bearing Labrador Trough of the New Quebec Orogen, which has elevated values of Cu, and other elements including Sb and As, over about half of its strike length, starting at the Smallwood Reservoir in the south and extending to Ungava Bay in the north. Other known geological features with a distinct signature in the composition of the lake sediments include the rocks of the Seal Lake Group in the southeastern corner of the study area; this area hosts host Cu mineralization and lake sediments display elevated values of U, Sb, Ag and Cd, amongst other elements.

In conclusion, the merging of the two datasets has been achieved with very few difficulties and it is hoped that the merged data will create an added stimulus to mineral exploration in both Quebec and Labrador.

Acknowledgements

This research was funded by the Geological Survey of Canada's Geo-mapping for Energy and Minerals (GEM-2) program. It was carried out in collaboration with the Ministère de l'Énergie et des Ressources naturelles du Québec (MERNQ) and the Geological Survey of Newfoundland and Labrador (GSNL). Heather Campbell, Beth McClenaghan, and Roger Paulen are thanked for reviewing earlier drafts of the manuscript.

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ALS Laboratories method codes covering the period 1983 through 2015

A table listing ALS methods codes through time is available on the AAG website for download as part of the **EXPLORE** 173 issue (Appendix attachment). This table is intended as a guide only for EXPLORE readers. Any specific information relating to any issued laboratory certificates should be confirmed with your ALS representative before being relied upon.

Ben Cooke
ALS Client Services Manager, Geochemistry Western Region, Australia

The Association of Applied Geochemists' Student Support Program — helping the up and coming

The Association of Applied Geochemists (AAG) is the only professional association dedicated to the science of applied geochemistry and the future of the AAG is in large part in the hands of the next generation of applied geochemists. Recognising this, the AAG offers a variety of incentives for applied geochemistry students to be a part of the Association, including subsidies for membership and attendance at the AAG's biennial symposium, prizes and awards for talks and posters presented at symposia, and for student-authored papers that are published in AAG's journal Geochemistry: Exploration, Environment, Analysis (GEEA).

AAG is not alone in recognising the importance of applied geochemistry students and the thesis work they undertake. Analytical laboratories are aware of the important focus that AAG puts on applied geochemistry, and that in several years applied geochemistry students will be the laboratorys' customers. The majority of theses undertaken by applied geochemistry students involve analytical work, the cost of which can be onerous, especially with increasing difficulty in securing funding to support students.

Considering both the AAG and analytical laboratories have an interest in students of applied geochemistry, AAG initiated a collaboration with laboratories in 2011 to broker in-kind analytical support for applied geochemistry students. The program attracted sufficient support from laboratories to run effectively until 2013, when a downturn in the exploration industry forced laboratories to reconsider their involvement, despite their endorsement of the value of the initiative.

The program recommenced in 2015, with sponsorship from Actlabs, ALS, Bureau Veritas Minerals, and Intertek-Genalysis. These laboratories offer a wide range of analytical services for research in applied geochemistry spanning the environmental as well as mineral exploration fields, from BSc through to PhD students. The application process for in-kind analytical support is simple (see Student page on the AAG website), https://www.appliedgeochemists.org/index.php/students/2-uncategorised/15-in-kind-analytical-research-funding-for-students.

If you are interested in this program, download an application form, fill it in, and submit it to: education@appliedgeochemists.org.

One condition of accepting the in-kind support is that students must report on their results either in GEEA or **EXPLORE**, the AAG's newsletter. To date, six applied geochemistry students have received support, covering a wide range of topics *(see next column)*.

Paul Morris
AAG Education Committee

Applicant: **Mathew Bodnar**
Year: 2016
Institution: University of British Columbia (Canada)
Degree: MSc
Thesis Title: *Mapping chemical dispersion above a buried VMS in a till covered terrain, Lara VMS deposit, Vancouver Island, Canada.*
Sponsoring Laboratory: ALS

Applicant: **Victor Vincent**
Year: 2016
Institution: Modibbo Adama University of Technology (Nigeria)
Degree: BSc
Thesis Title: *Geological investigation of sediment hosted sulphide deposits of Azara-Akiri-Wuse Area, Northcentral Nigeria*
Sponsoring Laboratory: ALS

Applicant: **Enerst Tata**
Year: 2014
Institution: University of Buea (Cameroon)
Degree: PhD
Thesis Title: *Felsic plutonism, hydrothermal alteration and granite-related gold mineralization, Batouri gold district, SE Cameroon: geochronology and geochemical constraints*
Sponsoring Laboratory: Intertek-Genalysis

Applicant: **Marcus Phua**
Year: 2014
Institution: University of Melbourne (Australia)
Degree: MSc
Thesis Title: *Petrogenesis of the gabbroic intrusions hosting magmatic Ni-Cu-PGE sulphides at Melba Flats, Western Tasmania*
Sponsoring Laboratory: Bureau Veritas - Minerals
Publication: SEG conference paper abstract, 2015

Applicant: **Andrew Lucas**
Year: 2011
Institution: University of Western Australia (Australia)
Degree: PhD
Thesis Title: *Evaluating the diffusive gradients in thin films technique for the detection of multi-element anomalies in soils*
Sponsoring Laboratory: Intertek-Genalysis
Publication: EXPLORE v161

Applicant: **Xin Du**
Year: 2011
Institution: University of Western Australia (Australia)
Degree: PhD
Thesis Title: *Particle size fractionation and chemical speciation of REE in a lateritic weathering profile in Western Australia*
Sponsoring Laboratory: Intertek-Genalysis
Publication: EXPLORE v157

Geochemical Nuggets

An example of gold variation in sediment from a poorly developed bar in a mountain stream on Vancouver Island, BC, Canada

Ray Lett, *Victoria, BC, Canada (raylett@shaw.ca)*

Introduction

Stream sediment geochemical surveys are a robust, economical exploration method for discovering new mineral deposits (Fletcher 1997). In British Columbia, Canada, most government and private sector-managed regional geochemical surveys use samples collected from active first and second order streams followed by analysis of the <0.177 mm fraction of the sample for a wide range of elements by techniques such as an Aqua Regia (AR) digestion combined with inductively coupled plasma mass spectroscopy (ICP-MS) (Jackaman & Lett 2013; Rukholv & Nasiri 2015). For most geochemical pathfinder elements (e.g. As, Cu, Pb, Mo, Zn), the average variability in element concentrations in a typical 0.5 kg stream sediment sample is reproducible within one standard deviation so that anomalous geochemical signals reflect mineralization within the stream catchment basin rather than the variation from sampling bias. However, the variability of heavy mineral grains with a high proportion of elements such as Au, W, Sn, and Pt can be large because they are erratically distributed through the sediment. This variability is due to hydraulic sorting of mineral grains (Rittenhouse & Thorp 1943) and the so called `nugget effect' where a larger, single grain can bias the analytical result (Day & Fletcher 1989).

Modelling mineral grain dispersion in streams can, to some degree, predict the optimum sediment sample and grain size for reducing the high sampling variability in different fluvial energy environments (Day & Fletcher 1991). Sand sized and finer sediment may be scoured from fast flowing streams typical of mountainous, high rainfall regions in western British Columbia, but gold grains are likely to be concentrated in turbulent reaches of a stream when the water flows rapidly over a rough stream bed. Larger gold particles can be expected to accumulate because turbulence often reflects stream bed smoothness and ultimately bedload transport capacity. Smaller gold grains may also become suspended in the turbulent water despite the their high density.

Under these conditions moss mats, attached to boulders and logs adjacent to the stream channel can capture suspended sediment, including the smaller gold grains, from the stream water and in the process greatly improve gold anomaly contrast (Matysek et al. 1988). Comparing element distribution in the material (e.g., bar sediment, moss mat sediment) typically sampled during regional surveys can help understand the geochemical behaviour of elements in different stream environments and suggest the best sampling strategy. This article describes the distribution of Au and other elements in stream and moss mat sediment and in heavy mineral concentrates along a poorly developed mid-channel bar in a branch of the Sombrio River on Southern Vancouver Island (Fig. 1).

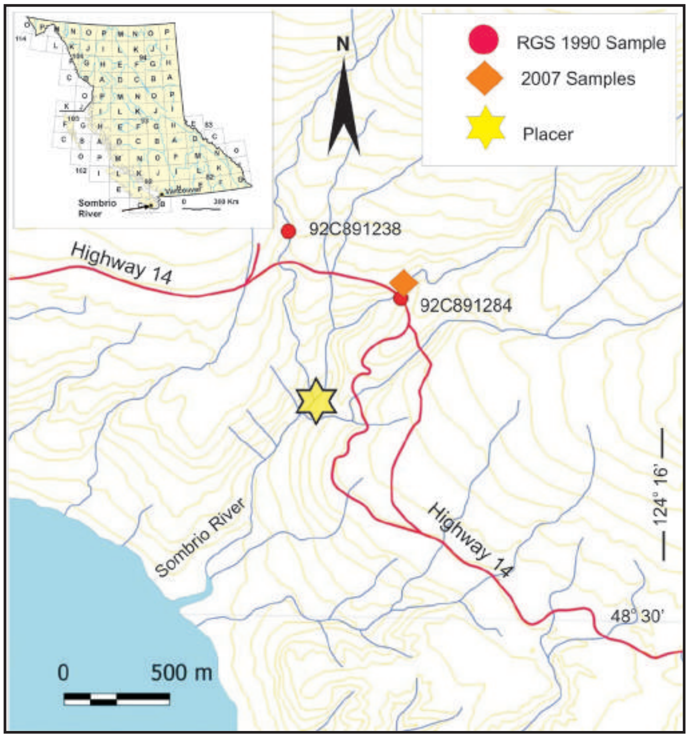

Figure 1. Sombrio River location and sediment sample sites in southern British Columbia, Canada.

Background - Geology - Source of the Gold

The Sombrio River flows south into the Pacific ocean (Strait of Juan de Fuca) from the San Juan Ridge, a minor physiographic division of Vancouver Island Ranges (Holland 1976). Bedrock underlying the catchment basin consists of schist, sandstone, greywacke and argillite of the Jurassic to Cretaceous Leech River Complex. These rocks can host small (<1 m long) quartz veins and stringers that have free gold, chalcopyrite and pyrite. For example, at the Sombrio 2 (MINFILE 092C 214) showing near the headwaters of the Sombrio River, diorite sills and dykes have intruded Leach River Complex rocks and have gold-bearing quartz veins with arsenopyrite and pyrite. West of the Sombrio River there are former placer gold deposits (MINFILE 092C 044) in deltaic sand and gravel deposited by a river that flowed through the Leech River valley. At one of the placer gold deposits, located 0.5 km downstream from the sample site in the Sombrio River, gold grains occur in bars or in bedrock crevices along the river bed (Fig. 1). A regional stream sediment survey in 1990 (Matysek et al. 1990) detected 88 ppb Au in the sediment near the present sample site and 800 ppb Au in another branch of the Sombrio River to the west (Fig. 1).

Sampling and analytical methods

In August 2007 sediment and bulk gravel samples were collected at the head, middle and tail of a longitudinal

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An example of gold variation...

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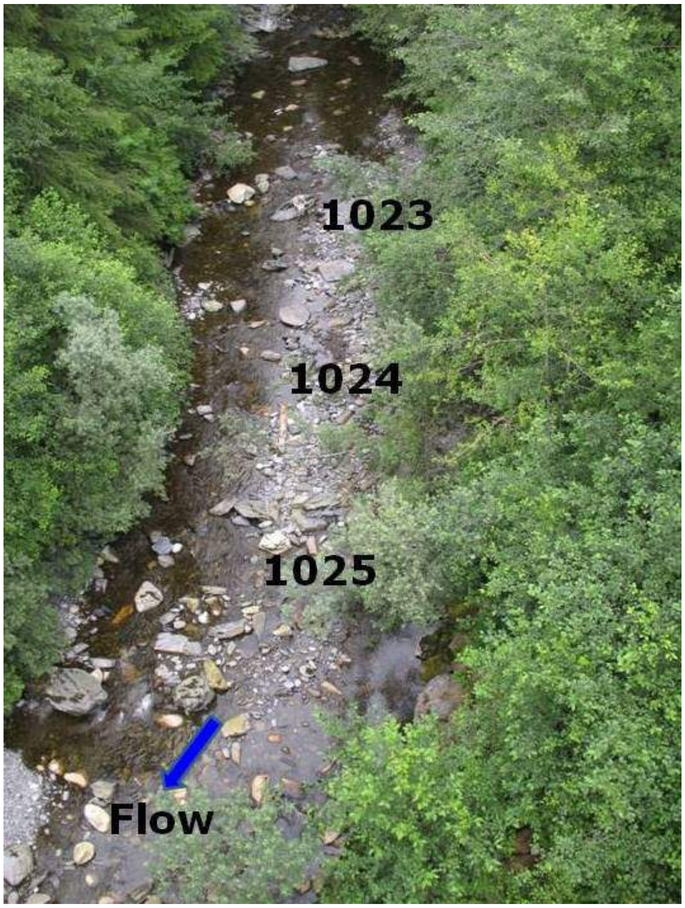

Figure 2. The Sombrio River showing sample site along the gravel-boulder bar. The three sites 92C071023, 92C071024 and 92C071025 where bulk sediment and surface stream sediment samples were collected are about 10 to 15 m apart identified as 1023, 1024 and 1025 in the figure. Moss mat samples were collected close to the bank on boulders to the right of the bar. Photograph credit to Z. Sandwith.

boulder-gravel bar in the Sombrio River upstream from the Highway 14 bridge (Fig. 2). This bar was selected because it is a previously reported stream sediment sample location from a typical regional geochemical sampling (RGS) survey (Matysek et al. 1990) and is used here to demonstrate how specific site selection can potentially influence results. The Sombrio River has a shoot and pool profile and drains a catchment area of an estimated 12 km2. There is a 2 m high rock ledge across the channel 30 m upstream from the bar head and this outcrop may be the source of the larger boulders scattered along the surface of the bar (Fig. 2). There is no recorded Sombrio River water discharge, but an Environment Canada (2016) gauge installed on Garbage Creek, located 15 km northeast of the Sombrio River, has historical discharge data that may be typical of the area. Garbage Creek drains a 2.9 km^2 catchment area and flows North into the San Juan River. In March 2007, the gauge recorded an annual maximum daily discharge of 7.06 m^3 sec-^{1} and in September annual minimum daily discharge of 0.011 m3 sec-^{1}. The average width of the Sombrio River at the midpoint of the bar is 7 m; the bar is roughly 40 m from head (upstream) to tail (downstream) and the deposit consists of poorly sorted boulder to sand sized sediment.

At each of the three sites, 0.5 - 0.7 kg of sand to silt sized sediment was collected from the surface of the bar and transferred to a Hubco™ sample bag. Gravel to sand sized sediment was excavated from a shallow pit at each sample point, sieved on site to recover 10-12 kg of <2 mm sized sediment and stored in a 6 mm PVC bag. Moss mats were collected from boulders along the east bank of the river at locations that correspond to the longitudinal bar sample points. At one of the moss mat sites, a duplicate sample was taken. Stream sediment and moss mat samples were dried at 40° C, disaggregated and sieved to <0.177 mm (-80 mesh). The samples were submitted to Acme Analytical Laboratories Ltd. (now Bureau Veritas Minerals), Vancouver where 15 g of the <0.177 mm size fraction was leached with 90 ml HNO_3-HCl-H_2O (1:1:1 v/v) for 1 hour, diluted to 300 ml and the solution analysed for 37 elements including Au by inductively coupled plasma–mass spectrometry (AR-ICPMS). The <0.177 mm fraction of the 1990 regional geochemical survey stream sediments samples were initially analysed by an Aqua Regia digestion followed by atomic absorption spectrometry (AAS) for trace elements and for Au by lead collection fire assay-AAS finish at Barringer Magenta Ltd., Calgary, Alberta. In 2010, the archived <0.177 mm samples were re-analysed by Acme Analytical Laboratories Ltd. for 57 elements by AR-ICPMS. Each <2 mm bulk sample was processed through a Morfee spiral concentrator to recover gold and other higher density grains. The gold grains were counted and the mineral concentrate photographed.

Results

Gold grain counts in the mineral concentrate and element concentrations in the stream and moss-mat sediment vary from the head of the bar to its tail (Table 1). However, concentrations of mineralization pathfinder element in the stream sediment and moss mat sediment at the three site along the bar are very similar and are below the 95th percentile geochemical threshold values established from

Sample	92C071023	92C071024	92C071025	92C071025*
Location UTM E	404913	404910	404907	404911
Location UTM N	5374204	5374200	5374197	5374197
Site type	Head Bar	Mid Bar	Tail Bar	RGS Site
Au ppb (river bar sediment)	454.4	8.6	1.9	
Au ppb (moss mat sediment)	2.7	7.1	1.3	58
Au grains in concentrate	6	8	13	
kg of <1.7 mm sediment sample	6.5	6	5	
Au grains normalized to 10 kg	4	5	7	

Table 1. Gold concentrations in the <0.177 mm fraction of stream sediments and moss mat sediments analysed by AR-ICPMS and gold grain count in heavy mineral concentrates in samples from the Sombrio River Bar. Sample 92C071025* is a field duplicate. Normalized gold grain counts are calculated from the ratio of the <2 mm sieved sediment sample weight to a 10 kg mass.

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An example of gold variation...

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the NTS 092C RGS data reported by Jackaman (2011). Only As in RGS sample 092C891284 just exceeds the 95th percentile geochemical threshold (Table 2). The highest Au value (454 ppb) detected is in the stream sediment from the surface at the head of the bar, whereas sediment Au values from the middle and tail sites along the bar are <10 ppb. Moss mat sediment Au values increase from <10 ppb at locations by the head and middle bar sites, but increase to 58 ppb Au by the tail of the bar. The percent mean difference $[((X_1-X_2)/(X_1+X_2)/2))*100)]$ between the duplicate moss mat sediment sample values is more than 25 percent for Au, Ag and Pb, but much smaller than 25 percent for the other elements. The visible number of gold grains in the mineral concentrates increases from 6 in the bar head sample to 13 in the bar tail sample. Normalized gold grain counts calculated from the ratio of the <2 mm sieved sediment sample weight to a 10 kg weight are 4 grains in the bar head sample, 4 grains in the mid bar sample, and 7 grains in the bar tail sample. The mineral concentrate from sample 92C071025 contains gold grains that are generally reshaped and range in size up to 1 mm (Fig. 3). Other minerals tentatively identified in the mineral concentrate are magnetite and garnet. The 1990 RGS detected 89 ppb Au in stream sediment taken from the Sombrio River near the gravel-boulder bar and 800 ppb in a stream sediment sample from second branch of the Sombrio River (Fig. 2).

Sample	1023SS	1023MM	1024SS	1024MM	1025SS	1025MM	1025MM (dup)	92C891238	92C891284	95th percentile
UTM E	404913	404916	404910	404913	404907	404910	404911	404372	404905	
UTM N	5374204	5374204	5374200	5374200	5374197	5374197	5374197	5374487	5374174	
Site type	Head bar	Head bar	Mid bar	Mid bar	Tail bar	Tail bar	Tail bar	RGS site	RGS site	92C RGS
Ag ppb	82	30	43	35	52	31	48	30	33	148
As ppm	21.3	16.6	14.2	14.1	12.1	14.9	17.3	9.3	23.3	23.2
Au ppb	454.4	2.7	8.6	7.1	1.9	1.3	58	*800*	*89*	16.6
Ba ppm	190.7	157	191.8	146	205.1	151.4	149.3	113	142.5	152
Bi ppm	0.13	0.11	0.12	0.12	0.12	0.11	0.11	0.09	0.08	0.27
Cd ppm	0.04	0.03	0.04	0.03	0.05	0.03	0.03	0.1	0.04	0.59
Co ppm	11.1	8.6	11.9	8.9	11.3	9.2	9	7	7.4	28.2
Cr ppm	48	37.3	51.8	39	52.2	39.5	38.1	69	33.8	78.9
Cu ppm	24.17	21.81	23.64	21.04	21.94	22.14	21.96	19	16.9	111.8
Fe pct	2.96	2.32	3.02	2.42	3.04	2.43	2.43	2.17	2.29	7.38
Hg ppb	10	7	11	13	-5	7	7	21	25	357
Mn ppm	347	260	395	294	373	278	284	253	268	1324.5
Mo ppm	0.36	0.32	0.35	0.32	0.35	0.29	0.3	0.33	0.36	2.39
Al pct	1.88	1.53	2.11	1.57	2.07	1.57	1.58	1.47	1.48	3.4
Ni ppm	22.3	18.3	21.9	18.1	23.2	19	19.2	17	18.3	52.6
Pb ppm	2.95	2.37	3.33	2.69	2.92	2.61	3.36	2	3.05	11.45
Sb ppm	0.21	0.12	0.16	0.17	0.22	0.14	0.15	0.16	0.13	0.8
V ppm	79	64	83	66	84	67	65	63	64	256
Ti pct	0.16	0.133	0.168	0.133	0.178	0.135	0.133	0.127	0.135	0.318
Zn ppm	50.9	41.3	53.9	40.3	55.4	41.2	41.8	41.5	42.2	125
Sample Wt g	15	15	15	15	0.5	7.5	7.5	0.5	0.5	

Table 2. Element concentrations in the <0.177 mm fraction of stream sediments (SS) and moss sediments (MM) analysed by AR-ICPMS. Samples collected in 2007 are prefixed by 92C07 and two regional geochemical survey moss mat sediments samples collected in 1989 are identified as 92C891238 and 92C891284. The < 0.177 mm fraction of these two samples was analysed by AR-ICPMS by Jackaman (2011). Element concentrations at the 95 percentile calculated from the regional survey data reported by Jackaman (2011) are shown for comparison to the stream sediment and moss mat sediment values. Gold values in italics (e.g., 800) were determined by a lead fire assay - AAS finish.

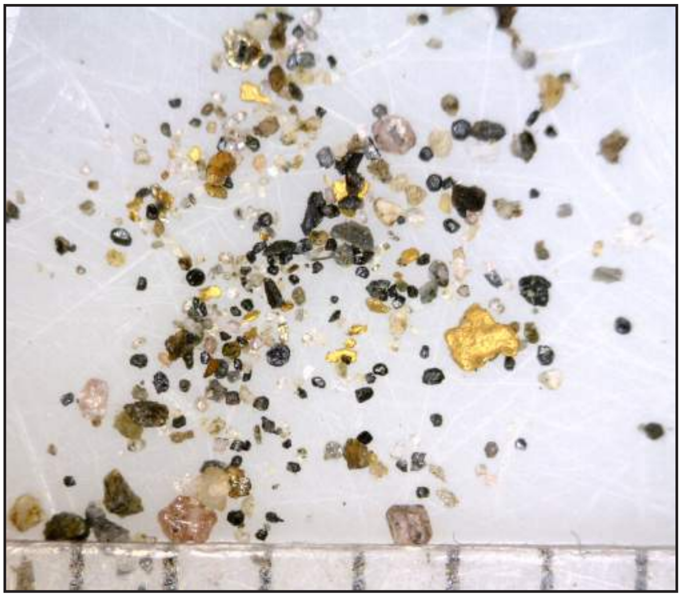

Figure 3. Photograph of heavy mineral concentrate from bulk sample 92C071025 showing gold grains and other minerals. Scale bar - 1 mm.

Within the Sombrio River drainage basin there is at

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An example of gold variation...

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least one Au-Cu-As mineral occurrence (Sombrio 2 - MINFILE 092C 214), but the background element concentrations found in sediment from the river bar likely reflect downstream bed load dilution of any mineralized sediment transported and deposited during high rainfall events. Gold appears concentrated in the surface sediment at the bar head whereas in the moss mat sediment the gold is higher towards the tail of the bar, although there is a large difference between moss mat sediment duplicate sample values. The difference between Au values in the stream and moss mat sediment is likely due to the sorting of the grains by size and density as the water flow varies over the bar. There may also be variable immersion of the moss in the river water during periods of high flow changing the amount of suspended gold captured from the water. This emphasises the need for care in sampling moss below the high water level. While sediment Au content decreases downstream from the bar head the number of gold grains increases towards the bar tail. Intuitively, the higher water turbulence near the bar head should concentrate higher density and coarser/larger minerals and, thus, increase the number of gold grains. One reason for the difference between the predicted and actual distribution of the gold grains and the Au content of sediment is that a large pool below the rock ledge upstream from the bar may dissipate energy during periods of turbulent flow and reduce sediment sorting along the bar. The concentration of trace elements typically associated with sediment mineral chemistry (e.g. Fe, Ti, Al) is higher in the bar surface sediment than in the moss mat sediment and the values in the surface sediment only vary slightly from bar head to bar tail (Table 2). This suggests that there has been limited winnowing of sediment from the bar during high water flow and that the bar is a relatively stable fluvial deposit. The distribution of the Au in the stream and moss mat sediment is ambiguous and is difficult to explain because of the small number of samples analysed. However, gold grains found in all the bar sediments and the Au content of moss mat sediment suggest bulk sediment sampling from stream bars and preparation of mineral concentrates complimented by moss mat sampling may be a viable strategy for detecting Au in high energy streams.

Conclusions

Sampling stream and moss-mat sediment from this river bar in a catchment basin draining a gold mineralized area demonstrates that:

- Sediment from the bar surface and moss-mats from the stream bank adjacent to the bar have variable Au contents.
- Gold concentrations in the sand-size fraction decreases downstream from the head of the bar towards the tail, however, the inverse is true for gold grain counts that increase slightly from the head of the bar towards the tail. The moss mat Au signature in the Sombrio River is ambiguous, but sampling moss mats has been proven effective for improving Au anomaly contrast in fast flowing mountain streams.
- Screened and concentrating bulk sediment samples by panning on site would be another (although slower) method for detecting the gold in stream bars.

Acknowledgments

Ms. Z. Sandwith is especially thanked for helping with sampling in the Sombrio River and for carrying several heavy bulk sediment samples from the river up a steep bank to Highway 14. The British Columbia Ministry of Energy and Mines, Geological Survey generously provided funds for the sampling and sample analysis as part of a student training exercise in geochemical sampling methods. Critical reviews by W. Jackaman, Noble Exploration Services and A. Hickin, British Columbia Geological Survey are very much appreciated and greatly improved the early drafts.

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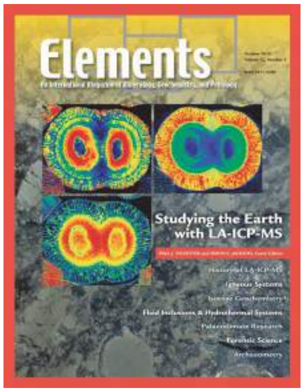
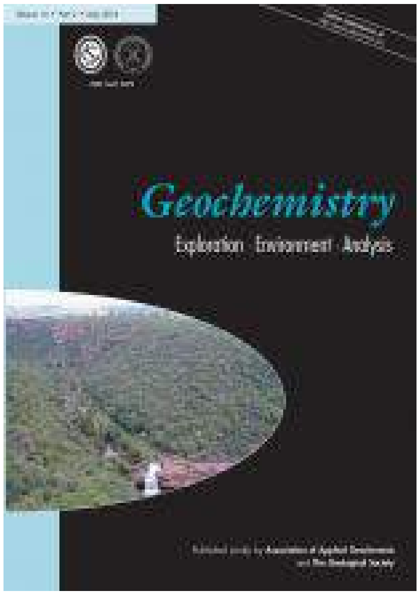


Volume 12, no. 5, Studying the Earth with LA-ICP-MS

The October edition of Elements focuses on the contribution made to the Earth Sciences by advances in laser ablation inductively coupled mass spectrometry. Sylvester and Jackson give a brief history of the development of the technique, followed by a description of the state of the art of major and trace analysis by Jenner and Arevalo. Woodhead, Horstwood and Cottle discuss recent advances in isotopic analyses by LA-ICP-MS, while Wagner, Fusswinkel, Wälle and Heinrich examine analysis of hydrothermal fluid inclusions using the technique. Müller and Fietzke describe the role of LA-ICP-MS in palaeoclimate research and Almirall and Trejos do the same for forensic science. Finally, Degryse and Vanhaeke look at the use of LA-ICP-MS in archeological non-destructive analyses. LA-ICP-MS is a method that has now moved out of research laboratories and into some commercial laboratories, so this issue of Elements is great way to catch up with the science.

Dennis Arne

Geochemistry: Exploration, Environment, Analysis



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Exploration ‘17

October 21 to 25, 2017, Toronto, Canada

Exploration ‘17 is the sixth of the very successful series of DMEC decennial mining 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.

www.exploration17.com/About.aspx

Posters

Deadline for Poster Abstracts: **January 31st, 2017.** A style guide and template will be available from www.exploration17.com in December 2016

Program Schedule

Oral presentations are by invitation only
http://www.exploration17.com/Program-Schedule.aspx

Workshops

Workshop 1 - Uncertainty in 3D modelling and Inversion

Workshop 2 - Integrated Spectral Geology

Workshop 3 - Advanced Concepts in Evaluating & Interpreting Geochemical Data

Workshop 4 - Integrated Interpretation - Modelling of Geological & Geophysical Data for Mineral Exploration

Workshop 5 - Application of Indicator Mineral Methods to Bedrock & Sediments

Workshop 6 - Advances in Geophysical Technology

Workshop 7 - Seismic Methods & Exploration

Workshop 8 - Improving Exploration with Petrophysics: The Application of Magnetic Remanence & Other Rock Physical Properties to Geophysical Targeting

Workshop 9 - Status & New Developments in Field Portable Geochemical Techniques and Site Technologies for Mineral Exploration

Workshop 10 - Future of Mineral Exploration Drilling & Sampling

Workshop 11 - Assay Quality Control: The Master Class

Workshop 12 - SEG DISC 2017, EM Fundamentals and Applications

Workshop 13 - Data Integration for the Next Generation of Mineral Exploration Models

Workshop 14 - Making Your Case: Clear, Memorable & Compelling

Workshop 5: **Application of Indicator Mineral Methods to Bedrock and Sediments, Sunday October 22, 2017**

This one-day short course will review principles, methods, and developments the application of indicator mineral methods to mineral exploration around the world by providing presentations by some of the most experienced practitioners in the field. Indicator mineral methods applied to exploration for a broad range of deposit will be reviewed, including gold, diamonds, VMS, porphyry copper-gold, rare metals, and tungsten. Topics will also in include heavy mineral sample processing methods and microanalytical techniques.

Speakers

Jamie Wilkinson, Natural History Museum and Imperial College London and ***David Cooke***, ARC Centre of Excellence in Ore Deposits (CODES)
Porphyry indicator minerals (PIMS) and porphyry vectoring and fertility tools (PVFTS)

Michael Seller, De Beers
Lithosphere thickness determinations and kimberlite diamond potential

Rob Chapman, The University of Leeds
Detrital gold as a pathfinder for hypogene mineralization

Paul Spry, Iowa State University
Trace element chemistry of silicates and oxides as indicators to metamorphosed base metal sulfide deposits in the Cambrian Kanmantoo Group, South Australia

Andy McDonald, Laurentian University
Overview of tourmaline as an indicator mineral in exploration

Sarah Dare, University of Ottawa
Overview of magnetite as an indicator mineral

Dan Kontak, Laurentian University
A review of scheelite chemistry and its use an a discriminator in ore-deposit settings, use as an indicator mineral and monitor of ore-forming processes

Stu Averill, Overburden Drilling Management Ltd.
Instructive oddities from 40 years of indicator mineral exploration

Beth McClenaghan, Geological Survey of Canada
Indicator mineral signature of the Strange Lake REE deposit, Labrador

Introduction to indicator mineral methods, sample processing & quality control

Dan Layton-Matthews, Queen's University
Microanalytical analysis of indicator minerals applied to mineral exploration

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Professor of Precambrian Geology
Professor of Earth Systems Modelling

Laurentian University is one of the recognized world leaders in mineral exploration research and is the top Canadian university in research funding for Economic Geology and in Applied Geophysics from the Natural Sciences and Engineering Research Council (NSERC). Laurentian University, located in Sudbury, Ontario, is the only university in Canada where geology and mineral exploration are integral components of the University's strategic plan.

With CAD $104 million in funding provided by the Canada First Research Excellence Fund (CFREF) and partners, Laurentian University, through strategic partnerships with five Canadian universities, six government geological surveys and three international research centres, will conduct Metal Earth - the largest ever mineral exploration research project undertaken in Canada. Metal Earth seeks to identify and understand the processes responsible for Earth's differential metal endowment during the Precambrian. This research initiative aims to transform our understanding of Earth's early evolution and how we explore for metals.

Metal Earth will be led by the Mineral Exploration Research Centre (MERC), the mineral deposit research arm of the Harquail School of Earth Sciences (HES), which is housed in the Willet Green Miller Centre in Sudbury.

Laurentian University is seeking individuals with demonstrated excellence in research and teaching. Successful candidates are expected to actively participate in Metal Earth's research in addition to developing their independent vigorous and externally-funded research programs. They will teach at the undergraduate and graduate levels in the HES as well as professional courses through the Goodman School of Mines and other units.

Laurentian University is inviting applications for the following four faculty positions in its award-winning Harquail School of Earth Sciences:

- **Research Chair in Exploration Targeting (tenured position) – beginning July 1, 2017**
  Applicants for this Research Chair will have achieved international prominence in mineral exploration or ore systems research, will have demonstrated leadership in managing large, multidisciplinary, collaborative geoscience projects, and will have a strong understanding of the system and mechanics of publicly funded research both within and outside Canada. He/she will provide leadership for national and international research programs that target ore systems through the integration of multi-scale geoscience (tectonic-structural-geophysical-geochemical-mineralogical-isotopic-surficial) data. This is a tenured position at the Associate or Full Professor level.
- **Professor of Exploration Geophysics (tenure track) – beginning July 1, 2017**
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For additional information regarding Laurentian University, MERC, and Metal Earth please visit their website at www.laurentian.ca, http://merc.laurentian.ca, http://merc.laurentian.ca/metalearth and http://hes.laurentian.ca. To apply, please forward your resume and cover letter to laurentian@boyden.com. Applications will be reviewed beginning in January 2017 but will be accepted until the positions are filled.

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2016

5-9 DECEMBER	American Exploration and Mining Association Annual Meeting. Sparks NV USA. Website: www.miningamerica.org
12-16 DECEMBER	AGU Fall Meeting. San Francisco CA USA. Website: fallmeeting.agu.org/2016/

2017

23-26 JANUARY	Mineral Exploration Roundup 2017. Vancouver BC Canada Website: www.amebc.ca/roundup/about-roundup
2-3 MARCH	6th International Conference "Ecological & Environmental Chemistry-2017". Chisinau Moldova. Website: eec-2017.mrda.md
5-8 MARCH	Prospectors and Developers Association of Canada Annual Convention. Toronto ON Canada. Website: www.pdac.ca/convention
20-26 MARCH	48th Lunar and Planetary Science Confeence. Woodlands TX USA. Website: www.hou.usra.edu/meetings/lpsc2017
11-14 APRIL	25th International Mining Congress and Exhibition of Turkey. Antalya Turkey. Website: imcet.org.tr/defaulten.asp
23-28 APRIL	European Geosciences Union General Assembly 2017. Vienna Austria. Website: tinyurl.com/j3ff8wn
27-28 APRIL	3rd International Conference on Geographical Information Systems: Theory, Applications and Management. Porto Portugal. Website: www.gistam.org
30 APRIL-3 MAY	Canadian Institute of Mining, Metallurgy, and Petroleum 2017 Conference & Exhibtion. Montreal QC Canada. Website: convention.cim.org/en/Montreal/2017/Home.aspx
6-11 MAY	European Workshop on Modern Developments and Applications in Microbeam Analysis. Konstanz Germany. Website: www.microbeamanalysis.eu/
9-11 MAY	8th World Conference on Sampling and Blending (WCSB8). Perth WA Australia. Website: www.wcsb8.com/
14-18 MAY	Geological Association of Canada/Mineralogical Association of Canada Annual Meeting. Kingston ON Canada. Website: www.kingstongacmac.ca/
15-17 MAY	XVIth International Conference: Geoinformatics, Theoretical and Applied Aspects. Kyiv Ukraine. Website: tinyurl.com/j54kayw
4-7 JUNE	14th International Estuarine Biogeochemistry Symposium. Rimouski QC Canada. Website: www.iebs2017.com/
4-7 JUNE	FUTORES II — Future understanding of tectonics, ores, resources, environment and sustainability. Townsville Qld Australia. Website: www.jcu.edu.au/futores
5-9 JUNE	13th International Congress of Applied Mineralogy Taranto Italy. Website: www.scientevents.com/amam-icam2017
5-9 JUNE	7th International Workshop on Compositional Data Analysis. Siena Italy. Website: www.compositionaldata.com/codawork2017
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25-30 JUNE	Catchment Science: Interactions of Hydrology, Biology & Geochemistry. Lewiston ME USA. Website: tinyurl.com/zst629v
26–30 JUNE	14th International Conference on Sustainable Use and Management of Soil, Sediment and Water Resources – AquaConSoil 2017. Lyon France. Website: www.aquaconsoil.org
4-8 JULY	32nd International conference of Society for Environmental Geochemistry and Health. Brussels Belgium. Website: segh-brussels.sciencesconf.org/
16-20 JULY	International Conference on the Biogeochemistry of Trace Elements. Zurich Switzerland. Website: icobte2017.ch/
16-21 JULY	13th International Conference on Mercury as a Global Pollutant Providence RI USA. Website: mercury2017.org/initial/index.php
4-9 AUGUST	Magmatism of the Earth and related strategic metal deposits. Miass Russia. Website (Facebook): tinyurl.com/zxsjpj6. Email: va_zaitsev@inbox.ru
12-17 AUGUST	21st World Congress of Soil Science. Rio de Janeiro Brazil. Website: 21wcss.org/
13-17 AUGUST	5th International Conference on Selenium in the Environment and Human Health. Stockholm Sweden. Website: se2017.se
13-18 AUGUST	Goldschmidt 2017. Paris France. Website: goldschmidt.info/2017
20-23 AUGUST	14th Biennial SGA Meeting. Quebec City QC Canada. Website: sga2017.ca/

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20-29 AUGUST	12th International Eclogite Conference. Åre Sweden. Website: www.geology.lu.se/IEC12
2-9 SEPTEMBER	18th Annual Conference of International Association for Mathematical Geosciences. Fremantle WA Australia. Website: http://iamg2017.com
11-14 SEPTEMBER	SIAM Conference Mathematical and Computational Issues in the Geosciences. Erlangen Germany. Website: www.siam.org/meetings/gs17
17-20 SEPTEMBER	SEG 2017. Beijing China. Website: www.seg2017.org/
17-22 SEPTEMBER	28th International Meeting on Organic Geochemistry. Florence Italy. Website: www.houseofgeoscience.org/imog/
21-25 OCTOBER	Exploration '17. Toronto ON Canada. Website: www.exploration17.com
22-25 OCTOBER	GSA Annual Meeting. Seattle WA USA. Website: www.geosociety.org/meetings/2017/
31 OCTOBER-2 NOVEMBER	10th Fennoscandian Exploration and Mining. Levi Finland. Website: fem.lappi.fi/en
7-8 DECEMBER	19th International Conference on Nuclear and Environmental Radiochemical Analysis. Sydney NSW Australia. Website: tinyurl.com/jsh9gsu

2018

16-21 JUNE	28th International Applied Geochemistry Symposium. Vancouver BC Canada. Website: rfg2018.org
8-13 JULY	Geoanalysis 2018. Sydney NSW Australia. Website: 2018.geoanalysis.info

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