

Indicator minerals for lithium exploration in glaciated terrain

M.B. McClenaghan^{1*}, D.M. Brushett², C.E. Beckett-Brown³, R.C. Paulen¹, and J.M. Rice¹

¹Natural Resources Canada, Geological Survey of Canada, 601 Booth Street, Ottawa, ON, K1A 0E8

²Nova Scotia Department of Natural Resources and Renewables, 1701 Hollis Street, Halifax, NS B3J 3M8

³Ontario Geological Survey, 933 Ramsey Lake Road, Sudbury, ON P3E 6B5

*beth.mcclenaghan@nrcan-rncan.gc.ca

INTRODUCTION

In 2021 and 2022, the Geological Survey of Canada (GSC) and the province of Nova Scotia Department of Natural Resources and Renewables (NSDNRR) collected glacial sediment (till) samples around a pair of known lithium-cesium-tantalum (LCT) pegmatites as part of critical mineral exploration research funded by the GSC's Targeted Geoscience Initiative (TGI) program. Only a few studies have ever investigated till indicator mineral methods for exploring for lithium-bearing pegmatites. To address this knowledge gap, a detailed glacial sediment and bedrock study was conducted around the known pegmatites to investigate how spodumene, the key Li ore mineral, is glacially dispersed in till. This indicator mineral study focuses on the North and South Brazil Lake LCT pegmatites in southwestern Nova Scotia, Canada (Fig. 1) (McClenaghan et al. 2023a,b, 2024; Brushett and Tupper 2021; Brushett et al. 2022, 2024). In these pegmatites, lithium is hosted in spodumene ($\text{LiAlSi}_2\text{O}_6$), a clinopyroxene and a highly sought after Li-bearing mineral for hard rock Li mining globally as it is less energy intensive to process than lepidolite (Gao et al. 2023).

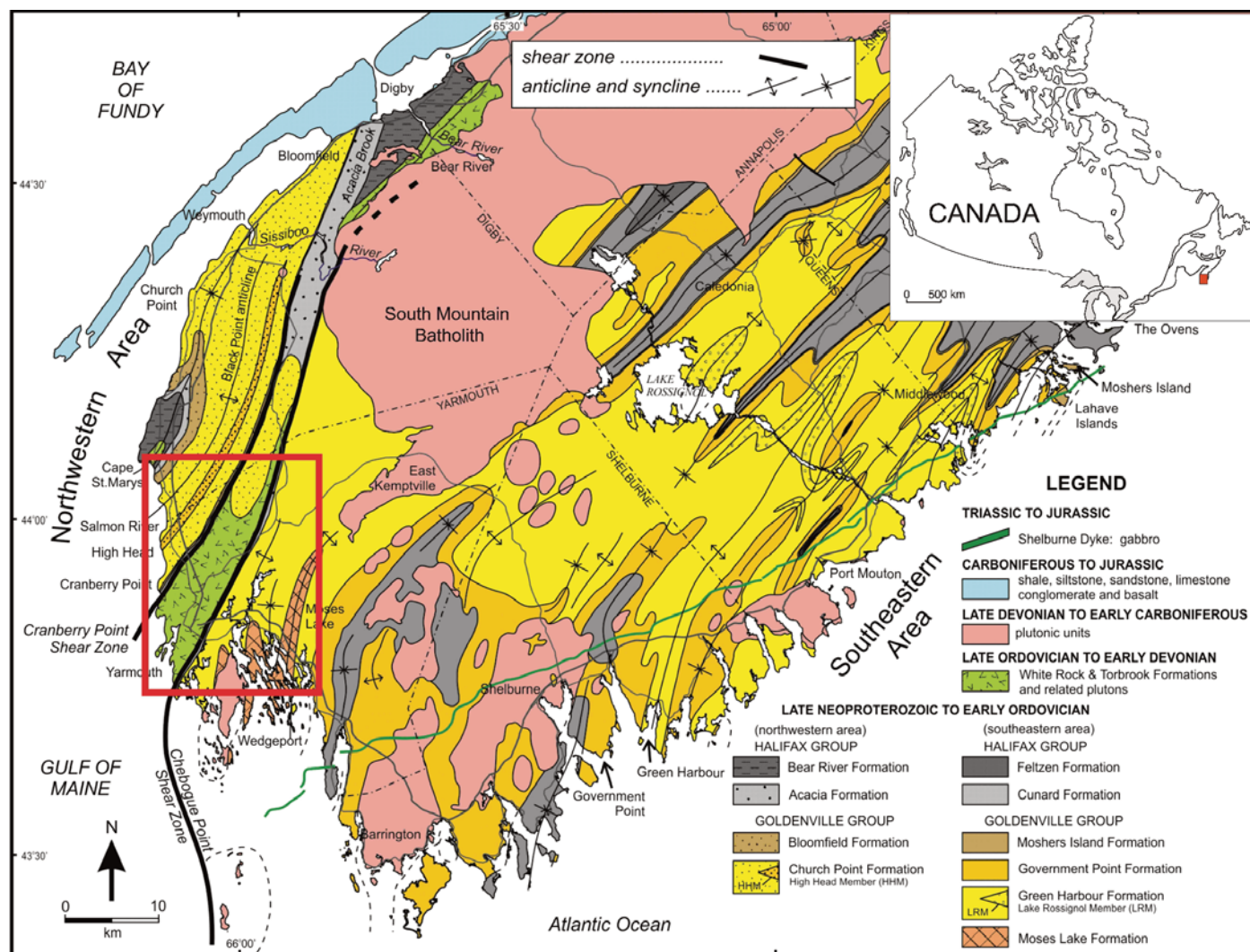


Fig 1. Bedrock geology of southwestern Nova Scotia (modified from White 2010; White et al. 2018). Location of the Brazil Lake study area is indicated by the red box.

oreas 
an analytichem company

TRUST YOUR DATA TRUST OREAS

Certified Reference Materials
produced to a superior level
of homogeneity for results you
can depend on.

First time. Every time.

- Gold & PGE
- Base Metals
- Battery Metals & REE

Custom Matrix-Matched



ACCREDITED REFERENCE MATERIAL PRODUCER ISO 17034

oreas.com



EXPLORE

Newsletter No. 203

June 2024

Editor:

Beth McClenaghan (bethmcclenaghan@sympatico.ca)

Business Manager:

Steve Cook, explorenewsletter@gmail.com

Back Issues: AAG Website (www.appliedgeochemists.org)

EXPLORE is published quarterly by the Association of Applied Geochemists, P.O. Box 567, 223 St. Lawrence Street, Merrickville, ON Canada K0G 1N0

EXPLORE is a trademark of the Association of Applied Geochemists

Layout of **EXPLORE** is by Elizabeth Ambrose (Ambrose-and-Associates@rogers.com)

EXPLORE Newsletter Advertising Rates (effective Jan. 2024)

ANNUAL CORPORATE SPONSORSHIP		USD	CAD
Full year		\$2,500	\$3,275
<i>Includes: Company logo on the front cover 20% off advertising rates</i>			

ADVERTISING RATES PER ISSUE (QUARTERLY)		USD	CAD
Full page	241h x 190w mm (9.5h x 7.5w in)	\$1,350	\$1,775
Half page	241h x 89w mm (9.5h x 3.5w in) or 124h x 190w mm (4¾h x 7.5w in)	\$750	\$980
1/3 page	241h x 51w mm (9.5h x 2w in) or 178h x 89w mm (7h x 3.5w in)	\$600	\$785
1/4 page	124h x 89w mm (4¾h x 3.5w in) or 241h x 41w mm (9.5h x 1½w in)	\$425	\$555
1/8 page	60h x 89w mm (2¾h x 3.5w in)	\$75	\$100

Please direct advertising inquiries to
Steve Cook (explorenewsletter@gmail.com)

Note from the Editor

Welcome to the second EXPLORE issue of 2024. This issue features an article describing the indicator minerals that can be used to explore for lithium pegmatites in glaciated terrain, using the Brazil Lake pegmatites in eastern Canada as an example. It was written by Beth McClenaghan, Denise Brushett, Chris Beckett-Brown, Roger Paulen, and Jessey Rice.

EXPLORE thanks all those who contributed to the writing and/or editing of this issue, listed in alphabetical order: Elizabeth Ambrose, Chris Beckett-Brown, Denise Brushett, John Carranza, Steve Cook, Bob Garrett, Jane Graham, Grant Hagedorn, Gwendy Hall, David Leng, Ray Lett, Roger Paulen, Sarah Paulen, Anna Petts, Jessey Rice, Behnam Sadeghi, and Yulia Uvarova.

Beth McClenaghan
Editor

Steve Cook,
Business Manager



TABLE OF CONTENTS

Indicator Minerals for Lithium Exploration in Glaciated Terrain	1
Note from the Editor	3
President's Message	4
New Book Release: A History of Geochemistry and Cosmochemistry, from Prehistory to the End of the Classical Period by Robert W. Boyle	12
Articles in Past Issues of EXPLORE	13
30 th International Applied Geochemistry Symposium	14
Call for AAG Medal Nominations	15
2021 AAG Gold Medal Winner: William K Fletcher	16
Recently Published in Elements	16
Geochemistry: Exploration, Environment, Analysis	17
Barringer, Back to the Future: Airborne Geochemistry and Many Related Topics	17
Welcome New AAG Members	18
Writing Geochemical Reports, 3 rd Edition	18
Obituary: Dr. Colin Dunn	19
Short Course Review: Till Geochemistry and Indicator Mineral Methods for Exploration in Glaciated Terrain	21
Calendar of Events	23
EXPLORE Publication Schedule	24

ADVERTISERS

Activation Laboratories Ltd.	11
ALS Global	6
Bruno Lemièrre	5
Bureau Veritas Minerals	13
CDN Resource Laboratories	9
DCGeo	8
Evident-Olympus	7
Lab West	8
MSA Labs	10
OREAS Certified Reference Materials	2
Overburden Drilling Management	4
SGS	12



Association of Applied Geochemists
Student Membership
\$10 US

Encourage a student to join!



President's Message

Welcome to the second issue of EXPLORE in 2024. In the last three months, the Association had a few activities and highlights. In collaboration with the Geological Society of London, AAG has been recruiting for a new Editor-in-Chief for our journal *Geochemistry: Exploration, Environment, Analysis* (GEEA). Scott Wood will be finishing in his role as Editor-in-Chief of the journal at the end of 2024, and we would like to extend our gratitude to Scott for all his hard work, not only managing the journal, but for raising the profile of applied geochemistry which is evident from a significant rise in GEEA's impact factor. The Association is also active in supporting our affiliated and associated organisations and societies. We are co-sponsoring *Workshop 21: International Union of Geological Sciences Manual of Standard Methods for Establishing the Global Geochemical Reference Network*

at IGC 2024 in South Korea from August 30–September 1, 2024. We are also supporting the Society of Economic Geologists (SEG) to promote the upcoming international conference *SEG 2024: Sustainable Mineral Exploration and Development* at the Safari Conference Centre, Windhoek, Namibia, from September 27–30, 2024. These efforts serve as a plan for our affiliation with other organisations in a mutually beneficial effort.

The Association has made the decision to assign DOI numbers to AAG publications, particularly the EXPLORE issues. Patrice de Caritat has volunteered to take the lead on acquiring DOI numbers, and the setup for this is in progress. Thank you, Patrice!

As you know, this year we are going to have the 30th International Applied Geochemistry Symposium (IAGS) in Adelaide, South Australia, 14th to 18th October, 2024. The scientific programme, field trips and workshops have been finalised, and all the information is available on the IAGS2024 website (<https://www.iags2024.com.au/>).

And while the preparation for the 30th IAGS is progressing well, we need to start planning for IAGS 2026. The International Applied Geochemistry Symposium is commonly run on a biennial basis, is held under the auspices of the AAG, representing a significant gathering of geochemists from all over the world, and is commonly alternating between the Northern and Southern Hemispheres. Hence, in 2026 it should ideally be held somewhere in the Northern Hemisphere. I encourage you to get in touch with AAG Council if you have an idea and would like to prepare a short bid to host the next IAGS event.

Looking forward to seeing many of you in Adelaide, Australia in a few months!

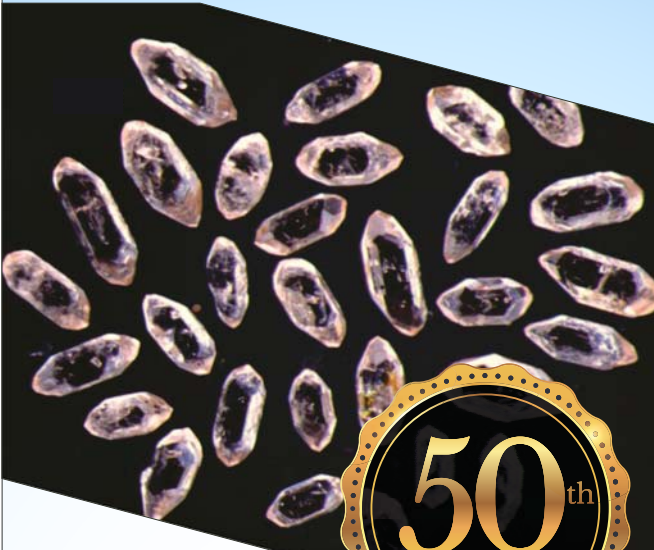
Yulia Uvarova
President





Mineral Separations

Electric-Pulse Disaggregation

Clean, Affordable, Fast





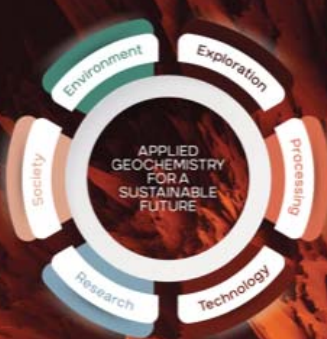


www.odm.ca
odm@storm.ca

14-18 OCTOBER 2024

IAGS

International Applied Geochemistry Symposium
30th edition



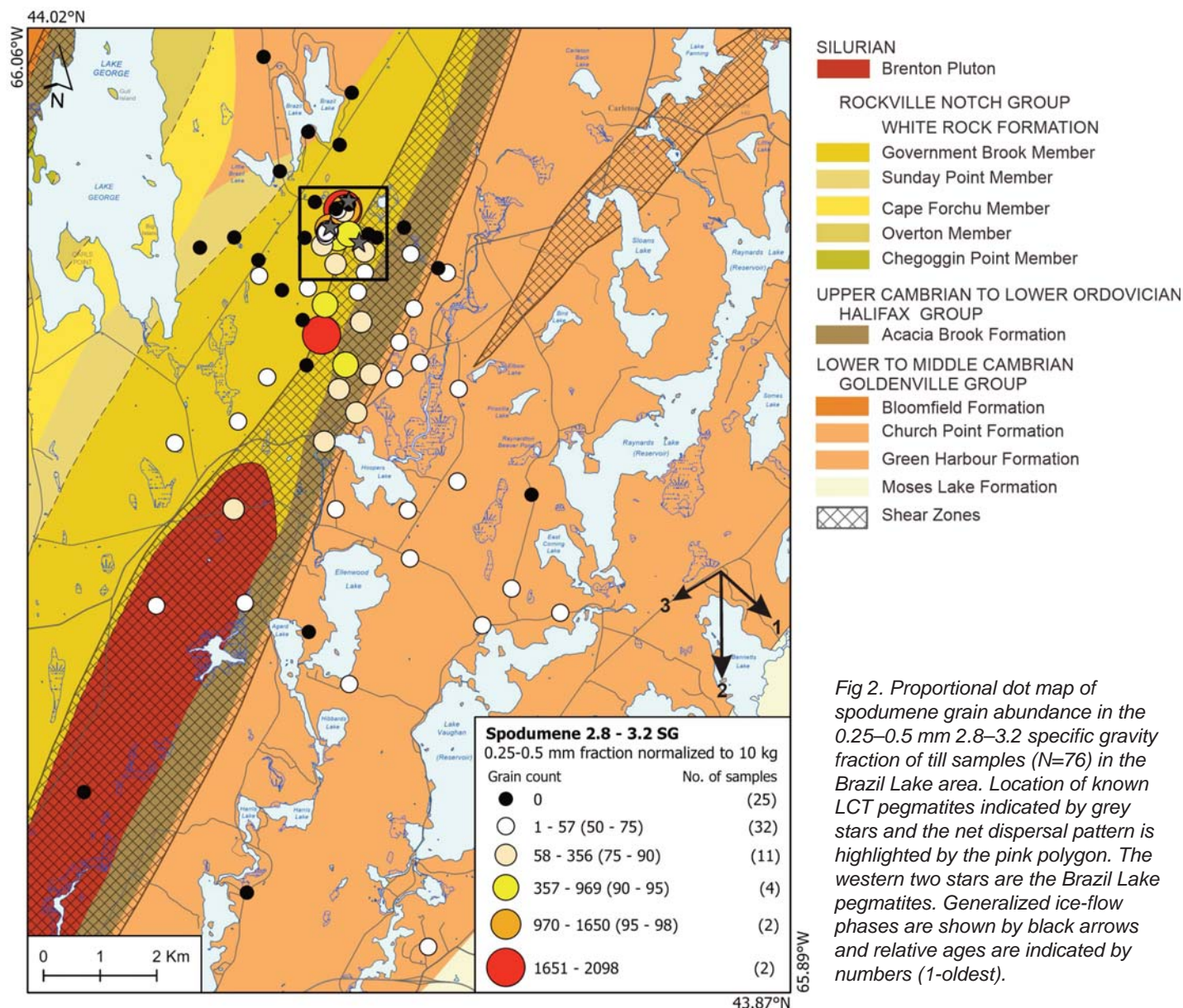


REGISTRATION OPEN / ABSTRACT OPPORTUNITIES
IAGS2024.COM.AU

Adelaide, Tarranya Australia

Indicator minerals for lithium exploration in glaciated terrain

continued from page 1



GEOLOGY

Bedrock geological setting

The study area is underlain by rocks of the Meguma terrane, the most easterly component of the northern Appalachian orogen (Hibbard et al. 2006; White et al. 2018), and that is characterized by a thick sequence of Cambrian to Early Ordovician metasedimentary rocks, comprising the meta-sandstone-dominated Goldenville Group and the overlying siltstone- and slate-dominated Halifax Group (White 2010). The majority of these rocks were intruded by the ca. 373 Ma peraluminous South Mountain Batholith and related granitoid rocks (Fig. 1, White and Barr 2017). Numerous tin, base, and precious metal occurrences are found throughout south-west Nova Scotia. The most significant deposit is the East Kemptville Sn deposit along the western edge of the South Mountain Batholith (e.g. O'Reilly and Kontak 1992; Fig. 1). There are numerous smaller granite-hosted greisen deposits and metasediment-hosted shear and replacement style Sn-Zn-Cu-Pb-In deposits, many of which are associated with the Kemptville Shear Zone, a zone of tectonic shearing comprising multiple shear and fault zones (Fig. 2). The Brazil Lake pegmatites are hosted by shallow marine metased-

continued on page 6



Bruno Lemièrè, Ph.D.
**Mining and Environmental
Geochemist**

Field and site instrumentation
and monitoring
Laboratory engineering

Data analysis
Know-how transfer
brunole45@orange.fr

28 av. Général Leclerc - 82300 Caussade - France +33 6 95902134
Operating also from New York, Montreal, Brussels and London

Indicator minerals for lithium exploration in glaciated terrain

continued from page 5

imentary rocks interbedded with minor mafic metavolcanic units, which locally include quartzite, amphibolite, and pelitic schist (Figs. 1, 2, White 2010; White and Barr 2017). Kontak (2006) suggested that the Brazil Lake pegmatites were emplaced in an active shear zone where high-temperature ductile deformation occurred during consolidation of the pegmatite. Age dates of tantalite (U-Pb) from the South pegmatite indicate that pegmatite crystallization occurred at ca. 395 Ma (Kontak et al. 2005; Kontak and Keyser 2009).

The pegmatite dykes are named and described with respect to their relative locations to each other, North or South. The brief description of the pegmatites below is summarized from Corey (1995), Kontak, (2004, 2006), Kontak et al. (2005), Barr and Cullen (2010), Black (2012) and Cullen et al. (2022). The dykes are 300 m apart and occur as lenticular forms with wider cores transitioning to thinly tapered ends. The North dyke is at least 700 m in length and reaches a maximum thickness of 21 m at its centre. The South dyke has a defined strike length of ~300 m and a thickness of ~8–12 m. Both dykes have southwest-plunging trends of ~30–40°. The pegmatites are albite-spodumene types and are characterized by coarse crystals of spodumene (Fig. 3) and K-feldspar, with intergranular spodumene, muscovite, albite, and quartz. Key minerals present in the pegmatites that could be useful indicator minerals for drift prospecting include white spodumene, black to blue tourmaline, black columbite/tantalite, blue apatite, green beryl, cassiterite, wolframite, sphalerite, zircon, epidote, topaz, titanite, and phosphate minerals. The recently discovered Army Road LCT pegmatite is just east of the Brazil Lake pegmatites (Fig. 2), although not much has been reported about the geology of this pegmatite.

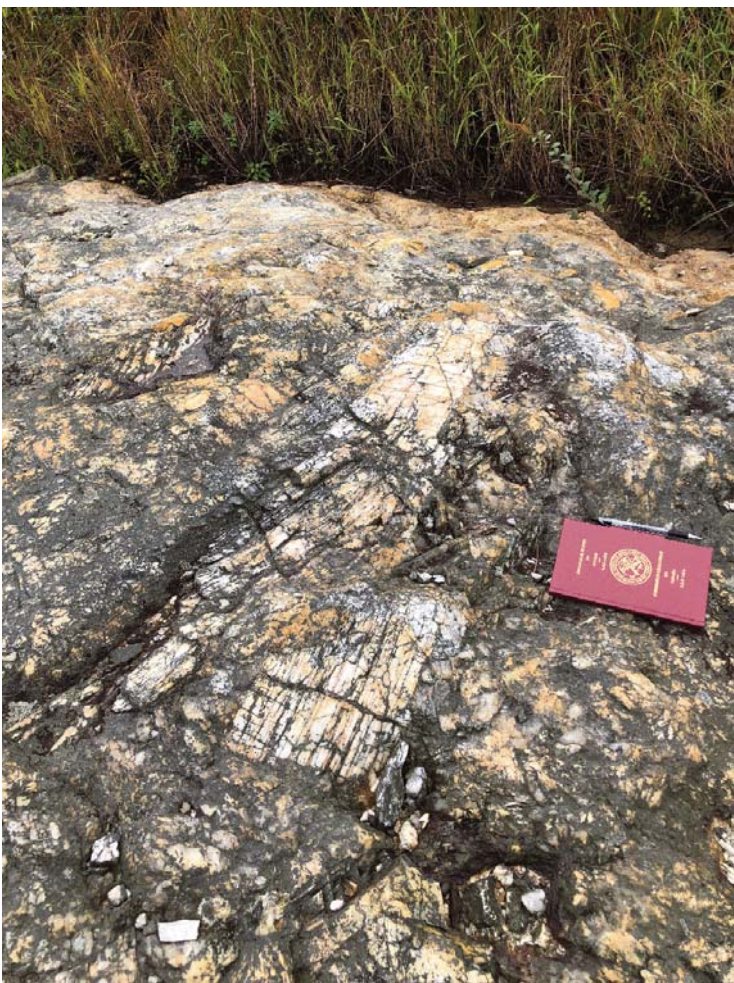


Fig. 3. Large spodumene crystals exposed on the weathered sub-cropping surface of the South pegmatite (photograph by M.B. McClenaghan, NRCan photo 2023-464).

continued on page 8



ALS method code ME-MS89L™

Exploration for trace level
lithium and rare earth elements



right solutions.
right partner.

Lithium hosted in pegmatites and jadarite can occur with economic grades of rare earths and other trace metals such as cesium and boron. ALS’s innovations in ICP-MS technology coupled with a sodium peroxide fusion provide a package suitable for lithium and accessory commodities.

Method	Analyte	Detection Level (ppm)
sodium peroxide fusion	Li	2
	B*	8
	Cs	0.1
	Dy	0.03
	Ho	0.01
	Nb	0.08
	Ta	0.04

*a selection of analytes reported by ME-MS89L™.
Boron can only be reported as an add-on to ME-MS89L™.

**EVIDENT**

New Vanta[™] Max Handheld XRF

for Exploration, Mining, Mineral Processing, and Environmental Applications

The Vanta Max handheld XRF analyzer delivers fast, accurate elemental analysis and material identification with the series' highest analytical capabilities.

- › Comfortable for all-day testing
- › Productive workflow
- › Rugged and reliable

Learn more at [EvidentScientific.com](https://www.evidentscientific.com).

Vanta is a trademark of Evident Corporation or its subsidiaries.

Indicator minerals for lithium exploration in glaciated terrain

continued from page 6

Surficial geology

The Brazil Lake area underwent extensive glacial modifications during the late Wisconsin glaciation, leaving thick unconsolidated glacial sediments in south-trending drumlins over much of the region. Till thickness is variable, ranging from thin veneers (<2 m) over parts of the pegmatites to drumlin ridges consisting of over 40 m of till (Brushett et al. 2024). The surficial geology of the region is the product of multiple glacial advances and retreats throughout several glacial events (Grant 1980; Stea and Grant 1982; Stea et al. 2011): 1) older east to southeastward ice-flow; 2) southward regional ice-flow; and 3) younger flow to southwest (Fig. 2).

METHODS

Five pegmatite samples (~1 kg) were collected to provide insights into the types and abundances of LCT pegmatite indicator minerals that could be in glacial sediments down ice. A total of 84 bulk (7–20 kg) heavy mineral till samples were collected from 77 sites according to the till sampling protocols established by the GSC (McClenaghan et al. 2020, 2023c). Sites consisted of hand-dug pits and till exposures in borrow pits, sections along local roads, or backhoe trenches dug 50 to 100 m south (down ice) of both the North and South pegmatites. Field data, site descriptions, and site photos are reported in GSC Open File 9148 (Brushett et al. 2024). Cobble to pebble-sized spodumene clasts (Fig. 4) were readily visible in till within 100 m down-ice (south) of the pegmatites.

Sample processing

The bulk till samples and bedrock samples were processed at Overburden Drilling Management Limited (ODM), Ottawa, Canada to produce mid-density and heavy mineral concentrates from which indicator minerals were counted and selected minerals removed for further study. Specific details about the methods used, fractions generated, quality control, and flow sheets are reported in McClenaghan et al. (2024). Briefly, the <2.0 mm fraction of each sample was processed to produce a preconcentrate using shaking table methods. The table preconcentrate was subsequently subjected to two heavy liquid separations and ferromagnetic separations to produce 2.8–3.2 specific gravity (SG) and >3.2 SG non-ferromagnetic heavy mineral concentrates for visual identification and counting of indicator minerals.

continued on page 10



Fig. 4. Photograph of spodumene clasts recovered while collecting till samples in backhoe trenches just down-ice of the pegmatites (photograph by M.B. McClenaghan, NRCAN photo 2022-590).



Geochemical exploration in glaciated terrain
Gold • Lithium • Base metals • Diamonds

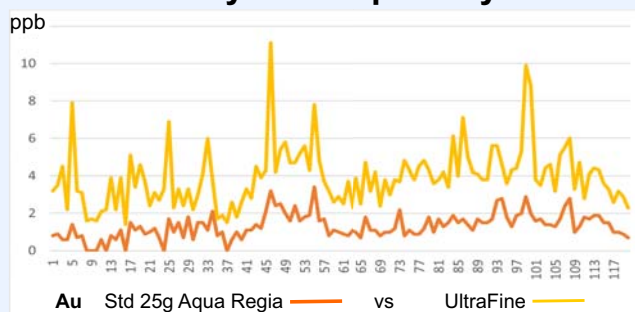
Don Cummings, PhD, PGeo
cummings1000@gmail.com / 819-213-4714 /
www.dcggeo.wordpress.com

LABWEST



IMPORT CERTIFICATE
IN PLACE
Easy to airfreight 200g samples

Low DL analysis of 2 µm clay fraction



- Small 200g sample
- Nugget effect eliminated
- 50 Elements including Au
- REEs also available
- Extended CSIRO data package also available

LabWest.net/UltraFine



Contact Blake Stacey for an orientation study
B.stacey@labwest.net

sustainability and
COMMITTED TO EXCELLENCE



CDN Resource Labs – Providing High Quality Certified Reference Material For Over 40 Years

CDN Resource Laboratories Ltd. takes pride in its over 40 years of dedicated service in the mining industry. With each passing year, we strive for continuous improvement, maintaining our steadfast commitment to sustainability and excellence.

www.cdnlabs.com



Indicator minerals for lithium exploration in glaciated terrain

continued from page 8

The 0.25–0.5 mm, 0.5–1.0 mm, and 1.0–2.0 mm non-ferromagnetic >3.2 SG fractions and the 0.25–0.5 mm non-ferromagnetic 2.8 to 3.2 SG fraction of bedrock and till samples were examined by ODM and potential indicator minerals were counted.

INDICATOR MINERALS

Raw mineral abundances were normalized to a 10 kg sample weight (table feed) and both raw and normalized counts are reported in McClenaghan et al. (2024) along with proportional dot maps for each of the key indicator minerals. Spodumene is the main Li-bearing mineral in the Brazil Lake pegmatites. It has a SG of 3.1–3.2 and a hardness of 6.5–7. It was identified in concentrates by its white colour, prismatic, generally flattened and elongated, striated, commonly massive crystal habit, and brittle fracture (Fig. 5) and, at times, its fluorescence under UV light. It is most abundant in the mid-density (2.8–3.2 SG) fraction as compared to the heavy mineral (>3.2 SG) fraction. It is most abundant in the smallest size fraction (0.25–0.5 mm), with the most anomalous till samples containing 100s to 1000s of grains/10 kg. In this study, spodumene is most abundant in till immediately south of the North and South pegmatites (maximum 2212 grains). Abundances decrease southward down ice, but spodumene is still detectable in till 12 km to the south. Other LCT indicator minerals recovered from till samples down ice include columbite/tantalite, apatite, tourmaline, cassiterite, and scheelite (McClenaghan et al. 2024).

Brazil Lake dispersal train

The threshold between background and anomalous concentrations of spodumene in till is zero grains, thus the presence of any spodumene grains in a till sample is significant. Spodumene abundance is highest in a central corridor trending southward from the Brazil Lake pegmatites for 12 km (Fig. 2), however, the overall pattern of spodumene dispersal is fan-shaped. The central core of the fan is oriented southward along the trend of the dominant and most vigorous (erosive) ice flow phase. The fan shape is the net result of three phases of ice flow (southeast, south, and southwest) eroding, transporting, and depositing glacial debris from the Brazil Lake pegmatites, and possibly other LCT pegmatites in the local area. In comparison, glacial dispersal patterns for Li (ppm) in the 1–2 mm fraction of till (Na-peroxide fusion or 4-acid digestion) form a fan-shaped pattern that is much shorter, only 6 km down ice of the Brazil Lake pegmatites (Brushett et al. 2024).

The GSC has published a detailed reporting of the bedrock and till indicator mineral data for the Brazil Lake pegmatites in an open file report (McClenaghan et al. 2024). A second GSC report (Brushett et al. 2024) describes the till geochemistry results for the <0.063 mm and 1–2 mm fractions of till samples collected around the pegmatites, including a comparison of Na-peroxide fusion, 4-acid digestion, and aqua regia digestion. Mineral chemistry and lithium isotope signatures will be determined for selected bedrock and till indicator minerals from the Brazil Lake pegmatites. Till stratigraphic studies are currently in progress to provide a better understanding of the glacial history and stratigraphic context of the Quaternary depositional record of southwestern Nova Scotia.



Fig. 5. Colour photograph of spodumene grains from a bedrock sample of the North Brazil Lake pegmatite. Photograph taken by Overburden Drilling Management Ltd).



MSALABS

Introducing Canada's first PhotonAssay unit,
the revolutionary technology delivering assay
results in just hours.



To find out more contact:
customer.service@msalabs.com

Indicator minerals for lithium exploration in glaciated terrain *continued from page 10*

RECOMMENDATIONS FOR LITHIUM EXPLORATION

This GSC study presents the first detailed investigation of the indicator mineral signatures of an LCT pegmatite in till. Till samples immediately down ice of the pegmatites contain 100s to 1000s of spodumene grains per 10 kg sample. Indicator minerals of Brazil Lake LCT pegmatites that have been recovered from till samples include spodumene, columbite-tantalite, apatite, tourmaline, scheelite, and cassiterite.


Spodumene is the most obvious and direct indicator of the presence of LCT pegmatites. Background concentrations of spodumene in till are zero, thus even one grain in a till sample is significant. Grain abundance should be normalized to 10 kg of <2 mm material (table feed) in order to compare results between till samples of variable weight. Spodumene, apatite, and tourmaline have a combined density range of 3.1–3.2 SG. In future till sampling programs for Li exploration, heavy liquid separations can be carried to produce a mid-density fraction that is 3.0–3.2 SG, instead of 2.8–3.2 SG, in order to optimize spodumene recovery and eliminate some of the lighter indicator minerals. Spodumene is most abundant in the 0.25–0.5 mm size fraction of till. To reduce time and cost, only this one size fraction could be recovered and examined for Li exploration. For more information about this study, refer to McClenaghan et al. (2024) for a detailed description of the till sampling methods, sample processing and mineral identification methods, indicator mineral results and distribution maps, and high quality colour photographs of the indicator minerals.

ACKNOWLEDGEMENTS

The authors thank J. Wightman, G. Morris, and C. Stanley for access to the Brazil Lake property, field visits, and advice that guided the fieldwork. Overburden Drilling Management Ltd. are thanked for their professional services, adaptation of the workflows, and patience with our numerous questions and requests. Two site visits were made to the Brazil Lake pegmatites with First Nation representatives in 2022. GSC and NSDNRR thank the Acadia First Nation for their interest in the research. S. Day (GSC) is thanked for his review of this article.

REFERENCES

- Barr, P.J.F. and Cullen, M.P. 2010. Technical report on the Brazil Lake lithium-bearing pegmatite property, Nova Scotia, Canada. <https://goldfieldsns.com/locations/brazil-lake/>
- Black, D.L. 2012. Report on prospecting, Brazil Lake property, EL 09083, EL09084, EL 09085; Assessment Report AR 2012-048, 476 p.
- Brushett, D.M. and Tupper, J. 2021. Till Geochemistry, indicator mineralogy, and surficial geology of the Brazil Lake pegmatite area, southwest Nova Scotia, Canada. *In*: MacDonald, D.R. and MacDonald, E.W. (eds), Geoscience and Mines Branch, Report of Activities 2020-2021. Nova Scotia Department of Natural Resources and Renewables, Report ME 2021-002, p. 1–9.
- Brushett, D.M., McClenaghan, M.B. and Paulen, R.C. 2022. Till geochemical data for the Brazil Lake Pegmatite area, Southwest Nova Scotia, Canada (NTS 21A/04, 20O/16 and 20P/13): till samples collected in 2020. Nova Scotia Department of Natural Resources and Renewables, Open File Report ME 2022-2.
- Brushett, D.M., Beckett-Brown, C.E., McClenaghan, M.B., Paulen, R.C., Rice, J.M., Haji Egeh, A. and Pelchat, P. 2024. Till geochemical data for the Brazil Lake pegmatite area, southwest Nova Scotia, Canada (NTS 21A/04, 20-O/16 and 20P/13): samples collected in 2020, 2021, and 2022. Geological Survey of Canada, Open File 9148.
- Corey, M. 1995. Diamond drilling of rare element pegmatites in southwestern Nova Scotia. Nova Scotia Mines and Energy Branches, Open File Report 95-001. https://novascotia.ca/natr/meb/data/pubs/ofr_me_1995-001.pdf <Accessed 2023/08/08>
- Cullen, M., Harrington, M. and Elgert, L. 2022. NI 43-101 Technical report on the mineral resources estimate for the Brazil Lake project (lithium-bearing pegmatite deposit) Nova Scotia, Canada.
- Gao, T.M., Fan, N., Chen, W. and Dai, T. 2023. Lithium extraction from hard rock lithium ores (spodumene, lepidolite, zinnwaldite, petalite): Technology, resources, environment and cost. *China Geology*, 6(1), 137–153. <https://doi.org/10.31035/cg2022088>
- Grant, D.R. 1980. Quaternary stratigraphy of southwestern Nova Scotia: glacial events and sea level changes. Geological Association of Canada, Mineralogical Association of Canada Field Trip Guidebook, Trip 9, 63 p.
- Hibbard, J.P., van Staal, C.R., Rankin, D. and Williams, H. 2006. Lithotectonic map of the Appalachian orogen (north),




Leaders in Rare Earth and Uranium Exploration Analysis

A global company with local full laboratory presence for over 35 years.

Complete Assay and Geochemical Services, Mineralogy, Environmental, On-site Laboratories and more.

actlabs.com



continued on page 12

Paid Advertisement

Indicator minerals for lithium exploration in glaciated terrain

continued from page 11

Canada-United States of America. Geological Survey of Canada Map 2041A, scale 1:1,500,000, 1 sheet.

Kontak, D.J. 2004. Geology of the southern lobe of the Brazil Lake LCT-type pegmatite (NTS 21A/04), Yarmouth County, Nova Scotia. Nova Scotia Department of Natural Resources, Mineral Resources Branch Report of Activities 2003, Report 2004-1, 41–68.

Kontak, D.J. 2006. Nature and origin of an LCT-suite pegmatite with late-stage sodium enrichment, Brazil Lake, Yarmouth County, Nova Scotia. I. Geological setting and petrology. *The Canadian Mineralogist*, 44(3), 563–598. <https://doi.org/10.2113/gscanmin.44.3.563>

Kontak, D.J. and Kyser, T.K. 2009. Nature and origin of an LCT-suite pegmatite with late-stage sodium enrichment, Brazil Lake, Yarmouth County, Nova Scotia. II. Implications of stable isotopes ($\delta^{18}\text{O}$, δD) for magma source, internal crystallization and nature of sodium metasomatism. *The Canadian Mineralogist*, 47(4), 745–764.

Kontak, D.J., Creaser, R.A., Heaman, L.M. and Archibald, D.A. 2005. U-Pb tantalite, Re-Os molybdenite, and $^{40}\text{Ar}/^{39}\text{Ar}$ muscovite dating of the Brazil Lake pegmatite, Nova Scotia: a possible shear-zone related origin for an LCT-type pegmatite. *Atlantic Geology*, 41(1), 17–29.

McClenaghan, M.B., Spirito, W.A., Plouffe, A., McMartin, I., Campbell, J.E., Paulen, R.C., Garrett, R.G., Hall, G.E.M., Pelchat, P. and Gauthier, M.S. 2020. Geological Survey of Canada till-sampling and analytical protocols: from field to archive, 2020 update. Geological Survey of Canada, Open File 8591, 73 p. <https://doi.org/10.4095/326162>.

McClenaghan, M.B., Brushett, D.M., Paulen, R.C., Beckett-Brown, C.E., Rice, J.M., Haji Egeh, A. and Nissen, A. 2023a. Critical metal indicator mineral studies of till samples collected around

continued on page 13

Geochemistry Testing

Trusted.
Independent.
Committed.



Unparalleled analytical support, where and when you need it

Our network of commercial, mobile and mine-site laboratories provides consistency across an unparalleled number of countries and mining camps. Our one team approach incorporates a global network of experienced managers and highly skilled assayers, utilizing state-of-the-art equipment to provide you with accurate analysis at fast turnaround times.

We are available where and when you need us.

NAM.NATURALRESOURCES@SGS.COM
WWW.SGS.CA/MINING

SGS

Paid Advertisement

New book release

A History of Geochemistry and Cosmochemistry, from Prehistory to the End of the Classical Period

Since Mendeleev outlined the modern periodic table in 1869, many new uses have been found for the 92 naturally occurring elements. This book travels back in time to describe the utilization of materials familiar (gold, copper, iron) and arcane (arsenic, boron, red ochre) and their practical history (mining, metallurgy, and crafts), with evidence from archaeology and geology. Together with the technological developments, author Robert Boyle portrays the advances in our understanding of materials science which led to modern geological and environmental sciences. It is a source book valuable to students of history and archaeology, mining and metallurgy, as well as to geologists, mineralogists and geochemists everywhere.

About the author, Bob Boyle (1920–2003)

Bob was a pioneer of the application of geochemistry to mining geology and mineral exploration. He was an eminent geochemist with a long career at the Geological Survey of Canada where he initiated the Geological Survey of Canada's regional geochemistry program in 1957. His publications spanned various mineral-deposit types and a wide spectrum of precious and base metals. Bob was a founding member of the Association of the Applied Geochemists in the 1970s, and was awarded the Association's highest honor, the Gold Medal, in 1999 in recognition of his lifetime of outstanding achievement in exploration geochemistry. Among Bob's many achievements and awards was his induction into the Canadian Mining Hall of Fame in 1997.

The book is available at: <https://www.cambridgescholars.com/product/978-1-5275-7614-8>

A History of Geochemistry
and Cosmochemistry,
from Prehistory to the
End of the Classical Period



Robert W. Boyle

Edited by

Graham C. Wilson, Charles Butt,
Robert Garrett and Heather Robinson



Indicator minerals for lithium exploration in glaciated terrain *continued from page 12*

the Brazil Lake LCT pegmatite, southwest Nova Scotia; Geological Survey of Canada, Open File 8960, 12 p. <https://doi.org/10.4095/331537>

McClenaghan, M.B., Brushett, D.M., Beckett-Brown, C.E., Paulen, R.C., Rice, J.M., Haji Egeh, A. and Nissen, A. 2023b. Indicator mineral studies at the Brazil Lake LCT pegmatites, southwest Nova Scotia. Geological Survey of Canada, Scientific Presentation 157. <https://doi.org/10.4095/331686>

McClenaghan, M.B., Paulen, R.C., Smith, I.R., Rice, J.M., Plouffe, A., McMartin, I., Campbell, J.E., Lehtonen, M., Parsasadr, M. and Beckett-Brown, C.E. 2023c. Review of till geochemistry and indicator mineral methods for mineral exploration in glaciated terrain. *Geochemistry: Exploration, Environment, Analysis*, 23 (4): geochem2023-013. <https://doi.org/10.1144/geochem2023-013>

McClenaghan, M.B., Brushett, D.M., Beckett-Brown, C.E., Paulen, R.C., Rice, J.M. and White, C. 2024. Indicator mineral data for till and bedrock samples from the Brazil Lake pegmatite area, southwest Nova Scotia (NTS 21A/04, 20-O/16 and 20P/13). Geological Survey of Canada, Open File 9189.

O'Reilly, G.A. and Kontak, D.J. 1992. The East Kemptville Tin Deposit and the southwest Nova Scotia Tin Domain. Nova Scotia Department of Natural Resources, Mines and Energy Branches Report 92-1, 65–74.

Stea, R.R. and Grant, D.R. 1982. Pleistocene geology and till geochemistry of southwestern Nova Scotia (sheets 7 and 8). Nova Scotia Department of Mines and Energy, Map 82-10, scale 1:100 000.

Stea, R.R., Seaman, A.A., Pronk, T., Parkhill, M.A., Allard, S. and Utting, D. 2011. The Appalachian Glacier Complex in Maritime Canada. *Developments in Quaternary Sciences*, 15, 631–659.

White, C.E. 2010. Stratigraphy of the lower Paleozoic Goldenville and Halifax groups in southwestern Nova Scotia. *Atlantic Geology*, 46, 136–154.

White, C.E. and Barr, S.M. 2017. Stratigraphy and depositional setting of the Silurian–Devonian Rockville Notch Group, Meguma terrane, Nova Scotia, Canada. *Atlantic Geology*, 53, 337–365.

White, C.E., Barr, S.M. and Linnemann, U. 2018. U–Pb (zircon) ages and provenance of the White Rock Formation of the Rockville Notch Group, Meguma terrane, Nova Scotia, Canada: evidence for the “Sardian gap” and West African origin. *Canadian Journal of Earth Sciences*, 55(6), 589–603.

ANALYTICAL LABORATORY SERVICES

FOR THE EXPLORATION &
MINING INDUSTRIES

- Assaying & Geochemical Analysis
- Mine Site Laboratories
- Spectral Services
- Environmental Services



<http://www.bvna.com/mining-laboratory-services>

bvmininfo@bureauveritas.com

Paid Advertisement



Articles in Past Issues of EXPLORE

1 year ago EXPLORE 199 (June 2023)

The log transformation explained

5 years ago EXPLORE 183 (June 2019)

Gold dispersion in transported cover sequences especially in chemical (palaeoredox front) and physical (unconformity) interfaces linked to the landscape history of Western Australia

10 years ago EXPLORE 163 (March 2014)

The evolution of the Geological Survey of Canada's regional reconnaissance geochemical drainage sediment and water surveys

20 years ago EXPLORE 124 (July 2004)

Technical Note: An unexpected aspect of EDTA partial digest extractions

30 years ago EXPLORE 84 (July 1994)

Molybdenum distribution in stream sediment grain fractions: A test programme from the Eastern Province, Zambia

<https://www.appliedgeochemists.org/explore-newsletter/explore-issues>



30th International Applied Geochemistry Symposium (IAGS)

The Local Organising Committee (LOC) and the Association of Applied Geochemists (AAG) welcome you to the 30th International Applied Geochemistry Symposium, IAGS 2024, Adelaide/Tartanya, Australia. This conference has the theme “Geochemistry for a Sustainable Future”. Join us and contribute to sharing advances in approaches and technologies for exploration, processing and the environment for social benefit. Scientific sessions will include an emphasis on critical minerals. The IAGS LOC is pleased to announce that the [International Association for Mathematical Geosciences \(IAMG\)](#) are partnering with IAGS and AAG to host sessions on ‘Big Data Analytics and Machine Learning Algorithms in Geochemistry’.



Dates to remember

IAGS 2024 runs from Monday 14th October to Friday, 18th October for the Scientific Program at the Adelaide Convention Centre. Wednesday 16th October will not have scheduled Scientific Program events to allow for tours and workshops.

Friday August 2, 2024

Early Bird Registrations Close / Full Price Opens

Monday October 14, 2024

Symposium Begins

Scientific Program

IAGS 2024 features oral and poster presentations providing insights into the latest developments of applied geochemistry. The six themes of the conference – Environment, Exploration, Technology, Define/Extract, Research & Society – have attracted a strong and diverse cohort of international, early career and industry presenters. This will ensure a great opportunity to promote the exchange of scientific knowledge, encourage research and development, and promote the application of geochemistry to exploration and the environment.

Oral Program: <https://www.iags2024.com.au/program>

Poster Program: <https://www.iags2024.com.au/poster-sessions>

Field trips

Five field trips are currently planned:

- Kapunda: in situ recovery (ISR) copper project
- Geochemistry of vineyard soils on the Adelaide plains and Willunga Basin (McLaren Vale)
- Hallett Cove geological trail
- Brukunga pyrite mine
- Geology and mineral deposits of the northern Flinders Ranges (4-day trip) including the World Heritage nominated Ediacaran fossil site

Please check website for more information. Signing up is easy! Just follow the prompts while registering.

Workshops

Workshops are planned covering a range of interesting topics including:

- Exploration geochemistry, applied geochemistry of porphyry copper deposits, ioGAS geochemical analysis software and molar element ratio analysis
- Regolith (critical zone) geology and geochemistry
- Geology and geochemistry of IOCG deposits
- Hyperspectral mineralogy and the National Virtual Core Library platform
- Data science for geoscientists
- AusGeochem platform, practical hydrogeochemistry and lab tours
- A technology workshop introducing a range of new geochemical and mineralogical technologies micro-analytical techniques, scanning and imaging technologies

Sponsors

The Organising Committee is seeking organisations interested in sponsoring the IAGS 2024, and invites potential Sponsors/Exhibitors to follow the link below, or to contact the committee for a prospectus. Participating as a Sponsor or Exhibitor provides your organisation with the opportunity to demonstrate your level of support and commitment to the industry and connects your organisation with your target audience.

Conference fees

The IAGS and AAG will provide membership registration for IAMG members. Students and participants from some developing countries will be able to apply for a bursary to support travel to IAGS 2024. Please check the conference website regularly for application details.

IAGS 2024 ... *continued from page 14*

TICKET TYPE	EARLY BIRD		STANDARD	
	Member	Non-Member	Member	Non-Member
All inclusive	980	1190	1190	1380
Sponsor / Exhibitor	650	650	650	650
Symposium	850	1050	1050	1250
Student	350	350	450	450
Gala Dinner	150	150	150	150

N.B. Price is in AUD and includes GST

All Inclusive registration:

Includes 4-day conference and gala dinner

Sponsor/Exhibitor registration:

4-day conference only for Sponsors/Exhibitors

Symposium registration:

4-day conference only

Student registration:

4-day conference

Gala Dinner registration:

Dinner only

Visa information

If you are planning on attending IAGS 2024 from overseas, please consider the various options before going through the registration phase. Australia has some tough immigration laws, so we don't want you to get stuck if you are considering a visit to Australia to attend the conference.

The visa that you will have to apply for depends on your passport. We have provided the following link, but please make sure you read the information thoroughly before starting the process of your visa application.

<https://immi.homeaffairs.gov.au/visas/getting-a-visa/visa-finder>

Good luck with this process, and make sure you are aware of the visa processing time, to make sure it's finalized before the conference.

More information is available on the website at <https://iags2024.com.au>

or

email iags2024@bie.com.au



CALL FOR AAG MEDAL NOMINATIONS

Significant contributions to applied geochemistry or service to AAG are recognised by award of either the AAG Gold or Past Presidents' (Silver) medals respectively. The history of how the medals came about and the formulation of guidelines for their award are discussed in the April 1992 issue of EXPLORE, issue 75, which can be found on the AAG website under Publications/EXPLORE newsletter/1990–1994.

Guidelines for nominating individuals for either medal are posted in 'The Association' section of the AAG website (www.appliedgeochemists.org) under the 'Awards' area. Past discussions of the guidelines indicated that the process for nominating individuals for either medal was a little cumbersome, to the extent that some nominations were not being made, and others took an unnecessarily long time to resolve. With this in mind, the 2012–2013 Awards & Medals Committee (Chair: Paul Morris. Committee members Eion Cameron, Pertti Sarala, and Chris Benn) revisited the guidelines to make the nomination process a little friendlier, with a more concise time frame for resolution. The revised guidelines for nominations are presented

3.0 NOMINATIONS

- 3.1 To be eligible for consideration for either award, nominations must be received by the Chairman of the Awards and Medals Committee on or before December 1st of any year.
- 3.2 For acceptance by the Awards and Medals Committee, nominations must be signed by a minimum of four (4) Fellows (voting members) of the Association in good standing. Nominations should include the following:
 - (a) A one-page recommendation from each of the four nominators;
 - (b) A resume or curriculum vitae of the nominee;
 - (c) An itemized list of the outstanding scientific achievements (Gold Medal) or the dedicated service to the Association (Silver Medal) of the nominee (maximum two pages).

Since members of the Awards Committee may not have personal knowledge of the nominee, the completeness and quality of the nomination will be critical in terms of evaluation and selection.

Nominations for either medal can be made any time to ejmcarranza@gmail.com and will be considered in the year of the nomination provided they are received prior to December 1.

John Carranza
Past President
Chair, Awards and Medals Committee





2021 Association of Applied Geochemists Gold Medal Winner William K. Fletcher

A recent Vancouver Geochemical Working Group (VGWG) talk on May 22, 2024 provided an opportunity for a long-delayed medal presentation in Vancouver. Dr. William K. ('K') Fletcher was presented with the AAG's 2021 Gold Medal in recognition of his exceptional contributions to the scientific field of exploration geochemistry. The medal, which is the highest award of the Association, was to have been presented to Dr. Fletcher at the 29th IAGS in Vina del Mar, Chile, in October 2022. However pandemic travel restrictions at that time prevented his attendance.

Dr. Fletcher obtained his PhD at Imperial College, University of London and taught at The University of British Columbia in Vancouver from 1968 until his retirement in 2003, at which time he occupied the Norman B. Keevil Chair in Mineral Exploration. His Gold Medal citation states, in part:

"K's most significant research at UBC centred on the fluvial transport of heavy minerals, including gold and cassiterite, in temperate and tropical regions, on the development of effective methods of sampling and analysis of stream sediments for mineral exploration, and in statistical evaluation of the results of regional geochemical exploration surveys. His work in stream sediment transport in various climatic regions remains a foundation of regional geochemical programs in the mineral exploration industry. He also made important contributions to our understanding of the distribution and behaviour of base and precious metals in soil, till and organic sediments in glaciated terrain. ...

Perhaps K's greatest contribution to the discipline of applied geochemistry, however, has been as a teacher and mentor, in training many young scientists at the M.Sc. and Ph.D. level. He supervised 23 graduate students, many of whom went on to important leadership roles as exploration geochemists in industry, academia, and government. He was very generous with both his time and ideas, and no fewer than 6 of his graduate students were awarded the Student Paper Prize of the Association of Exploration Geochemists for papers co-authored with K. With his energy, enthusiasm, and many years of leadership in geochemical research and in teaching students, he played no small role in helping to make Vancouver the important global centre of exploration geochemistry it has become."

The award of the Association's Gold Medal to K Fletcher was originally announced in EXPLORE 191 (June 2021) and in ELEMENTS magazine (February 2022), and further information is provided there.

Stephen Cook



K Fletcher (left) was presented with the AAG gold medal by Steve Cook (right) in Vancouver on May 22, 2024. Photograph from Dave Heberlein.



Recently Published in Elements

April 2024, v. 20, no. 2

Paired Metamorphic Belts of SW Japan: Metamorphic Records of a Subduction System

This issue of *Elements* guides readers through a premier example of paired metamorphism: the Cretaceous Sanbagawa-Ryoke metamorphic pair of Japan. Estimates of pressure, temperature, the age and duration of metamorphism, and the tectonic framework in which metamorphism took place help us to develop quantitative models—both for the evolution of SW Japan and subduction systems in general.

There are two AAG news items in this issue. The first is a citation for R.G. Garrett – AAG Gold Medal Award 2022. The second is an abstract for an article that appeared in issue 199 (June 2023) of the EXPLORE newsletter, namely *The Log Transformation Explained* by Robert G. Garrett.



Reminder

AAG members can access past issues of *Elements* at
<http://elementsmagazine.org/member-login/>
 using their e-mail address and AAG member ID
 John Carranza

Geochemistry: Exploration, Environment, Analysis

VOLUME 24, ISSUE 2, MAY 2024

Research Articles

New methodological approach for deep penetrating geochemistry and environmental studies, Part 1: on-site soil extraction of trace and rare earth elements

A. de Junet, C. Builleux, A. Poszwa, S. Devin, P. Sarala, S. Pospiech, M. Middleton, and J-P. Pinheiro
<https://doi.org/10.1144/geochem2023-056>

Factor analysis in residual soils of the Iberian Pyrite Belt (Spain): comparison between raw data, log-transformation data and compositional data

I. Martín-Méndez, J. Llamas-Borrajó, A. Llamas Lois, and J. Locutura
<https://doi.org/10.1144/geochem2024-005>

Mapping exploration targets through multifractal modelling of soil geochemical data in the Xiaohongshilazi Pb–Zn–(Ag) ore district, Jilin Province, NE China

Huchao Ma, Da Wang, Feng Bai, Xiaoxuan Zhang, Gaotian Wang, Saina Dong, and Guilong Wang
<https://doi.org/10.1144/geochem2023-067>

Graph convolutional network for lithological classification and mapping using stream sediment geochemical data and geophysical data

Hao Fang, Yue Liu, and Qingteng Zhang
<https://doi.org/10.1144/geochem2024-006>

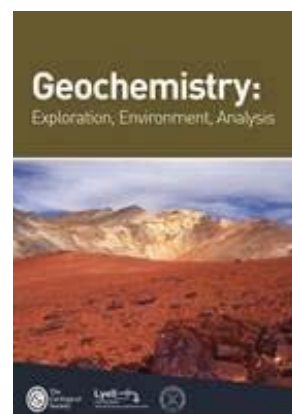
Thermophysical properties and geochemical characteristics of granites in the Tengchong area: indications for resource potential of hot dry rocks

Lixia Xu, Wei Zhang, Guiling Wang, and Yuzhong Liao
<https://doi.org/10.1144/geochem2024-001>

Thematic collection: Reviews in exploration geochemistry

Practical applications of quality assurance and quality control in mineral exploration, resource estimation and mining programmes: a review of recommended international practices

B.W. Smee, L. Bloom, D. Arne, and D. Heberlein
<https://doi.org/10.1144/geochem2023-046>



Barringer

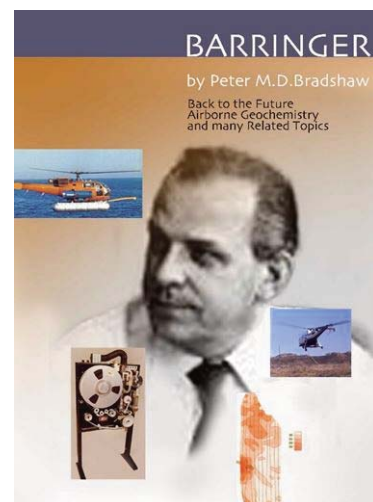
Back to the Future: Airborne Geochemistry and many Related Topics

by Peter M.D. Bradshaw

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

The guide may be downloaded free of charge from the AAG website:

<https://www.appliedgeochemists.org/publications>



Welcome New AAG Members

REGULAR MEMBERS

Regular Members are non-voting members of the Association and are actively engaged in the field of applied geochemistry at the time of their application and for at least two years prior to the date of joining.

Emily Sportsman

Stantec Co.
355 Goldco Circle
Golden, Colorado 80403
United States
Member #4540

Christina Stouraiti

Associate Professor,
National and Kapodistrian University of
Athens
Panepistimiopolis Zografou, Athens
15784 Greece
Membership #4532

Dr. Haicheng Wang

Associate Research Fellow,
China Geological Survey
No 55 Honglian South Road, Xicheng
District
Xicheng Qu, Beijing Shi
100055 China
Membership #4533

Yihui Xiong

Professor, China University of Geoscience
No.388 Lumo Road, Wuhan, P.R. China
Wuhan Shi, Hubei Sheng
430074 China
Membership # 4534

Dr. Ziye Wang

Associate Professor
No.388 Lumo Road, Wuhan, P.R. China
Wuhan Shi, Hubei Sheng
430074 China
Membership #4535

Ben Kimpton

Senior Geologist, Caspin Resources Ltd
Ground Floor, 675 Murray Street
West Perth, WA
6005 Australia
Membership #4536

Nicholas Wyndham

Student, University of Adelaide
188 Barton Terrace West, North
Adelaide
SA 5006 Australia
Membership # 4537

Milo Pavlovich

Student, The College of William and
Mary
4005 Greenway, Baltimore, MD
21218 United States
Membership #4538

Dr. Yoram Teitler

Research Scientist, CSIRO
ARRC, 26 Dick Perry Lane
Kensington, WA 6151
Australia
Member #4541

Dr. Yanlu Xing

CSIRO Mineral Resources,
Gate 3, Normanby Road
Clayton, VIC
3168 Australia
Member #4542

FELLOWS

Fellows are voting members of the Association and are actively engaged in the field of applied geochemistry. They are Regular AAG Members who are nominated to be a Fellow by a Fellow of the Association by completing the Nominating Sponsor's Form. Consider becoming a Fellow of the AAG.

Bimin Zhang

Institute of Geophysical and Geochemical
Exploration
84 Jinguang Rd, Langfang ShiHebei
Sheng,
065000, China
Member #3922

Dr Maria J Batista

Geologist (LNEG)
Rus A, No 19
Fonte da Talaha, Coimbra
Portugal 3030-242
Member # 3499 (since 2019)

STUDENT MEMBERS

The Association also has student memberships. These members are students that are enrolled in an approved course of instruction or training in a field of pure or applied science at a recognized institution. Student members pay minimal membership fees.

Dr. Yuexin Lu

84 Jinguang Rd, Langfang Shi
HE 065000, China
Member #4539



Writing Geochemical Reports, 3rd Edition

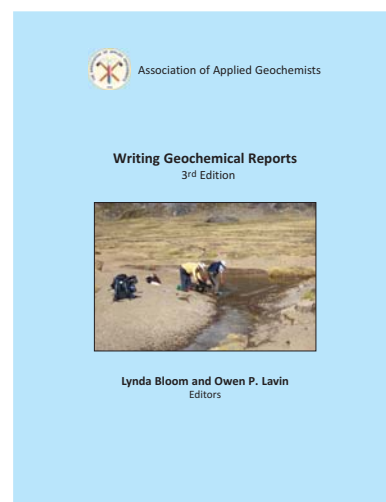
Guidelines for surficial geochemical surveys

Edited by Lynda Bloom and Owen Lavin

The Association of Applied Geochemists has developed international standards for writing geochemical reports that provide clear instructions for reporting geochemical results, together with the requisite supporting information to evaluate these results for accuracy, integrity and credibility. The target audience for these guidelines is anyone charged with reporting geochemical results, which includes, but is not limited to, company geoscientists, external consultants and contractors, government scientists, and university scientists and students. The guidelines focus on preparation of an electronic publication that provides a systematic and permanent record of the work performed and take into account the ability to bundle text, tables, figures, images, and oversized maps into one electronic file. The third edition of this guide was released in 2022 and expands the original mandate of Writing Geochemical Reports (1st and 2nd editions) to include multiple types of geochemical surveys with survey-specific recommendations.

The guide may be downloaded free of charge from the AAG website:

<https://www.appliedgeochemists.org/publications>



Obituary

Dr. Colin Dunn – Biogeochemist extraordinaire

Dr. Colin Dunn died at the age of 83 on March 20, 2024 in Sidney, BC, Canada. He will be immensely missed by many members of the mineral exploration community worldwide.

Following completion of his PhD at London University in 1972, Colin spent much of his career first at the Saskatchewan Geological Survey in central Canada and then at the Geological Survey of Canada (GSC; 1985-1998). Upon leaving the GSC, he and Sara moved to British Columbia (BC) in western Canada where he set up his flourishing consulting business which continued until recently. Colin was an active member of the AAG and in 2014 was awarded its highest honor, the Gold Medal for excellence in mineral exploration using biogeochemistry (<https://www.appliedgeochemists.org/gold-medal/2014-colin-dunn>). A glimpse into the variety of his projects and publications can be gleaned from his book 'Biogeochemistry in Mineral Exploration', published by Elsevier in 2007.

I was fortunate to have the office adjacent to Colin's at the GSC; this resulted not only in our friendship but in our collaboration to improve and expand analytical capabilities for biogeochemical media and to compare 'biosurveys' (Colin) with 'hydrosurveys' (me) over the same areas. We travelled together to conferences and workshops worldwide, meetings where Colin seemed to know and greet almost everyone, a testament to his vivacious and warm personality. Colin was a great listener, with an inquiring mind. He gave the best talks, so well organized and clear, just like his papers. His talks were well augmented with photos from his field work, perhaps the most audacious being those photos showing treetop sampling by helicopter in British Columbia. It is a technique that Colin and Rob Scagel, a forester, designed to collect surficial media in difficult, hilly densely treed areas. Colin emphasized to the skilled pilot that he must be careful to hover over the tallest tree lest the sampler be engulfed in severed twigs and needles!

I asked a few people who worked on various research-oriented surveys with Colin to contribute some anecdotes. There is a clear theme running through all of them and it is a reflection on Colin's character: always positive, enthusiastic (even under tough field conditions), generous, ever-curious, keen to experiment with new species or techniques, patient, great sense of humour (British!), self-deprecating, mentor, friend and collaborator. These friendships were usually cemented over a bottle of red and a good meal, curry if possible!



Colin "under the shade of a coolabah tree" at Merty Merty, Strzelecki Desert, South Australia. Colin insisted that the iconic hat with corks tied to the brim (to deter blowflies) would ensure that he seamlessly integrated into local outback communities ... despite the frank and fearless contrary advice and assessments from his travelling companions! Photo from Steve Hill.



Colin collecting plant cuticles with a vacuum cleaner. "Who said that biogeochemistry didn't suck!?" (Colin's words). Photo from Dave Heberlein.

Dave Heberlein (Western Canada), with whom he often worked in BC, was amazed at Colin's almost encyclopedic knowledge of the different metal uptake characteristics of various species and their tissues. Dave found that Colin was a delight to work with, so generous with his time and knowledge in teaching and advancing this field of mineral exploration.

Tony Christie (New Zealand) first met Colin at the IAGS in Beijing in 1993. So impressed was he with Colin's talks and chats, that he arranged to test the technique with Colin on various gold prospects over the years in New Zealand. Even in arduous conditions, Colin was jovial and positive and keen to get the work done.

Steve Hill (Australia) commented on how much Colin relished getting to know fellow researchers and their projects during his regular visits to Australia, especially into South Australia and western NSW to Broken Hill, Tibooburra, Arkaroola, Olympic Dam, Tunkillia and Kangaroo Island. Colin and Helen Waldron published an outstanding frontier study for the Geological Survey of South Australia on plant biogeochemistry across the South Australian portion of the Nullarbor

Colin E. Dunn Obituary *continued from page 19*

Plain in which Colin adored the irony of conducting this study across a geographical feature named because of its apparent lack of trees (ie. “null – arbor” meaning “no trees”).

Peter Rogers (Eastern Canada), a good friend from the mid-1980s, secured funding to carry out a reconnaissance biogeochemical survey using balsam fir and spruce twigs and bark in Eastern Nova Scotia with Colin. It was a resounding success, easily delineating most known metallogenic features, especially for gold and led to numerous joint projects some of which are described in Colin’s book.

Dave Cohen (Australia) first met Colin in 1984 on a foray to the famous Hemlo gold deposit in northern Ontario, where he was collecting samples for his biogeochemistry MSc at Queen’s University. After instruction from Colin in the more subtle aspects of plant sampling, Colin asked “What species do you intend to sample?” Dave indicated it would be balsam fir, mountain maple, white spruce and alder. From Colin: “Ah, which of the two sub-species of alder are you sampling – *Alnus crispa* or *Alnus rugosa*?” And from Dave: “There are two sub-species?”, to which Colin replied “Yes, and they take up metals differently”. This is one of the rules Colin was adamant about: *never mix species or sub-species in one survey!*

Helen Waldron (Australia) had the pleasure of working with Colin on many of his Australian projects as well as in Canada, Sweden and New Zealand. She recounts that he made a significant contribution to the use of biogeochemistry in exploration in Australia through the CRE LEME, courses, lectures, research projects and direct involvement in exploration programs for various commodities in several states, sampling a wide range of plants including, amongst others: spinifex, saltbush, mulga and eucalypts. Some projects he did just for fun, like searching for Ni accumulator plants at Ravensthorpe, sampling slime from hot springs in the Flinders Ranges and studying chemical variations in eucalypts at Dean Nicolle’s Currency Creek Arboretum.

Readers can find examples of Colin’s excellent Powerpoint presentations (e.g. from Exploration ’07) and papers online. Colin’s legacy is huge: his comprehensive book, many research papers and published surveys, and numerous people who have benefitted from his shared skill and knowledge but it is his indomitable fun-loving spirit that will be greatly missed by so many of us.

Gwendy Hall (in association with the above-mentioned contributors)
Ottawa, Canada

A special session dedicated to Colin will be held at the 30th IAGS in Adelaide October 14–18, 2024.



Colin at beech forest Orogenic Au prospect, Reefton, NZ in 2012. Photo from Tony Christie.



Colin, Helen Waldron, and Gwendy Hall taking a break at the IAGS in 2007 in Oviedo, Spain. Photo from Beth McClenaghan.



Treetop sampling in northern Manitoba. Photo from Steve Cook.

Short Course Review

TILL GEOCHEMISTRY AND INDICATOR MINERAL METHODS FOR EXPLORATION IN GLACIATED TERRAINS

2024 Prospectors & Developers Association of Canada, Course 3

A 1.5 day short course was held in conjunction with the March 2024 Prospectors and Developers Association of Canada (PDAC) annual conference in Toronto, Canada that highlighted the current state of knowledge for drift prospecting in glaciated terrains. The course focussed on the application of till geochemistry and indicator minerals to mineral exploration. The course was organized by Roger Paulen and Beth McClenaghan, both of the Geological Survey of Canada (GSC), and included presentations from both experienced and up-and-coming geoscientists from government, academia, and industry. The 50+ attendees had quite diverse backgrounds as well, including students, explorationists, and researchers, showing the continued interest in the use of till geochemistry and indicator minerals methods to explore for buried mineral deposits.

The course opened with a thorough overview of glacial dynamics and sediment dispersal (Martin Ross, University of Waterloo), essential knowledge for understanding dispersal trains. This talk paired well with the following presentation on how to determine glacial transport directions that have influenced a landscape (Roger Paulen, GSC). Traditional methods such as striations and surficial mapping along with newer methods like remote sensed data sets and LiDAR were discussed. Combined, the two opening presentations provided a background in the concepts needed to understand glacial dispersal from mineral deposits.

The next set of presentations described current till sampling procedures and protocols along with lab methodologies for processing till samples. These included a presentation on surface sampling techniques (Jessey Rice, GSC) which reinforced the concept of collecting unoxidized C-horizon material, and how to find it. Following this talk, was a presentation on techniques to sample till at depth through shallow overburden drilling (Dave Sacco, Palmer/SLG). Using a small specialized drill rig, Dave showed how deeper till units can be sampled in a variety of glaciated terrains across Canada to ultimately vector back to mineralization. The lab methods presentation showed a variety of different techniques that are available to analyze till samples (Chris Beckett-Brown, Ontario Geological Survey [OGS]). This presentation had a strong emphasis on Quality Assurance and Quality Control, aspects that are integral to the interpretation of geochemical and mineralogical datasets. Some new methodologies highlighted in the talk included automated mineralogy, processing and digesting different till size fractions (i.e. 1 – 2 mm for digestion), and microXRF on heavy mineral concentrates.

The focus then switched to practical examples of finding mineral deposits at depth using the glacial concepts, till sampling procedures and analytical methodologies explored earlier in the day. This included Tower Resources' rapid discovery of the Lightning and Thunder Au Zones in an intensely explored district around Kamloops, BC using high-density till sampling (Stu Averill, Overburden Drilling Management Ltd.). Subsequent presentations on volcanogenic massive sulphide (Beth McClenaghan GSC), Ni-Cu-PGE (Dan Layton-Matthews, Queen's University) and porphyry Cu (Chris Beckett-Brown, OGS) exploration showcased till pathfinder elements and typical indicator mineral signatures for each deposit type. An overview of research into lithium pegmatites was provided by Denise Brushett (Nova Scotia Department of Natural Resources and Renewables) that was of particular interest to industry. The surficial geochemical and indicator mineral responses of the Brazil Lake pegmatite field was described. Recommendations for regional-scale lithium exploration included the commonly-used aqua regia digest on the >0.063 mm fraction as a first pass to detect pegmatites, however, for local-scale to site-specific exploration, a total digestion method applied to the 1 – 2 mm fraction was recommended. This section was capped by a presentation on the history of drift exploration in the Abitibi Greenstone Belt, an area of thick surficial sediment cover (Beth McClenaghan, GSC) where till sampling methods have been successfully applied for more than 60 years. The presentation showed that surface and deep till sampling techniques have contributed to numerous gold deposit discoveries in a region with complex ice flow history, multiple till units, and extensive cover of glacial lake sediments.

The second day started with a presentation on machine learning and AI and their applications to drift prospecting. The use of machine learning on till geochemical data (Mohammad Parsa, GSC) was certainly the most ground-breaking research presented. After reviewing the basic concepts and methods of machine learning, geological datasets (bands) including till geochemistry were combined to produce a prospectivity map of the northern Bathurst Mining Camp. All the code used in his example is published on GitHub and provides users with an excellent resource to use should they want to apply these methods to their own geological datasets. Another presentation on the application of LiDAR in the interpretation of streamlined landforms (Syed Bukhari, University of Toronto) also indicated the strength of machine learning algorithms to identify glacial features. Using this research methodology, it is easier to identify landforms produced by different ice flow phases in a region and determine what part of the 'ice stream' system they are from.

A final presentation on the influence of ice streams on the Canadian Shield (Roger Paulen, GSC) incorporated much of the previous material covered by the course. It showed how ice streams change and react to shifting subglacial conditions and how ice streams influence the glacial dispersal of debris over varying distances. Using some of the automated methods described above, the audience was left with a broader knowledge of where ice streams have influenced the landscape and the types of terrain features they leave behind.

Overall, the course provided a knowledgeable and diverse perspective on the current state of till geochemistry and indicator minerals methods in glaciated terrains. The many examples were appreciated as it showcased that the pro-

continued on page 22

Short Course Review *continued from page 21*

cesses and methodologies used in till sampling are robust and extremely capable of detecting mineral deposits at depth. The wide range of topics and commodity types covered by the presentations and their accompanying well written short course notes were greatly appreciated as the material can be referred after the course and allows practitioners to find references on topics of particular interest. I look forward to this type of short course being offered again at the PDAC convention again in just a few years time.


The short course notes are currently being converted into a Geological Survey of Canada open file publication that will be available to download for free by the end of August, 2024.

Grant Hagedorn


Ontario Geological Survey



Short course speakers: standing left to right, Syed Bukhari, Mohammad Parsa, Denise Brushett, Dan Layton-Matthews, Martin Ross, Stu Averill, Chris Beckett-Brown. Seated left to right, Roger Paulen, Beth McClenaghan, Jessey Rice, Dave Sacco.



SUSTAINABLE MINERAL EXPLORATION AND DEVELOPMENT
Windhoek, Namibia | September 27–30, 2024



You are invited to
SEG 2024
Sustainable Mineral Exploration and Development

Our conference will be held in Windhoek, Namibia—a country known for its spectacular geology, unique ore deposits, and leading the way in the achievement of mineral resource sustainability of the African continent.

Register today at www.seg2024.org!

10 FIELD TRIPS • 7 WORKSHOPS • EXHIBITS • PRESENTATIONS

Events

SEG 2024 will feature invited and submitted presentations and posters that will provide updates on the latest developments in the field of economic geology and highlight the regional geology. Ten field trips and seven workshops are scheduled before and after the conference, but these additional events are quickly selling out.

Sign up today to ensure your spot.



We look forward to seeing you in Namibia!

Register today at www.seg2024.org!

Session Themes

- **The Energy Transition: Metals of the Future**
- **Specialty Metals and Materials**
- **Innovative Technology Developments in Mineral Deposit Science**
- **Africa's Iconic Ore Deposits**
- **New Discoveries and Developments**
- **Resource Development: ESG from Exploration to Remediation**
- **Gold: Enhanced Discovery and Development**
- **Vital High-Volume Base Metals**





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.

The status of the meetings was confirmed at the time of publication, but users of the listing are strongly advised to carry out their own research as to the validity of an announcement.

Please let us know of your events by sending details to:

Ray Lett, Email: Raylett@shaw.ca

or

Elizabeth Ambrose, Email: eambrose0048@rogers.com

2024

- 29 June – 8 July XXIV International Multidisciplinary Scientific GeoConference - Surveying, Geology and Mining, Ecology and Management (SGEM). Varna, Bulgaria. Website: www.sgem.org/index.php
- 8–12 July 12th International Kimberlite Conference. Yellowknife, Northwest Territories, Canada. Website: 12ikc.ca
- 15–18 July 11th Annual International Conference on Geology & Earth Science. Athens, Greece. Website: www.atiner.gr/geology
- 21–26 July International Conference on Mercury as a Global Pollutant. Cape Town, South Africa. Website: tinyurl.com/mw37tdh4
- 28 July – 1 August Microscopy & Microanalysis 2024, Cleveland, Ohio USA. Website: tinyurl.com/mpwbhchw7
- 28 July – 2 August Contemporary Applications of Organic Geochemical Research (Gordon Research Conference). Holderness, New Hampshire, USA. Website: www.grc.org/organic-geochemistry-conference/2024
- 4–9 August Biomineralization (Gordon Research Conference). New London, New Hampshire, USA. Website: www.grc.org/biomineralization-conference/2024
- 6–8 August International Ni-Cu Symposium. Thunder Bay, Ontario, Canada. Website: ec.lakeheadu.ca/ni-cu
- 11–15 August IWA World Water Congress & Exhibition. Toronto, Ontario Canada. Website: worldwatercongress.org
- 11–18 August ISEG: International Symposium on Environmental Geochemistry. Galway, Ireland. Website: www.universityofgalway.ie/iseh-iceph
- 18–23 August 4th European Mineralogical Conference. Dublin, Ireland. Website: emc-2024.org
- 18–25 August Goldschmidt 2024. Chicago, Illinois USA. Website: tinyurl.com/5cr87s7e
- 24–30 August 35th International Geographical Congress. Dublin, Ireland. Website: igc2024dublin.org
- 25–27 August 14th International Conference on Environmental Pollution and Remediation (2024). Barcelona, Spain. Website: icepr.org
- 25–31 August 37th International Geological Congress. Busan, Republic of Korea. Website: www.igc2024korea.org
- 4–6 September Discoveries in the Tasmanides. Albury, New South Wales, Australia. Website: www.minesandwines.com.au
- 15–18 September Interfaces Against Pollution 2024. Torino, Italy. Website: www.iap2024torino.it/iap-2024-torino
- 15–19 September Geoanalysis 2024. Wuhan, China. Website: tinyurl.com/yeyj8nuh
- 16–20 September 13th International Conference on Acid Rock Drainage (ICARD 2024), Halifax, Nova Scotia, Canada. Website: icard2024.cim.org/
- 22–25 September GSA Connects 2024. Anaheim CA USA. Website: community.geosociety.org/gsa2024/home
- 27–30 September SEG 2024 Conference in Namibia. Windhoek Namibia. Website: tinyurl.com/zsb3kkrf
- 2–4 October Mongolia Mining 2024. Ulanbataar Mongolia. Website: mongolia-mining.mn
- 6–9 October MS&T24: Materials Science & Technology. Pittsburgh PA USA. Website: www.matscitech.org/MST/MST24
- 14–18 October 30th International Applied Geochemistry Symposium (IAGS). Adelaide SA Australia. Website: iags2024.com.au
- 20–24 October Ross International Symposium: Geochemistry for sustainable development, SIPS 2024, Crete, Greece. Website: flogen.org/sips2024/
- 7–9 November International Conference on Geology and Earth Sciences. Bali, Indonesia. Website: icges.org
- 13–16 November Geological Society of America (GSA) 2024 Annual Scientific Meeting, Seattle, Washington, USA. Website: gsa2024.org
- 22–24 November Seventh International Workshop on Environment and Geoscience (IWEG 2024). Shanghai, China. Website: www.iwegconf.org
- 25–28 November Mediterranean Geosciences Union Annual Meeting. Barcelona, Spain. Website: 2024.medgu.org
- 1–6 December American Exploration & Mining Association (AEMA) Annual Meeting. Reno, Nevada, USA. Website: tinyurl.com/yuf7yk8m

2025

- 20–23 January Association of Mining and Mineral Exploration BC (AMEBC) Cordilleran Round Up Convention, Vancouver, British Columbia, Canada. Website: roundup.amebc.ca
- 2–5 March Prospectors and Developers Convention, Toronto, Canada. Website: pdac.ca/convention
- 2–7 March European Winter Conference on Plasma Spectrochemistry. Berlin, Germany. Website: ewcps2025.de
- 20–21 March GEMS 2025 - International Conference on Geology Engineering and Marine Sciences. Wuhan, China. Website: gems.isgcpi.com/
- 27 April – 2 May European Geosciences Union, EGU, EGU 2025 - European Geosciences Union General Assembly. Vienna, Austria. Website: egu25.eu/
- 3–7 August 18th SGA Biennial Meeting. Golden, Colorado USA. Website: sga2025.org
- 8–12 September Eurosoil 2025. Seville, Spain. Website: soilscience.eu/eurosoil-2025



EXPLORE Publication Schedule

Quarterly newsletters are published in March, June, September, December

• **Deadlines** for submission of articles or advertisements:

March newsletter: January 15

June newsletter: April 15

September newsletter: July 15

December newsletter: October 15

- **Manuscripts** should be double-spaced and submitted in digital format using Microsoft WORD®. Articles should be between 2000 and 3000 words. Do **not** embed figures or tables in the text file.
- **Figures and/or photos** (colour or black and white) should be submitted as separate high-resolution (2000 dpi or higher) tiff, jpeg or PDF files.
- **Tables** should be submitted as separate digital files in Microsoft® EXCEL format.
- All scientific/technical articles will be reviewed. Contributions may be edited for clarity or brevity.
- Formats for headings, abbreviations, scientific notations, references and figures must follow the Guide to Authors for *Geochemistry: Exploration, Environment, Analysis* (GEEA) that are posted on the GEEA website at:
<https://www.geolsoc.org.uk/geea-authorinfo>
- An **abstract** of about 250 words must also be submitted 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

Geological Survey of Canada 601 Booth Street, Ottawa, ON, CANADA K1A 0E8

Email: bethmcclenaghan@sympatico.ca

THE ASSOCIATION OF APPLIED GEOCHEMISTS

P.O. Box 567, 223 St. Lawrence Street, Merrickville, Ontario K0G 1N0 CANADA

www.appliedgeochemists.org

OFFICERS

January – December 2024

President, Yulia Uvarova

CSIRO
26 Dick Perry Ave.
Kensington W.A., AUSTRALIA 6151
yulia.uvarova@csiro.au

Vice-President, Renguang Zuo

State Key Laboratory of Geological
Processes and Mineral Resources (GPMR)
China University of Geosciences (CUG)
Wuhan 430074, CHINA
zrguang@cug.edu.cn

Treasurer, Gwendy E.M. Hall

110 Aaron Merrick Drive
Merrickville, ON K0G 1N0 CANADA
gwendyhall@gmail.com

Secretary, David B. Smith

U.S. Geological Survey
Box 25046, MS 973
Denver, CO 80225, USA
dbsmith13@gmail.com

Past President, John Carranza

Department of Geology
University of the Free State
205 Nelson Mandela Drive
Park West, Bloemfontein
SOUTH AFRICA 9301
ejmcarranza@gmail.com

COUNCILLORS

2023–2024

Aaron Baensch
aaron_baensch@hotmail.com
Ray Lett
Raylett@shaw.ca
Paul Morris,
xrficpms@outlook.com
Ryan Noble,
Ryan.noble@csiro.au
Pim van Geffen
Pim.VanGeffen@csaglobal.com

2024–2025

Mark Arundell
mark@imex.au
Patrice de Caritat
patrice.decaritat@gmail.com
Behnam Sadeghi
z5218858@zmail.unsw.edu.au
Alexander Seyfarth
Alexander.Seyfarth@sgs.com
Cliff Stanley
cliff.stanley@acadiu.ca

REGIONAL COUNCILLORS

Brazil

João Larizzatti
joao.larizzatti@cprm.gov.br

Chile

Brian Townley
btownley@ing.uchile.cl

China

Renguang Zuo
zrguang@cug.edu.cn

Northern Europe

Perti Sarala
perti.sarala@oulu.fi

Southern Europe

Benedetto De Vivo
bdevivo@unina.it

Southeast Asia

Iftikhar Malik
malik.iftikhar@gmail.com

Northern Africa

Silas Sunday Dada
sdada@aol.edu.ng

Southern Africa

Theo Davies
theo.clavellpr3@gmail.com

UK and Republic of Ireland

Kate Knights
kknights@hotmail.com

AAG COMMITTEES

New Membership

Paul Morris
xrficpms@outlook.com

Awards and Medals

John Carranza
ejmcarranza@gmail.com
Chris Benn
Perti Sarala
Theo Davies
Yulia Uvarova

Education

David Murphy, *Chair*
davidkmurphy@gmail.com
Erick Weiland
erickweiland@terra-technology.com
Eric Grunsky egrunsky@gmail.com
James Kidder james.kidder@outlook.com
Ray Lett raylett@shaw.ca

Symposia

David Cohen d.cohen@unsw.edu.au

AAG COORDINATORS

AAG Student Paper Prize

David Cohen
d.cohen@unsw.edu.au

AAG Website

Web maintenance
Elizabeth Ambrose
eambrose0048@rogers.com

Geoscience Councils

David Cohen
d.cohen@unsw.edu.au

GEEA

Scott Wood
scott.wood@ndsu.edu

EXPLORE

Beth McClenaghan
bethmcclenaghan@sympatico.ca

Steve Cook
explorenewsletter@gmail.com

ELEMENTS

John Carranza
ejmcarranza@gmail.com

AAG Regional Councillors

Renguang Zuo
zrguang@cug.edu.cn

AAG BUSINESS MANAGER

Jane Graham

P.O. Box 567
223 St. Lawrence Street
Merrickville, ON K0G 1N0
CANADA
office@appliedgeochemists.org