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 (LiAlSi2O6), 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.
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Note from the Editor

Welcome New AAG Members .................................................... 18
Writing Geochemical Reports, 3rd 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 Lemière ............................................................. 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

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

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<table>
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<tr>
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<th>USD</th>
<th>CAD</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>Includes: Company logo on the front cover</td>
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</tbody>
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<tr>
<th>ADVERTISING RATES PER ISSUE (QUARTERLY)</th>
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<th>CAD</th>
</tr>
</thead>
<tbody>
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Note from the Editor

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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, Gwendi 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
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
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 southwest 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-
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.

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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.
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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 anomalouc 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.
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

Hibbard, J.P., van Staal, C.R., Rankin, D. and Williams, H. 2006. Lithotectonic map of the Appalachian orogen (north),
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
Indicator minerals for lithium exploration in glaciated terrain

continued from page 12


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
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.


**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.
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.


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.

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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
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

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://elementsverse.org/member-login/ using their e-mail address and AAG member ID
John Carranza
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-Borrajo, 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

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 geophysical methods created at BRL are well known while the contributions to exploration geochemistry and many other fields are not. This book documents the many advances in geochemical theory, as well as the ground, airborne and remote sensing techniques plus analytical methods that were conceived and developed under the leadership of Tony Barringer. Innovative concepts backed by pioneering research funded by BRL on the movement of metals in rock, soil and vegetation remain important areas of investigation. Tony Barringer's ability to bring together a diverse team including geologists, geochemists and physicists with electrical, optical and aeronautical engineers under one roof, provide leadership, a highly stimulating environment and financial support, was truly remarkable. This led to ground breaking advances in a number of different fields, including: exploration geochemistry for minerals and oil and gas; environmental monitoring from the ground, aircraft and space; and civilian and armed forces security. The underlying scientific principles for many of the inventions, now upgraded with modern electronics, are still considered state of the art. One of the many inventions from the BRL “incubator” described in this book is Ionscan, 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
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

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!

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 “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.

continued on page 20
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.
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-
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.

SEG 2024
Sustainable Mineral Exploration and Development
Windhoek, Namibia | September 27–30, 2024

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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.

Please let us know of your events by sending details to:
Ray Lett, Email: Raylett@shaw.ca
Elizabeth Ambrose, Email: eambrose0048@rogers.com

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.

2024

29 June –8 July  

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/mpw8chc7

28 July – 2 August  

4–9 August  

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  

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.iaip2024torino.it/iaip-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  

2–5 March  
Prospects 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

2025

20–23 January  

2–5 March  
Prospects 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:
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Geological Survey of Canada 601 Booth Street, Ottawa, ON, CANADA K1A 0E8
Email: bethmcclenaghan@sympatico.ca