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Lithium analysis of brines and minerals for exploration and resource definition

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Introduction

Lithium has been dubbed "white petroleum" by the media, vying with copper to become the "new oil", as electricity from renewable power substitutes for fossil fuels in the coming energy transition where internal combustion engines will be replaced by electric motors. Car manufacturers are quickly increasing production of electric vehicles, many planning to be totally electric over the next dozen years (Volkswagen 2020). Lithium is the primary choice for electric car batteries as it is lightweight, has a high energy density and can be repeatedly recharged. Gigafactories have been constructed for the manufacture of lithium batteries in the US, China and Europe. Lithium-ion batteries are also the battery of choice for grid storage electricity from renewable sources. This, in turn, has ramped up demand for lithium, with production doubling over the past decade to the extent that lithium usage for rechargeable batteries constituted 56% of total lithium consumption (Kavanagh *et al.* 2018). This dwarfs its previous industrial usage for greases, ceramics and in medical applications (Bibienne *et al.* 2020).

While prices for lithium have fluctuated in the past few years, a recent trend tracked by S&P Global Market Intelligence (2022) shows that Chinese battery-grade lithium carbonate prices have risen by 500% since mid-2020 to early 2022. This has driven production and investment in the industry; financings for new lithium and specialty commodity projects are at an all-time high of almost \$6 billion in 2021 with the prospect of demand doubling within the next three years (Fig. 1).



Figure 1. Global projected lithium demand (kt Lithium Carbonate Equivalent (LCE)) to 2030 (Cochilco 2022)

Lithium is produced from two main sources: low-grade lithium brines, and pegmatite deposits that represent concentrated sources of lithium (Kesler *et al.* 2012). Australia is the largest global producer at 40,000 tonnes of the 82,000 tonne global lithium production, mostly from pegmatite resources in Western Australia (USGS 2021). Other sources of lithium include: volcanic clay deposits, where lithium occurs within clay minerals such as hectorite; loosely held adsorbed lithium ions in clay minerals; and the unique jadarite (a lithium silicate borate) -bearing volcano-sedimentary deposits in the Jadar valley in Serbia (Bowell *et al.* 2020). This deposit could provide 10% of global Li demand were it to be developed. New development projects are equally divided between brines and hard rock sources (Fig. 2), but 81.8% of new lithium production will come from hard rock sources (S&P Global Market Intelligence 2022).



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Notes from the Editor

Welcome to the first **EXPLORE** issue of 2022. This issue features an article describing the analytical methods for determining lithium content in brines, rocks and sediments and was written by Hugh de Souza, Alexander Seyfarth, Nicholas Turner, and John Woods.

EXPLORE thanks all those who contributed to the writing and/or editing of this issue, listed in alphabetical order: Steve Amor, Al Arsenault, John Carranza, Zhaoshan Chang, Silas Sunday Dada, Hugh de Souza, Mary Doherty, Bob Garrett, Richard Howarth, David Leng, Marty McCurdy, Jessey Rice, Alexander Seyfarth, Dave Smith, Brian Townley, Nicholas Turner, Yulia Uvarova, and John Woods.

Beth McClenaghan

Editor

Steve Cook, Business Manager





President's Report

It is a great honour that the Association of Applied Geochemists (AAG) has bestowed upon me to serve as its President for 2022–2023. I thank Dennis Arne for leading the AAG strongly over the past two years, which were made difficult by the covid-19 pandemic. So difficult were those two years that the AAG was unable to celebrate its 50th anniversary at the 29th International Applied Geochemistry Symposium (IAGS), which was scheduled originally for November 2020 in Viña del Mar, Chile. I also thank Brian Townley, chair of the local organizing committee, for persevering in the organization of the 29th IAGS in those two difficult years. We are now hopeful, even though covid-19 has not fully gone away yet, that we will be able to finally hold the 29th IAGS in the same

Chilean city on October 16-22, 2022.

Dennis Arne will continue to serve on the Executive Council as Past President and chair of the Awards and Medals Committee, along with Gwendy Hall (Treasurer) and Dave Smith (Secretary). I thank Yulia Uvarova for agreeing to take on the role of AAG Vice President and as coordinator of Regional Councillors. I welcome the new councillors for 2022–2023, namely Renguang Zuo, Alexander Seyfarth, Cliff Stanley, Jamil Sader and Thomas Bissig (with Alexander and Jamil both starting their 1st term). I acknowledge the existing councillors for 2021–2022, namely Patrice de Caritat, Dave Heberlein, Paul Morris, Ryan Noble, Pim van Geffen and Steve Cook. The AAG Council is supported further by its Regional Councillors, namely Kate Knights (UK and Republic of Ireland), Theo Davies (Africa), Joao Larizzatti (Brazil), Brian Townley (Chile), Pertti Sarala (Northern Europe), Benedetto de Vivo (Southern Europe) and Iftikhar Malik (Southeast Asia). We have a new Regional Councillor for Northern Africa, Silas Sunday Dada, and Theo Davies continues as Regional Councillor for Southern Africa.

I thank the outgoing councillors (2020–2021) Maurizo Barbieri, Steve Cook, Beth McClenaghan, David Murphy and Yulia Uvarova for their contributions in the last two years, and Steve Cook for his role as chair of the Awards and Medals Committee. David Murphy continues as chair of the Education Committee, Beth McClenaghan continues as Coordinator for EXPLORE, Steve Cook continues as the Business Manager for EXPLORE, and of course Yulia Uvarova is now Vice President and coordinator of Regional Councillors. The other Fellows who will continue their service to AAG are Paul Morris (chair of New Membership Committee), David Cohen (chair of Symposia Committee, coordinator of AAG Student Paper Prize, and of Geoscience Councils), Scott Wood (editor of GEEA) and Tom Meuzelaar (webmaster of AAG Website). It will be a pleasure working with the above-mentioned Fellows as well as with AI Arsenault, AAG's business manager, and I am thank them in advance for the support and contributions they will be providing AAG during my term.

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In spite of the rescheduling of the 29th IGAS, we had at most 5% increase in our membership during 2021. This is a positive sign but we need to be more proactive in promoting and engaging with the next generation of [applied] geochemists. To this end, the AAG council has endorsed a number of projects and I will mention here just a couple of them. First, the development of a continuing professional development program (CPD) is progressing under the expert leadership of David Cohen. Second, a special volume of papers on the fundamentals of exploration geochemistry will be published in GEEA, with Thomas Bissig, Ryan Noble, Beth McClenaghan and Dennis Arne as guest editors. The topics/papers that will be included in this special volume will capture some of the collective knowledge and wisdom held by Members and Fellows of the AAG, and will provide some of the content for the CPD program. Hopefully, once completed, these and the other existing and future projects of AAG will attract new memberships. We hope to increase not only the number of young Members and Fellow but also the number of Senior Members and Fellows because the recently revised AAG by-law has removed the necessity of establishing whether a Senior Member or Fellow is actually retired and replaced it with just a set age of 65 for eligibility.

Finally, let us hope that 2022 is the year the covid-19 pandemic ends, and I hope to meet many of you at the 29^{th} IAGS.

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John Carranza,
AAG President
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Figure 2. New lithium projects, five hard rock and four brine projects - spodumene projects will account for 81.8% of the expected 355,000-tonne LCE capacity increase (S&P Global Market Intelligence 2022).

Lithium brine deposits represent approximately 70% of global lithium reserves and occur mainly in salars in the Lithium Triangle in South America where the borders of Bolivia, Argentina and Chile meet (Munk *et al.* 2016). As indicated by Bowell et al. (2020), lithium brines are hypersaline fluids with salinities between 1.7 and 24 times that of seawater. Lithium is concentrated after a long solar evaporation period of between 12 to 24 months, followed by chemical methods to extract lithium compounds. Lithium production from brine sources is estimated to be about 40% of global production mainly from the Lithium Triangle (USGS 2021).

Properties

Lithium is the third element in the periodic table and belongs to the alkali metal group. It is the least dense solid element with a density of 0.534 g/cm³, about half that of water. Lithium is highly reactive with a single valence electron that is easily lost to form a small cation, allowing it to substitute in a wide range of minerals. Hofstra *et al.* (2013) have indicated that lithium's small ionic radius and +1 charge enables it to have a much higher diffusion rate compared with other alkali metals. This property may allow lithium to migrate from lithophile element enriched rhyolitic tuffs, to form brines in enclosed terrestrial basins. It may also help produce surface *continued on page 6*



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soil anomalies in transported materials over buried pegmatites as discussed below.

Lithium has a very low ionization energy compared with other alkali metals, and is easily excited for atomic emission spectroscopy, atomic absorption spectroscopy (AAS) or inductively coupled plasma – atomic emission spectroscopy (ICP-AES). In a flame, lithium compounds and minerals have a characteristic crimson colour that is very recognisable in flame blowpipe tests (Read 1970). Lithium is also easily excited by a laser which is the basis for laser-induced breakdown spectroscopy (LIBS) instruments.

Under X-ray irradiation, lithium emits a very low energy K alpha line at 54 eV that can only be detected by specialized X-ray detectors (Burgess *et al.* 2013). This means that lithium cannot be detected by laboratory X-ray fluorescence (XRF) energy dispersive or wavelength dispersive instruments or by portable XRF systems. Although this may be considered unfortunate, it has allowed the widespread use of lithium metaborate/tetraborate flux mixes for preparing homogenized glass disks for whole rock analysis by XRF and other spectroscopic methods. In geochemical laboratory design, an important consideration should be the isolation of labs using lithium fluxes from those areas carrying out digestions for lithium determination.

Another consequence of lithium producing only a weak X-ray is that lithium-bearing minerals cannot be completely identified in electron beam instruments used for automated mineralogy, such as QEMSCAN, MLA or TIMA-X, since these techniques rely on energy dispersive X-ray spectrometry to measure mineral chemistry. Instead, alumino-silicate ratios and other elemental data are used to identify the various lithium-bearing minerals and determine their modal abundances. Because the lithium grade alone does not directly correspond to the overall value of an ore body, these modal abundances are important in understanding lithium deportment in pegmatites in order to assess the mineral resource. Its value is determined instead by the proportion of lithium minerals that can be sold to the higher priced battery markets. This problem has provided the impetus to develop alternate lithium mineral quantification methods such as the use of Fourier Transform Infra-Red spectroscopy (FTIR) discussed below.

Lithium in minerals cannot be determined by the wavelength dispersive X-ray detectors in electron probe microanalysis systems commonly used for quantitative determination of mineral chemistry. However, the development and widespread use of laser ablation inductively coupled plasma – mass spectrometry (LA-ICP-MS) systems has alleviated this situation in recent years; ICP-MS uses atomic mass to measure elemental abundance.



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Analysis of lithium brines

The lithium content of brines is best determined by ICP-based techniques rather than AAS due to their ability to measure other elements of interest simultaneously. The high level of total dissolved solids (TDS) in brines (typically 5-15% TDS) does pose an issue as the high salt content can quickly clog nebulizers and cones in ICP instrumentation and burner apertures in AAS instruments (Potts 1992). Pre-dilution of the brine samples and humidifiers for the carrier gas can lessen the salt content entering the plasma or flame. A second issue is that the high salt content increases the background and matrix interferences, causing a rise in detection limits. However, there are no significant spectral interferences for lithium using either ICP-AES, due to its high emission wavelengths, or ICP-MS because of its low mass.

Typical lower detection limits (LDLs) for lithium in brines are 2-10 mg/L by ICP-AES and 0.01 mg/L by ICP-MS compared to LDLs of 0.01 mg/L and 0.0001 mg/L, respectively in groundwaters with low TDS. ICP-MS methods would be required to determine lower levels of lithium in groundwaters, geothermal brines or oil field brines, where concentrations can be between 0.1 and 700 mg/L (Kavanagh *et al.* 2018).

Lithium in minerals

Volcanic clay lithium deposits, such as those found in Nevada, where lithium occurs in the clay mineral hectorite, or as an inter-layer cation, or absorbed on clay mineral surfaces, are easily analysed for lithium and multi-element packages



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using a four-acid digestion (a mixture of hydrofluoric, perchloric, nitric and hydrochloric acids). It might be expected that aqua regia digestion would extract all the lithium from such mineral hosts, but it is not recommended since there are some indications that aqua regia digestions extract slightly less lithium than four-acid digestions (Hilsher *et al.* 2021). However, jadarite is easily dissolved in mineral acids for the determination of lithium and other elements (Stanley *et al.* 2007).

Rare element granitic pegmatites are currently the main source of lithium from hard rock ores. They are also the source of metals such as Be, Rb, Cs, Ta, Nb, Sn, and the rare earth elements. Granitic pegmatites are widespread, but the rare metal pegmatites make up less than 1% of this group and lithium-bearing pegmatites are an even smaller proportion (Kesler *et al.* 2012; London 2016; Bowell *et al.* 2020). These rare element granitic pegmatites are further sub-divided into Lithium-Caesium-Tantalum (LCT) and Niobium-Yttrium-Fluoride (NYF) families (Černý 1991), with the former being the main source of lithium. The mineralogy of the rare element granitic pegmatites can be very complex, for example, 44% of the 124 lithium-bearing minerals known to exist occur in LCT pegmatites (Grew 2020). Of these, the key minerals for lithium extraction are spodumene, petalite and lepidolite, with spodumene being the most important ore mineral currently mined.



Figure 3. Lithium-Caesium-Tantalum (LCT) pegmatite showing metre-sized white spodumene crystals with quartz, albite and petalite. M.A. Laporte, SGS Geological Services.

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Analysis of spodumene-bearing pegmatites for lithium is challenging because it appears to be a highly refractory mineral that does not readily dissolve in four-acid digestions using methods followed by commercial laboratories. Aqua regia (nitric and hydrochloric acid) is clearly not strong enough since it lacks the hydrofluoric acid that is key to breaking down silicates. This leaves the fusion methods as alternatives, but lithium metaborate fusions have to be excluded for obvious reasons, leaving sodium peroxide fusion as the only method available for spodumene-bearing ores. Laboratory observations indicate that sodium peroxide fusion methods have a higher recovery of lithium than four-acid digestions. For example, in the OREAS reference material database, OREAS 753 is an LCT pegmatite with coarse spodumene and is certified at 1.02% Li using peroxide fusion ICP-AES versus 0.985% Li with four-acid digestion (https://www.oreas.com/ crm/oreas-753/). An analysis of a large geochemical database for an LCT pegmatite shows a consistent underestimate of Li content by four-acid digestion of approximately 4% (Yann Camus pers. comm.). A similar trend is seen in aluminium content which is the other major element besides silicon in spodumene. Silicon is volatilized during four-acid digestion as SiF₄ and cannot be determined. However, other lithium-bearing minerals in LCT pegmatites appear to dissolve well in four-acid digestions. In summary, sodium peroxide fusion is the preferred method because it decomposes all of the pegmatite, including refractory minerals such as tourmaline, zircon, cassiterite and garnet.

Li in surficial geochemical exploration

Many of the lithium-bearing mineral species, other than spodumene and tourmaline, are likely to break down in the surficial environment and release their ions. As we have seen from the concentrations in brines, lithium is a highly mobile element and likely to disperse upward and outward from LCT pegmatites. Galeschuk and Vanstone (2007) indicated that geochemical methods for discovery of buried LCT pegmatites are essential because these bodies are not responsive to geophysical methods. Downhole lithogeochemical methods clearly show a lithium halo around the pegmatite, while surficial soil geochemistry using the Enzyme Leach method shows weak apical anomalies for Li and Ta as well as haloes for Rb and Cs. Studies conducted using the Mobile Metal Ion (MMI) method for surficial soils over buried LCT pegmatites show clear Li, Cs and Rb surficial responses at the Thompson Brothers property in the Snow Lake area of Manitoba, Canada (SGS 2017) and they led to the discovery nearby of the high-grade D8 spodumene-bearing pegmatite on the Zoro property of Foremost Lithium Resource and Technology (Grammatikopoulos et al. 2020). More recent work using MMI on vegetation at a property near Leaf Rapids in northern Manitoba indicates good Li, Cs and Ta responses over a buried LCT



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pegmatite (M. Fedikow, pers comm 2021).

One benefit of refractory spodumene, as referred to by Černý (1991), is that it may serve as an important indicator mineral for the very rare LCT pegmatites in the same way as G10 garnets are for diamond-bearing kimberlites. The hardness of the mineral and its resistance to chemical breakdown would ensure its survival in glacial till and stream sediment dispersion trains. With a specific gravity (SG) of 3.15, it would be recovered in the mid-density mineral fraction as SG >3.2 is the standard threshold between light and heavy fractions in indicator mineral processing of sediment samples. As mentioned previously, a sodium peroxide fusion-based method would be the preferred analysis for these sediment samples. If portable instrumentation were available, portable LIBS would be the recommended instrument for lithium analysis.

FTIR analysis of Pegmatites

FTIR spectroscopy is an established method for determining qualitative mineral identification based on an infrared spectrum of absorption or emission (Griffiths and de Hasseth 2007). It is similar to X-ray diffraction (XRD) in that it identifies and quantifies a wide range of minerals, but based on molecular vibrations and rotations from specific bonds. The Bruker Alpha II unit collects high-spectral-resolution data over a wide range from $500 - 4000 \text{ cm}^{-1}$ with a resolution of 4 cm⁻¹ in attenuated total reflection (ATR) mode based on a diamond system ideal for minerals which have a high hardness

index. FTIR provides a low-cost rapid solution with a two- minute analysis time for pegmatite mineral analysis without the need for complex sample preparation. It uses standard analytical pulps for analysis. Calibration and validation details are discussed in Woods (2019). The calibration graphs for Li and spodumene are displayed in Figure 4 and the range of minerals determined is shown in Table 1. The Li and Ta analysis may be considered a chemometric measurement where these elemental data are derived from predictive modelling generated from FTIR data using machine learning techniques indicating not only lithium content but its distribution in spodumene and in micaceous phases.



Figure 4. Calibrations developed for Li and spodumene analysis by FTIR by SGS Perth (Woods 2019).

	Range							
Mineral	From	То	Mineral	From	То	Mineral	From	То
Apatite	1.0	70.0	Quartz	1.0	100.0	Total TiO2	1.5	3.5
Calcite	1.0	100.0	Siderite	1.0	30.0			
Chlorite	1.0	100.0	Smectite	1.0	100.0			
Dolomite	1.0	100.0	Spodumene	1.0	100.0			
Goethite	1.0	20.0	Biotite	1.0	60.0			
Illite	1.0	100.0	Muscovite	1.0	40.0			
K Feldspar	1.0	50.0	Tantalum	1.0	45.0			
Kaolinite	1.0	100.0	Total Alumina	20.0	60.0			
Petalite	1.0	40.0	Total FeOxide	3.0	30.0			
Plagioclase	1.0	100.0	Total Silica	1.0	35.0			
		FTIR with	ATR on Pulp scan with q	uantifcatio	n on gener	ic BULK mineral setup.		
		all IR activ	ve minerals normalized to	o 100%				



Portable systems

As noted, lithium does not emit a measurable X-ray that can be detected by portable X-ray systems although Brand & Brand (2017) and Brand *et al.* (2020) have developed an algorithm to estimate lithium content in LCT pegmatites using pXRF data from other elements in a pegmatite sample.

Laser-induced breakdown spectroscopy (LIBS) uses an intense laser to generate emissions and can measure lithium in solid samples. Both LIBS and portable LIBS (pLIBS) have been used for assaying pegmatite-derived exploration, grade control and production samples. The assays are carried out on pressed pellets of the analytical grade using reference materials and samples analysed by other techniques for calibration. Lithium and other major elements such as Na, Mg, Al, Si, K, Ca, Ti, V, Cr, Mn and Fe can be determined simultaneously. Accuracy and precision are limited by sample preparation, but initial data show they are comparable to pressed pellet pXRF. As an added feature, the spatially resolved Li signal from the pellet can be used to evaluate homogeneity of the preparation. Portable LIBS instruments, with their lower power, analyse a smaller area than benchtop units and are more suited to early stage exploration due to their inferior precision and accuracy. LIBS applications look promising and will benefit from more comparison with AAS- and ICP-based assays.

Our group has also carried out several studies to test the ability of core scanning systems to detect lithium and lithium minerals. For elemental scanning, LIBS-equipped scanning systems are under investigation to characterise lithium distribution as lithium is not detected by XRF based sensors. Hyperspectral scanning using VNIR-SWIR cameras cannot

easily detect lithium-bearing minerals in pegmatite. The goal is that scanning systems equipped with LWIR or FTIR cameras will be able to detect these minerals such as spodumene, petalite and lepidolite.

Conclusions

As the effort to replace fossil fuels gathers pace lithium is rapidly becoming a leading industrial resource because of its physical properties that make it suitable for battery storage and one that would not be easily replaced by other metals. The concern is whether there are sufficient lithium resources available to meet the demand for the metal. In this, proper lithium analysis in the exploration and resource definition of lithium sources is critical, particularly for the analysis of spodumene-bearing hard rock resources where sodium peroxide fusion is currently the only viable digestion method for complete recovery of lithium. Developing portable system technologies such as FTIR and LIBS will be central to field-based analytical schemes for lithium.

Acknowledgements

We are grateful to numerous colleagues in the SGS Geochemistry, Geological Services and Metallurgy/Mineralogy groups who have shared with us and discussed many of the issues surrounding the analysis and extraction of lithium and its minerals in numerous projects over the last decade. We would like to thank Gwendy Hall and Bob Garrett for their review of the manuscript and also Beth McClenaghan, Editor of EXPLORE, for her encouragement and support in completing this article.

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Recently Published in Elements

October 2021, volume 17, no. 5, Carbonatites

The articles in this issue explore the recent models for the formation and evolution of carbonatites in the crust or mantle, the tectonic and temporal controls on their formation, why they are so enriched in rare earth elements, and their minerals that are economically significant. There are three AAG news items in this issue. The first is a citation for Qiuming Cheng, who was the 2020 AAG Gold Medal awardee. The second is an abstract of an article that appeared in issue 190 (February 2021) of the **EXPLORE** newsletter, namely "Sinclair: Australia's First Caesium Deposit: Discovery and Exploration Implications" by Nigel W. Brand, David J. Crook, Stuart T. Kerr, Sophie O. Sciarrone, Naomi J. Potter, Christabel J. Brand and Geoffrey E. Batt. The third is an abstract of an article that appeared in issue 191 (June 2021) of the EXPLORE newsletter, namely "Integration of Geochemical and Mineralogical Data: An Example from the Central Victorian Goldfields, Australia" by Dennis Arne.

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



John Carranza



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OBITUARY

John Somerville Tooms (1927-2021)

The death, on 2nd December 2021, of one of the early pioneers of applied geochemistry in mineral exploration and in understanding the nature of undersea mineral resources, marks the end of an era.

John was born in 1927 at Darfield, near Christchurch, in the South Island of New Zealand, the second of the four children of Irish-born John Douglas Tooms and his wife, Florence May Telfer. His father came from an engineering background and since 1919 had served as an officer on cargo ships which travelled between England, Australia and New Zealand. His parents emigrated to the South Island of New Zealand, where his father became an apiarist and farmer, selling the honey he produced to the New Zealand Shipping Company, which operated between New Zealand and the UK. John was born the next year and twins (Margaret Lucy and Patrick Telfer) followed in 1932. By 1935, New Zealand was beginning to emerge from the effects of the Great Depression, but his honey sales no longer brought in enough income and in 1936 the family returned to England where, by 1939, his father was works manager of a motor engineering company in Surrey. He eventually returned to sea, but in 1954 he was lost overboard from the ship on which he was serving.



With the outbreak of war, John served in the Parachute Regiment and Infantry, during which time he was sent to Italy to guard Italian prisoners-of-war. Discharged in 1945, he subsequently attended the University of Wales, Cardiff, where he was awarded his BSc in Geology and Chemistry in 1951 and BSc (First Class Honours) in Geology in 1952, and also married Mary Elizabeth Vaughan Sweeting (1929-2019); they subsequently had two children, Elisabeth and Paul, but separated in 1972 and divorced in 1978.

Imperial College

Following his graduation, John wished to undertake a higher degree, and was invited by Professor David Williams, Head of the Mining Geology Department of the Royal School of Mines at the Imperial College of Science and Technology (ICST), London, to begin research in his Department. Supervised by (Professor) John Stuart Webb (1920-2007), a Lecturer in the Mining Geology Department, who at that time was establishing the science of applied geochemistry in the UK, John's dissertation was on *Geochemical dispersion related to copper mineralization in Northern Rhodesia*. Two years later, the Geochemical Prospecting Research Centre (GPRC) was established within Mining Geology, with Webb as its Research Director. John's doctorate was awarded in 1955 and he was then appointed a Department of Scientific and Industrial Research Senior Research Fellow (1955-58), an ICST Research Fellow (1958-65) and Reader in Applied Geochemistry (1965-72), acting as Webb's principal assistant throughout.

The transition, from geochemistry applied to mineral exploration, to regional geochemistry began in 1960 with a project to map the varying concentrations of copper, lead, zinc, cobalt, nickel, chromium, titanium, vanadium, manganese and other elements in stream sediments over the 7,770 km² Livingstone-Namwala Concession area of Northern Rhodesia (now Zambia). Marine geochemical exploration followed the next year, with an initial study (supervised by Webb) of the geochemical dispersion of copper and zinc from a pyritic ore body in the coastal environment of Vana Levu island, Fiji.

With the broadened scope of the GPRC's activities it was renamed the Applied Geochemistry Research Group in 1963. John and another member of staff were charged by Webb with dividing up the new areas of research between them. John graciously gave his colleague, Ian Nichol (1933-2018) first choice: he selected regional geochemistry and its implications for environmental problems, consequently John ended up heading marine geochemistry more or less by default. Nevertheless, he threw himself into the new endeavour with his characteristic energy, initiating projects on placers, phosphorites, manganese nodules and hydrothermal deposits which lasted into the early 1970s. As a result, his supervision of students' dissertation topics changed in 1963 from mineral exploration to marine projects. The first of these was a study of the dispersion of tin in the bedrock, stream sediments, beach sands and unconsolidated marine sediments of Mounts Bay, Cornwall. It was followed the next year by David Cronan's doctoral study of the geochemistry of pelagic manganese nodules from the Indian and Pacific Oceans.

'Although John's sojourn in the field of marine minerals was brief in terms of his career as a whole, it was marked by a realism that was in sharp contrast to the mindless optimism that characterised much of the field at that time, and provided a foundation for continuing marine minerals work which lasted until the Group's demise in 1988, when it continued within the ICST Geology Department' (D. Cronan, pers. comm.). John left the AGRG in 1972 for personal reasons and Cronan took over the marine work from him.

During his time in the GPRC and AGRG, John supervised twenty-eight doctoral and six masters dissertations.

John Somerville Tooms... continued from page 14

The majority of these were concerned with mineral exploration, but twelve with marine geochemistry. He was also involved as a consultant or contractor to the United Nations, governments and mining companies in North and South America, Europe, Australasia, Oceania, Africa and Asia.

The United Nations

From 1970 to 1980, John acted as a Technical Adviser to the UN Headquarters, advising on, and developing, projects with national staff of the developing countries. On leaving the ICST in 1972, he joined the United Nations Development Programme (UNDP) as a Project Manager, initially to 'strengthen' the Ethiopian Geological Survey (1973-75). When he finished this project in 1975, he was posted to Nepal, but as he had never been able to take any leave in Ethiopia (because one of his UN appointed geologists had been captured by the Eritrean Liberation Front and he was involved in negotiating for his release), it was decided that he should take a long holiday. With Efrosini and their children, Alexis and Therese, they drove to his next posting in Nepal, travelling to Kathmandu via a challenging forty-two day journey from England, through Europe, Pakistan, Afghanistan and India. He then became responsible for mineral exploration in Nepal, a task made more difficult because 'for much of the period he also acted as his own Economic Geologist and Applied Geochemist' as a result of the UNDP financial crisis in 1975-78. From 1978 to 1986, he was Operations Manager and Technical Manager of the UN Revolving Fund for Natural Resources Exploration, at the UN Headquarters in New York, responsible for all aspects of its work, and living in Chappaqua in New York State.

On his retirement to Cyprus in 1986, he grew olive and fruit trees, built many drystone walls, became a member of an archaeological group and a wild-flower photographer, as well as remaining a consultant to the Revolving Fund and to the Cyprus Geological Survey.

In 2001 he and Efrosini travelled to Australia to visit their son. Intending to live there, they moved to Toowomba, near Brisbane but in 2005 decided to return to Cyprus, buying an old house in the village of Prastio, which they then restored. However, in 2010 John's health deteriorated and they consequently returned to England in 2012, to live in York, where he died on 2nd December 2021. He is survived by his wife, their children, and by his children from his previous marriage.

When John was being considered for the job in Nepal, the Assistant Administrator and Regional Representative for UNDP in Ethiopia, Richard B. Stedman (1920-2013; who eventually retired as Assistant Secretary-General of the UN), wrote to his counterpart in Nepal 'Tooms is hard working, technically sound and well motivated. He has done good work here. He is also a man of principle – he tells them the truth, whether they want to hear it or not. I have wished once or twice that he was a little more adept at "rolling with the punch", but I don't know many New Zealanders who are! I think he's a good, slightly tough supervisor. His staff is loyal to him. In short, if you want a good, technically sound, hard working character, and are prepared to accept slightly rough edges - which have shown themselves to be polishable in Ethiopia - you couldn't do better than John Tooms.'

The writer thanks Mrs. E. Tooms and Prof. D. Cronan for their assistance.

Richard J. Howarth

Want to make prospectivity maps across Canada, the United States, and Australia?

Check out this new Geological Survey of Canada Open File comprising datasets from the Geological Survey of Canada, United States Geological Survey, and Geoscience Australia. The work was completed as part of the Critical Minerals Mapping Initiative (<u>www.criticalminerals.org</u>). Geological and geophysical datasets are spatially indexed using Uber's H3 discrete global grid system (<u>https://eng.uber.com/h3/</u>)

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Thomas Bissig



Thomas graduated in 1997 from the Swiss Federal Institute of Technology (ETH) with a diploma in Earth Sciences. He carried out his PhD research at Queen's University, Kingston, on the metallogeny of the El Indio belt, Chile/Argentina. He graduated in 2001 after which he took a position as post-doctoral fellow at MDRU at the University of British Columbia, Canada where he worked on Central Peru and in the Guerrero Terrane of Mexico. Thomas was a Professor at the Universidad Católica del Norte in Antofagasta Chile from 2004 to the end of 2007, after which he returned to MDRU as a Research Associate. In March 2017, he joined Goldcorp Inc., now Newmont Goldcorp as Director Geochemistry. He left Newmont in 2020 and in October 2021 joined Copperbank Resources Corp as VP Exploration.

Thomas has been involved in research topics ranging from regional metallogeny and magma fertility to landscape evolution and exploration geochemistry. He is author on more than 30 peer reviewed publications and numerous published reports and conference abstracts. His main interest in being part of the AAG council is to support mentoring of young professionals and keep the communication between industry and academia open.

Jamil Sader

Dr. Jamil Sader obtained his B.Sc. from the University of Saskatchewan, his M.Sc. from the University of Texas at Dallas, and his Ph.D. from the University of Ottawa. He has over 20 years of experience in academic, technical, and senior management roles with government and small to large cap exploration/mining companies including MMG Resources, Anglo American, and Bureau Veritas Minerals. His extensive experience, from field geologist to senior management, has provided him a deep technical understanding across many facets of base, precious, and critical metals, and an extensive global network of geoscience professionals. Dr. Sader became an Association of Applied Geochemists Fellow in November, 2021, and is currently President of MineScience Advisors.



Alexander Seyfarth



Alexander Seyfarth is an x-ray spectroscopist with over 20 years of experience with XRF and XRD. Alexander holds a Diploma in Mineralogy from University Giessen (1996). Thesis work for his graduate studies was done on chemical and phase investigation of kiln deposits using XRF, EPMA, and XRD as well as Rietveld structure refinement on isolated phases. Starting out as Application Scientist in Germany with Siemens, he was transferred to the US where he is now a proud citizen, still living in the Midwest (Wisconsin). As the resident "Geo Scientist" he got to travel within the Americas to mine sites, cement plants and quarries and present application and theory-based talks at trade shows, conferences for Bruker and Thermo Fisher Scientific in various functions. With a group of other XRF trainers he continued the XRF course from University of Western Ontario and moved it to Hamilton College; expanding it back to its roots in South Africa. Associated Volunteer Researcher with Colorado School of Mines as of 2021 for Direct XRF core scanning.

Since 2017, he is back fulltime to the geochemistry world as Global Technical Manager for XRF with SGS Natural Resource Division and active in both SGS internal technical formation as well as externally with focus on the new and smaller devices such as PXRF and Micro LIBS.

Professional interest lies within research, promoting and expanding XRF (and LIBS on solids) within the community as well as modern Gamma activation analysis for Gold assaying. Datafusion of chemical and mineralogical assays as well as advancing the Chemometric based methods are part of the current research with vendors. Focus for AAG work would be within the training and education of future geochemists as well as promoting and establishing best practices for new types of instrumentation leveraging the extensive contacts to the various instrument vendors. Having spent over 25 years at trade shows and conferences, he can sell and qualify leads as well.

AAG Councillors... continued from page 16

Cliff Stanley

Professor Cliff Stanley, P.Geo. is the Professor of Applied Geochemistry in the Department of Earth & Environmental Science, Acadia University, Nova Scotia, Canada. Cliff received his B.Sc. in Earth Science from Dartmouth College (1980), worked for three years for Anaconda Minerals Company as a geochemist, and then returned to academia to complete his masters and doctorate at University of British Columbia (UBC) (1984, 1988) under the supervision of Dr. Alastair Sinclair. Prior to Acadia University, Cliff worked for two years as a research associate at Queen's University with Dr. Ian Nichol in lithogeochemistry, and for seven years as Adjunct Professor in the MDRU at UBC, leading research in alkalic porphyry Cu-Au deposits, lithogeochemistry, and Broken Hill-type mineral deposits. Cliff has been a member of the Association since 1981, and has previously served as councilor for the Association for 12 years. In addition, Cliff has been a distinguished lecturer for the AAG (2004) in lithogeochemistry, and for the CIM (2008) and AusIMM (2009) in geochemical quality control. Cliff has published extensively in sampling and quality control, partial digestion pedogeochemistry, lithogeochemistry, and geochemical data analysis. In 2017, Cliff was awarded the Chayes Prize for contributions to research in numerical petrology by the IAMG.



Renguang Zuo,



Professor Renguang Zuo obtained his Ph.D. in Mineral Resources Prospecting in 2009 from the China University of Geosciences. He became a Fellow of AAG in 2016. Since 2021, he has been the Professor and Founding Director of the Research Center for Solid Earth Big Data, China University of Geosciences (Wuhan), China. Since 2012 he has also been Professor at the State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences (Wuhan), China. In 2014, he was a Senior visiting fellow at James Cook University, Australia. From 2010 to 2012, Dr. Zuo was an Associate professor, State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences (Wuhan), China. Prior to this he was an instructor here from 2009 to 2010. Professor Renguang Zuo has held several positions within AAG Council including Councilor of the Association in (2017-2018, 2019-2020), Associate editor for Geochemistry: Exploration, Environment, Analysis (2017-2018) and Editorial board for Geochemistry: Exploration, Environment, Analysis(2019-present). The focus of Professor Renguang Zuo's research is on developing novel methods for

processing geochemical survey data and identifying geochemical anomalies associated

with mineralization. He has published more than 120 SCI-indexed papers in various international peer-review journals. He is an associate editor for Journal of Geochemical Exploration, Natural Resources Research, Ore Geology Reviews, and Computers & Geosciences. He is also a Councilor for the International Association for Mathematical Geosciences and a Fellow of the Society of Economic Geologists.

Dennis Arne (ex offico)

Dennis Arne has 40 years experience in geology and applied geochemistry globally. He has overseen regional geochemical exploration programs in the Yukon, British Columbia, Nunavut and northern Quebec in Canada, the USA, eastern Australia, Suriname, Sudan and Laos. He was Managing Director and Principal Consultant - Geochemistry of CSA Global Canada until late 2017, General Manager and Principal Consultant – Geochemistry for Revelation Geoscience (purchased by CSA Global in 2012), Principal Consulting Geochemist with ioGlobal (now Reflex Geochemistry) and formerly Senior Geochemist with Geoscience Victoria (now Geological Survey of Victoria, Australia). Dennis is currently director and principal consulting geochemist at Telemark Geosciences and was until recently Director of Exploration for E79 Resources. He is a Fellow and past President of the Association of Applied Geochemists, is a



Member and a Registered Professional Geoscientist (Geochemistry) of the Australian Institute of Geoscientists, and a registered Professional Geoscientist in British Columbia, Canada.

Welcome New AAG Members

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Mr. Benjamin Nicolson Consultant Geologist New Finds Mineral Exploration 3 Margaret Street Ashfield, WA AUSTRALIA 6054 Membership no. 4469



Geochemical Exploration, a two-week short course at Colorado School of Mines

Mary Doherty and Zhaoshan Chang, Colorado School of Mines, Golden Colorado, USA

A geochemical exploration block course is offered at Colorado School of Mines (CSM) annually as part of a non-thesis Professional Master in Mineral Exploration Degree Program. The 2021 Exploration Geochemistry course was completed in October, 2021 (12 straight days and five hours per day), covering aspects of exploration geochemistry and mineral chemistry and including two full days spent in the field and half a day in the laser ablation-ICP-MS laboratory run by Dr. Chang at CSM. The course was made stronger by excellent contributions from active geochemists. We are indebted to contributions from Garth Graham and Karen Kelley (U.S. Geological Survey), Beth McClenaghan (Geological Survey of Canada), Kiel Arndt and Brian Cellura (Newmont), and Erick Weiland and Madhumitha Raghav (Freeport McMoRan). Students learned the basics of geochemical applications, the latest in technology applications, and practiced in the field on



Montezuma Mining district drainage effluent at the mixing of two drainages, destination for field trip day 2.

Arndt (Newmont), and complemented by a discussion and demonstration of hyperspectral survey data for exploration by Brian Cellura (Newmont). Soil Survey discussions used an excellent soil orientation survey at the Pebble Deposit, Alaska, completed by Eppinger et al. (2013). Students learned critical aspects of planning and interpreting orientation surveys while interpreting these soil data.



Looking North at Red Mountain and the Urad/Henderson Molybdenum mine, destination for field trip Day 1.

sampling programs from exploration to environmental geochemistry, plus the use of field portable instruments.

Fundamental principles of exploration geochemistry were introduced, including basic chemistry, use of pathfinders in exploration, laboratory considerations in sample preparation and analysis, quality control procedures, and coarse gold and sample representivity considerations. Relative error and precision calculations using the coefficient of variation were presented and applied and %CV⁹⁵ (Lawie and Stanley, 2007), accuracy was estimated, and the value of exploration and ore definition quality control were emphasized. The geochemical software application ioGAS was introduced and used by the students for exercises in the interpretation of quality control data, stream sediment, soil, lithogeochemical and mineral chemistry datasets.

Hydrogeochemistry was presented by guest speaker Garth Graham, and he

and Karen Kelley (U.S. Geological Survey) demonstrated clean sampling procedures in the field. The Stream Sediment Geochemistry module was presented by guest speaker Kiel



Students learning about stream sediment and water sampling.

Geochemical Exploration, a two-week short course... continued from page 19



Kiel Arndt presenting Stream Sediment Geochemistry.

Lithogeochemistry was introduced by Zhaoshan Chang, followed by a half day reviewing indicator mineral contributions to exploration: prospectivity, proximity, and vectoring mineral chemistry. The students spent some time in the CSM mineral chemistry laboratory (LA-ICP-MS/MS) with a state-of-theart setup of Resolution-SE 193nm ArF laser ablation system coupled with an Agilent 8900 triple quadrupole ICP-MS. Students interpreted a set of mineral chemistry data. The application of indicator mineral surveys in regions of Canada

covered by post-glacial sediments were broadly summarized by Beth McClenaghan (Geological Survey of Canada) who provided a complete view of the state of indicator mineral research and application from lab to reconnaissance field work.

The field component for exploration geochemistry is of course the most fun, where out in the field students once again benefited from the generous contributions of a number of guests in our two days in Colorado sunshine (and snow). Day 1 field programs focused on the Cripple Creek catchment basin, which extends from the Urad/ Henderson Mines 40 miles downstream into



Beth McClenaghan presenting Indicator Mineral Geochemistry via Zoom.



Mary Doherty introducing soil and biogeochemistry sample collection procedures have impacted the stream chemistry and to students.

Golden (and the home of the Coors Brewery). Along the way, the drainage captures not only the Mo-W occurrences, but the historic Au mining districts of Central City-Black Hawk, and uranium occurrences. Those make for interesting discussions and observations of the geochemistry, environmental geochemistry and spectral responses from these well exposed occurrences. Students were introduced to sampling procedures for stream sediment and water, and hyperspectral measurements were observed within the catchment basins. On Day 2, field activities moved into the Montezuma historic mining district (base metal-Ag veins). The historic Pennsylvania Mine and district

provide a great example of the pH change and

associated redox deposition, useful for discussion of both stream sediment and soil/regolith chemistry controlled by pH, Fe-, Al-, and/or Mn oxides.

Thank you to Garth Graham and Karen Kelley (USGS), Kiel Arndt and Brian Cellura (Newmont) for their comments and field demonstrations. We must admit to thoroughly enjoying introducing the Master's students to these two classic mineral districts and their geochemistry, both of which were the subject of publications by Paul Theobald. Back to the classroom, environmental considerations were presented by guest speakers Erick Weiland and Madhumitha Raghav (Freeport), who provided interesting perspectives of the link between exploration geochemistry and environmental engineering at major global sites. The course is rounded out with an introduction to data analysis, statistical methods, and multivariate statistical applications. No course can end without discussing mineral deposit discoveries aided by significant geochemical programs and the future technology opportunities for exploration geochemistry.

Geochemical Exploration, a two-week short course... continued from page 20



Exploration Geochemistry for mineral exploration is one of the 8 block-mode courses provided for the Professional Master Degree program at Colorado School of Mines (CSM) and available in person to domestic and international professional geologists. This one-year non-thesis Master's degree includes courses in economic geology, exploration geochemistry, exploration geophysics, hydrothermal Geochemistry, new developments in economic geology, SWIR (Short Wavelength Infra-Red) techniques, LA-ICP-MS technology, skarns and related deposits, exploration project and business management, structural analysis, data analytics, and an intensive ore deposits field program. A strength of the program at CSM is the link to associated departments including the Geophysics Department, Mining Engineering Department, and the Business and Economics Department. We welcome

students from many countries, and the program is amenable to students who may be working full time and wish to take one or two 2-week course(s) per semester. For more information, please email mineralexploration@mines.edu.





Zhaoshan Chang demonstrating his new ASD FieldSpec 4 High Resolution NG for short wavelength infra-red (SWIR) spectral analysis.

Master's students collecting stream sediments, heavy minerals, and water samples in groups.





Garth Graham and Karen Kelley demonstrating ultra-clean water sampling procedures.

New AAG Regional Councillor for Northern Africa







Born on Sunday November 9, 1947 in Nigeria, Silas Sunday Dada commenced his education at the SIM Central Primary School in 1954 and proceeded to the SIM Titcombe College, Egbe in 1963 where he obtained his West African School Certificate (Grade 1) in 1967 and the Higher School Certificate (HSC) in 1969. He taught at the Playfair Memorial College, Oro-Ago in 1970 before proceeding to the University of Ibadan where he graduated in 1973 with a Second Class (Upper Division) in Geology.

Silas Sunday Dada is Professor of Applied Geology and pioneer Pro-Chancellor and Chairman of the Governing Council of Anchor University, Ayobo, Lagos, former President of the Nigerian Mining & Geosciences Society (NMGS, 2017 - 2019), former Provost of the College of Pure and Applied Sciences (January 2015-February 2017) at Kwara State University, Malete near Ilorin; pioneer Dean of College of Natural and Applied Sciences and former Deputy Vice Chancellor of Salem University, Lokoja (2009-2012). He was appointed to these positions with over 40 years of professional contributions including outstanding field and laboratory practice in mineral exploration, teaching, research, consultancy services and a strong background of high-level exposure and training in applied sciences, curriculum development and administration.

While in the services of the Nigerian Mining Corporation, Jos, he obtained an M.Sc. in Applied Geology (Mineral Exploration option) in 1979 from the then University of Ife, Ile-Ife (Nigeria). He proceeded to France in 1984 where he obtained Diplome d'etude Approfondie (DEA) in Petrology-Geochemistry-Structural Geology and a PhD in Isotope Geochemistry and Geochronology from University of Science and Technology, Montpellier (France). Prior to 1984, he was involved in petroleum and later mineral exploration (clays, uranium, gold, lead/zinc, tin, tantalite etc.) covering practically all states of Nigeria. From his post-doctoral research at the University of Paris (1990-1991) to his return to Nigeria, Professor Dada successfully developed and taught several geology courses at all levels.

He has initiated research projects and established collaborative research teams across several institutions, developed several researchers and students in NAGAMS (later NMGS) and NAPE as member of the NAPE-UAP Committee. His research output includes over 65 publications in learned journals and books besides several technical



Bruno Lemière, Ph.D Mining and Environmental Geochemist

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28 av. Général Leclerc - 82300 Caussade - France - +33 6 95902134 Operating also from New York, Montreal, Brussels or London reports, conference papers, and seminar presentations - including award winning research presentations on the Precambrian evolution of the Nigerian continental crust. Professor Dada has travelled widely, visiting TOTAL operations and top universities offering high-level research in the geosciences in France with a focus on recent developments, roles and possible collaborations with African universities.

He is currently in collaboration with the University of Science and Technology (USTL) Montpellier (France), looking into the commencement of Plate Tectonic Model through the use of primitive early (Archaean) rocks, including those from Nigeria by the application of the U-Pb and Lu-Hf radiogenic isotopes. He is Fellow of several geoscience associations and societies, including the Association of Applied Geochemists.

New AAG President and Vice-President for 2022

AAG President - John Carranza

John is the AAG's new President for 2022-2023. He started his career as an exploration geologist/geochemist (1983–2001) in the Bureau of Mines & Geosciences of the Philippines. He delineated mineralised land through systematic drainage geochemical surveys during his tenure there. After obtaining his PhD in 2002 on mineral potential mapping (from TUDelft, The Netherlands), he was a Researcher at the Department of Earth Systems Analysis, International Institute for Geo-Information Science and Earth Observation (ITC), The Netherlands, from 2001 to 2003. Then, he was Assistant Professor (GIS Predictive Modelling in Geological/Mineral Exploration) at the University of Twente, The Netherlands, from 2003 to 2012. He was Associate Professor (Computational Modelling Applied to Exploration & Mining Geology) at the Economic Geology Research Unit, James Cook University, Queensland, Australia, from January 2013 to January 2016. He was Visiting Professor at the State University of Campinas, Brazil, from August 2015 to August 2017. He was Professor of Geological Sciences at the University of KwaZulu-Natal, South Africa, from September 2017 to December 2021. He is currently Professor of Economic Geology at the University of the Free State, South Africa.



His fields of expertise are (a) geochemistry for mineral exploration, ore genesis and geo-environmental studies, (b) spatial mathematics/statistics for predictive modeling of mineral resources and geological hazards, and (c) remote sensing for geological/mineral exploration. He has published a book "Geochemical Anomaly and Mineral Prospectivity Mapping in GIS". He is Editor-in-Chief of Natural Resources Research journal, Senior Associate Editor of Geochemistry: Exploration, Environment, Analysis, and Associate Editor of Ore Geology Reviews and Journal of Geochemical Exploration.

AAG Vice President - Yulia Uvarova



Yulia is the AAG's new Vice President for 2022-2023. She obtained her B.Sc. in Geology from Moscow State University in 2001 and her Ph.D. in Geology from the University of Manitoba in 2008. From 2000-2002, she worked at the Vernadsky Institute of Geochemistry and Analytical Chemistry, Moscow, Russia as a Research Assistant. From 2003-2008 she was a teaching assistant at the University of Manitoba. From 2008-2012, Yulia worked at Queens' University, in the Queen's Facility for Isotope Research, where her research focused on geochemistry, mineralogy, petrology and genesis of economic mineral deposits, uranium in particular; development of new exploration tools for search of U deposits; behaviour of HFSE in high-temperature systems; geochemistry of non-traditional isotopic systems and application of these systems to elucidate processes responsible for deposit formation. Yulia holds a Research Scientist position in CSIRO Mineral Resources, Perth and works in a team of researchers developing new workflows and techniques for mapping the distal footprints of metalliferous mineral systems through drilling and sampling and developing the science of understanding large geochemical footprints of mineral systems and their detection on the surface.



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 on February 11th 2022, but further changes are likely, and 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: Steve Amor, Email: <u>steve.amor2007@gmail.com</u> or

Tom Meuzelaar, AAG Webmaster, tom@lifecyclegeo.com

2022

Virtual Meetings

 28-31 MARCH
 15th Biennial Meeting of the Society for Geology Applied to Mineral Deposits. Website: tinyurl.com/ ykkf5wx8
 24-29 JULY
 15th International Conference on Mercury as a Global Pollutant. Website: tinyurl.com/2ch7e6fa
 27-29 APRIL
 International Conference on Geographical Information Systems Theory, Applications and Management. Website: www.gistam.org

In-Person or Hybrid Meetings (status as of February 11th, 2022)

International Mining Geology Conference 2022. Brisbane QLD Australia. Website: tinyurl.com/sk4uc 22-23 MARCH Biogeochemical Processes Across Space and Time (Gordon Research Conference). Castelldefels 30 APRIL-1 MAY Spain. Website: tinyurl.com/bnknc845 CIM Convention. Vancouver BC Canada. Website: convention.cim.org 1-4 MAY Gordon Research Seminar - Ocean Biogeochemistry. Castelldefels Spain. Website: tinyurl.com/ 1-6 MAY d5cha6at 2-5 MAY Geological Society of Nevada 2022 Symposium. Sparks NV USA. Website: www.gsnsymposium.org Discoveries in the Tasmanides, - Mines and Wines. Orange NSW. Website: www.minesandwines. 11-13 MAY com.au GAC/MAC Annual Meeting. Halifax NS Canada. Website: tinyurl.com/2ex2vx4v 15-18 MAY Geochemistry of Mineral Deposits (Gordon Research Conference). Castelldefels Spain. Website: 22-27 MAY tinyurl.com/yxtyprqc 10th World Conference on Sampling and Blending. Kristiansand Norway. Website: wcsb10.com 31 MAY-2 JUNE

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ALS method code ME-MS89L[™]

Exploration for trace level lithium and rare earth elements

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 commodites.

Method	Analyte	Detection Level (ppm)
	Li	2
	В*	8
sodium peroxide fusion	Cs	0.1
	Dy	0.03
	Но	0.01
	Nb	0.8
	Та	0.04

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

Contraction of the second seco	ALENDAR OF OVENTS continued from page 24
10-12 JUNE	3rd International Conference on Geology and Earth Sciences. Bangkok Thailand. Website: icges.org
20-22 JUNE	Geoconvention 2022. Calgary AB Canada. Website: geoconvention.com
26-29 JUNE	International Congress on 3D Materials Science. Washington DC USA. Website: exhpo.com/int/3dms
27-29 JUNE	Australasian Environmental Isotope Conference. Ballina NSW Australia. Website: www.conferences. com.au/2022aeic
3-6 JULY	XII South American Symposium on Isotope Geology. Santiago Chile. Website: ssagi.science
7 JULY	Target 2022: Innovating now for our future. Perth WA Australia. Website: www.aig.org.au/events/ target-2022
10-15 JULY	Goldschmidt 2022. Honolulu HI USA. Website: tinyurl.com/3p95at6w
11-14 JULY	9th Annual International Conference on Geology & Earth Science. Athens Greece. Website: www. atiner.gr/geology
13-16 JULY	Euroscience Open Forum 2022. Leiden Netherlands. Website: www.esof.eu
14-16 JULY	7th International Conference on Water Pollution and Treatment. Frankfurt Germany. Website: www. icwpt.net
16-18 JULY	5th International Workshop on Environment and Geoscience. Qingdao China. Website: www. iwegconf.org
18-22 JULY	23rd General Meeting of the International Mineralogical Association. Lyon France. Website: <u>www.</u> ima2022.fr
18-22 JULY	International Geographic Union Centennial Congress. Paris France. Website: tinyurl.com/bdhdshtx
30-31 JULY	Organic Geochemistry (Gordon Research Seminar). Holderness NH USA. Website: tinyurl.com/ sywdr9ma
30 JULY – 2 AUGUST	12th International Conference on Environmental Catalysis. Osaka Japan. Website: tinyurl. com/2p8b467m
31 JULY - 4 AUGUST	Microscopy and Microanalysis 2022. Portland OR USA. Website: www.microscopy.org/MandM/2022
31 JULY - 5 AUGUST	World Congress of Soil Science 2022. Glasgow UK. Website: www.soils.org.uk/wcss2022
31 JULY - 5 AUGUST	Gordon Research Conference - Organic Geochemistry. Holderness NH USA. Website: tinyurl. com/2wxmt6m7
3-5 AUGUST	12th International Conference on Environmental Pollution and Remediation. Prague Czech Republic. Website: icepr.org
6-12 AUGUST	Geoanalysis 2022. Freiberg Germany. Website: tinyurl.com/bdfhr49w
14-18 AUGUST	6th IAGOD Quadrennial Symposium. Dublin Ireland. Website: <u>www.iagod.org/node/116</u>
13-14 AUGUST	Biomineralization (Gordon Research Conference). Castelldefels Spain. Website: tinyurl. com/5865ckbt
14-19 AUGUST	Biomineralization (Gordon Research Conference). Castelldefels Spain. Website: tinyurl. com/5865ckbt
22-26 AUGUST	International Sedimentological Congress. Beijing China. Website: <u>www.isc2022.org.cn/En</u>
23-26 AUGUST	International Symposium on Environmental Geochemistry. Moscow Russia. Website: iseg2022.org
27-30 AUGUST	SEG 2022 Conference. Denver CO USA. Website: tinyurl.com/3m7dnmtv
29 AUGUST - 3 SEPTEMBER	21st Annual Conference of International Association for Mathematical Geosciences. Nancy France. Website: www.iamgconferences.org/iamg2022



The AAG-SGS Student Presentation Prize

The Association of Applied Geochemists, through the support of SGS Mineral Services, awards a prize for the

Best oral presentation by a student at the biannual International Applied Geochemistry Symposium (IAGS)

The intent of this prize is to encourage the presentation of high quality research by students at an International Applied Geochemistry Symposium (IAGS) and provide further incentive to publish the results of the research in the Association's journal, *Geochemistry: Exploration, Environment, Analysis* (GEEA). The winner is determined based on feedback from a group of judges that includes Fellows and Members of the Association. Criteria for judging the presentations include excellence and originality in research design, research execution, interpretation, and the oral presentation itself. Honours, Masters, and Doctoral students are all eligible. The format of the presentation may vary between IAGS.

The Rules

- 1. The paper must be presented by the student at an IAGS as an oral paper, in the format specified by the IAGS organizing committee.
- The conference presentation and paper must be largely based on research performed as a student. The student's supervisor or Head of Department may be asked to verify this condition.
- 3. The decision of the AAG Symposium Co-ordinator (in consultation with a representative from SGS) is final and no correspondence will be entered into.
- 4. Entry in the competition is automatic for students (but students may elect to "opt out").
- 5. The detailed criteria and process for assessing the best paper will be determined by the AAG Symposium Co-ordinator in consultation with the AAG Council and the LOC.
- 6. A paper substantially derived from the material presented at the IAGS and submitted for publication in the Association's journal *Geochemistry: Exploration, Environment, Analysis* within the timeframe specified by the AAG (normally 12 months) will be eligible for the increased value of the prize.

The Prize

- 1. \$700 CAD from SGS Minerals Services (normally presented to the winner at the end of the relevant IAGS) with a further \$300 CAD from AAG if a paper related to the oral presentation is submitted to GEEA within the nominated time frame after the IAGS;
- 2. A 2-year membership of the Association, including subscription to GEEA and EXPLORE; and
- 3. A certificate of recognition.

David Cohen

Chair of Student Prize Committee University of New South Wales Email: <u>d.cohen@unsw.edu.au</u>



11-15 SEPTEMBER	IWA World Water Congress & Exhibition. Copenhagen Denmark. Website: worldwatercongress.org
5-9 SEPTEMBER	8th World Multidisciplinary Earth Science Symposium. Prague Czech Republic. Website: www.mess-earth.org
7-11 SEPTEMBER	XXII Congress of Carpathian Balkan Geological Association. Plovdiv Bulgaria. cbga2022.geology. bas.bg
12-15 SEPTEMBER	Earth Mantle Workshop. Toulouse France. Website: emaw2021.sciencesconf.org
12-16 SEPTEMBER	10th International Conference of the International Association of Geomorphologists. Coimbra Portugal. Website: www.icg2022.eu
13-15 SEPTEMBER	14th International Symposium on Nuclear and Environmental Radiochemical Analysis. York UK. Website: tinyurl.com/4mw4n924
21-23 SEPTEMBER	Mongolia Mining 2022. Ulaanbaatar Mongolia. Website: mongolia-mining.com
9-12 OCTOBER	GSA 2022 Annual Meeting. Denver CO USA. Website: tinyurl.com/fuyh2t3z
23-28 OCTOBER	29th International Applied Geochemistry Symposium (IAGS). Viña del Mar Chile. Website: iags2021. cl
17-19 OCTOBER	16th International Congress of the Geological Society of Greece. Patras Greece. Website: gsg2022. gr
4-9 DECEMBER	American Exploration & Mining Association (AEMA) Annual Meeting. Sparks NV USA. Website: tinyurl.com/ycktxmut

2023

29 JANUARY-3 FEBRUARY	Winter Conference on Plasma Spectrochemistry. Ljubljana Slovenia. Website: ewcps2021.si
18-23 JUNE	Catchment Science: Interactions of Hydrology, Biology and Geochemistry (Gordon Research Conference). Andover NH USA. Website: tinyurl.com/2p968pxe
16-21 JULY	Chemical Oceanography (Gordon Research Conference). Manchester NH USA. Website: tinyurl. com/mu7ybfz6
25-27 JULY	6th International Archean Symposium. Perth WA Australia. Website: 6ias.org
28 JULY	Target 2023: Innovating now for our future. Perth WA Australia. Website: www.aig.org.au/events/ target-2022/





Association of Applied Geochemists Student Membership \$10 US

Encourage a student to join!



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