

## Cesium Deposits

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### Introduction

Cesium or caesium? Cesium is the accepted spelling of element 55 by the American Ceramic Society (ACS). Caesium is the International Union of Pure and Applied Chemistry's (IUPAC) preferred spelling. Both are used interchangeably. Its chemical symbol is Cs. Cesium was discovered by Bunsen and Kirchhoff in 1860 through emission spectroscopy and in etymology finds its name in the Latin "Caesius" for the sky-blue lines in its emission spectrum.

It is a little known element, the bulk of which is used in oil and gas well servicing in the form of cesium formate. It is also used as catalysts in plastics, petroleum refining to remove sulphur, experimental Magneto Hydro Dynamic (MHD) power generation, in cesium clocks for telecommunications and GPS navigation, specialty glasses, opto-electronics, ion-propulsion motors, high-density alkaline batteries, and solar cells where it extends the electromagnetic spectrum. As a dense medium, cesium formate is also used in metallurgical test work, to separate DNA and, because of its density, it has a potential use in coal cleaning (Tuck 2020; Pickup *et al.* 2020). Cesium has one stable isotope, Cs<sup>133</sup> whereas <sup>137</sup>/<sub>55</sub> Cs or radiocesium is an artificially produced isotope used in cancer treatment. It has a potential application in the sequestration nuclear waste (Cerný 1978; Yoshinobu *et al.* 2014). It has no known natural bioavailability and is used in the food preparation industry.

Cesium has chemical and physical properties similar to the other Group I elements and has a melting point of 28.4°C. It is explosively pyrophoric when added to water. Of the alkali metals, cesium has the lowest crustal abundance at 0.3 ppm. In contrast, rubidium has a crustal abundance of 9 ppm and lithium has a crustal abundance of 2 ppm (Chemical Rubber Company Handbook 2016-2017). Twenty-two minerals are known to host cesium (Webmineral.com 2019), and the present authors propose to add another mineral, Cs-pharmacosiderite.

Primarily, cesium has been recovered from the minerals pollucite and lepidolite hosted in "giant" pegmatites such as Tanco in central Canada, Bikita in Zimbabwe, and the Yichun granite in China (Fig. 1). These sources are now problematic; production at Tanco ceased due to safety issues related to the fall of loose rock and Bikita by exhaustion of stockpiles. The small Sinclair deposit in Australia was mined out in 2019, and several small cesium deposits have been identified in Africa, the U.S. and Canada but none have reached systematic production.

A second type of cesium deposit is formed through greisenizing. The Yichun rare metal granite in China is an example of Li – Cs greisenizing formed by hydrothermal alteration of precursor composite intrusives.

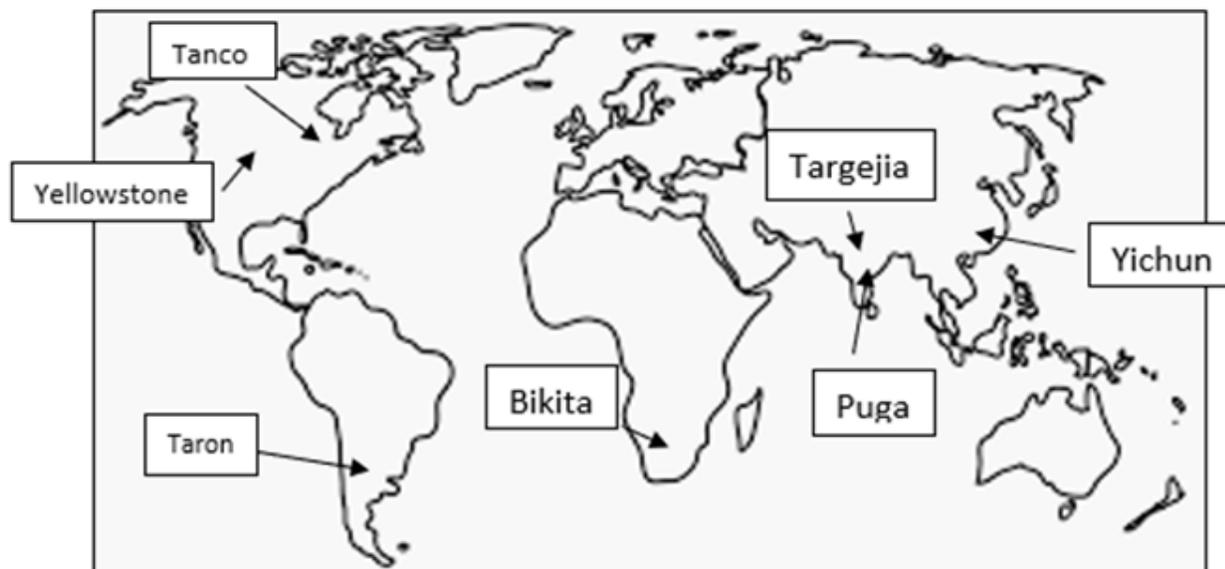


Figure 1. World map showing the location of described or mentioned cesium-bearing deposits.



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# EXPLORE

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Quarterly newsletters are published in  
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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.
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<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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## Notes from the Editor

Welcome to the third **EXPLORE** issue of 2020. This issue features two articles about cesium deposits. The first describes cesium deposits in general and was written by David Trueman, Bruce Downing, and Tom Richards. The second article describes the Taron Cs-Tl deposit in Argentina and was written by David Trueman, Bruce Downing, Taylor Ledoux and Tom Richards.

**EXPLORE** thanks all those who contributed to the writing and/or editing of this issue, listed in alphabetical order: Steve Amor, Dennis Arne, Al Arsenault, John Carranza, Steve Cook, Hugh de Souza, Bruce Downing, Robert Garrett, Taylor Ledoux, David Leng, Tom Meuzelaar, Robert Linnen, Jessey Rice, Tom Richards, and David Trueman.

**Beth McClenaghan**  
Editor



## President's Message

The State of Victoria in Australia is under renewed restrictions to combat a second wave of Covid-19 as I sit down to write this report. The city of Melbourne is mid-way through a stage 4 lockdown and regional Victoria is under stage 3 restrictions. All Victorians must wear a mask when outside their homes. This second wave has been more deadly than the initial wave to hit Australia, with hundreds dead (mainly the elderly), tens of thousands thrown out of work as businesses have been forced to close their doors for a second time, and billions of dollars wiped from the national economy. Yet Australia has fared better than most countries.

It is clear that Covid-19 will be with us for a while yet, notwithstanding optimism that successful vaccines are on the way. Those of us in the earth sciences have had to dramatically change the way we work. International travel is but a dim memory and state borders are largely closed in Australia. Amongst the economic uncertainty though, there are opportunities for those of us working within the mineral resource industry. Economic uncertainty has led to a dramatic increase in the price of gold, and other commodities such as iron ore and copper are seeing a resurgence in their price. Restrictions on travel mean that those located close to project areas are being called upon to undertake work programs and become the eyes and ears of those stranded in other jurisdictions. The collaboration required can necessitate on-line meetings at odd hours of the day, so previous office routines have been thrown out the window. As many of us are working from home now, the distinction between work and personal life has become blurred, although that 6 am on-line meeting can be offset by taking the dogs for a mid-morning walk. It's a win-win for everyone (especially the dogs!).

Which brings me to the AGM in a roundabout way. AAG will have our virtual AGM at the beginning of September. The AAG has adopted Zoom as its on-line meeting platform and I hope that many of our members will have taken the opportunity to attend the AGM. Our first council meeting on Zoom was well attended and I believe that many of us are becoming comfortable with such platforms. Circumstances have led to the widespread adoption of a technology that has the potential to enhance the way we interact as an organisation on an international level. There is also an unofficial contest underway to come up with the most outlandish virtual background for your camera!

I announced some changes to the AAG website in my previous report, and further changes have recently been completed. We have a new "Presentations" link (<https://www.appliedgeochemists.org/presentations>) on the public home page that will take you to presentations by previous distinguished lecturers, as well as more recent presentations given by AAG members. I would encourage anyone with presentations of a geochemical nature that they would like to share to click on the "Other Presentations" link (<https://www.appliedgeochemists.org/presentations/other-presentations>) and pitch their material. The goal is for the AAG website to become the go to site for geochemical content to highlight our expertise and as a way of attracting new members.

Make no mistake about it, there is an interest in applied geochemistry out there. Australia has had an abundance of geochemical fare online in the past few months, aided and abetted by the Australian Institute of Geoscientists (AIG). There was a discussion form on careers in geochemistry hosted by the Queensland chapter of the AIG on June 19. On June 24, Mark Arundell gave a webinar on applied geochemistry organised by the South Australian branch of the AIG entitled "The Value in the Shallow". This presentation was followed in late June and early July by three seven-hour online modules on exploration geochemistry organised by the Economic Geology Research Unit (EGRU) at James Cook University in Townsville. These modules were attended by 20 virtual participants, just under half of whom were from outside of Australia. The course involved a series of PowerPoint presentations interspersed with practical problems using ioGAS™ software. It was fully subscribed and is being re-offered in late September (<https://www.jcu.edu.au/economic-geology-research-centre/2020-professional-development-courses>). Starting on July 21, the IMDEX crew (Dave Lawie and Fred Blaine) teamed up with Nick Oliver and Nick Cook to present four three-hour sessions over four consecutive days called ioGAS™ PluggedIn. That is a lot of geochemistry, and the advantage of webinars is that people can attend from anywhere

in the world, provided they don't mind the start times.

Looking into next year, the AAG is committed to providing face to face short courses in geochemistry at our 29<sup>th</sup> IAGS in Viña del Mar, Chile in October 2021, as well as the Society for Geology Applied to Mineral Deposits (SGA) meeting in Rotorua, New Zealand in November (<https://e-sga.org/meetings/sga-biennial-meetings/>). These two events were originally planned to be a year apart but are now separated by just a month (and the Pacific Ocean, thankfully!) thanks to Covid-19. Let's hope they go ahead. It's just not the same sharing a glass of beer or wine online.

### Bruno Lemièrre, Ph.D Geochemist

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**Dennis Arne**  
President



## Cesium Deposits... *continued from page 1*

A third type of cesium deposit is found in the form of epithermal geysers (hot spring environment) and several have been identified including the Targejia deposit in Tibet and the Taron deposit in Argentina, and although of lower cesium grades and widely varying mineral assemblages may be equal or larger in their contained cesium than the large pegmatite sources. In Yellowstone National Park in the northwest USA, Li-Cs greisen is ongoing and Li – Cs assemblages are forming at very low temperatures and pressures in various sedimentary rocks and rhyolites. The authors consider Targejia and Yellowstone as active analogues to the Taron deposit (see description of this deposit in second article in this issue). Cesium brines are reported to occur in Tibet and China by Hu *et al.* (1988), in India in the Puga Valley by Chowdry *et al.* (1974) and at Amarillo (Mina Antuco) in Argentina by Richards (pers. comm. 2020).

The source of Cs-bearing pegmatites is probably from fractionation of S-type granites (Cerný *et al.* 2012). The source of Cs-bearing geysers is probably similar to that at Yellowstone in which large volumes of rhyolite over the Yellowstone mantle plume are being leached by circulating epithermal fluids.

Cesium is now on the U.S., Canadian and several other government's list of critical elements and there is a global burgeoning of exploration for Cs-bearing pegmatites. At present, Albemarle Corp. and Sinomine Specialty Fluids (formerly Cabot Specialty Fluids) in China control the cesium refining industry and supply chain. At present there is no mine production of cesium. This literature review was undertaken to characterize the importance of geology, geochemistry, mineralogy, and geometallurgy of these types of cesium deposits and offer some insights as to the origins of such novel deposits.

### The Tanco Pegmatite, Canada

"Nothing on earth is more refined than a pollucite-bearing pegmatite" (London 2019).

The Archean Tanco pegmatite was discovered by prospector Jack Nutt when exploring for tin at Bernic Lake in Manitoba, central Canada (Fig. 1), in the late 1920s. The tin was apparently identified from blowpipe testing of mineralization in a separate and smaller pegmatite dyke from the larger Tanco pegmatite. The geology of the deposit is shown in Figure 2.

The Tanco pegmatite was emplaced in an essentially horizontal position (Brisbin 1986) and shows fractional crystallization (Brown *et al.* 2017) culminating in upwardly disposed zones of lithium phosphates, spodumene, lepidolite, pollucite, and quartz. A north – south cross section fence diagram is shown in Figure 2, after Stillings *et al.* (2006) and the mineralogy of the zoning is shown in Table 1 after Cerný (2005). The constituent mineralogy of the Tanco pegmatite is

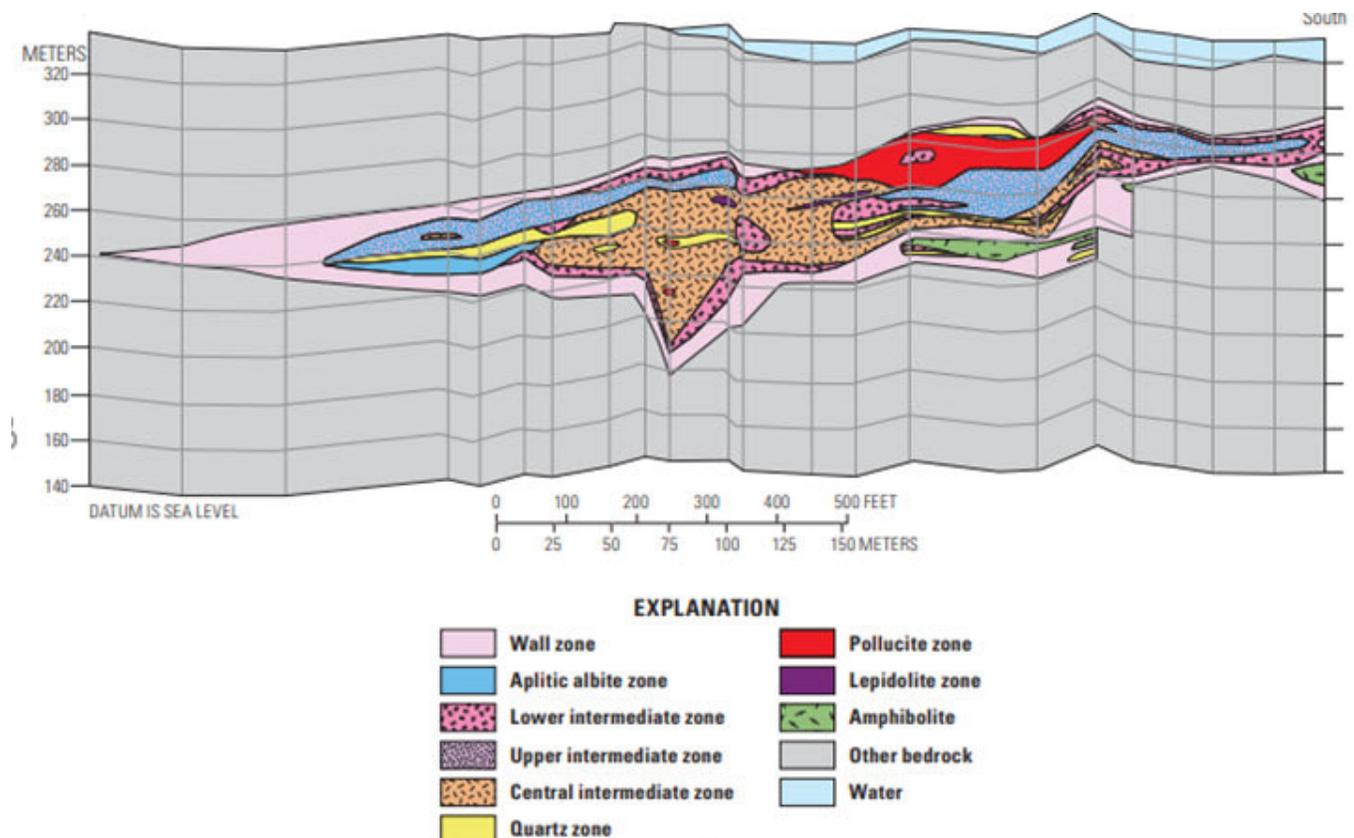


Figure 2. North – south cross section through the Tanco pegmatite showing internal zoning, from Stillings *et al.* (2006). Note vertical exaggeration.

## Cesium Deposits... *continued from page 5*

provided in Table 1 which shows the nine major mineralogical zones that fractionally crystallized in the temporal sequence of (1) to (9). Cesium is found as constituents of two zones, (5) and (8). In zone (8) it is the dominant mineral. The pollucite zone was discovered while driving a decline for access to the tantalum orebody.

A description of the pollucite zone by Cerný and Simpson (1978) is as follows: "Pollucite forms pods and nodules from 1 to 2 m in diameter and several large lenticular bodies.....the largest of these, 180 x 75 x 12 m in size, is located in the eastern flank of the pegmatite, and three smaller bodies are found in the western part.....masses of pollucite show simple smooth boundaries against quartz, and are anhedral with respect to all other primary constituents of zone (5) where pollucite may locally cement fractured or brecciated silicate assemblages but it is never observed as a replacement".

The Tanco deposit underwent several stages of low temperature hydrothermal alteration. Three consecutive alteration stages may be distinguished: (i) coarse polygonal veining by microcline, albite, quartz and lepidolite; (ii) fine braided veining which carries spodumene, lithian muscovite and adularia, and (iii) replacement by kaolinite and montmorillonite (+/- quartz, calcite) but it is considered a closed system and the alteration phases derived internally. The authors consider this as endo-greising and Cerný's "nauchshub" or "resupply" in the Czech language. The preproduction pollucite resource at Tanco was approximately 46,000 tonnes of contained Cs<sub>2</sub>O at 12.8% Cs<sub>2</sub>O (Tetrattech 2011).

Table 1. Mineralogy and zoning of the Tanco Pegmatite after Cerny (2005)

Zone	Main constituents	Characteristic subordinate (accessory) & rare minerals
Exomorphic unit	Biotite, tourmaline, holmquistite	Arsenopyrite
(1) Border zone	Albite, quartz	Tourmaline, apatite, (biotite), beryl, triphylite
(2) Wall zone	Albite, quartz	Beryl, (tourmaline), muscovite, Li-muscovite, microcline-perthite
(3) Aplitic albite zone	Albite, quartz, (muscovite)	Muscovite, Ta-oxides, beryl, (apatite), tourmaline, cassiterite, ilmenite, zircon, sulphides
(4) Lower intermediate zone	Microcline-perthite, quartz, spodumene, amblygonite	Li-muscovite, lithiophyllite, lepidolite, petalite, Ta-oxides
(5) Upper intermediate zone	Spodumene, quartz, amblygonite	Microcline-perthite, <b>pollucite<sup>(1)</sup></b> , lithiophyllite, (albite, Li-muscovite), petalite, eucryptite, Ta-oxides
(6) Central intermediate zone	Microcline-perthite, quartz, albite, muscovite	Beryl, (Ta-oxides), zircon, ilmenite, spodumene, sulphides, lithiophyllite, apatite, cassiterite
(7) Quartz zone	Quartz	Spodumene, amblygonite
(8) Pollucite zone	<b>Pollucite</b>	Quartz, spodumene, petalite, muscovite, lepidolite, albite, microcline, apatite
(9) Lepidolite zone	Li-muscovite, lepidolite, microcline-perthite	Albite, quartz, beryl, (Ta-oxides, cassiterite), zircon

<sup>(1)</sup> Red script denotes zeolites in this and subsequent tables

*continued on page 8*



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### The Yichun Granite, Jiangxi Province, China

The Mesozoic Yichun granite is located in Jiangxi Province, China (Fig. 1). The granite has been mined for Ta-Nb and Li-Cs and byproduct clay minerals. It is a composite intrusion consisting of 3 units: a protolithionite-muscovite granite, a Li-mica granite, a topaz lepidolite granite and later pegmatites (Yin *et al.* 1995; Huang *et al.* 2002) and was intruded into Neoproterozoic mica schists (Fig. 3).

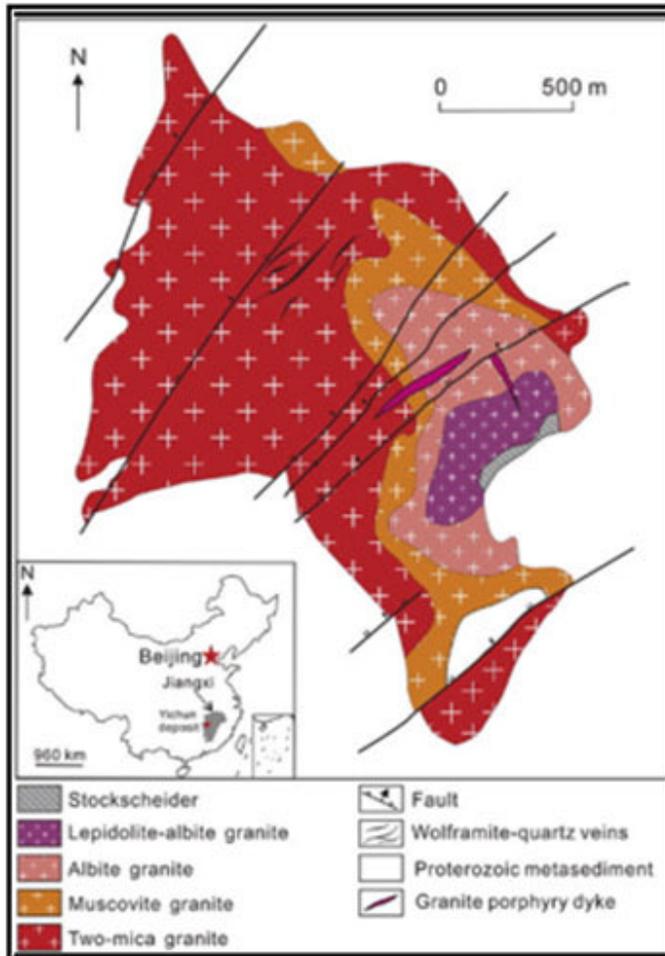


Figure 3. Bedrock geology map of the Yichun deposit, after Li *et al.* (2017).

(White *et al.* 1975). The location of drill holes Y-1,-2,-3,-5 in the Lower and Upper Geyser Basins are shown in Figure 4. These holes were selected for their mineral occurrences listed in Table 2. Of interest is lepidolite and analcime forming in Drill Hole Y-3 at depths of 23.8 to 28.5 m at a temperature of 130° to 140° C, and a presumed pressure of 245 kPa uncorrected for density or site elevation.

The lepidolite is described by Bargar *et al.* (1973) as “linings and partial fillings of cavities....of intergranular cavities of conglomerate and coarse-grained sandstone. Lepidolite occurs as polycrystalline mats displaying pearly lustre; individual platy crystals range from less than 0.01 mm to 0.04 mm across, with a few grains up to 0.1 mm..... Hydrothermal analcime and pyrite occur in the same sections as lepidolite”. Bargar & Beeson (1985) further describe the analcime as forming “0.025-0.5 mm isotropic, euhedral, trapezohedral crystals” in “groundmass and vesicle fillings”.

The rocks hosting the analcime are described by Keith *et al.* (1983) as “Cs is selectively concentrated in analcime” and “the Cs content of analcime-bearing altered sedimentary rocks is as high as 3000 ppm and altered rhyolite lava flows.....now contain up to 250 ppm Cs”. Keith *et al.* (1983) also describes concentrates, presumably handpicked, of Yellowstone analcime as containing as much as 4700 ppm Cs. The present authors consider the lepidolite an exo-greisen mica and as having been derived from the rhyolites.

The Yellowstone area does not have a quantified Cs resource. It could have a significant value given the volumes of the underlying rhyolites being leached. There are no Cs brine resources known.

Of interest is the topaz – lepidolite granite unit which was the latest phase in the intrusive sequence and, as described by Wang *et al.* (2004), has an albite-rich facies containing pollucite and a Cs-dominant analogue of polyolithionite that assays 1709 ppm Cs. Wang *et al.* (2004) also described lepidolite with Cs-rich zones that contain up to 25.8% Cs<sub>2</sub>O and suggested this lepidolite may be a Cs-dominant analogue of polyolithionite. Yin *et al.* (1995) commented that occurrence of a cesian-lepidolite implies the presence of a Cs-rich late magmatic fluid.

Wang commented further that “according to their distribution and compositional characteristics, pollucite and the Cs-dominant analogue of polyolithionite seem to have formed at the late-magmatic or magmatic to hydrothermal transition stage of evolution of the leucocratic magma” and interpret the system at Yichun in its final stages to be open and deriving fluids for the greisen from the surrounding mica schist. The authors of this EXPLORE article consider this an example of exo-greisen. The grade of Cs<sub>2</sub>O in the topaz lepidolite granite at Yichun is 0.18% Cs<sub>2</sub>O in an unspecified tonnage (Wang *et al.* 2004).

### Yellowstone Geysers, Wyoming

The Yellowstone Plateau in northwest Wyoming, USA, consists of Pliocene and Pleistocene rhyolitic pyroclastic rocks and lesser flow rocks. The areal extent of these rocks at Yellowstone is estimated to be some 2900 km<sup>2</sup> (Abedini *et al.* 2007) and with its collapsed caldera is estimated to incorporate some 3700 km<sup>3</sup> (Christiansen 2001). Subjacent and intercalated with these are basaltic rocks and underlying older rocks are Precambrian crystalline basement, Phanerozoic carbonates, sandstones, redbeds, mudstone, coal, and shales including oil bearing traps.

Between 1967 and 1969, the United States Geological Survey undertook the drilling of 13 holes in Yellowstone Park

## Cesium Deposits... continued from page 8

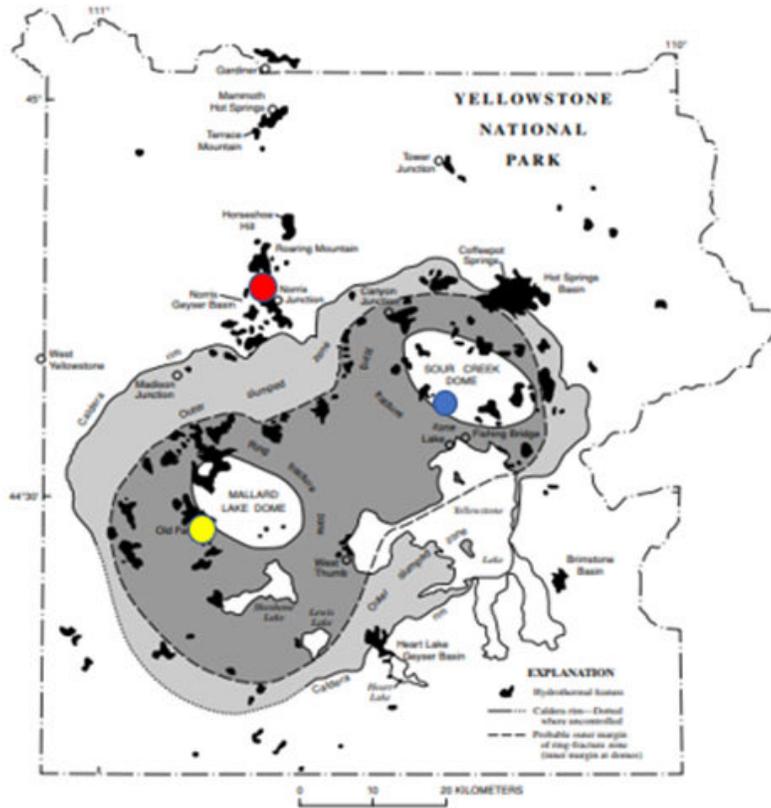


Figure 4. Drill hole locations at Yellowstone Park, Wyoming, holes Y-1-8 and Y-13 located at the yellow dot, holes Y-9 and Y-12 at the red dot, and hole Y-11 at the blue dot (after Christiansen 2001).

### Exploration for cesium

Trueman (1978), in collaboration with Dr. Alexi Beus of the National Academy of Sciences, Moscow, developed litho-geochemical and gravitational methods for the exploration of granitic pegmatites. Subsequently Trueman & Cerný (1982) published more definitive work utilizing mineral chemistry and practical guidelines to map distribution within pegmatite fields and narrow down targets for rare metal exploration. These methods have been improved upon and now utilize soil, botanical, sediment, till and water geochemistry (Bradley *et al.* 2010; Steiner 2019). Galeschuk & Vanstone (2007) show examples of down hole Cs geochemical data for core samples. It should be cautioned that diamond drill greases are waterproof and accordingly may contain considerable lithium, a pathfinder element in exploration geochemistry, and used at the Tanco Mine.

Lithium, rubidium, and cesium usually are detected in geochemical surveys for granitic rocks; especially those that are highly fractionated. Surveys in active geyser or paleo-geyser terrain responded significantly to cesium analysis, and also arsenic, manganese, and thallium. Arsenic and manganese are routinely detected in the percent ranges and thallium up to 0.74%; the highest thallium values known to the authors or colleagues.

In the course of writing this paper, it became apparent that the widely held cesium resource at the Tanco Mine (Cerný *et al.* 1996) of 317,515 tonnes @ 21.98% Cs in production turned out to be 12.82% Cs (Tetrattech 2011). Also, according to reports by Pioneer Resources Ltd. (2020), the Sinclair Mine in Australia produced 10,000 tonnes of run of mine pollucite ore in 2018, and in 2019 were delivered with a shortfall of contained cesium.

### Geometallurgy of Cesium

Three principle methods of processing pollucite are by acid digestion, alkaline decomposition, or direct reduction (Ferguson & Gorrie 2011). At Tanco, the pollucite is digested in hot 35 - 45% sulphuric acid and a cesium alum is precipitated (Butterman *et al.* 2005). The alum is further digested to form cesium sulphate that is in turn reacted with formic acid to produce cesium formate and is the preferred commercial process for producing cesium (Tetrattech 2011).

Table 2. Minerals present in Drill Holes Y-1,-2,-3,-5 at Yellowstone, Wyoming, after Bargar *et al.* (1973) and Bargar *et al.* (1987)

Lepidolite	$K(Li,Al,Rb)_2(Al,Si)_4O_{10}(F,OH)_2$
Quartz	$SiO_2$
Analcime	$(Na,Cs)AlSi_2O_6 \cdot H_2O$
Pyrite	$FeS_2$
Calcite	$CaCO_3$
Fluorite	$CaF_2$
Chalcedony	$SiO_2$
Clinoptilolite	$(Na,K,Ca)_{2-3}Al_3(Al,Si)_2Si_{13}O_{36} \cdot 12H_2O$
Darchiardiite	$K_4(Si_{20}Al_4O_{48}) \cdot 13H_2O$
Pectolite	$NaCa_2(Si_3O_8)(OH)$
Montmorillonite	$(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2 \cdot nH_2O$
Yugawaralite	$CaAl_2Si_6O_{16} \cdot 4H_2O$
Mordenite	$(Ca,Na_2K_2)Al_2Si_{10}O_{24} \cdot 7H_2O$
Epistilbite	$CaAl_2Si_6O_{16} \cdot 5H_2O$
Albite?	$NaAlSi_3O_8$
Truscottite	$(Ca,Mn)_{14}Si_{24}O_{58}(OH)_8 \cdot 2H_2O$
$\beta$ -cristobalite	$SiO_2$
$\alpha$ cristobalite	$SiO_2$
Opal	$SiO_2 \cdot nH_2O$
Hyalite	$SiO_2 \cdot nH_2O$
Erionite	$SiO_2 \cdot nH_2O$
Kaolin	$Al_2(Si_2O_5)(OH)_4$
Illite	$K_{0.65}Al_2O(AI_{0.65}Si_{3.35}O_{10})(OH)_2$
Celadonite	$K(MgFe^{2+})Fe^{3+}(Si_4O_{10})(OH)_2$
Manganite	$MnO(OH)$
Cryptomelane	$K(Mn^{4+},Mn^{3+})O_{16}$
Pyrolusite	$MnO_2$

continued on page 10

## Cesium Deposits... *continued from page 9*

This process is not dissimilar to the metallurgy developed for the Taron deposit in that it employs a hot sulphuric acid digestion, precipitation, and redigestion to yield cesium hydroxide; a saleable commodity and a starting point for other cesium compounds (Mokmeli *et al.* 2017, 2018). A second stage of testing led to SO<sub>2</sub> sparging with a significant reduction in acid requirements. An alkaline leach process has also been developed at the University of British Columbia, Canada. According to Butterman *et al.* (2005) in an alkaline decomposition process, pollucite is roasted with a CaCO<sub>3</sub>–CaCl<sub>2</sub> mixture or a Na<sub>2</sub>CO<sub>3</sub>–NaCl mixture, then leached with water or dilute ammonia to extract a dilute CsCl solution and converting the chloride to cesium alum.

Direct reduction to produce cesium metal involves heating pollucite with calcium, potassium or sodium metal in a vacuum or an inert atmosphere (Butterman *et al.* 2005). Hu *et al.* (1988) reported a 98% extraction of cesium from the Yichun deposit using Solvent Extraction (SX). Arnold *et al.* (1965) reported a 99% extraction of cesium from pollucite of an unspecified origin with SX, and the Cs brines in Tibet and China are reported as targets for SX by Hu *et al.* (1988).

### Discussion and Conclusions

According to Cerný & Ercit (2005), pegmatitic granites and cesium-bearing pegmatitic granites were probably derived from underlying S-type granites. Rare metal granites such as the Yichun are probably products of continuing fractionation (Huang *et al.* 2002) of earlier granitic phases. According to Keith *et al.* (1983), the cesium source rocks at Yellowstone are the underlying rhyolites which are being leached by epithermal fluids and at Taron, the source rocks were probably Miocene rhyolites (Richards 2005).

In the described deposits, crystallization has proceeded through hydrothermal phases with zeolite mineralization and then deuteric alteration. Pollucite and lepidolite formed at Tanco and Yichun, lepidolite and analcime at Yellowstone, and those ultimately broke down to clays as shown in Figure 5.

The presence of microbes have been well documented at Targejia in active geysers in cesian opal in Tibet (Zhao *et al.* 2008; Wang *et al.* 2012; Zhang 2014). Microbial activity is abundant at Yellowstone at shallow depths and Bargar *et al.* (1985) described what they interpreted as micrometer sized rod-like, threadlike and irregular microorganisms in liquid rich fluid inclusions in quartz from drill holes. However, they had difficulty reconciling a PT regime of 190°C and 1.24 kPa in which the microbes were present.

Cesium is a little known rare metal and there is little cesium research being conducted, other than for the

radioactive Cs isotopes and their sequestration. The authors welcome any new advances in the understanding of the geology and geochemistry of cesium together with research and development in, for example, a cesium battery which could be expected to have a higher power density (amount of power per unit volume) than lithium contemporaries. As with many elements, uses will be found if they are available.

### Acknowledgements

Thank you to Robert Linnen, Beth McClenaghan, and Robert Garrett for critically reading the manuscript and marshalling it into a readable document. The senior author, who spent 7 years with Tanco, would like to thank Cascadero Copper Corp. for its support of field work in 2010 and ongoing research. The second author is an advisor to Cascadero Copper Corp. and was responsible for initiating the metallurgical studies at the University of British Columbia and retaining Dr. Peter Winterburn as an advisor.

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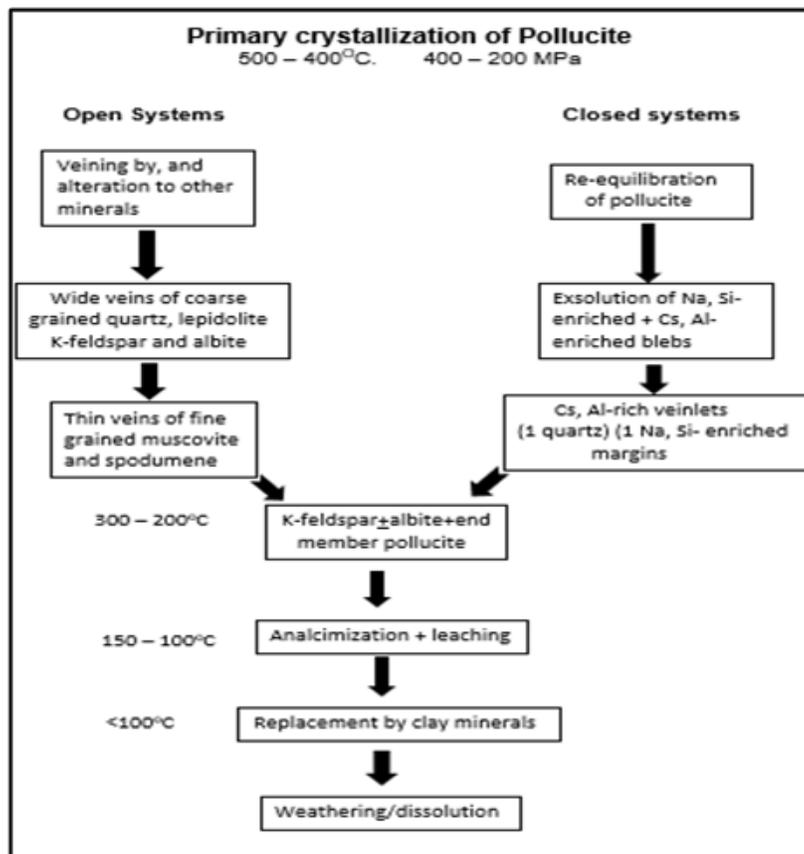
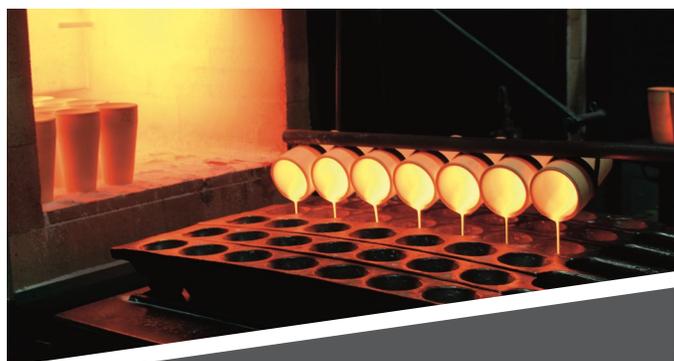


Figure 5. Pressure temperature data from Teertstra & Cerny (1995) and online at <http://www.iza-online.org/natural/Datasheets/Pollucite/Pollucite.html>

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# The Taron Cesium-Thallium Epithermal Geyserite Deposit, Salta Province, Argentina

David Trueman<sup>1</sup>, Bruce Downing<sup>2</sup>, Taylor Ledoux<sup>3</sup> and Tom Richards<sup>4</sup>

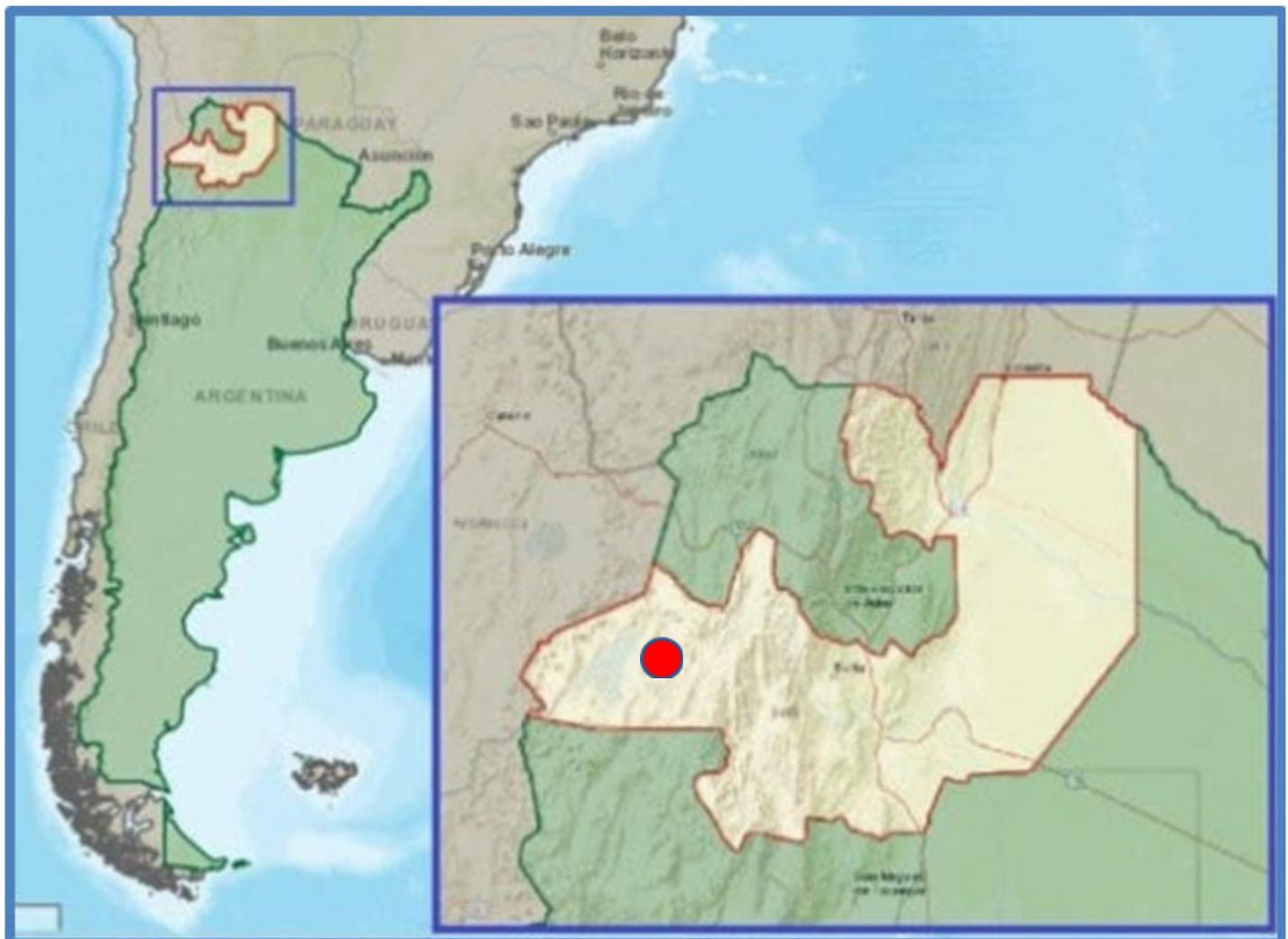
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## Introduction

The Taron cesium-thallium deposit in Salta Province, Argentina (Fig.1 and inset map) (Richards 2005) is a newly recognized type of deposit that is enriched in cesium (Cs) with highly anomalous concentrations of thallium, arsenic, and manganese. The deposit was formed during a Miocene epithermal event which erupted in hot spring geyser activity forming a variety of minerals, colloids, glasses, and clays collectively termed geysersites. Albeit inactive, the Taron deposit is one of 12 other deposits in the Salta Province which display cesium enrichment. The area itself is one of 4 global locales where cesium enrichment has been documented inclusive of Tibet (Zhao *et al.* 2008), India (Chowdry *et al.* 1974) and Yellowstone National Park, Wyoming (Bargar & Beeson 1981; Dahlquist 2017).

The Taron Cs-Tl deposit was a litho-geochemical discovery, found during regional exploration by geologists working for a Vancouver-based exploration company. Prior to this work targeted for precious metals in Salta Province, geologists working for Cascadero Copper Inc. had recognized the association of silver with manganese deposits in the area and routine geochemical sampling of described manganese deposits led to the discovery of Taron in 2004. The discovery was based on ACME Analytical Laboratories and subsequently, Bureau Veritas, 60-element ICP-ES analysis which fortuitously included Cs as an additional element in the exploration package.

Figure 1. Location map of the Taron Cs deposit circled in red (inset map) in Salta Province, Argentina.



**The Taron Cesium-Thallium Epithermal Geyserate Deposit...** *continued from page 13*

The Taron property (Fig. 2) is about 50 km south of the village of Pocitos on the railroad between Antofagasta, Chile and the city of Salta. It is accessible by vehicle over poorly maintained roads or by helicopter.



Figure 2. Panoramic view of the Taron Cs-Tl deposit. White and off-white triangles are 10 metre backhoe trench samples (photo courtesy of T. Richards).

**Geology and Mineralogy**

The Taron deposit occurs within the Ochaqui Basin, an informal name assigned to the graben-like structure composed of Miocene (Simpson 2017) sedimentary and volcanic rocks. Predominant rock types include derived mudstones, arkosic, lithic and volcanic wackes with intercalated conglomeratic facies; one of which contains pebble to boulder sized clasts of orbicular granodiorite derived from the Precambrian basement rock of the Faja Irruptiva (Fig. 3). Other conglomerates contain thinly laminated pebble to cobble sized clasts derived from the Proterozoic Puncovascana Group schists.

*continued on page 15*



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New LDL, ppm	0.0004 / 0.0002	0.006 / 0.003	0.005 / 0.003	0.002 / 0.001

**ORDER OF MAGNITUDE IMPROVEMENT**

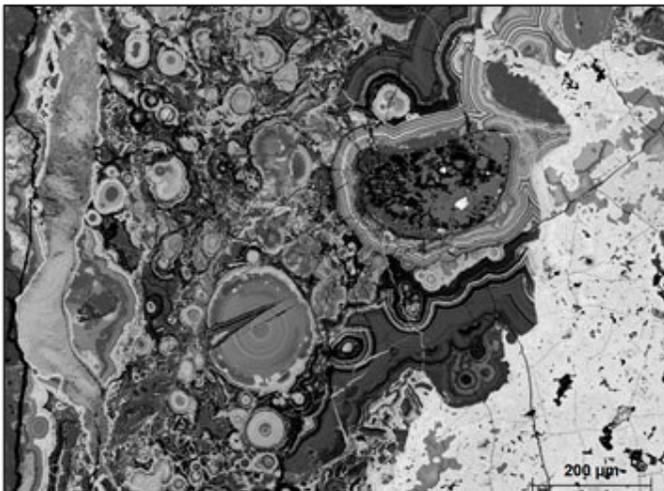
## The Taron Cesium-Thallium Epithermal Geyserate Deposit... *continued from page 14*

All of the above rock types form an unconformable valley fill (Fig. 3) set in a graben structure bound by high angle faults that form its eastern contact. To the west, lying in unconformity, are manganeseiferous clastic rocks that hosted several, now closed, manganese mines. These rocks overlie the Faja orbicular granodiorite and in turn are cut by dykes and veins of cryptomelane and hollandite.



*Figure 3. Cross section showing chaotic nature of valley fill at Taron. The black horizon is manganese stained. Stratigraphic section is approximately 3 metres in thickness. (photo courtesy of T. Richards).*

Petrographic, XRD and SEM studies have been conducted at Taron by Hamilton (2005), LeCouteur (2009), and Ledoux *et al.* (2020). The deposit is dominated by cryptocrystalline silica, manganates, arsenates, and oxides (Fig. 4, Table 1). Collectively, these are known as geysерites.



*Figure 4. Colloidal cements at Taron.*

*Table 1. Minerals present in the Taron deposit. The major rock forming minerals are excluded from the table and the tabulated minerals are assemblages unique to the epithermal and alteration event. It is anticipated that additional and possibly new minerals will be discovered.*

Cesian opal	$\text{SiO}_2 \cdot n\text{H}_2\text{O}$
Chalcedony	$\text{SiO}_2$
Goethite	$\alpha\text{-Fe}^{3+}\text{O}_9(\text{OH})$
Hematite	$\text{Fe}_2\text{O}_3$
Hollandite	$\text{Ba}(\text{Mn}^{4+}_6\text{Mn}^{3+}_2)\text{O}_{16}$
Coronadite	$\text{Pb}(\text{Mn}^{4+}_6\text{Mn}^{3+}_2)\text{O}_{16}$
Cryptomelane	$\text{K}(\text{Mn}^{4+}_7\text{Mn}^{2+})\text{O}_{16}$
Hollandite (supergroup)	$(\text{Ti}, \text{K}, \text{Ba}, \text{Zn}, \text{Cu})(\text{Mn}^{4+}, \text{Mn}^{3+})_8\text{O}_{16}$
Ramsdellite	$\text{MnO}_2$
Rancieite	$\text{Mg}_{0.29}\text{Mn}_{0.58}\text{O}_4 \cdot 1.7\text{H}_2\text{O}$
Todorokite	$(\text{Na}, \text{Ca}, \text{K}, \text{Ba}, \text{Sr})_{1-x}(\text{Mn}, \text{Mg}, \text{Al})_6\text{O}_{12} \cdot 3\text{-}4\text{H}_2\text{O}$
Romanechite	$(\text{Ba}, \text{H}_2\text{O})_2(\text{Mn}^{4+}\text{Mn}^{3+})_5\text{O}^{10}$
Pharmacosiderite	$(\text{Cs}, \text{Rb}, \text{K})\text{Fe}_4(\text{AsO}_4)_3(\text{OH})_4 \cdot 6\text{-}7\text{H}_2\text{O}$
Saialufite	$(\text{Na}, \text{Ca}, \text{Cu})_2\text{Mn}^{3+}_3\text{O}_2(\text{AsO}_4)_2(\text{CO}_3) \cdot 3\text{H}_2\text{O}$
Ludlockite	$\text{PbFe}_4\text{As}_{10}\text{O}_{22}$
Yukonite	$\text{Ca}_3\text{Fe}(\text{AsO}_4)_2(\text{OH})_3 \cdot 5\text{H}_2\text{O}$
Wallkilldellite	$\text{Ca}_4\text{Mn}^{2+}_3(\text{AsO}_4)_2(\text{OH})_4 \cdot 18\text{H}_2\text{O}$
Covellite	$\text{CuS}$

Cesium is predominantly hosted in pharmacosiderite; an arsenate mineral which can contain up to 12% Cs. Analysis with XRD and SEM indicate thallium is hosted within the manganate hollandite which can contain up to 3.4% Tl. Fp-XRF and point sample litho-geochemistry of individual mineral samples extracted from drill core show a positive correlation of Tl with Mn, K, Ba, Cu, and Zn – suggesting these elements are all present in hollandite's extensive solid solution.

# The Taron Cesium-Thallium Epithermal Geyserite Deposit... *continued from page 15*

## Geochemistry

In 2017, Cascadero Copper drilled 36 core holes in the Taron deposit. A geochemical database of 1239 samples was compiled from split two metre diamond drill hole interval assays that were analyzed at Bureau Veritas Labs in Vancouver. Their MA250 analytical procedure was used which combined 4-acid digestion with ICP-ES/ICP-MS analysis.

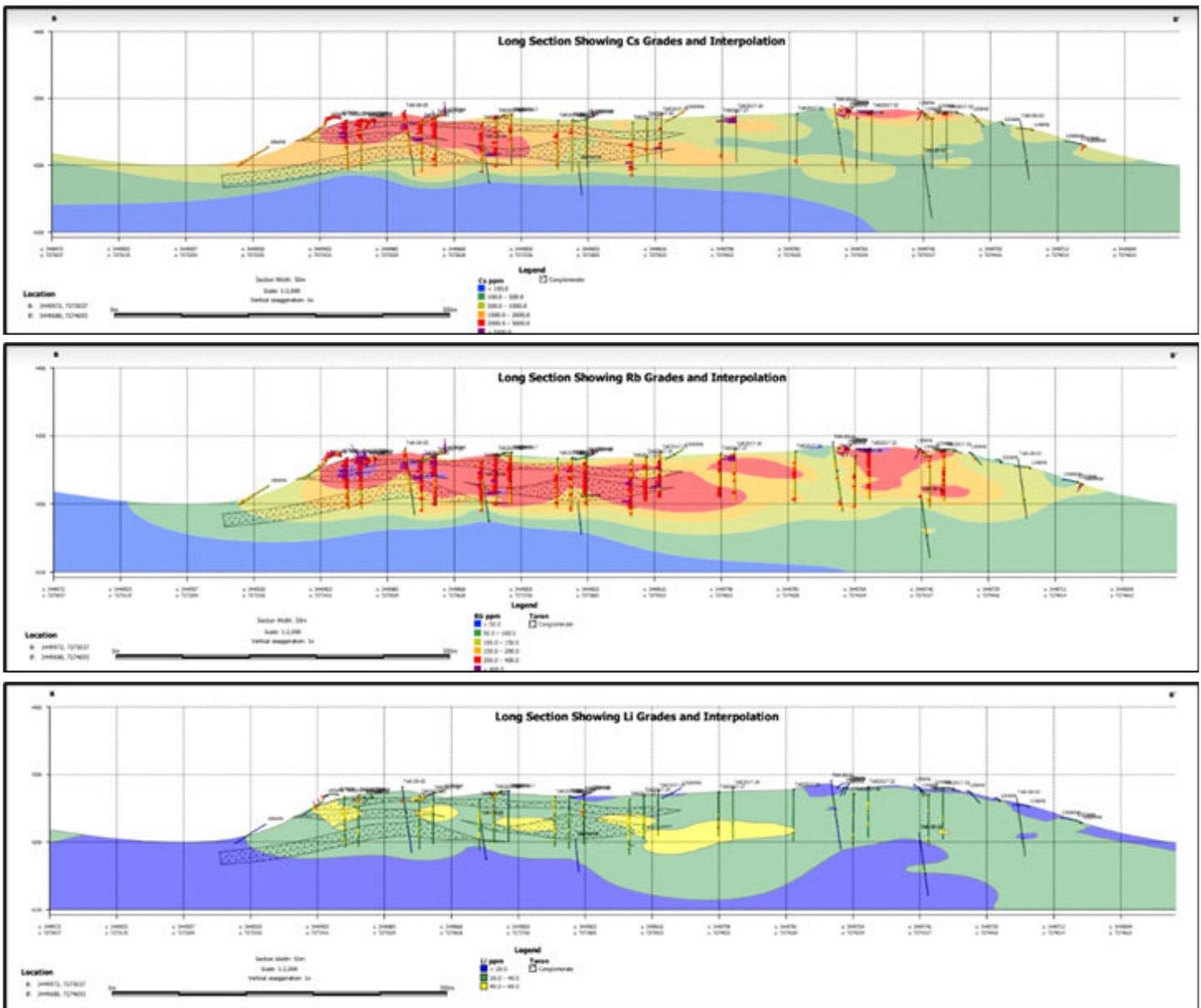
Because no specific standards were available to monitor the Cs analysis, Dr. B. Smee and CDN Resource Laboratories (CDN RL) were retained for the purpose of creating one. Pollucite from the Tanco Mine in Manitoba was utilized. Sample blanks were also provided by CDN RL.

Notable analytical values for bedrock samples from the Taron deposit are presented in Table 2 which shows high values for Cs, Rb, Li, Tl, As and Mn.

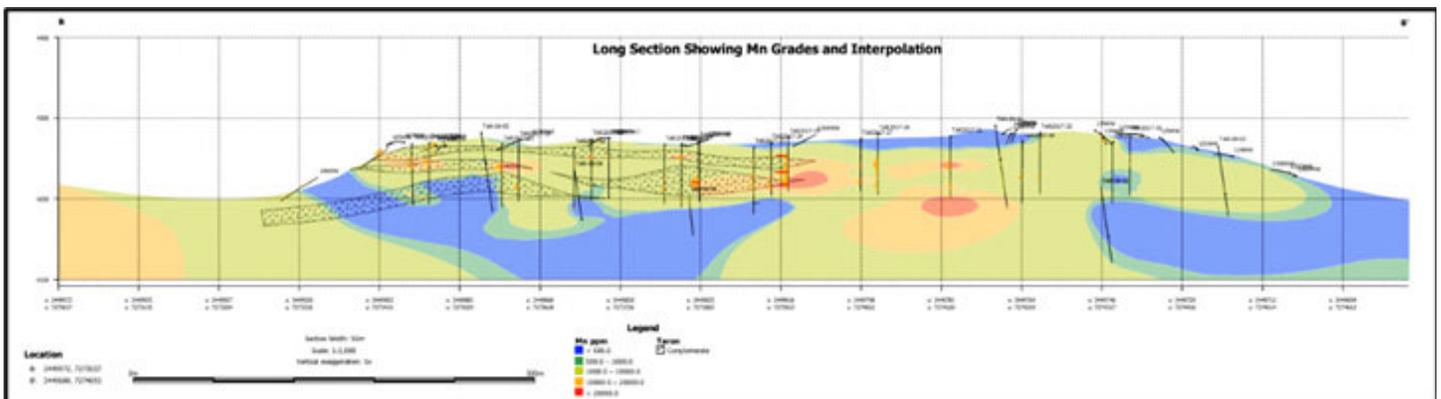
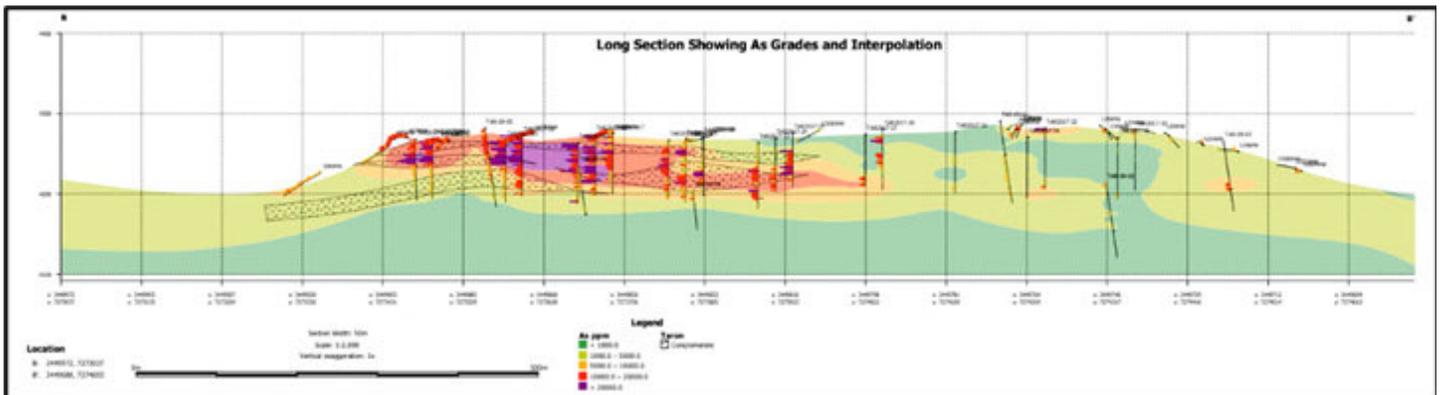
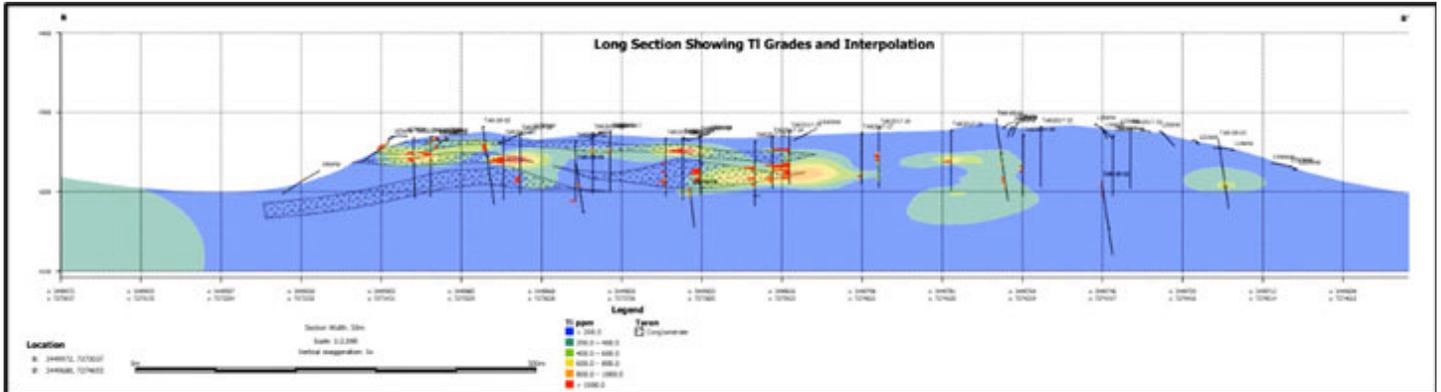
*Table 2. Summary of analytical results for bedrock samples from the Taron deposit.*

ppm	Minimum	Maximum	Mean	Median
Cs	52	15763	1406	1011
Rb	63	1364	221	194
Li	10	182	37	35
Tl	0.01	7440	229	31
As	5	57606	7482	4520
Mn	129	150089	6092	1050

*Figure 5. Stacked sequence showing (top to bottom) concentrations of Cs, Rb, Li, Tl, As, and Mn across the deposit.*



## The Taron Cesium-Thallium Epithermal Geysierite Deposit... *continued from page 16*



Longitudinal sections, cross sections, and maps were plotted for the elements shown in Table 2. The simple geology, in the uppermost section of Figure 5, shows no control on the concentrations of the described elements and the mineralized envelope is essentially formless. It was hoped that the element distribution patterns would reveal the plumbing of the epithermal system around drill hole 2017-1 which was collared in travertine. A next logical choice is that the fault flanking the eastern side of mineralization provided a conduit for geysering and hot spring activity.

### Discussion and Conclusions

Normally, fractionating granitic systems of an S-type granite of a compositional equivalent to the Macusani glass (Barnes *et al.* 1970) would be expected to crystallize minerals accommodating Li, Rb, and Cs (Large Ion Lithophile Elements) in that sequence as magmas pass through the solidus and subsolidus, hydrothermal stages. At Taron, a reversal of process is seen such that extremely high fractionated elements such as TI, Mn, and Cs are present in high concentrations.

To explain this observation, the authors took appropriate and comparable element data from Taron (Table 3) and normalized it to averaged Macusani glass (Barnes *et al.* 1970; Pichivant *et al.* 1987). The resulting spider plot is shown in Figure 6. Of interest is the Li, Rb, and Cs plot which suggests a reversely fractionating system.

## The Taron Cesium-Thallium Epithermal Geysirite Deposit... *continued from page 17*

Figure 6. Spider plot of the Taron bedrock data normalized to the Macusani glass.

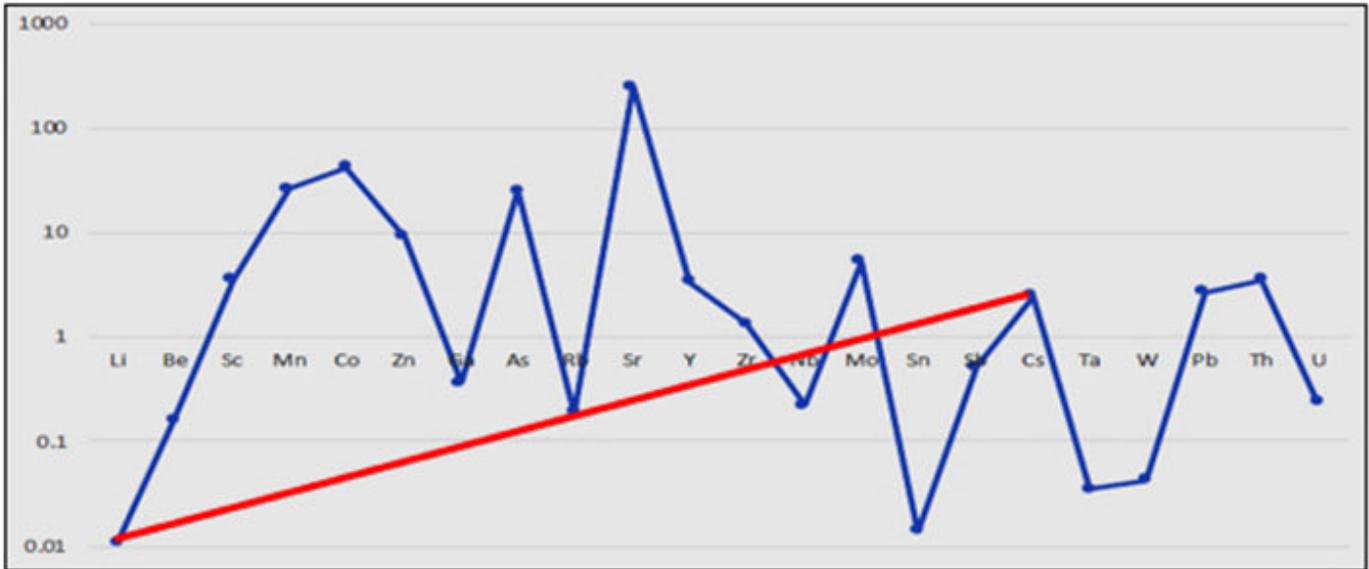


Table 3. Mean values for selected elements at Taron and the Macusani glass. Data for the Macusani glass are the high values from the given ranges of Barnes *et al.* (1973) assuming that the higher values represent a better dissolution method. Oxide data from Barnes *et al.* (1973) were converted back to elemental values.

ppm	Taron	Macusani glass
Li	37	3404
Be	6.6	41.1
Sc	8	2.2
Mn	6092	465
Co	29.9	0.71
Zn	861	97
Ga	15.5	42.4
As	7842	314
Rb	221	1179
Sr	359	1.62
Y	16.8	5.16
Zr	48	39
Nb	9.9	44
Mo	2.6	0.4
Sn	2.5	194
Cs	1406	566
Ta	0.9	26.9
W	3.1	73
Pb	22.6	7
Th	9.8	2.3
U	6.5	23.1

Two processes appear to have been operative at Taron: (1) remelting of an S-type granite or partial anatexis, reversing an expected fraction in the freezing of the same, and epithermal circulation of pregnant fluids to a place of geysering or hot spring circulation where the epithermal minerals formed and (2) selective concentration of Cs in pharmacosiderite.

At Yellowstone National Park, USA, Li- and Rb-bearing lepidolite and Cs-bearing analcime greisens are actively forming in sedimentary and volcanic rocks (Bargar & Beeson 1981, 1985) and considered by Keith *et al.* (1983) to be formed from hydrothermal fluid circulation through the voluminous underlying rhyolites and volcanic detritus.

Much has been written on the subject of microbial uptake of Cs (Zhao *et al.* 2005; Kong *et al.* 2007) for example, at Targejia, Tibet. At Taron, the authors explain the morphology of pharmacosiderite, a normally isometric mineral, by appealing to microbial action, leaving what are interpreted to be fossil casts (Fig. 7) containing as much as 12% Cs.

Thallium concentrations of up to 3.4% rocks are unknown in the literature and research is being conducted at the University of British Columbia to determine its mineral hosts. Future research should also consider the mineral form of fluorine and boron. Metallurgical samples from Taron assayed 540 to 1727 ppm F and the boron mineral, ulexite, was seen forming in warm springs in the local area. The Taron deposit warrants more research into its origin, mineralogy, geochemistry and metallurgy with the goal of resource development.

## The Taron Cesium-Thallium Epithermal Geysirite Deposit... *continued from page 18*

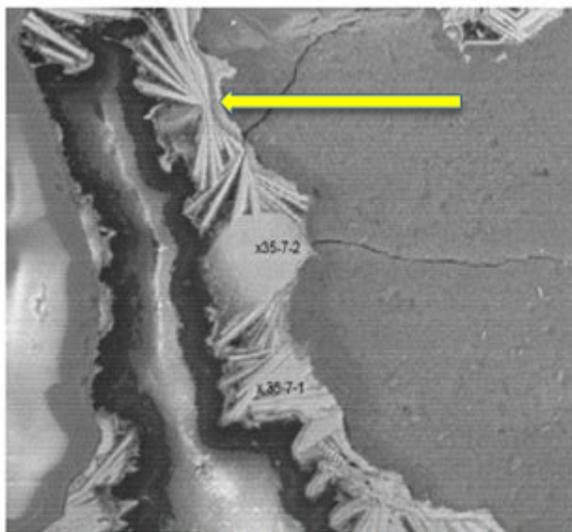


Figure 7. Arrow indicates microbe fossil casts(?) consisting of 10.6% to 11.5% Cs in pharmacosiderite casts. SEM back scattered image field of view is 0.4 mm.

It is also interesting to note at Spor Mountain, Utah, for example, in cycles of S-type rhyolitic volcanism, that the first cycle contains more enriched large ion lithophile elements and high field strength elements but are relatively depleted in the second cycle (Lindsey 1975; Burt *et al.* 1981).

### Acknowledgements

Cascadero Copper Corporation is acknowledged and thanked for permission to write this paper. Barry Smee and the late Peter Winterburn are recognized for their support. Charles Parkinson kindly modelled the Taron trench and drill core data for the authors.

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**OBITUARY****Lloyd D. James**

Lloyd D James died peacefully on June 17<sup>th</sup> at his home in West Wales, UK. Lloyd was born in North London in 1932 to David and Kathryn James. His father moved the family to Hertfordshire in 1939 to avoid wartime bombing and to work at De Haviland's military aircraft factory as an electrician.

Growing up near the De Haviland's runway gave Lloyd a life-long interest in aviation. He witnessed early test flights of several new British war aircraft. He also recalled the clouds of Allied D-Day bombers heading toward the English Channel. In his early teens, Lloyd cycled through much of England with his best friend, Don Aspinall.

Lloyd was a hard-working student which eventually earned him a place at the Imperial College, Royal School of Mines. Prior to starting his college education, Lloyd served for two years as a communication specialist in the British Royal Air Force. After completing his compulsory

service, he went on to complete a degree in Geology. Early job postings took him to northern Canada, Mexico, and southern Italy.

Lloyd married his first wife Nola Skuse in 1963 in Hertfordshire, England. He completed his doctoral research in geochemistry and welcomed a son, Ian, in 1965. After a two-year post in Ankara as a British advisor to the Turkish government, the family returned to England to welcome a daughter, Sue in 1967.

Lloyd moved his young family to Salt Lake City, Utah in 1969 to take a position with an American mining company (ASARCO). Life in Salt Lake included hiking, skiing, and numerous road trips to the many beauty spots of the US Mountain West. The family moved again to Denver, Colorado in 1979 for Lloyd's job. After leaving ASARCO, Lloyd took a two-year contract with the then mineral division of Royal Dutch Shell in 1983 which took the family to the Hague, Netherlands. Lloyd and Nola relished their time in Holland which afforded them travel to nearby European countries and visits to friends and relatives in the UK. The family returned to Denver in 1985 and Lloyd primarily worked as an independent consultant for the balance of his career.

After the death of his wife, Nola in 2003, Lloyd began to spend more time in England to work on genealogy with his sister, Daphne, and to enjoy his retirement. After about a year, Lloyd reconnected with an old friend, Joy Hughes, who he had known since his days working with the British government in Southern Italy. The two quickly became close and married in 2006. They relocated to the Welsh Coast where they lived happily until Lloyd's passing.

Lloyd traveled extensively throughout his education and working life. He completed his doctoral work in Sierra Leone, East Africa. Other projects took him to Myanmar, Burundi, Yemen, Australia, and Southern Africa.

Lloyd is preceded in death by his parents: David and Kathryn James and his first wife Nola James. He is survived by his second wife, Joy James, his children, Ian and Sue James, his sister and brother in law, Daphne and Glyn Parry, his nephew David, his nieces, Lynn and Julie, and his stepsons Martyn, Gavin, and Glyn Hughes. Lloyd was a kind and caring man with a quick wit and enduring sense of humor. He will be profoundly missed.

**Ian James**

## OBITUARY

**Ian Devereux (1940-2020)**

Dr. Ian Devereux passed away on 25 April 2020 at the age of 80. He was well known to the geochemical community as the owner of Rocklabs, a small New Zealand company making sample preparation equipment that he grew into a world leader. Ian completed his PhD in isotope geochemistry in 1968 at the University of Victoria while working for the Department of Scientific and Industrial Research (DSIR). His thesis was based on the use of oxygen isotopes in microfossils to document climate change in the Tertiary, one of the first studies of this kind. Shortly after, he founded Rocklabs in 1969 in partnership with a local lab owner Dr. Jim Spratt. Ian took over full ownership of the Rocklabs equipment business in the mid 1970s.

Ian realised that his products needed to be simple to operate even though the engineering behind them might be complex. Reliability was essential especially as they were to be used at mine site labs most likely to be in remote locations. The local Australasian market for geological sample preparation equipment was relatively small, so Ian decided at a very early stage that the market for his niche product was global. Although Ian considered himself a scientist and a very knowledgeable one at that, he was an astute businessman who grew Rocklabs into a \$20m company with over a thousand clients in 95 countries before completing its sale to Scott Automation in 2010. As he grew Rocklabs globally, he was epitomised as one of New Zealand export "Vikings", a group of innovative and entrepreneurial small business people who were at the core of the country's development as an export nation into a global market from the mid 1970s and onward. Ian was very much a one-man band in popularising his product, constantly on the road around the world. He was always present at the annual meeting of the Canadian Mineral Analysts, an association of lab analysts from Canadian mining and exploration labs.

Innovation was at the heart of Ian's business approach; it came from his deep interest in and questioning of existing lab processes and an ability to devise simple solutions to improve them. His goal was to increase the effectiveness of sample preparation equipment and help the operator to produce a quality product consistently, through properly designed equipment that could be operated safely. Starting with a simple ring mill pulverizer that developed a reputation for reliability, he introduced products such as the hydraulic crusher that enabled contamination free crushing of rocks. The multi-mill was an interesting solution to contamination control and improving efficiency – it was unlike anything else in the sample preparation equipment world. It could pulverize 80 samples simultaneously over a 12 hour period. Each compartment operated as a low energy rod mill that gently pulverized the sample and minimized contamination unlike the high energy action of conventional ring mills. His continuous ring mill (CRM) consisting of three stacked ring mills that provided an alternate method of pulverizing large samples compared to the very large pulverizers used by some labs.

The Boyd crusher was unique in being the first double acting jaw crusher that was designed to reduce drill core to -2mm in a single step. Each jaw moving independently with a slight oscillatory motion allowed progressive crushing of the sample as it dropped through the jaws and replaced a two-step process employed by many labs. The importance of this innovation was that it improved the representivity of the sample split expressed by Pierre Gy's Fundamental Sampling Equation which shows the importance of reducing particle diameter in minimizing the sampling error. The Boyd, in combination with the CRM, was an efficient way of processing large samples to analytical fineness. A further innovation was his development of the rotary sample divider. Rotary sample dividers were known as the best way to split a sample with an order of magnitude improvement in splitting error over the riffle splitter, which was the standard at the time. Existing rotary dividers were awkward to use in a sample preparation lab setting and not easy to clean. He designed a rotary splitter that could split the output from the Boyd as it was crushed, with split proportions easily adjusted. In combination these innovations were a step change in the quality of sample preparation procedures, while the mechanisation introduced resulted in productivity and health and safety improvements for sample preparation technicians. They are in use in sample preparation labs around the world to this day and constitute his legacy to our industry.

From his travels to numerous mine sites, Ian knew that the mining industry was looking for further productivity improvements through automation and he used some of these components such as the Boyd, the CRM and the rotary sample divider as basic building blocks in customised automated systems. Mechanical conveyors were used to move material between components, with the system controlled by programmable logic controllers. These mechanised systems were significantly less expensive and more reliable than the automated systems based on the robotics that were available in the 1990s.

Following the Bre-X scandal in 1997 and increased scrutiny of lab QC procedures, Ian realised there was an opportunity for marketing reliable certified reference materials for precious metals analysis that were easily available. Most rock standards at the time came from government agencies and were expensive and only available in limited quantity. As those from Rocklabs were inexpensive enough for frequent insertion, available as sachets for individual use or in larger packs for labs and distributed globally through the Rocklabs sales network, they quickly became a popular and widely used product.

In person, Ian was affable and easy going, always the raconteur with a raft of stories from his extensive travels and from the labs he visited around the world. He was softly spoken and always a gentleman. In conversing with him one quickly became aware of his intelligence and wide knowledge. He could be very persuasive which no doubt contributed to his success in selling Rocklabs' products and solutions. Money was never central to Ian's vision and he shared his wealth widely; he instituted a profit-sharing scheme at Rocklabs that along with his people-centric management style ensured a strong and loyal team that propelled its growth.

Our sympathies go to Ian's family and to his many friends and colleagues. May he rest in peace.

## AAG Councillor Elections for the Term 2021-2022

Each year the Association of Applied Geochemists (AAG) needs motivated and energetic AAG Fellows to stand for election to the position of “Ordinary Councillor.” Fortunately, each year some of our most outstanding Fellows are ready, willing, and able to meet this challenge. However, this year I’m sending this to **ALL MEMBERS**, to encourage those Members that have the experience and enthusiasm to be involved, to convert your membership status and look to make a bigger contribution to the AAG (see the website for details).

This note is the annual reminder to AAG Fellows (and Members that could become Fellows) that we need your participation on Council. It is our sincere hope that this email might entice more people to step forward for election to this important position. If you are not eligible to become a Fellow, but want to be more involved, please send me an email message as we are looking to get more of our junior members active in the AAG and other opportunities will be coming available.

### *Councillor Job Description*

The AAG By-laws state that “the affairs of the Association shall be managed by its board of directors, to be known as its Council.” The affairs managed by Council vary from reviewing and ranking proposals to host our biennial Symposium to approving application for new membership to developing marketing strategies for sustaining and growing our membership. These affairs are discussed and decisions made at Council teleconferences usually held 3-4 times per year. Each teleconference lasts about 1 hour. In addition, there is often a running email discussion about a selected issue or two between each teleconference. So for a commitment of about 5 hours of your time per year, you can help influence the future of your Association. If you want to spend more than the minimum time required, there is plenty of opportunity to do so through committee assignments and voluntary efforts that greatly benefit the Association.

### *Qualifications and length of term*

The only qualification for serving as Councillor is to be a Fellow in good standing with the Association. Please note the difference between being a *Member* of AAG and being a *Fellow* of the AAG. A Fellow is required to have more training and professional experience than a Member. Consult the AAG web site, Membership section, for further details. If you are not currently a Fellow and have an interest in serving on Council, please go through the relatively painless process of converting to Fellowship status in AAG.

Each Councillor serves a term of two years and can then stand for election to a second two-year term. The By-laws forbid serving more than two consecutive terms, although someone who has served two consecutive terms can stand for election again after sitting out for at least one year. Elections are usually held in October-November of the year for a term covering the following two years. Our next election will be in **October-November 2020** for the term of **2021-2022**.

### *How to get on the ballot*

If you are interested in placing your name into consideration for election to AAG Council, simply express your interest to the AAG Secretary (Dave Smith, email: [dbsmith13@gmail.com](mailto:dbsmith13@gmail.com)) by **October 15, 2020** and include a short paragraph (no more than 250 words) summarizing your career experience. This summary should include the following:

- Your name
- Year that you became a Fellow of AAG
- Earth science degrees obtained, year of graduation of each, and institution of each
- Employment—list major employers and state years worked for each, e.g. 1980-1990, and describe the type of work
- Position(s) held as part of AAG or other past contributions to AAG
- 2-3 sentences about your professional experiences in applied geochemistry

All that is asked is that you bring energy and ideas to Council and are willing to share in making decisions that will carry the Association forward into a successful future. We look forward to hearing from you.

**Denise Arne**

President, Association of Applied Geochemists



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## AAG new Cameron-Hall Copper Medal



The **Cameron-Hall Copper Medal** is a new medal of the AAG. It is awarded annually to the best paper published each year in the Association's journal, *Geochemistry: Exploration, Environment, Analysis* (GEEA). The first award of this new medal and for the year 2019, is the recent paper in GEEA (vol. 19, Part 4, p. 474-486) entitled '*Identification of the expression of earthquake induced surface flooding by groundwater using detailed regolith mapping at the buried Atlántida Deposit, northern Chile*' written by A.E. Brown, P.A. Winterburn, and T. Bissig. A formal presentation of the Cameron-Hall Copper Medal to the winners will be held at the 29<sup>th</sup> International Applied Geochemistry Symposium (IAGS) in October, 2021.

### Stephen Cook

AAG Past President

Chair, Awards & Medals Committee

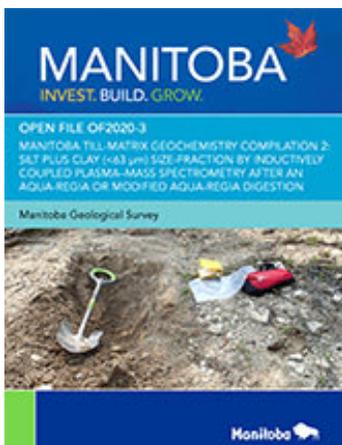
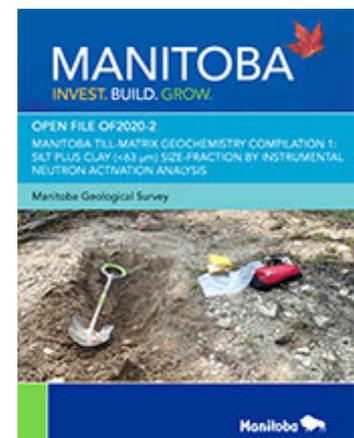


## New geochemical data releases for Manitoba, Canada

### OF2020-2

#### Manitoba till-matrix geochemistry compilation 1: silt plus clay (<63 µm) size-fraction by instrumental neutron activation analysis

This Open File provides a digital dataset for till geochemistry surveys carried out in Manitoba, Canada. Dataset 1 is a compilation of 32 projects that include almost 7000 till samples, with the silt plus clay (<63 µm) size fraction of the till matrix analyzed by instrumental neutron activation analysis. These data can be brought into GIS software, and integrated with other geoscience data, to generate new exploration targets and design follow-up exploration programs. Dataset includes recently unearthed unpublished archival data.



### OF2020-3

#### Manitoba till-matrix geochemistry compilation 2: silt plus clay (<63 µm) size-fraction by inductively coupled plasma-mass spectrometry after an aqua-regia or modified aqua-regia digestion

This Open File provides a digital dataset for till geochemistry surveys carried out in Manitoba. Dataset 2 is a compilation of 23 projects that includes 3365 till samples where the silt plus clay (<63 µm) size fraction of the till matrix was analyzed by inductively coupled plasma-mass spectrometry after an aqua-regia or modified aqua-regia digestion. These data can be brought into GIS software, and integrated with other geoscience data, to generate new exploration targets and design follow-up exploration programs.

Both publications may be downloaded for free: <https://www.gov.mb.ca/iem/info/libmin/newpubs.html#may26>



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## AAG Annual General Meeting

Attention AAG Members! The next Annual General Meeting (AGM) of the Association of Applied Geochemists is scheduled to take place on Wednesday September 9, 2020 at 11 pm Ottawa, Canada time, 9 pm Denver, USA time, and on Thursday, September 10 in Melbourne, Australia at 1 pm, Perth, Australia at 11 am and Johannesburg, South Africa at 5 am.

Zoom video conferencing software (<https://zoom.us/>) will be used to hold the meeting and if you wish to participate, please notify Al Arseneault at the AAG Business Office (email address below) so that he may provide you with connection instructions.

**Dennis Arne**, President

**Al Arseneault**, AAG Office Business Manager  
[office@appliedgeochemists.org](mailto:office@appliedgeochemists.org)



## 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](http://www.appliedgeochemists.org).

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

Steve Amor, Email: [steve.amor2007@gmail.com](mailto:steve.amor2007@gmail.com)

or

Tom Meuzelaar, AAG Webmaster, [tom@lifecyclegeo.com](mailto:tom@lifecyclegeo.com)

The status of the meetings was confirmed on August 23<sup>rd</sup> 2020, 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.

### 2020

- 5-7 OCTOBER 20th Peruvian Geological Congress. Lima, Peru. Website: [tinyurl.com/y8h9tu5u](http://tinyurl.com/y8h9tu5u)
- 26-30 OCTOBER GSA 2020 Connects Online. Website: [community.geosociety.org/gsa2020/home](http://community.geosociety.org/gsa2020/home)
- 25-29 OCTOBER 18th International Conference on Heavy Metals in the Environment. Seoul South Korea. Website: [ichmet2020.org](http://ichmet2020.org)
- 2-5 NOVEMBER 3rd Conference of the Arabian Journal of Geosciences. Sousse Tunisia. Website: [www.cajg.org](http://www.cajg.org)
- 23-27 NOVEMBER 7th SGA-IUGS-SEG-UNESCO Short Course on African Metallogeny. Windhoek Namibia. Website: [tinyurl.com/y4b8d2mk](http://tinyurl.com/y4b8d2mk)
- 30 NOVEMBER – 4 DECEMBER American Exploration and Mining Association Annual Meeting. Sparks NV USA. Website: [www.miningamerica.org/2020-annual-meeting](http://www.miningamerica.org/2020-annual-meeting)
- 7-11 DECEMBER AGU Fall Meeting. Online. Website: [tinyurl.com/y3lmdbvb](http://tinyurl.com/y3lmdbvb)

### 2021

- 18-21 JANUARY Mineral Exploration Roundup 2021. Vancouver BC Canada. Website: [roundup.amebc.ca](http://roundup.amebc.ca)
- 9-12 FEBRUARY Australian Earth Sciences Convention. Hobart TAS Australia. Website: [www.aesconvention.com.au](http://www.aesconvention.com.au)
- 7-10 MARCH Prospectors and Developers Association of Canada Annual Convention. Toronto ON Canada. Website: [www.pdac.ca/convention](http://www.pdac.ca/convention)
- 14-18 MARCH Minerals, Metals & Materials Society 2021 Annual Meeting & Exhibition. Orlando FL USA. Website: [www.tms.org/tms2021](http://www.tms.org/tms2021)
- 23-25 APRIL 3rd International Conference on Geographical Information Systems Theory, Applications and Management. Prague Czech Republic. Website: [www.gistam.org](http://www.gistam.org)
- 25-30 APRIL EGU General Assembly 2021. Vienna Austria. Website: [www.egu2021.eu](http://www.egu2021.eu)
- 9-14 MAY IWA World Water Congress & Exhibition 2020. Copenhagen Denmark. Website: [tinyurl.com/y4s4u9fm](http://tinyurl.com/y4s4u9fm)
- 17-19 MAY GAC-MAC Joint Annual Meeting London ON Canada. Website: [gacmac2021.ca](http://gacmac2021.ca)
- 17-20 MAY Geological Society of Nevada 2021 Symposium. Sparks NV USA. Website: [www.gsnssymposium.org](http://www.gsnssymposium.org)
- 1-3 JUNE 9th World Conference on Sampling and Blending. Kristiansand Norway. Website: [wcsb10.com](http://wcsb10.com)
- 14-18 JUNE 9th International Workshop on Compositional Data Analysis. Toulouse France. Website: [www.coda-association.org/en/codawork2021](http://www.coda-association.org/en/codawork2021)
- 21-24 JUNE SIAM Conference Mathematical and Computational Issues in the Geosciences. Milan Italy. Website: [www.siam.org/conferences/cm/conference/gc21](http://www.siam.org/conferences/cm/conference/gc21)
- 4-9 JULY Goldschmidt 2021. Lyon France. Website: [tinyurl.com/y869e3wo](http://tinyurl.com/y869e3wo)
- 8-9 JULY Sampling 2020. Lima Peru. Website: [tinyurl.com/y8ddlbox](http://tinyurl.com/y8ddlbox)
- 1-6 AUGUST Geoanalysis 2021. Freiberg Germany. Website: [geoanalysis2021.de](http://geoanalysis2021.de)
- 16-20 AUGUST 12th International Kimberlite Conference. Yellowknife NT Canada. Website: [12ikc.ca](http://12ikc.ca)
- 16-21 AUGUST 36th International Geological Congress, Delhi India. Website: [www.36igc.org](http://www.36igc.org)
- 23-27 AUGUST Eurosoil 2021. Geneva Switzerland. Website: [eurosoil2020.com](http://eurosoil2020.com)
- 29 AUGUST-2 SEPTEMBER 3rd European Mineralogical Conference. Cracow Poland. Website: [emc2020.ptmin.eu/](http://emc2020.ptmin.eu/)



## CALENDAR OF EVENTS... *continued from page 25*

- 12-17 SEPTEMBER 30th International Meeting on Organic Geochemistry. Montpellier France.  
Website: [eage.eventsair.com/imog-2021](http://eage.eventsair.com/imog-2021)
- 13-17 SEPTEMBER 41st International Symposium on Environmental Analytical Chemistry. Regensburg Germany.  
Website: [iaeac.com](http://iaeac.com)
- 9-17 OCTOBER 28th Colloquium of African Geology (18th Conference of the Geological Society of Africa). Fez Morocco. Website: [www.fsdmfes.ac.ma/CAG28](http://www.fsdmfes.ac.ma/CAG28)
- 24-29 OCTOBER 29th International Applied Geochemistry Symposium (IAGS). Viña del Mar Chile. Website: [iags2020.cl](http://iags2020.cl)
- 2-4 NOVEMBER 13th Fennoscandian Exploration and Mining. Levi Finland. Website: [femconference.fi](http://femconference.fi)
- 15-18 NOVEMBER 15th Biennial Meeting of the Society for Geology Applied to Mineral Deposits. Rotorua New Zealand.  
Website: [confer.eventsair.com/sga2021](http://confer.eventsair.com/sga2021)

### 2022

- 24-29 JULY 15th International Conference on Mercury as a Global Pollutant. Cape Town South Africa.  
Website: [www.ilmexhibitions.com/mercury2022](http://www.ilmexhibitions.com/mercury2022)
- 31 JULY- 5 AUGUST World Congress of Soil Science 2022. Glasgow UK. Website: [www.soils.org.uk/wcss2022](http://www.soils.org.uk/wcss2022)
- 15-19 AUGUST 12th International Kimberlite Conference. Yellowknife NT Canada. Website: [12ikc.ca](http://12ikc.ca)
- 22-26 AUGUST International Sedimentological Congress. Beijing China. Website: [isc2022.scievent.com](http://isc2022.scievent.com)
- 13-15 SEPTEMBER 14th International Symposium on Nuclear and Environmental Radiochemical Analysis. York UK.  
Website: [tinyurl.com/y989mvvz](http://tinyurl.com/y989mvvz)

### 2023

- 29 JANUARY- 3 FEBRUARY Winter Conference on Plasma Spectrochemistry. Ljubljana Slovenia.  
Website: <https://ewcps2021.si>



## Scientific Presentations on AAG website

Scientific presentations given by other AAG members are now available for viewing on the AAG website, in 3 categories listed below. Just click on *Presentations* on the home page main menu banner. <https://www.appliedgeochemists.org/presentations>

- Listing of past AAG distinguished lecturers, their presentation topics, and some of their digital presentations as pdf files: <https://www.appliedgeochemists.org/presentations/aag-distinguished-lecturer>
- Presentations given by AAG members that are directly associated with the AAG:

<https://www.appliedgeochemists.org/presentations/aag-presentations>

- "Other Presentations" section for members and non-members to submit non-AAG presentations of general interest to the geochemistry community. This content requires review and approval by AAG before it is available on the AAG website:

<https://www.appliedgeochemists.org/presentations/other-presentations>



## Heavy Mineral Extractions

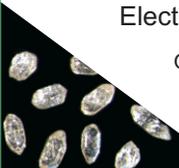


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## Practical Problems in Applied Geochemistry: now on the AAG Website

A new section has been added to the AAG website entitled "Case Studies". It can be accessed by **AAG members** from the header menu on the AAG home page which will automatically take you to a member login page first and then on to the case studies section. This section hosts practical problems in applied geochemistry with the first example posted being a practical problem in stream sediment geochemistry from northern Vancouver Island in western Canada. This case study will hopefully be the first of many practical problems in applied geochemistry to be added to this new section of the AAG website. Please take a look and use the contact button to provide Denise Arne with feedback, suggestions, or questions.

Web link: <https://www.appliedgeochemists.org>



## Welcome New AAG Members in 2020

### Regular Members

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

Dr. Carolina Rodriguez  
Geochemist, CODELCO  
Av. Santa Maria 0206, depot 1201  
Providencia, Region Metropolitana  
CHILE  
Membership # 4430

### Fellows

**Fellows** are voting members of the Association and are actively engaged in the field of applied geochemistry. They are nominated to be a Fellow by an established Fellow of the Association by completing the Nominating Sponsor's Form.

### Student Members

**Student Members** are students that are enrolled in an approved course of instruction or training in a field of pure or applied science at a recognized institution. Student members pay minimal membership fees.



## Geochemistry News links:

Geological Survey of Sweden News, including their 'Exploration Newsletter'  
<https://www.sgu.se/en/about-sgu/news/>

USGS Geology News  
<https://www.usgs.gov/news/news-releases>

Geoscience Australia News  
<https://www.usgs.gov/news/news-releases>

Geological Survey of Finland News  
<https://www.gtk.fi/en/category/news/>



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## Recently Published in Elements

June 2020, Volume 16, no. 3, *Redox Engine of Earth*

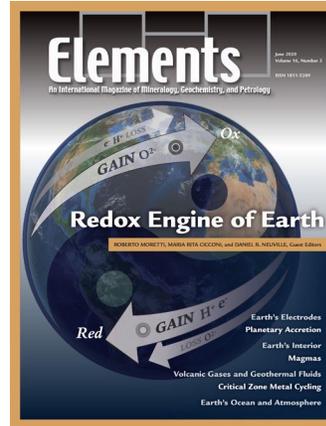
This issue comprises seven articles that illustrate how understanding redox processes can help us to understand much of Earth's activity. There are two AAG news items in this issue. First, obituary for Vale David John Gray (1961 – 2019). Second, abstract of an article that appeared in issue 184 (September 2019) of the **EXPLORE** newsletter, namely "Rapid hydrogeochemistry: A summary of two field studies from central and southern interior British Columbia, Canada using a photometer and voltammeter to measure trace elements in water" by Ron Yehia, David R. Heberlein, and Ray E. Lett.

August 2020, Volume 16, no. 4, *Lithium: Less is More*

This issue comprises six articles reviewing the many roles that lithium plays in natural systems. The only AAG news item in this issue describes the profiles of AAG councillors for 2020–2021.

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

John Carranza



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