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The use of bulk cyanide leach in gold assays of drill core and rock samples

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INTRODUCTION

The use of cyanide in the form of NaCN to digest Au and other metals for analysis is well established (e.g. Wang and Forssberg 1990). Most exploration geologists will be familiar with the use of bulk cyanide leach (BCL), also referred to as bulk leach extractable gold (BLEG), applied to surficial samples, such as stream sediments and soil (Rate et al. 2010). This contribution reviews some of the advantages of using BCL on rock and drill core samples.

The analysis of pulverized rock material may be conducted using a standard BCL, with or without agitation such as a bottle roll, or an accelerated process using LeachWELL™ 60X (Menne and Revey 1994). Factors that need to be considered to ensure efficacy of Au recovery include liberation of Au particles for digestion, the strength of the NaCN solution, grain size of the liberated Au particles, duration of the digestion, pH of the solution, oxidation of the lixiviant, and the presence of activated carbon (preg-robbing) or copper and iron sulphides (cyanicides) (Rate et al. 2010; Cetin et al. 2017; Kianinia et al. 2018). In many regards the use of BCL assays overlaps with metallurgical testing and can be used to give an early indication of anticipated Au recoveries from exploration samples, although BCL analyses from geochemical laboratories do not generally include pH control or the addition of other additives common to metallurgical test laboratories.

It must be borne in mind that a BCL assay for Au may not be a total analysis if Au is encapsulated in quartz (i.e. not liberated) or in sulphides at the atomic level (i.e. refractory), or because of the many factors outlined in the preceding paragraph. Therefore, to compare BCL data with fire assay (FA) data, it is necessary to undertake a fire assay of the BCL tailings. The BCL assay and the tailings assay are then summed to provide a total assay for the sample. There is also clearly valuable information in the component of Au not digested in NaCN.

CASE STUDIES

Some styles of Au mineralization are mineralogically complex. An example is illustrated in Figure 1 showing a reflected photomicrograph from an Australian Au deposit that will provide the source of much of the data presented in this article. The sample consists of an intergrowth of gangue minerals, mainly quartz and carbonate, with Pb-Sb-Ag sulphosalts (dark grey), aurostibite (light grey; $AuSb_2$), primary Au containing up to 20% Ag (pale yellow), and supergene Au of high fineness (orange-yellow colour) associated with the decomposition of aurostibite. Historically, coarse Au was recovered from this deposit using gravity methods and floatation was used to concentrate the sulphosalts and aurostibite for smelting. The deposit therefore contains both free and unliberated (at a nominal 85% passing 75 mm grain size) or refractory Au, the proportions of which may vary across the deposit.

A summary of LeachWELL™ (LW) and tails FA data are presented from this deposit in Table 1. The 25 g FA assay results with duplicate analyses for most samples can be contrasted with combined 200 g LW analyses and 25 g FA assays of the LW tails. More significantly from a mineral processing perspective, a ratio of cyanide-soluble to total Au can also be calculated for each sample. These ratios vary from a low of 8.2% to a high of 98%, indicating significant variation in the proportion of free Au in samples derived from different areas of the deposit as a function of mineralogy. This information can be built into block models to allow planning for mineral processing requirements.

One aspect that is easily controlled in using BCL is the digestion time, which influences the size of the Au grains to be dissolved. A BCL for exploration purposes may use a dilute NaCN solution to avoid digest-

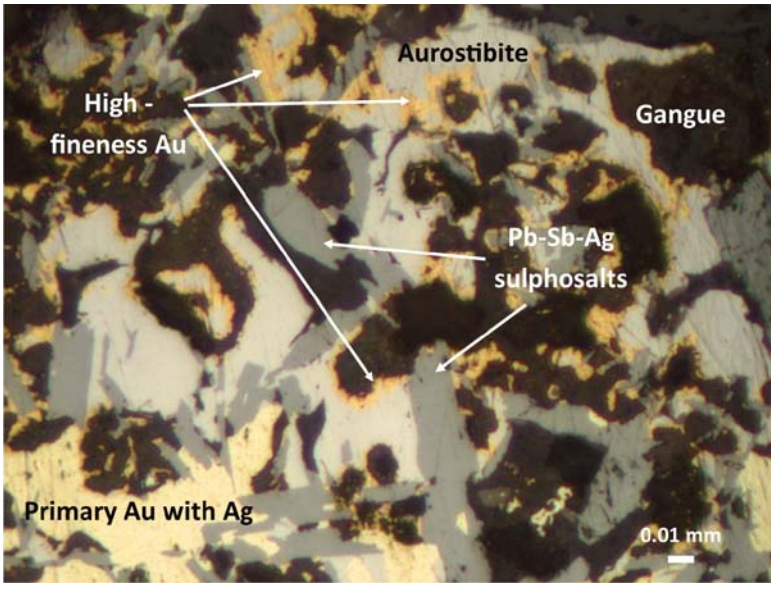

Fig. 1. *Reflected light photomicrograph of complex mineralization from an Australian Au deposit.*

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Note from the Editor

Welcome to the third EXPLORE issue of 2024. This issue features an article describing the use of bulk cyanide leach in gold assays of drill core and rock samples. It was written by Dennis Arne.

EXPLORE thanks all those who contributed to the writing and/or editing of this issue, listed in alphabetical order: Elizabeth Ambrose, Dennis Arne, Lynda Bloom, John Carranza, Steve Cook, Jane Graham, Ray Lett, Jessey Rice, Behnam Sadeghi, and Yulia Uvarova.

Beth McClenaghan
Editor

Steve Cook,
Business Manager

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President's Message

Welcome to the third issue of EXPLORE of 2024. In my last message, I updated you that we were recruiting a new Editor-in-Chief for the Geochemistry: Exploration, Environment, Analysis (GEEA) journal in collaboration with the Geological Society of London. The process is going well, and we are expecting a public announcement to coincide with the 30th International Applied Geochemistry Symposium in Adelaide, South Australia, 14th to 18th October 2024, so stay tuned!

Another exciting news item that I would like to share with you is that Ryan Noble has picked up the baton from David Cohen, our long-time AAG Symposia Coordinator. I would like to sincerely thank David for his outstanding job in this position, and I am very grateful to Ryan for taking up this important role. David is not going far, but he will need to give his full attention to the bid for the 38th IGC to be hosted in Melbourne, Australia, and, if the bid is successful, David will steer the Organising Committee along with the other co-Secretary General and Co-chairs until September 2028. David, we wish you all the best with the bid, which will be presented to the Committee in August in Busan, South Korea! In the meantime, Ryan has already started looking for a location to host IAGS 2026, so please reach out to him if you have an idea and would like to prepare a bid to host the next IAGS event.

In regards to the 30th International Applied Geochemistry Symposium in Adelaide, South Australia, 14th to 18th October 2024, the scientific programme, field trips and workshops have been finalised, and all the information is available on the IAGS 2024 website. Recently, we also announced student bursaries on the website. The bursary program provides undergraduate and postgraduate students with the opportunity to participate in the IAGS 2024. Awardees are eligible to receive reimbursement for the associated costs of registration and travel (if applicable). This applies to those of you who have registered for the IAGS already. If you are an eligible student, please consider taking advantage of this opportunity, and if you are a supervisor, please consider this for your students. We would love to welcome a large and diverse cohort of the new generation of geochemists at the conference. More information is available here:

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Yulia Uvarova
President

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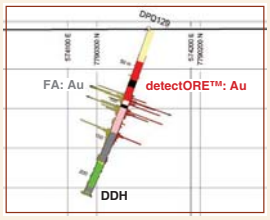

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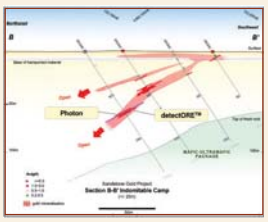

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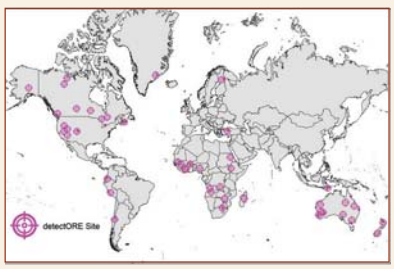

Visit us at the 30th International Applied Geochemistry Symposium (IAGS) in Adelaide, South Australia (14 – 18 October 2024)

The use of bulk cyanide leach in gold assays of drill core and rock samples

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Table 1. *Summary of conventional fire assay (FA) and Leach-WELL™ (LW) + tails fire assay Au results from fresh samples in a deposit containing both free and refractory/ unliberated Au (n/a = not applicable).*

Sample	25 g FA (ppm)	25 g FA Repeat (ppm)	200 g LW (ppm)	25 g LW tails FA (ppm)	Total Au (LW + tails FA) (ppm)	Cyanide-soluble Au to total Au (%)
Sample 8	13.16	n/a	1.16	12.73	13.89	8.8
Sample 9	17.23	13.03	5.00	12.32	17.32	33.0
Sample 10	5.23	n/a	0.43	5.35	5.78	8.2
Sample 11	13.12	12.33	4.72	5.50	10.22	37.0
Sample 12	30.24	30.6	19.95	12.38	32.33	65.6
Sample 13	38.70	27.98	47.85	0.75	48.60	98.0

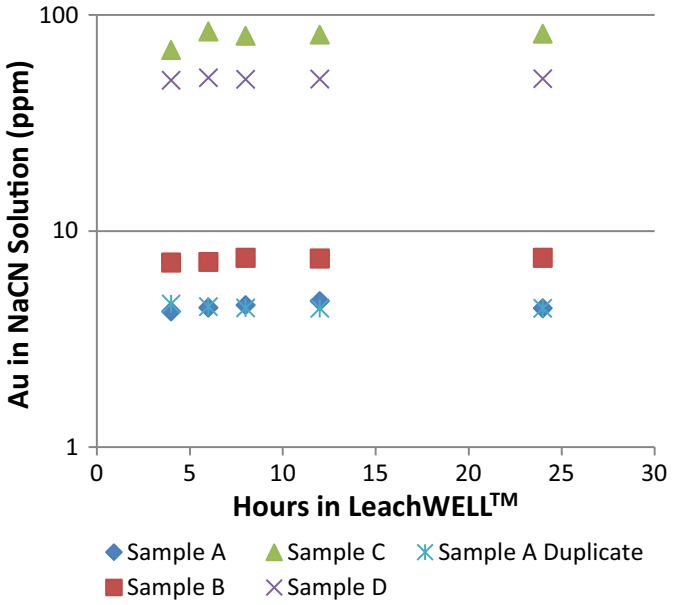

Fig. 2. *Gold concentration in solution at various times during a static accelerated bulk cyanide leach (LeachWELL™) digest.*

ing the larger Au grains that produce a nugget effect. However, for an accelerated BCL such as LW used on drill core or rock samples, it is necessary to ensure that even the coarse Au is dissolved. Many labs will offer a standard 4-hour static digestion time, but the appropriateness of this duration should be established at the outset by drawing off the pregnant solution at various times to determine when the Au concentration plateaus (Fig. 2). A 4-hour digestion is adequate for some samples in this trial (e.g. sample D), but not for all. Sample A required 6 hours before reaching a plateau in the Au concentration whereas it is arguable that sample B required 8 hours. Time trials such as these can be used to optimize the leach duration of a BCL by selecting a leach time that dissolves the largest Au grains in the samples.

Another obvious benefit to the use of BCL for Au assay is that it uses a larger sample mass than normally available for most routine Au analyses. In this regard, the advantages are similar to those obtained using screened metallics fire assay or PhotonAssay™ (Dominy et al. 2024). Analyses of particulate Au suffer from the effects of nuggetty distribution within a pulverized sample. An improvement in the relative precision of sampling is typically achieved either using a finer grain size or an increased sampling mass (Stanley 2007; Smee et al. 2024), both of which act to increase the number of Au particles in the sample. The number of Au particles in a sample can also be increased by an increase in grade but, for obvious reasons, this is outside the control of either the sampler or the analyst!

Changes in relative precision related to changes in sample mass can be assessed using duplicate samples and the calculation of the average coefficient of variation (CV_{AVG}) for many duplicate analyses for a particular range of grades (Stanley and Lawie 2007; Abzalov 2008, 2011; Smee et al. 2024). Duplicates include the use of core, reverse circulation (RC) rock chips, coarse crush material (preparation duplicates) or pulps. It is important to understand that an increase in the mass of the sample pulp using BCL only improves the relative precision of sub-sampling pulp material. It has no effect on the relative precision of sampling drill core or cuttings, which are the main sources of uncertainty (Stanley and Smee 2007), although it can reduce the total CV_{AVG} estimated from field duplicates because the variances associated with each sub-sampling stage are additive (Equation 1).

$$\sigma_T^2 = \sigma_{FS}^2 + \sigma_{CS}^2 + \sigma_{PS}^2 + \sigma_A^2 \qquad \textit{Equation 1}$$

where σ_T^2 = total variance; σ_{FS}^2 = field sampling variance; σ_{CS}^2 = coarse crush sub-sampling variance; σ_{PS}^2 = pulp sub-sampling variance; σ_A^2 = analytical variance.

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Table 2. *Summary of pulp duplicate data from drill core samples in a deposit containing coarse free Au.*

	25 g FA CV_{AVG} %	400 g Bulk CV_{AVG} %	25 g FA s^2	400 g Bulk s^2	400 g Bulk Predicted* s^2
Pulp Duplicates	28.4	8.8	806.4	77.4	50.4

*predicted using equation 5 from Stanley (2007) assuming a homogenous distribution of Au

CV_{AVG} - average coefficient of variation; FA - fire assay

An example of where an improvement in the relative precision (i.e. 2 times CV_{AVG}) of sub-sampling pulp material from a Au deposit containing nuggetty free Au is provided in Table 2. The CV_{AVG} for Au values that are greater than an order of magnitude above the LLD based on 9 pulp duplicate 25 g fire assays (FA) is 28.4%, which is not an unusual result. A CV_{AVG} for nominal 400 g bulk analyses used data from 25 samples, with 400 g LW analyses paired with data from nominal 400 g screen fire assays (SFA; also referred to as screened metallics), although there is a slight negative bias in the SFA relative to the LW results. A more rigorous assessment of the improvement in relative precision from using BCL would involve the analysis of duplicate LW analyses. Regardless, and based on the data available, the CV_{AVG} for the bulk analyses averages 8.8% for all samples.

A better indication of the changes in relative precision for the two masses of analyzed pulp lies in the relative variances (CV_{AVG}^2) of the data. The pulp duplicate relative variances for all samples have been reduced from 806.4 for the 25 g FA duplicate analyses to 77.4 for the 400 g bulk analyses, or just over an order of magnitude reduction, which is significant but slightly less than the decrease expected for the increase in sample mass using the relationship in equation 5 from Stanley (2007).

A common observation in moving from conventional fire assay charge weights to bulk analyses, be they BCL or SFA, is an increase in overall grade (Campbell-Hicks 1996). Table 3 shows the results of re-assaying of a 12 m high-grade Au intersection from an epithermal Au deposit in Turkey using 500 g SFA compared to the original 50 g fire assays. Overall, there is an increase in Au grade over the high-grade interval with the bulk analyses. The median increase in grade on a sample-by-sample basis is 8.6 %, which is significant if it can be maintained across an entire resource estimate. A similar effect is also apparent in the data from Table 1. Of course, these are small data sets with much variability and the bulk analyses would need to be carried through all ore-grade intersections before the economic benefit would be realized, but they serve to illustrate the potential monetary value of more precise assay data.

Table 3. *Comparison of 50 g fire assay and 500 g screen fire assay results from an epithermal Au deposit in Turkey (from Pilot Gold press release 22/01/2013).*

From (m)	To (m)	Interval (m)	Au (g/t) original 50 g fire assay	Au (g/t) screened metallics	Change %
116.0	117.5	1.5	2.3	2.4	4.1
117.5	119.0	1.5	47.9	44.7	-6.6
119.0	120.5	1.5	12.8	13.5	5.4
120.5	122.0	1.5	338.0	382.0	13.1
122.0	123.5	1.5	236.0	231.0	-2.3
123.5	125.0	1.5	73.0	92.8	27.1
125.0	126.5	1.5	681.0	880.0	29.3
126.5	128.0	1.5	17.2	16.2	-5.6
128.0	129.5	1.5	140.0	157.0	11.8
129.5	131.0	1.5	3.9	3.6	-6.6

There would have been adequate pulverized material available in the Pilot Gold example to supply a 500 g sample for screened metallics and conventional fire assay from a single 1 kg crusher split. However, if the screened metallics assay required the pulverization of additional crushed material, this sample would constitute a coarse crush duplicate and add an extra component of uncertainty into the comparison of the screened metallics results with conventional fire assays.

The coarse fraction from a screened metallic assay is typically >100 microns and can provide an indication of the proportion of Au in the sample that might be recoverable using gravity separation (L. Bloom, pers. comm., June 2024), much as the cyanide-soluble Au in a BCL assay provides an indication of Au recovery during cyanide treatment.

The reason for the increase in average Au grades using bulk analytical methods lies in the narrowing of the variance

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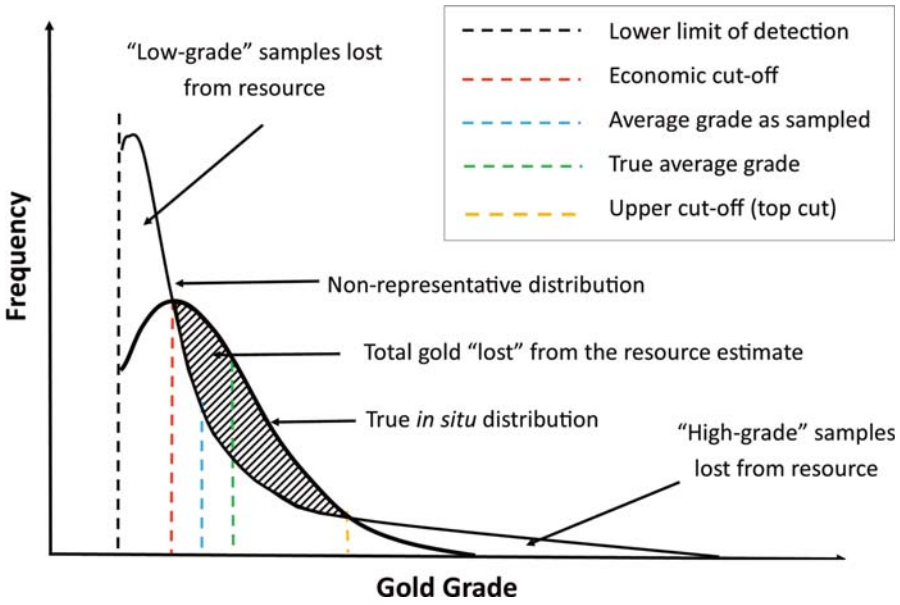

Fig. 3. *A schematic real in situ distribution of Au in a deposit compared to a distribution skewed and flattened by imprecise assay data (modified from Sketchley 1998).*

with more precise data (Sketchley 1998). Imprecise data results in a spread in the data, with more samples falling below the lower limit of detection as well as below economic cut-off grades. At the same time, more samples will display unnaturally high values that, in a resource estimate, will be removed (or top-cut) from the estimation (Fig. 3). Broadening the natural in situ distribution of Au results in a lowering of average grade and effectively the apparent "loss" of Au from the distribution. Recovering this "lost" Au using bulk analytical methods more than justifies the added analytical costs to produce more precise assay data that reflect the true value of the resource.

As a practical example of the use of BCL to support conventional 50 g fire assay results, E79 Resources routinely used a 500 g LW with a tails fire assay in 2021 to verify 50 g fire assay results for drill core intersections containing visible Au associated with abundant associated pyrite from its Victorian tenements in Australia. Samples were selected for BCL based on the presence of visible Au within an intersection rather than on initial fire assays to minimize the selection bias in samples for BCL. For example, an extremely high-grade Au intercept over 0.60 m in drillhole HVD002 that returned a 50 g fire assay of 2,430 g/t Au was confirmed by a LW + tails fire assay of 2,443 (E79 Resources press release dated August 9, 2021). In a press release dated January 27, 2022, E79 Resources upgraded previously released 50 g fire assay results

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for drilling intercepts to 2.3 m @ 40.5 g/t from 2.3 m @14.4 g/t (drillhole HVD006) and 5.4 m @ 70.0 g/t from 5.4 m @ 32 g/t (drillhole HVD007) based on LW with tails fire assay results. Further, the LW + tails fire assay results indicated that >99% of Au within the samples was digested in the BCL despite the presence of abundant sulphide minerals in the samples. It is important to note that certified reference materials included with the original assays containing lesser amounts of sulphide were acceptable and that the significant under-reporting of Au in these examples was only revealed using BCL. The reason for the significant under-reporting of Au assays from the original 50 g fire assays was never determined, but the LW + tails results were subsequently replicated by conventional fire assay using a gravimetric finish, suggesting an issue with the original AAS instrumental finish.

CONCLUSION

The use of BCL methods for the analysis of rock and drill core samples provides information on the amount of cyanide-soluble Au in a sample as a proportion of the Au present when combined with a total analysis of the cyanide tailings. It also provides improvements in the relative precision of Au assays due to the larger sample mass used compared to conventional total analyses, such as fire assay. The use of BCL at an early stage of a project can identify potential issues with Au recovery and highlight areas for focused metallurgical test work. More representative sampling using a larger sample mass often leads to higher Au grades that can more than offset the higher analytical cost with an increase in estimated value.

ACKNOWLEDGMENTS

The author would like to thank Lynda Bloom for a thoughtful review of the original submission. While the present manuscript has certainly benefited as a result, the material presented remains the responsibility of the author. I would also like to dedicate this article to the late Ed Dronseika. Ed was always up for a geochemical challenge and usually found a solution (literally!).

REFERENCES

Abzalov, M. 2008. Quality control of assay data: A review of procedures for measuring and monitoring precision and accuracy. Exploration and Mining Geology, 17, 131–144.

Abzalov, M. 2011. Sampling errors and control of assay data quality in exploration and mining geology. *In:* Ivanov, O. (ed.), Applications and Experiences of Quality Control. Intech Open. 611–644.

Cambell-Hicks, C. 1996. Resource estimation and control by cyanide assay techniques. *In:* Proceedings. Randol Gold Form, Olympic Valley, California, April 1996, 19–28.

Cetin, M.C., Altun, N.E., Atalay, M.U. and Büyüktanır, K. 2017. Bottle roll testing for cyanidation of gold ores: Problems related to standardized procedures on difficult-to-process ores. *In:* Proceedings. 3rd World Congress on Mechanical, Chemical, and Material Engineering (MCM'17), Rome, Italy, June 8–10, 2017, Paper No. MMME 148. https://doi.org/10.11159/mmme17.148

Dominy, S.C., Graham, J.C., Esbensen, K.H. and Purevgerel, S. 2024. Application of PhotonAssay™ to coarse-gold mineralisation – the importance of rig to assay optimisation. Sampling Science & Technology, 1, 2–30. https://doi.org/10.62178/sst.001.002

Kianinia, Y., Khalesi, M.R., Abdollahy, M., Hefter, G., Senanayake, G., Hnedkovsky, L., Darban, A.K. and Shahbazi, M. 2018. Predicting cyanide consumption in gold aeaching: A kinetic and thermodynamic modeling approach. Minerals, 8. https://doi.org/10.3390/min8030110

Menne, D. and Revy, T. 1994. Accelerated cyanidation assays using LeachWELL™ 60X – the Bannockburn experience. Proceedings of the AusIMM Annual Conference, Darwin, August 1994, 287–289.

Rate, A.W., Vidot, J., Hamon, R.E., Radford, N.W., Griffin, W.J., Bettenay, L.F. and Gilkes, R.J. 2010. Systematic evaluation of bulk cyanide leach (BCL) parameters affecting extractability of

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metals from soils. Geochemistry: Exploration, Environment, Analysis, 10, 189–198.

Sketchley, D.A. 1998. Gold deposits: Establishing sampling protocols and monitoring quality control. Exploration and Mining Geology, 7, 129–138.

Smee, B.W., Bloom, L., Arne, D. and Heberlein, D. 2024. Practical applications of quality assurance and quality control in mineral exploration, resource estimation and mining programmes: a review of recommended international practices. Geochemistry: Exploration, Environment, Analysis. https://doi.org/10.1144/geochem2023-046

Stanley, C.R. 2007. The fundamental relationship between sample mass and sampling variance in real geological samples and corresponding ideal statistical models. Exploration and Mining Geology, 16, 111–125.

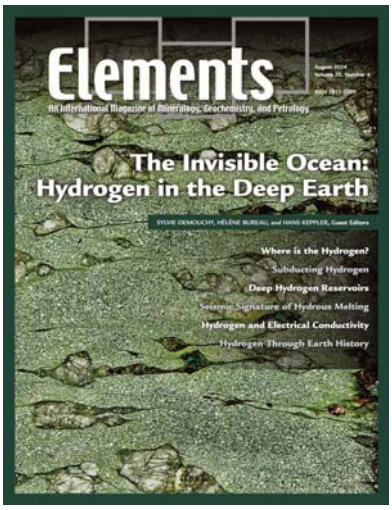
Stanley, C.R. and Lawie, D. 2007. Average relative error in geochemical determinations: Clarification, calculations and a plea for consistency. Exploration and Mining Geology, 16, 267–275.

Stanley, C.R. and Smee, B.W. 2007. Strategies for reducing sampling errors in exploration and resource definition drilling programs for gold deposits. Geochemistry: Exploration, Environment, Analysis, 7, 329–340.

Wang, X. and Forssberg, K.S. 1990. The chemistry of cyanide-metal complexes in relation to hydrometallurgical processes of precious metals. Mineral Processing and Extractive Metallurgy Review, 6, 81–125.

Recently Published in Elements

August 2024, v. 20, no. 4
The Invisible Ocean: Hydrogen in the Deep Earth



This issue of Elements reviews the most notable discoveries constraining the H cycle in the deep Earth. These discoveries include novel techniques for detecting H, insights into the size of deep reservoirs, constraints from inclusions in ultradeep diamonds, advances in seismic and magnetotelluric imaging that afford unique data on the storage and mobility of water in Earth´s interior, and models of the early Earth and of its habitability.

There are three AAG news items in this issue. The first is a bio-sketch of Yulia Uvarova to introduce her as the AAG's new President for 2024–2025. The second is a bio-sketch of Renguang Zuo to introduce him as the AAG's new Vice President for 2024–2025. The third is an abstract for an article that appeared in EXPLORE issue 202 (March 2024), namely "Heavy Mineral Exploration on the Continental Scale" by Alexander T. Walker, Brent I.A. McInnes, Patrice de Caritat, and Evgeniy Bastrakov.

Reminder

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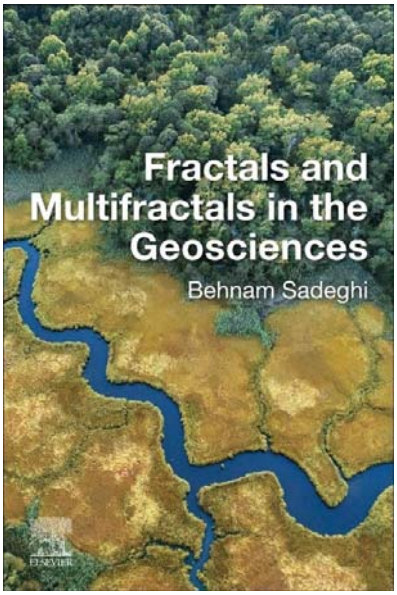
John Carranza

New book release

Fractals and Multifractals in the Geosciences

Behnam Sadeghi

Association of Applied Geochemists Councilor, Dr. Behnam Sadeghi, has recently published a new book with Elsevier, titled *Fractals and Multifractals in the Geosciences*. This book details the application of a wide range of multifractal methods, including the novel methods developed by the author, along with the assessment of uncertainty in sample classification and stability of spatial patterns. It also provides criteria for the selection of the most effective combination of data pre-processing and multifractal modelling to extract desired features or signals in the data. The book specifically aims to introduce, apply, and test novel multifractal models that account directly for changes in relationships between variables, as well as the effects of distance between samples and the source of anomalous metal contents in geoscience samples. Linked to this will be an assessment of the effects of different pre-processing of data prior to the application of the models and quantification/model uncertainty in geochemical anomaly maps, associated with sample classification and spatial interpolation. Also included are a variety of exploration and environmental projects in 2-D and 3-D in Sweden (throughout the country), Cyprus (Southern half of the country), Turkey (Western Turkey) and Iran (Central Iran), on various mineralisation types, including VMS, IOCG, and orogenic gold, using a variety of geochemical samples.



Fractals and Multifractals in the Geosciences will be invaluable for exploration and applied geochemists, urban and environmental geochemists, mathematical geoscientists, geostatisticians, computational geoscientists, data scientists, and GIS professionals, mining engineers, petroleum engineers, exploration geophysicists, mining and petroleum industry decision-makers and stakeholders, who need to better understand fractal geometry, along with its theory and applications in geochemical anomaly targeting that are helpful for decision-making for follow-up sampling and explorations.

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Geochemistry: Exploration, Environment, Analysis

VOLUME 24, ISSUE 3, AUGUST 2024

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https://doi.org/10.1144/geochem2023-068

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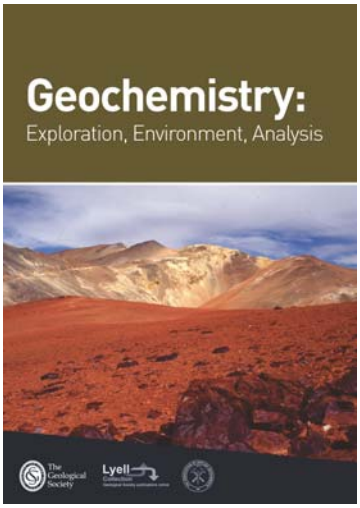
T.P. Junqueira, B. Vriens, M.I. Leybourne, A.L. Harrison, K.V. Sullivan, H. Jeong, and D.F. Araújo
https://doi.org/10.1144/geochem2024-003

Assessing soil contamination by potentially toxic elements in artisanal and small-scale gold mining sites of the Adamawa Region, Cameroon
S.D. Danga, L.E. Nga, T.V. Makhubela, B. Ibrahim, D.L. Bitom and J.D. Kramers
https://doi.org/10.1144/geochem2023-055

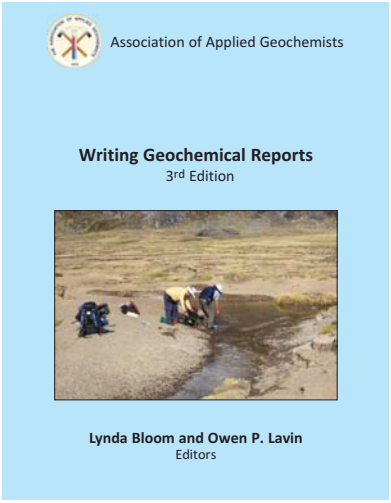


Free Publications Available from the Association of Applied Geochemists' Website

Writing Geochemical Reports, 3rd Edition

Guidelines for surficial geochemical surveys

Edited by Lynda Bloom and Owen Lavin



The Association of Applied Geochemists has developed international standards for writing geochemical reports that provide clear instructions for reporting geochemical results, together with the requisite supporting information to evaluate these results for accuracy, integrity and credibility.

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

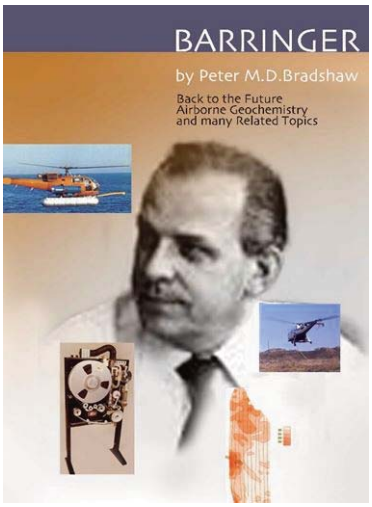
The guide may be downloaded free of charge from the AAG website:

https://www.appliedgeochemists.org/publications

Barringer

Back to the Future: Airborne Geochemistry and many Related Topics

by Peter M.D. Bradshaw



The 1960s and 70s were marked by an explosion in mineral exploration and remote sensing technology. A leader throughout this period was Dr. Anthony (Tony) Barringer and his team at Barringer Research Ltd. (BRL). The highly successful airborne geophysical methods created at BRL are well known while the contributions to exploration geochemistry and many other fields are not. This book documents the many advances in geochemical theory, as well as the ground, airborne and remote sensing techniques plus analytical methods that were conceived and developed under the leadership of Tony Barringer. Innovative concepts backed by pioneering research funded by BRL on the movement of metals in rock, soil and vegetation remain important areas of investigation.

Tony Barringer's ability to bring together a diverse team including geologists, geochemists and physicists with electrical, optical and aeronautical engineers under one roof, provide leadership, a highly stimulating environment and financial support, was truly remarkable. This led to ground breaking advances in a number of different fields, including: exploration geochemistry for minerals and oil and gas; environmental monitoring from the ground, aircraft and space; and civilian and armed forces security. The underlying scientific principles for many of the inventions, now upgraded with modern electronics, are still considered state of the art. One of the many inventions from the BRL "incubator" described in this book is Ionscan, the drug and explosive screening device used in most airports today, which was conceived and developed by BRL in conjunction with technology for the detection of mineral deposits.

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

https://www.appliedgeochemists.org/publications

30th International Applied Geochemistry Symposium (IAGS)

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

Dates to remember

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

Friday August 2, 2024	**Early Bird Registrations Close / Full Price Opens**
Monday October 14, 2024	**Symposium Begins**

Scientific Program

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

Oral Program: https://www.iags2024.com.au/program
Poster Program: https://www.iags2024.com.au/poster-sessions

Field trips

Five pre- and post-meeting field trips are planned:

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

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

Workshops

Twelve workshops are planned, covering a range of interesting topics, including the following:

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

Sponsors

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

Conference fees

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

continued on page 16

IAGS 2024 ... *continued from page 15*

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

N.B. Price is in AUD and includes GST

All Inclusive registration:
Includes 4-day conference and gala dinner

Sponsor/Exhibitor registration:
4-day conference only for Sponsors/Exhibitors

Symposium registration:
4-day conference only

Student registration:
4-day conference

Gala Dinner registration:
Dinner only

Visa information

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

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

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

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

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

or

email iags2024@bie.com.au

CALL FOR AAG MEDAL NOMINATIONS

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

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

3.0 NOMINATIONS

3.1 To be eligible for consideration for either award, nominations must be received by the Chairman of the Awards and Medals Committee on or before December 1st of any year.

3.2 For acceptance by the Awards and Medals Committee, nominations must be signed by a minimum of four (4) Fellows (voting members) of the Association in good standing.
Nominations should include the following:

(a) A one-page recommendation from each of the four nominators;
(b) A resume or curriculum vitae of the nominee;
(c) An itemized list of the outstanding scientific achievements (Gold Medal) or the dedicated service to the Association (Silver Medal) of the nominee (maximum two pages).

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

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

John Carranza
Past President
Chair, Awards and Medals Committee

Welcome New AAG Members

REGULAR MEMBERS

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

Dr Gordon Webb
Consultant Geologist
Minvect Pty Ltd
4 Schurmann Street
Natimuk, VIC
3409 Australia
Membership #4543

Dr Jaime Poblete Alvarado
Associate Professor
Casual Senior Research Assistant/
Exploration Geologist
University of Queensland
5/248 Given Terrace
Paddington, QLD
4064 Australia
Membership #4544

Nametsegang Mothobi
Exploration Geologist, Sandfire Resources
PO Box 151, Sefhare, Ghanzi
Botswana
Membership #4550

Dr Adrienne Brotodewo
Research Fellow
University of South Australia
25 Exeter Tce, Renown Park
South Australia
5008 Australia
Membership #4549

Kath Hodgson
Geologist, Larvotto Resources
22 Basuto Rise,
Brigadoon, WA
6069 Australia
Membership #4548

Steve Tambanis
106 New Street
Brighton, VIC
3186 Australia
Membership #4547

Simon Griffiths
Chief Geochemist
Third Planet Exploration Services Ltd
IWG Castlemead, Suite 335,
Lower Castle Street
Bristol BS1 3AG
Great Britain
Membership #4546

FELLOWS

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

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

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

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

STUDENT MEMBERS

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

Articles in Past Issues of EXPLORE

1 year ago EXPLORE 200 (September 2023)
Portable X-ray Fluorescence (pXRF) detectORE™ analysis for Au in soils from the Archean Pilbara Craton, Western Australia

5 years ago EXPLORE 184 (September 2019)
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

10 years ago EXPLORE 164 (September 2014)
Reproducibility of gold analyses in stream sediment samples from the White Gold District and Dawson Range, Yukon Territory, Canada

20 years ago EXPLORE 125 (October 2004)
A different kind of ore-identifying mine waters suitable for metal recovery

30 years ago EXPLORE 85 (October 1994)
Geochemical exploration for precious metals (Au and PGE) in Gansu Province, China

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

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.

2024

4–6 September .	Discoveries in the Tasmanides. Albury, New South Wales, Australia. Website: www.minesandwines.com.au
8–12 September	Canadian Mineral Analysts Conference. Kamloops, British Columbia, Canada. Website: https://2024cma.com
13–14 September	Denver Mineral Exploration Symposium 2024. Denver, Colorado, USA. https://www.explorationsymposium.com
15–18 September	Interfaces Against Pollution 2024. Torino, Italy. Website: www.iap2024torino.it/iap-2024-torino
15–19 September	September 12th International Conference on the Analysis of Geological and Environmental materials, Geoanalysis 2024. Wuhan, China. Website: geoanalysis 2024.acount.org
16–20 September	13th International Conference on Acid Rock Drainage (ICARD 2024). Halifax, Nova Scotia, Canada. Website: icard2024.cim.org/
22–25 September	GSA Connects 2024. Anaheim CA USA. Website: community.geosociety.org/gsa2024/home
27–30 September	Society of Economic Geologists, SEG 2024 Conference. Windhoek, Namibia. Website: segweb.org/SEG-2024/SEG-Conference/SEG-2024/Home.aspx
2–4 October.	Mongolia Mining 2024. Ulanbataar Mongolia. Website: mongolia-mining.mn
6–9 October	MS&T24: Materials Science &Technology. Pittsburgh PA USA. Website: www.matscitech.org/MST/MST24
14–18 October	30th International Applied Geochemistry Symposium (IAGS). Adelaide SA Australia. Website: iags2024.com.au
20–24 October	Gold24 International Symposium. Perth, Australia. Website: https://www.aig.org.au/events/gold24-international-symposium/
20–24 October	Ross International Symposium: Geochemistry for sustainable development, SIPS 2024, Crete, Greece. Website: flogen.org/sips2024/

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CALENDAR OF EVENTS

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2024 continued

7–9 November	International Conference on Geology and Earth Sciences. Bali, Indonesia. Website: icges.org
13–16 November	Geological Society of America (GSA) 2024 Annual Scientific Meeting, Seattle, Washington, USA. Website: gsa2024.org
22–24 November	Seventh International Workshop on Environment and Geoscience (IWEG 2024). Shanghai, China. Website: www.iwegconf.org
25–28 November	Mediterranean Geosciences Union Annual Meeting. Barcelona, Spain. Website: 2024.medgu.org
1–6 December	American Exploration & Mining Association (AEMA) Annual Meeting. Reno ,Nevada, USA. Website: tinyurl.com/yuf7yk8m

2025

20–23 January	Association of Mining and Mineral Exploration BC (AMEBC) Cordilleran Round Up Convention, Vancouver, British Columbia, Canada. Website: roundup.amebc.ca
2–5 March	Prospectors and Developers Convention, Toronto, Canada, Website: pdac.ca/convention
2–7 March	European Winter Conference on Plasma Spectrochemistry. Berlin, Germany. Website: ewcps2025.de
20–21 March	GEMS 2025 - International Conference on Geology Engineering and Marine Sciences. Wuhan, China. Website: gems.isgcpi.com/
27 April – 2 May	European Geosciences Union, EGU, EGU 2025 - European Geosciences Union General Assembly. Vienna, Austria, Website: egu25.eu/
6-11 July	Goldschmidt 2025 Conference, Prague, Czech Republic. Website: https://conf.goldschmidt.info/goldschmidt/2025/meetingapp.cgi
16–21 July	Third IAGC International Conference (IAGC-3), Cagliari, Italy. Website: https://www.unica.it/wri-18/
3–7 August	18th SGA Biennial Meeting. Golden. Colorado USA. Website: sga2025.org
8–12 September	Eurosoil 2025. Seville, Spain. Website: soilscience.eu/eurosoil-2025

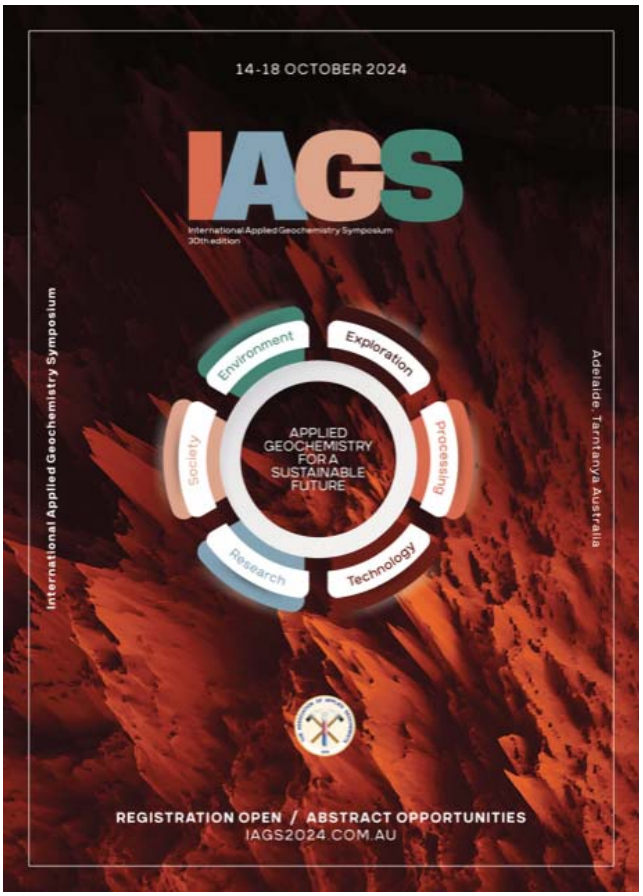
The status of the meetings was confirmed at the time of publication, but users of the listing are strongly advised to carry out their own research as to the validity of an announcement.

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

Ray Lett, Email: Raylett@shaw.ca

or

Elizabeth Ambrose, Email: eambrose0048@rogers.com



EXPLORE Publication Schedule

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

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

March newsletter: January 15 June newsletter: April 15
September newsletter: July 15 December newsletter: October 15

- **Manuscripts** should be double-spaced and submitted in digital format using Microsoft WORD®. Articles should be between 2000 and 3000 words. Do **not** embed figures or tables in the text file.
- **Photos** (colour or black and white) should be submitted as separate high-resolution (minimum 300 dpi at the scale of reproduction) PNG, TIFF, JPEG or PDF files.
- **Figures** should be submitted as separate EPS, PDF or original software (e.g. CDR, AI) files.
- **Tables** should be submitted as separate digital files in Microsoft EXCEL® format (i.e. XLS).
- All scientific/technical articles will be reviewed. Contributions may be edited for clarity or brevity.
- Formats for headings, abbreviations, scientific notations, references and figures must follow the Guide to Authors for *Geochemistry: Exploration, Environment, Analysis* (GEEA) that are posted on the GEEA website at: https://www.geolsoc.org.uk/geea-authorinfo
- An **abstract** of about 250 words must also be submitted that summarizes the content of the article. This abstract will be published in the journal ELEMENTS on the home page at https://www.elementsmagazine.org.

Submissions should be sent to the Editor of **EXPLORE**:
Beth McClenaghan
Geological Survey of Canada 601 Booth Street, Ottawa, ON, CANADA K1A 0E8
Email: bethmcclenaghan@sympatico.ca

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