

Why minus 80 mesh?

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The Editor wrote, "I am wondering if you know the history behind the selection of -80 mesh as the size for soil geochemistry?" I replied that I had heard two stories, both relating back to the early days (1950s) of John Webb and his students from Imperial College, London, working in Zambia:

1. It was the only size of bolting cloth they could get from Johannesburg; and,
2. It was a compromise good for both residual soils and stream sediments. That fraction contained both clays and fine grained weathering products, as well as slightly coarser fine fraction minerals. It tended to reduce the amount of 'diluent' quartz.

It turns out that both of those reasons are true, but are not the whole story, which is much more interesting and involves the development of geochemical prospecting methods for both soils and stream sediments at the U.S. Geological Survey (USGS) during the 1940s and 1950s.

Herb Hawkes wrote up his memories of the start of geochemical prospecting studies at the USGS in his address to the Association's Appalachian regional meeting in Fredericton in 1976 (Hawkes 1976). As a response to a request for innovative project proposals from the USGS Chief Geologist in 1944 he, Helen Cannon and Lyman Huff made proposals to investigate geochemical and geobotanical prospecting methods. These were accepted and funds were provided in the 1946-47 budget to form a Geochemical Prospecting Research Group. They were joined by other USGS members including Hal Bloom, Frank Canney, Tom Lovering and V.P. (Pete) Sokoloff, amongst others (Hawkes 1996). Both Bert Lakin and Fred Ward, analytical chemists, joined at that time from the U.S. Department of Agriculture's Bureau of Plant Industry. Sokoloff was born in Tomsk, Russia in 1905, and came to the U.S. following the 1917 Revolution. He likely gained a degree in chemistry from the University of Arizona, and followed with a PhD in pedology from UC Berkeley in 1937 (Branagan 2007). He then worked for the U.S. Department of Agriculture before joining the USGS's Military Geology Unit, led by C.B. Hunt in 1943. When the geochemical prospecting research group was formed in 1946, he was a natural addition. His knowledge of Russian was invaluable in the light of the founding prospecting work of Russian geochemists in the 1930s and 40s, and he undertook the translation of several of their publications.

One of the Russian papers was 'Geochemical Methods of Prospecting for Ore Deposits' by Sergeev (1941). The soil sampling and preparation procedure described is clearly 'whole soil', i.e. the <2 mm fraction, which was pulverized to about 200 mesh (0.074 mm). Soil scientists have traditionally defined soil as material finer than pebbles, the dividing line between pebbles and sand being 2 mm diameter. Some sixteen years later Ginzburg (1957) wrote "... 1951 Manual of Metallometric Survey and 1955 MG and ON Manual differ in their recommendation of the particle size to be tested (in 1951: <1 mm; in 1955: <0.6 mm) which is assumed to be the same for any kind of ore". The sample material was pulverized to <0.1 mm prior to analysis. In Beus & Gregorian (1975), all the examples of the analysis of different soil and stream sediment sample size fractions are from studies outside of Russia. From this, it has to be concluded that 'minus 80 mesh' was not something learnt from the Russian literature.

Looking at African examples, Roberts (1953) describes field work undertaken in 1948 and 1949 in Nigeria and the analysis of 50 g aliquots of 'whole soil' containing fragments up ½ inch across. In the same area in late 1951, Hawkes (1954) sampled soils and the minus 80 mesh fraction was analysed following methods described by Bloom & Crowe (1953).

Thus, the focus returns to the USGS and the Geochemical Prospecting Unit (Hawkes 1976). The following text describing activities following formation of the Unit in 1946 is relevant "However, experiments in mining areas conveniently located with respect to the Survey's laboratory in Denver suggested that it [geochemistry] might be a very powerful ore guide when used on stream sediments. The idea of using traces of ore metals in stream alluvium as an ore guide had been investigated by Lovering et al. (1950) several years earlier in the San Manuel district of Arizona, which at that time had not been contaminated with mine dumps. In my own experimental work with this method near Denver, the fact that all the samples I took were contaminated to a greater or lesser extent from dumps and mine drainage was not appreciated as a major problem at that time. What was appreciated was that stream sediment sampling appeared to be a completely new approach to primary prospecting of virgin areas that might lead to spectacular discoveries".

This latter statement is somewhat surprising as Russian geochemists had demonstrated the effectiveness of heavy mineral¹ surveys using stream sediments (Fersman 1939), but perhaps at the time, 1947-48, the USGS translation had not been completed.

Hawkes' own work in Tennessee undertaken in December 1947 (Hawkes & Lakin, 1949) focused on residual clay

¹ 'shlikh' in Russian.



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September newsletter: July 15

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Figures and/or photos (colour or black and white) should be submitted as separate .eps files. Alternate file formats include high resolution (2400 dpi or higher) tiff, jpeg or PDF files.

Tables should be submitted as separate digital files in Microsoft® EXCEL format.

All scientific/technical articles will be reviewed. All 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.geolosc.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 fourth and final **EXPLORE** issue of 2019. This issue features two articles. The first describes the history behind the use of the -80 mesh fraction for geochemical analysis by Bob Garrett. The second reports on a geochemical study of the Precambrian basement complex rocks in southeastern Nigeria by C.U. Ibe, S.C. Obiora, and T.C. Davies. This research article is published in **EXPLORE** as a requirement for the 2016 analytical support received by the senior author as part of the Association of Applied Geochemists Student Support Initiative.

EXPLORE thanks all those who contributed to the writing and/or editing of the four issues in 2019, listed in alphabetical order: Steve Amor, Dennis Arne, Al Arsenault, John Carranza, David Cohen, Steve Cook, David Corrigan, Patrice de Caritat, Theo Davies, Benedetto De Vivo, Travis Ferbey, Bob Garrett, Tomás Grijalva, Stew Hamilton, Dave Heberlein, David Leng, Ray Lett, Matt Leybourne, Leslie Logan, Tom Meuzelaar, Paul Morris, Ryan Noble, S. Obiora, Mike Parkhill, Madhu Raghav, Walid Salama, Steve Smith, Brian Townley, Ibe Chinedu Ibe, Pim van Geffen, Ron Yehia, and Renguang Zuo.

In this last issue of 2019, **EXPLORE** gratefully acknowledges our advertisers for their continuing financial support. Below is the team that has provided readers with four excellent issues this year. We wish all AAG members and other readers of **EXPLORE** a successful year in 2020.

Beth McClenaghan, Editor

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Steve Amor, Calendar of Events

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John Carranza, *Elements* content

Steve Cook, President's Letter

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Beth McClenaghan, Editor

President's Message



This is my final Presidents message to you, the members of the AAG, before the end of my term of office on December 31. It has been an honour to have led the Association over the past two years, treading the ground previously occupied by the many notable geochemists who have gone before me over the past half-century. I am very pleased to be able to pass the baton into the very capable hands of Dennis Arne, who will serve as President for 2020-2021. Dennis, who is resident in Victoria, Australia, has had a distinguished global geochemical career in academia, mineral exploration and consulting, and I am confident that he will bring a great deal of energy and vision to the office.

In reviewing the events of the past two years, we have seen both encouraging highs and sad lows. The high point, without question, was the successful 28th IAGS (International Applied Geochemistry Symposium) held in Vancouver in June 2018 as part of the wider Resources for Future Generations (RFG 2018) conference. Considering our relatively modest membership relative to other societies, the AAG certainly punched above its weight class in contributing to the conference. An excellent slate of technical sessions and short courses, warm and sunny weather, a spectacular venue and the unique Gala Dinner setting at the Vancouver Aquarium all contributed to the success of the meeting, which was ably organized by a hardworking LOC headed by Peter Winterburn. I was pleased to award two Gold Medals of the Association to Stu Averill and for Reijo Salminen at the Gala Dinner, and a Silver Medal to David Cohen. The IAGS was and is the flagship event of the AAG, but was by no means the only one over the past two years. First, the AAG was a co-sponsor of the PACRIM 2019 (Mineral Systems of the Pacific Rim) congress in Auckland, New Zealand, which was held April 3-5 of this year. Here, the AAG sponsored an exploration geochemistry session as well as a day-long exploration geochemistry workshop. AAG Fellows were sponsored to variously give keynote presentations on exploration geochemistry, chair sessions and run the geochemistry workshop. Secondly, the AAG also sponsored the recent Australian Institute of Geoscientists (AIG) applied mineralogy in exploration seminar in Perth, Western Australia on April 9, 2019.

In addition to these events, there have been several other positive developments. We welcomed a new Editor-in-Chief, Dr. Scott Wood, for our journal **Geochemistry: Exploration, Environment, Analysis** (GEEA) last year, and for the first time we now have a regional councilor for Mexico, Tomas Israel Grijalva Rodriguez of the Mexican Geological Survey (SGM). Our Association remains on a solid financial footing, and both our website and our newsletter, **EXPLORE**, continue to provide AAG information and technical articles to geochemists and other geoscientists. The website, for example, now hosts downloadable pdf files of the abstract volumes for all previous symposia of the Association.

Conversely, the past few years have also seen the passing of several prominent members of the geochemical community. Professors Ian Nichol, Gerry Govett, Kurt Kyser and Peter Winterburn, for example, were all individuals who had, in different eras, played leading roles in the education of upcoming generations of geochemists. They had also all played prominent roles in the activities of the AAG over the years, variously as Presidents, Councilors, journal editors and symposia chairs. In the cases of Kurt and Peter, they left us far too early; an obituary for Peter is contained elsewhere in this issue.

Looking ahead now to the events of the coming year, planning is well underway for the upcoming 29th IAGS in Viña del Mar, Chile, to be held November 8-13, 2020. We will be sponsoring this event in collaboration with the Sociedad Geologica Chilena (SGCh). The theme is "Facing the challenges of today using applied geochemistry". Local organizing committee President Brian Townley (Universidad de Chile) and his team have put together a comprehensive program of technical sessions, workshops and field trips for a geologically spectacular part of the world. The Second Circular is now available at the symposium website at iags2020.cl, and I would encourage everyone to check it out at your earliest opportunity. More broadly, the upcoming Council term is a particularly significant one given that 2020 will be the 50th anniversary of the founding of the Association, in 1970, as the Association of Exploration Geochemists (AEG). It will mark the close of our first half century, but more importantly it will also mark the beginning of our next 50 years. We

face a number of challenges, some of which I outlined in my inaugural Presidents Message in 2018 – increasing our relatively stable membership, widening the involvement of Members and Fellows in the running of the Association, sustainable expansion of our educational research support for the next generation of geochemists and, very importantly, helping to ensure that those interested men and women in all countries have the opportunity to pursue careers as applied geochemists. Challenges these may be, but I am confident that we will be able to meet them, and I look forward to continuing to work, as Past President, with the new President and Council over the coming two years.

Bruno Lemière, Ph.D Geochemist

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Stephen Cook



Why minus 80 mesh?... *continued from page 1*

soils associated with zinc deposits. No details are provided concerning sample preparation, only a statement that samples were taken with a soil auger “consisting of three or four small fragments of clay weighing in all about 5 grams”. Lakin *et al.* (1949) report “Pulverize this small sub-sample in an agate or mullite mortar to an impalpable powder and take a sample for analysis”. So this work involved no particular size fraction, it was pulverized ‘whole soil’, and that soil was dominantly clay.

The work that Lovering *et al.* (1950) undertook in winter 1947-48 in Pinal County, Arizona, involved the sampling of soil and stream alluvium, sieve analysis, and the subsequent analysis of the sieve fractions. Samples “were taken and separated into fractions representing coarse fragments (2.0 to 0.208 mm, +80 mesh) coarse fragments ground fine, and fine fragments (less than 0.208 mm)”. It should be noted that 0.208 mm is the largest particle size to pass [diagonally] through a 180 μm wire cloth sieve, i.e. 80 mesh (Table 10-13, p. 987; CRC 1972). The authors report, “The use of the fine fractions for sampling has two advantages: it concentrates the copper content and avoids grinding”, and “In the routine sampling only the fraction less than 80 mesh in diameter was collected”. Lovering *et al.* (1950) concluded “The most favourable geochemical approach appears to be studies of the copper dispersion in soils and alluvium. Samples of alluvium more than one mile downstream from the outcrop show a significant copper anomaly. The dispersion can be traced most easily by sampling only the fine fraction, because the copper tends to concentrate in the silt and clay fraction”.

Subsequent papers by USGS geochemists report using the minus 80 mesh fraction for their studies, e.g., Canney *et al.* (1953) – for Co in 1953; and, Kennedy (1952) – for Pb, Zn in 1948-50. More importantly, analytical method papers were of great importance in spreading the geochemical prospecting methodology and the use of the minus 80 mesh fine fraction. Huff (1951) stated “The writer has used the following two procedures for sample preparation: A. Collect 100 to 500 grams of the material, dry, and sieve through a stainless-steel sieve with 2.0-mm openings. Crush fines in an iron mortar to a powder. B. Collect 100 to 500 grams of the material, dry, sieve through a stainless-steel with 0.2-mm openings (80-mesh sieve). Do not crush. Two possible alternatives are suggested for the method of measuring the amount of sample to be digested. Weighing the sample is accurate but is not as quick as measuring with a volumetric scoop. The writer usually uses a scoop having a capacity of 0.25 cu cm that is made by drilling a small cavity, which will hold about $\frac{1}{3}$ gram of soil, in a plastic bar”. A similar measurement procedure is described by Bloom (1955) “Lucite scoop. A Lucite bar, about $\frac{1}{2}$ in by $\frac{3}{8}$ in by 3 in, drilled at one end to contain about 0.1 g of minus 80 mesh soil”.

Lakin *et al.* (1952) refer to the Hawkes & Lakin (1949) paper and the use of ground ‘whole soil’, and the Lovering *et al.* (1950) paper and their use of the minus 80 mesh fine fraction, and the requirement for 2 mm and 80 mesh sieves. Summarizing USGS work, Hawkes (1957) stated “The size fraction of the soil [or sediment] used for analysis may make some difference in the significance of the data. In some problems it has been found that the metal content of the fine fraction was somewhat, but not greatly, higher than the coarse fraction. In other experiments no significant variation with size was apparent. The standard procedure for Geological Survey work has been to collect the fines (minus 80 mesh) for analysis and discard the coarse fraction. This avoids the need of grinding the sample before analysis and may cut down erratic data resulting from possible coarse fragments of oxidized ore minerals such as lead carbonate and malachite. An alternative procedure is to collect all sizes less than 2 mm in diameter and grind before analysis. This procedure may be preferable where the soil lacks an appreciable proportion of fines or where the ore metal is concentrated in the coarser sizes”.

From the foregoing it is suggested that minus 80 mesh was introduced by Tom Lovering in his soil and stream sediment orientation survey undertaken in the winter of 1947-48 in Arizona (Lovering *et al.* 1950). The analytical procedure used by Hy Almond (the analyst in the Lovering-Huff-Almond team) to determine Cu in the soils and alluvium was from soil science (Holmes 1945) and called for the analysis of minus 100 mesh (<0.15 mm) material ground from the less than 2 mm fraction of the soil. Perhaps, in discussion between the three colleagues, Lovering, Huff and Almond, it was Almond who suggested that the minus 80 mesh fraction would provide sufficiently homogeneous material for analysis. As previously noted, the largest particle that will pass through an 80 mesh sieve is 0.208 mm, and 0.208 mm is close to an order of magnitude less than 2 mm. Perhaps it was this logic that caused them to take a Tyler² 80 mesh screen to the field and investigate the less than 0.2 mm fraction. They found it effective and easily implemented without the need for grinding – and as they say, ‘the rest is history’.

In early 1952, John Webb travelled to the U.S. and Canada and with Herb Hawkes they undertook a six week tour of commercial and academic geochemical exploration projects. They also visited Harry Warren and Robert Delavault at the University of British Columbia (Hawkes 1976; Howarth 2010). This visit was the beginning of a long association that led to the publication of the classic geochemistry textbook ‘Geochemistry in Mineral Exploration’ written by Hawkes & Webb in 1962. When Webb returned to Imperial College in London, he prepared a report on this visit (Webb 1953) that was delivered orally at the Institution of Mining and Metallurgy in December. There he stated “The dry sample is sieved and tests have shown that the minus 80 mesh fraction is generally satisfactory”. Brotzen *et al.* (1967) reported “A geochemical prospecting course by J.S. Webb and H.W. Lakin at Imperial College, London, in 1953, and the Oslo conference in 1953

² The Tyler (1910) 80-mesh screen has a nominal opening of 0.175mm, the ASTM (1961) 80 mesh has a nominal 0.177 mm opening. The nearest BSS (410/1969) sieve is 85 mesh with a nominal opening of 0.180 mm. In practice, any of these sieves would prove adequate and may be considered equivalent

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of the OEEC [Organization for European Economic Cooperation] Technical Assistance Project 144 (Webb & Lakin) were events that greatly influenced the acceleration and development of geochemical prospecting in Fennoscandia. Their influence was probably most conspicuous in Norway, where at the time, the application of geochemical prospecting was less advanced than in Finland and Sweden". And so the wheel turned, it was from Sweden that knowledge of the potential of geochemical prospecting, dominantly biogeochemical surveys, had first spread to North America through Nils Brundin and Hans Lundberg in the 1930s and kindled interest there.

The work of John Webb and his students in Africa carried the analytical methods and use of the minus 80 mesh fraction developed by the USGS to that continent, where quite possibly "It was the only size of bolting³ cloth they could get from Johannesburg". Concerning the validation of the selection of the minus 80 mesh fraction by soil and stream sediment orientation surveys, Lovering's work is the first example. The highly successful prospecting campaign undertaken by Hawkes *et al.* (1960) in New Brunswick and Québec, Canada in 1954 and 1955 using the Bloom (1955) test for exchangeable heavy metals was another, where "... after drying, the samples were passed through a non-contaminating sieve, the coarse fraction discarded, and the fines [presumably minus 80 mesh] placed in a properly numbered coin envelope pending analysis", where a scoop was used to measure an aliquot for analysis. Orientation work was limited to determining dispersion train lengths, work around known mines and prospects demonstrating dispersion trains several miles long, and "... it was arbitrarily assumed that a given sample would not fail to indicate the presence of a base-metal deposit in the drainage basin if that deposit occurred within two miles of the sample site". It was this work that led to the recognition of areas of low and high geochemical relief, with the latter being associated with base-metal mineral potential. This in turn greatly promoted the execution of reconnaissance regional geochemical surveys, often using the Bloom test in the field to guide exploration. This was the author's introduction to the art and science of geochemical prospecting in Cape Breton Island, Nova Scotia, as a summer field assistant in 1962.

Subsequently, several studies in Africa were undertaken by John Webb's Geochemical Prospecting Research Centre (GPRC), later to become the Applied Geochemical Research Group (AGRG). The hypothesis was, where chemical weathering had occurred in these residual soil terrains, together with comminution in stream channels, the fine fraction would contain sufficient material derived from mineralization to be useful for exploration. However, some mineral occurrences composed of resistate minerals, may, on weathering, not yield fine fraction materials; those minerals may be in the coarse fraction of soils and sediments, due to the mineralogy of the occurrence. For example, James (1957) studying chromite deposits associated with the Great Dyke (Zimbabwe) investigated the Cr content of fractions yielded by 20, 36, 80, 135 and 200 mesh sieves. He found that Cr levels were highest in the minus 80 plus 200 mesh fraction, reflecting the size of the chromite crystals in the chromite seams when sampling 12 inches below surface. He concluded that "For most of the work, however, the -80 mesh (minus 0.2 mm) was to be entirely satisfactory", and that "-80 mesh is a practical exploration procedure".

Webb (1958) reported in 1956 on studies in Africa, mostly using the minus 80 mesh fraction. Also included were studies of Pb in soil by depth and size fraction in South Africa, for Cu in Ugandan stream sediments in the minus 80 and 200 mesh fractions, and for total and cold extractable Cu in Ugandan and Zambian stream sediments together with contrasts. He concluded that favourable contrasts exist in the minus 80 mesh fraction, and it is practical in requiring only a single screen preparation.

Debnam & Webb (1960) undertook studies of Be in various size fractions in soils and sediments around pegmatites in Uganda and Zambia. They found maximum levels in soils at 0-3, 12-18 and 24-36 inches and in fractions finer than 0.107 mm. Higher concentrations in surface soils were due to the removal of finer-lighter material by wind and rain. In the minus 80 mesh fraction of stream sediments, dispersion trains were >5 miles with a contrast of >10. They concluded, "... for all practical purposes analyzing the -80-mesh fraction permits the detection of longer dispersion trains than is possible when coarser fractions are examined."

Watts (1960) studied the dispersion of Nb as pyrochlore in soils and stream sediments derived from carbonatites in the Namwala Concession area of Zambia (Webb *et al.* 1964). The less than 20 mesh (1.075 mm) fractions of soils and stream sediments were further fractionated with 28, 82, 125 and 200 (0.076 mm) mesh sieves and the silt (<0.02 mm) and clay (<0.002 mm) fractions recovered. In soils, pyrochlore and Nb are enriched in surface layers by the preferential leaching and elutriation of the soluble and lighter components of the parent carbonatites, maximizing in the fine sand fraction, which was also reflected in the minus 80 mesh fraction. In stream sediments, proximity to a source of pyrochlore was indicated by a relative increase in the proportion of Nb present in the minus 20 plus 200 mesh fraction relative to the minus 200 mesh fraction, and that anomalies related to a significant deposit should be detected by analyzing the minus 80 mesh fraction of samples collected one mile apart.

Webb *et al.* (1964) report on an eastern Canada orientation survey at a regional scale. They note, "During the course of an extensive geochemical mineral reconnaissance carried out in New Brunswick in 1954 (Hawkes *et al.* 1956), broad-scale patterns were observed in the base metal content of stream sediments that appeared to be related to the distribution of the major geological units. As distinct from the local, highly anomalous values related to mineralization,

³ Bolting cloth is a firm fabric, originally woven of silk, used in the production of flour in the food industry. Now more often manufactured out of nylon.

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these patterns were developed merely as minor variations in the level and homogeneity of the background values associated with essentially unmineralized rocks. This observation suggested that multi-metal analysis of stream sediment samples might serve as a basis for compiling regional geochemical maps showing the distribution of the minor elements in relation, not only to mineralization, but to bedrock geology as a whole". In 1957 in southern Zambia, Selection Trust (Namwala Concessions Ltd.) had collected a suite of stream sediment samples, retaining the minus 80 mesh fraction for analysis for Cu, Zn and Ni. However, this work did not identify any economically significant mineral resources, but did "indicate a possible relationship with the bedrock geology". These samples were made available to the GPRC and they were re-sampled to generate a network of low-order stream samples at a density of one site per square mile over the 3,000 square mile (7770 km²) of the study area. These were analysed by semi-quantitative DC-arc spectroscopy for 17 elements along with Zn and cold extractable Cu by colorimetry.

The authors reported:

1. The major geological units are associated with broad-scale patterns of variation in the range and mean concentration levels of several metals, notably, Pb, Zn, Cu, Cx Cu, Ni, Cr, V, Mn and, to a lesser extent, Co and Ti. The patterns are evident in both mineralized and barren formations.
2. In ground underlain by the unmineralized formations, the patterns mostly appear as variations in the level and range of normal background values, and are related to the lithology and composition of the bedrock.
3. In addition to the extensive patterns associated with the major geological units, smaller-scale patterns are also developed in stream sediments draining individual formations and rocks of similar lithology.
4. Despite the generally weak nature of the mineralization, the more strongly mineralized rocks are associated with more or less extensive patterns of abnormally high metal content.

The above studies confirmed the general utility of the minus 80 mesh fraction, and subsequently it was broadly adopted by the geochemical exploration community. Plant et al. (1988) reported on 39 recent regional geochemical surveys covering in excess of 5,000 km²; of these, 23 (59%) employed the minus 80 mesh fraction. Two surveys used the minus 60, 10 surveys used fractions finer than 80 mesh (half of which were finer than 100 mesh), two organic materials, and two were unspecified. Where the minus 80 mesh fraction has not been used there have often been special considerations, such as desert terrain and the presence of fine wind-blown material, mountainous environments with high stream flow rates, and seasonal variation considerations related to monsoonal climates.



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CONCLUSIONS

1. Use of the minus 80 mesh fraction was first proposed by Lovering et al. (1950) of the USGS based on field work around copper occurrences in Arizona in the winter of 1946-47, and was quickly adopted by their colleagues;
2. The widespread adoption of the minus 80 mesh fraction was facilitated by the publication of papers on analytical methods developed by USGS chemists-geochemists specifying the use of that fraction, such as Lakin et al. (1949, 1952), Huff (1951), Bloom & Crowe (1953) and Bloom (1955). These papers, frequently published in *Economic Geology*, were widely read by mineral explorers around the world; and,
3. Orientation surveys, other than the work of Lovering *et al.* were *post-hoc*, studies involving the minus 80 mesh and other fractions. These confirmed the general applicability of the minus 80 mesh fraction as the fraction of choice for both soils and stream sediments in both detailed and regional reconnaissance surveys.

In light of the last conclusion, a final note is offered:

The art and science of exploration geochemistry requires that methods, i.e. the combination of material, size and possibly

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Why minus 80 mesh?... *continued from page 8*

mineralogical fraction, and analytical procedures, that maximize the contrast between background and anomaly be developed and used.

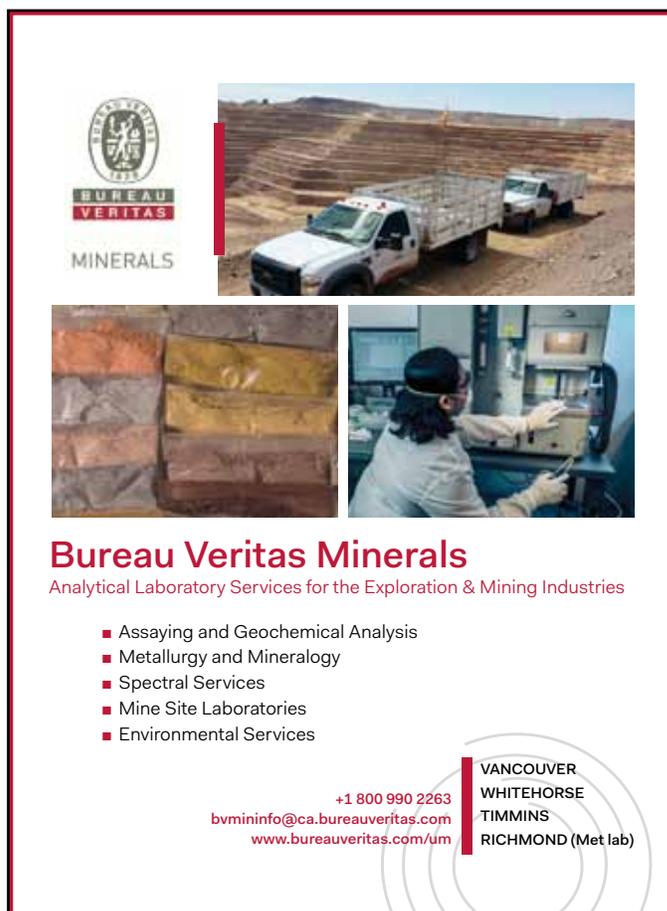
Over the last 70 years the use of the minus 80 mesh fraction for soil and stream sediment analysis has proven effective and led to the successful discovery of primarily base metal mineral resources. However, that does not mean the use of the minus 80 mesh should be taken for granted, as directed orientation work may indicate a more suitable size fraction for specific trace elements and mineralogical conditions, in particular precious metals.

ACKNOWLEDGEMENTS

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Scott Wood, GEEA Editor (left) and Steve Cook, AAG president (right) at the Geological Society of London (GEEA publisher) booth at the Society for Geology Applied to Mineral Deposits (SGA) conference in Glasgow, Scotland in late August, 2019.

AAG Student Support Initiative Publication of Results:

Petrological and geochemical study of the Precambrian basement complex rocks in Katchuan Irruan areas, southeast of Ogoja, Southeastern Nigeria

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INTRODUCTION

Pan-African tectonics and crustal evolution have been the subjects of much discussion over the last thirty years or so (Rahman *et al.* 1988; Ekwueme 1987). The Nigerian Precambrian Basement Complex (Fig. 1) is made up of gneisses and migmatites, weakly migmatized to unmigmatized parashists (also referred to as “Younger Metasediments” or “Schist belts”) and rocks of the Older Granite suite comprising of granite, granodiorite, charnockite (hypersthene granites), syenite, as well as minor gabbroic and dioritic rocks. Unmetamorphosed diabase and rhyolitic porphyry dykes, pegmatite dykes and numerous veins of quartz- feldspathic composition are commonly found in the Basement Complex (Oyawoye 1964, 1970; Rahaman 1976, 1989; Makanjuola 1982; Ekwueme 1987, 1994; Olarewaju 1987; Obiora 2005, 2006).

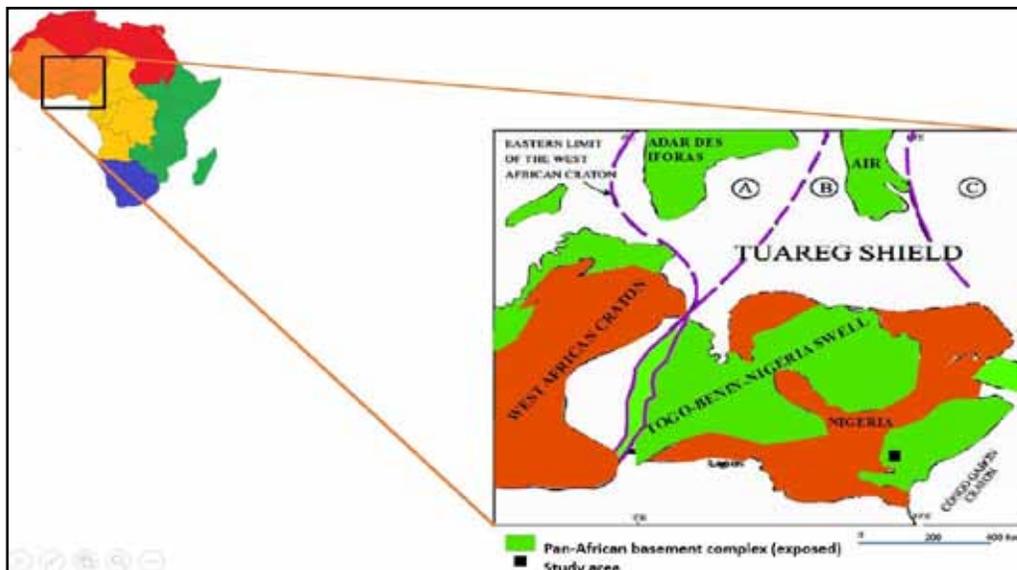


Figure 1. The location of the Precambrian Basement Complex in Nigeria between the West African craton, the Congo-Gabon craton and the southern part of the Tuareg shield (after Ibe & Obiora 2019).

(A) Western part of the Tuareg shield called the Pharusian belt; (B) central part (the Hoggar-Air segment); (C) eastern part (the East-Saharan craton).

The Precambrian Basement Complex rocks in the study area have previously received little attention. Much of the information on the geology of the area is contained in geological maps of Nigeria produced by the Nigerian Geological Survey Agency where it is shown to be underlain by “Undifferentiated Basement”, “Granulites terrain” and “Granitoids” (Nigerian Geological Survey Agency 1994, 2004, 2011). The present study was therefore undertaken to map and delineate the different varieties of rock within the Precambrian Basement Complex in the study area (Fig. 2), as well as to perform detailed petrographic and geochemical studies (major-, trace-, and rare-earth elements, [REE]) on the rocks for their proper classification and assessment of their petrogenesis, provenance and tectonic origin.

REGIONAL GEOLOGY

The study area (Fig. 2) is located within the extension of the Bamenda highlands of Cameroun into southeastern Nigeria, otherwise referred to as the “Bamenda massif”. The Bamenda massif constitutes the southeastern Nigerian Precambrian Basement Complex. The Precambrian Basement Complex of Nigeria belongs to the Pan-African trans-Saharan belt which is located east of the West African craton and northwest of the Congo-Gabon craton (Fig. 1). Based on evidence from the eastern and northeastern margins of the West African craton, it has been observed by previous authors that the Pan-African trans-Saharan belt evolved by plate tectonic processes that involved the collision of the active margin of the Pharusian belt (Tuareg shield) and the passive continental margin of the West-African craton, about 600 Ma (Fig. 1, Burke & Dewey 1972; Leblanc 1981; Black *et al.* 1979; Caby *et al.* 1981). Subduction and consequent collision at the eastern margin of the West African craton (McCurry & Wright 1977) produced extensive melting of the older rock suites resulting in the emplacement of the mainly calc-alkaline granitoids and basaltic intrusions.

A high positive gravity anomaly which occurs in a narrow zone within the Dahomeyide orogen located at the southeastern margin of the West African Craton in Togo and Benin Republic is an evidence of evolution by plate tectonic

Petrological and geochemical study of the Precambrian... *continued from page 11*

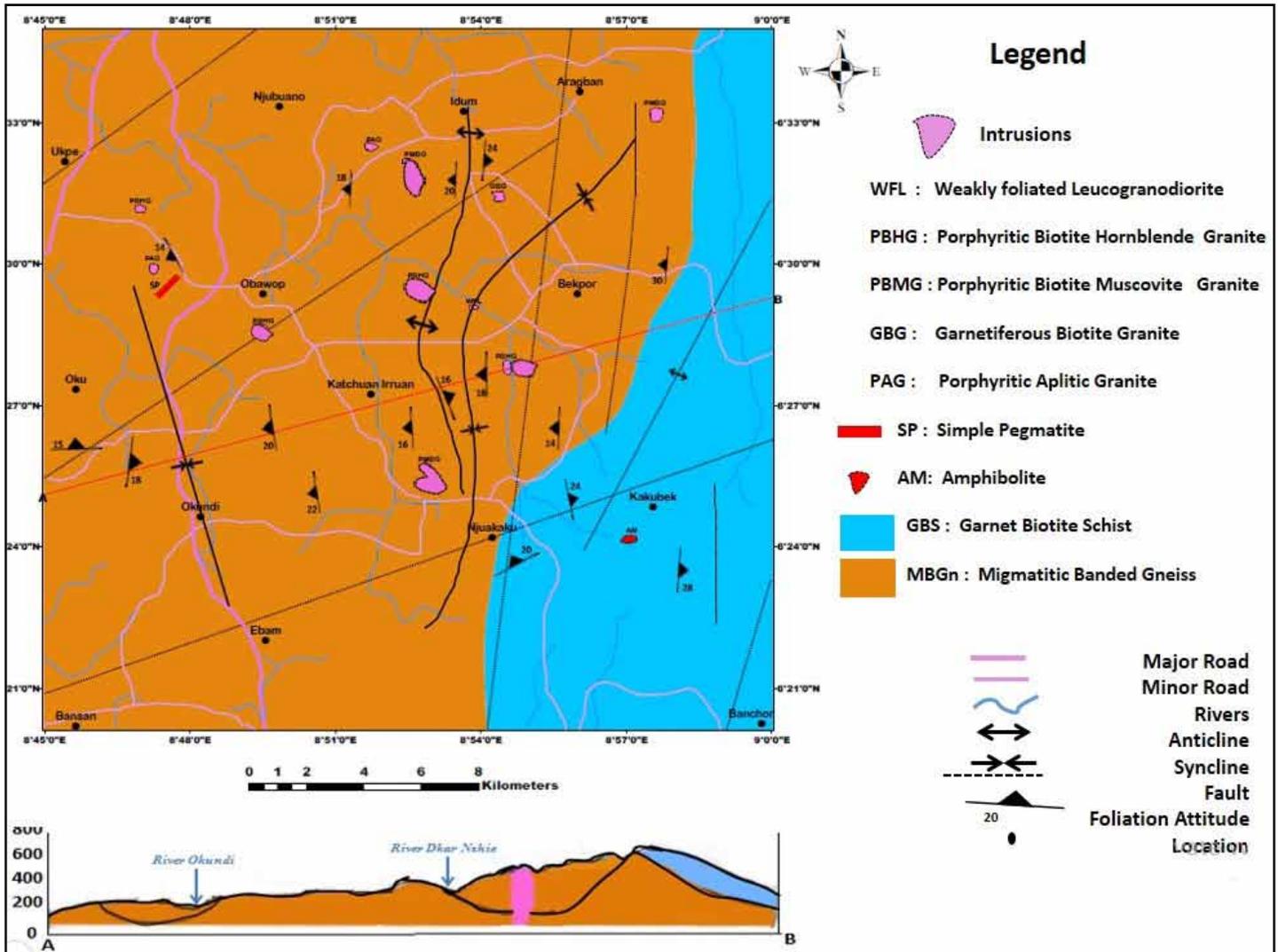


Figure 2. Geological map of the study area.

processes involving the collision of the Pharusian belt and the West African craton (Obiora 2012). The collision at this plate margin is thought to have led to the reactivation and remobilization of the internal region of the Pan-African belt. The Nigerian Precambrian Basement Complex lies within the remobilized part of the belt.

The Nigerian Precambrian Basement Complex rocks are also believed to be the results of at least four major orogenic cycles of deformation, metamorphism, reactivation and remobilization corresponding to the Liberian ($2,650 \pm 150$ Ma), the Eburnean ($2,000 \pm 50$ Ma), the Kibaran ($1,100 \pm 200$ Ma), and the Pan-African cycles (600 ± 150 Ma). Using the International Geologic Time Scale (2002), these ages can be referred to as, "Paleoarchean to Mesoproterozoic (3,600 to 1,600 Ma)" for Liberian and Eburnean, "Mesoproterozoic to Neoproterozoic (1,600 to 1,000 Ma)" for Kibaran and "Neoproterozoic to Early Paleozoic (1,000 to 545 Ma)" for Pan-African.

ANALYTICAL PROCEDURES

Fifty (50) fresh representative samples consisting of twenty four (24) migmatitic banded gneiss (MBGn), six (6) garnet biotite schist (GBS), two (2) amphibolite (Am) and two (2) garnetiferous biotite granite (GBG), four (4) porphyritic biotite muscovite granite (PBMG), three (3) porphyritic biotite hornblende granite (PBHG), three (3) weakly foliated leucogranodiorite (WFL), three (3) porphyritic aplitic granite (PAG), and two (2) simple pegmatite (SP) were selected for geochemical analysis. The samples were crushed in a jaw crusher at the Inorganic Geochemistry Research Laboratory of the Department of Geology, University of Nigeria, Nsukka. The crushed samples were pulverized in a Vibrating Disc Mill. Final size reduction, mixing and homogenization to $< 75 \mu\text{m}$ were done with a Mixer Mill. One hundred grams (100 g) of each sample were thereafter packaged and dispatched to Bureau Veritas Minerals Pty Ltd, Perth, Western Australia courtesy of the Association of Applied Geochemists (In-kind analytical support for major and trace element geochemistry using X-Ray Fluorescence (XRF) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS)).

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The samples were fused with sodium peroxide and subsequently the melt was dissolved in dilute hydrochloric acid for analysis. Due to high furnace temperatures, volatile components were lost. This fusion procedure is particularly efficient for determination of major element composition (including silica) in the samples and for breaking down refractory mineral species for total trace element contents. Boron was determined by Inductively Coupled Plasma-Optical Emission Spectrometry (ICP OES). The samples were cast using a 66:34 flux with 4% lithium nitrate added to form a glass bead. The major elements were determined by X-Ray fluorescence spectrometry (XRF) except for FeO, which was determined volumetrically.

RESULTS

Composition of the gneisses and schists

The gneisses have values of SiO₂ in the range of 57.1 to 73.84 wt.% with a mean value of 67.44%. They contain moderate Al₂O₃ (13.3-16.6 wt.%), low TiO₂ (0.1-1.15 wt.%), MgO (0.06-3.57 wt.%), MnO (0.03-0.14 wt.%) and high K₂O (0.95-5.08 wt.%), Na₂O (2.18-6.69 wt.%) and CaO (0.28-8.26 wt.%) compared to the other rocks. The Fe-number (Fe*) ranges from 3.96 to 13.4 and they are enriched in alumina (12.3-17.1). They are generally quartz, K-feldspar, albite, anorthite, hypersthene and corundum normative.

Trace element data on the rocks from the study area have been normalized to upper continental crust after McLennan & Taylor (1981) and plotted as spidergram (Fig. 3a). The rocks show an overall enrichment of the large ion lithophile elements (LILEs: K, Th, Ba and Rb) and the high-field strength elements (HFSE: REE, Zr, Hf, Y, Th) which usually occur in accessory minerals such as rutile and zircon. The chondrite-normalized REE pattern for the rocks show LREE enrichment relative to MREE and HREE (Fig. 3b). The rocks exhibit a negative Eu anomaly and show inclined MREE and flat HREE (Fig. 3b). Specifically, the Eu-anomalies, expressed as (Eu/Eu*) ranges from 0.03 to 1.4 in the gneisses and from 0.09 to 1.1 in the schist. The fractionation La_N/Yb_N ratios range from 7 to 93 for the gneisses and 1.9 to 46.4 for the schist.

The schists (GMS) have moderate Al₂O₃/(K₂O + Na₂O) values (2.31-3.85), low MgO (3.56-5.91 wt.%) and CaO (0.74 to 2.92 wt.%) contents with MgO exceeding CaO. Contents of K₂O are generally greater than those of Na₂O. In the CIPW norm, Garnet Biotite Schist (GBS) is enriched in quartz. Further discrimination of the sedimentary protolith of the gneisses

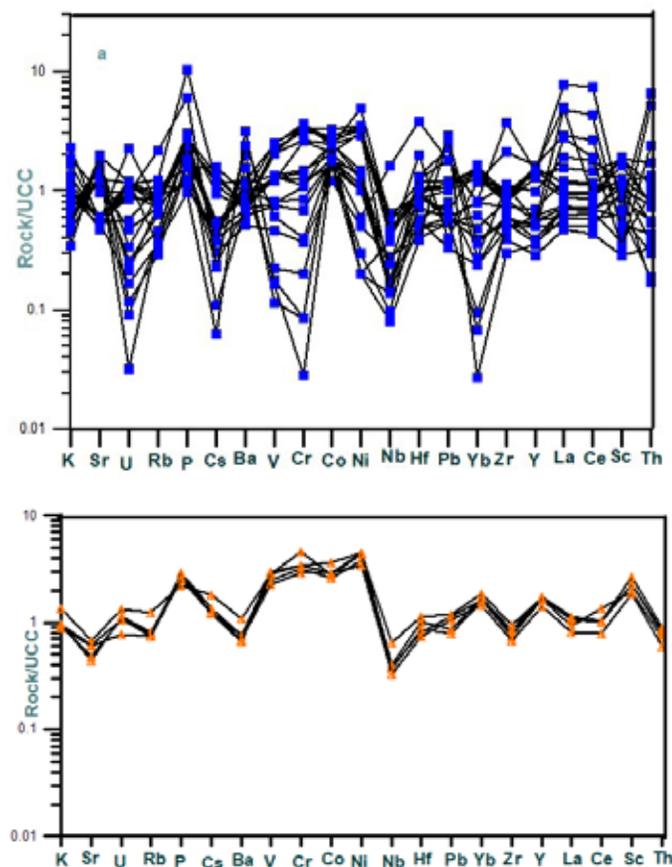


Figure 3. UCC normalized spidergram for the Gneisses (blue) and Schists (brown).

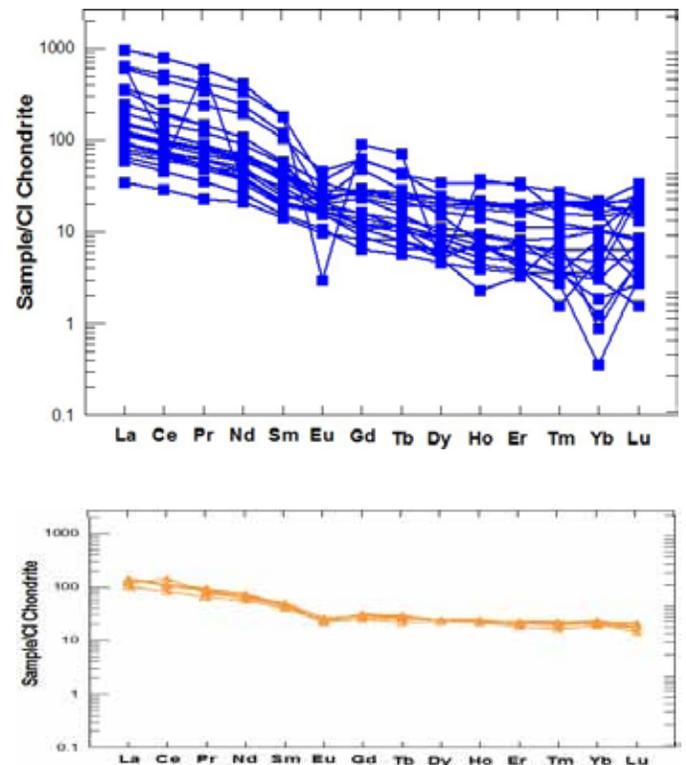


Figure 3b. Chondrite-normalized REE diagrams for the Gneisses and Schists (Symbols same as Figure 3a) (Values from Sun & McDonough 1991).

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and schists, the plot of $\log(\text{Fe}_2\text{O}_3(t)/\text{K}_2\text{O})$ vs $\log(\text{SiO}_2/\text{Al}_2\text{O}_3)$ after Herron (1988) (Fig. 4) was utilized. The gneisses plot in the Fe-shale, Fe-sand and greywacke and arkose regions whereas the schists plot in the shale and greywacke regions.

Provenance of the gneisses and schists

In order to characterize the provenance of the protoliths of the metamorphic rocks in the eastern part of the southeastern metamorphic basement complex of Nigeria, the major-element-based diagram of Roser & Korsch (1988) (Fig. 5) is used because this bivariate plot uses parameters that are largely independent of grain-size effects (sandstone vs mudstone). The discriminant functions of the diagram use Al_2O_3 , TiO_2 , Fe_2O_3 , MgO , CaO , Na_2O , and K_2O contents as variables. These functions discriminate among four sedimentary provenances: P1: mafic, ocean island arc; P2: intermediate, mature island arc; P3: felsic, active continental margin; and P4: recycled, granitic-gneissic or sedimentary source. The gneisses and schists plot on the P2 and P3 fields.

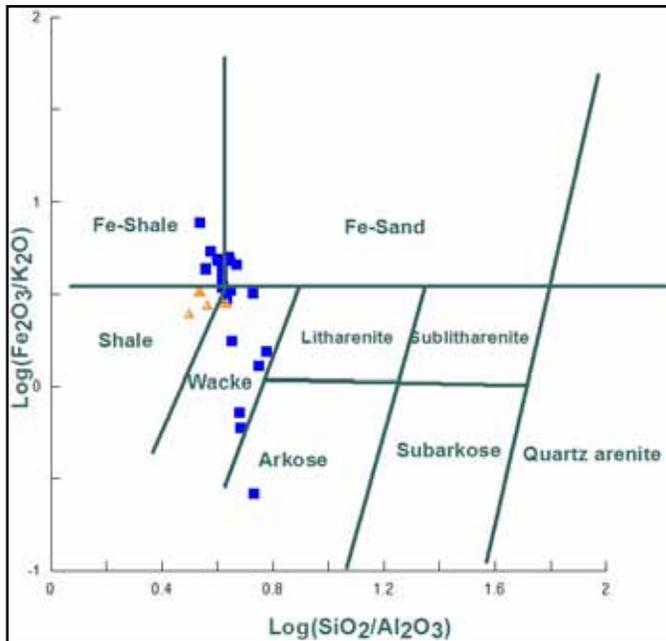


Figure 4. Plots of gneisses and schists on the $\log(\text{SiO}_2/\text{Al}_2\text{O}_3)$ vs. $\log(\text{Fe}_2\text{O}_3(t)/\text{K}_2\text{O})$ diagram of Herron (1988), for the discrimination of sedimentary protoliths.

intermediate, mature island arc; P3: felsic, active continental margin; and P4: recycled, granitic-gneissic or sedimentary source. The gneisses and schists plot on the P2 and P3 fields. P2 would indicate a provenance from a mature island arc, whereas P3 indicate a provenance from active continental margin.

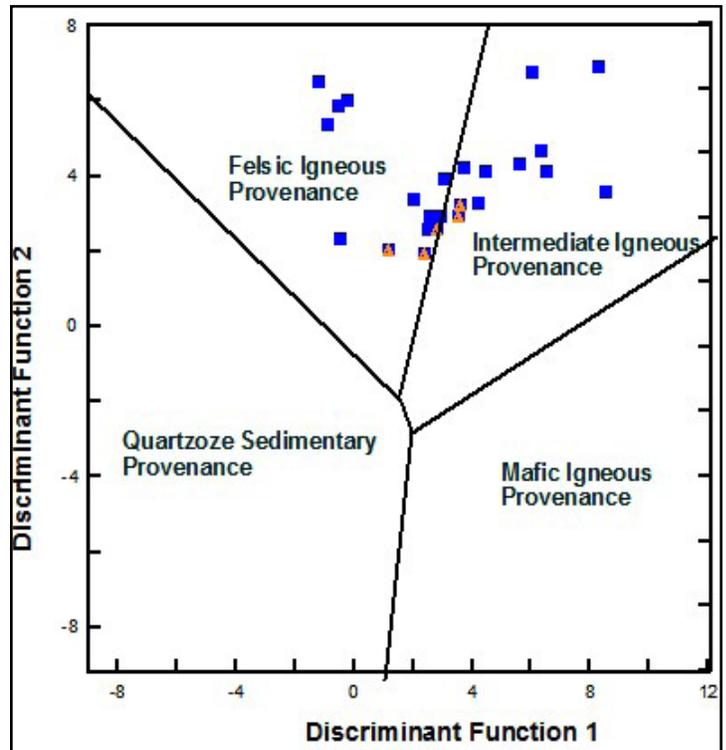


Figure 5. Discriminant function diagram for the provenance signatures of sandstone-mudstone suites after Roser & Korsch (1988).

$$\text{Discriminant function 1} = -1.773\text{TiO}_2 + 0.607\text{Al}_2\text{O}_3 + 0.76\text{Fe}_2\text{O}_3(\text{total}) - 1.5\text{MgO} + 0.616\text{CaO} + 0.509\text{Na}_2\text{O} - 1.224\text{K}_2\text{O} - 9.09$$

$$\text{Discriminant function 2} = 0.445\text{TiO}_2 + 0.07\text{Al}_2\text{O}_3 - 0.25\text{Fe}_2\text{O}_3(\text{total}) - 1.142\text{MgO} + 0.438\text{CaO} + 1.475\text{Na}_2\text{O} + 1.426\text{K}_2\text{O} - 6.9$$

P1- Mafic, First-cycle basaltic and lesser andesitic detritus

P2- Intermediate, dominantly andesitic detritus

P3- Felsic-Acid, plutonic and volcanic detritus

P4- Recycled mature polycyclic quartzose detritus

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Tectonic setting of gneisses and schists

Bathia & Crook (1986) assigned the sedimentary basins to four tectonic settings: oceanic-island arc, continental arc, active continental margins and passive continental margins. Most of the samples plot in the field of active continental margin and continental arc (Fig. 6). In the ternary plot of $\text{La}-\text{Th}-\text{Sc}$ and $\text{Th}-\text{Sc}-\text{Zr}/10$, the gneisses and schists plot in the field of continental arcs and active continental margin (Fig. 6).

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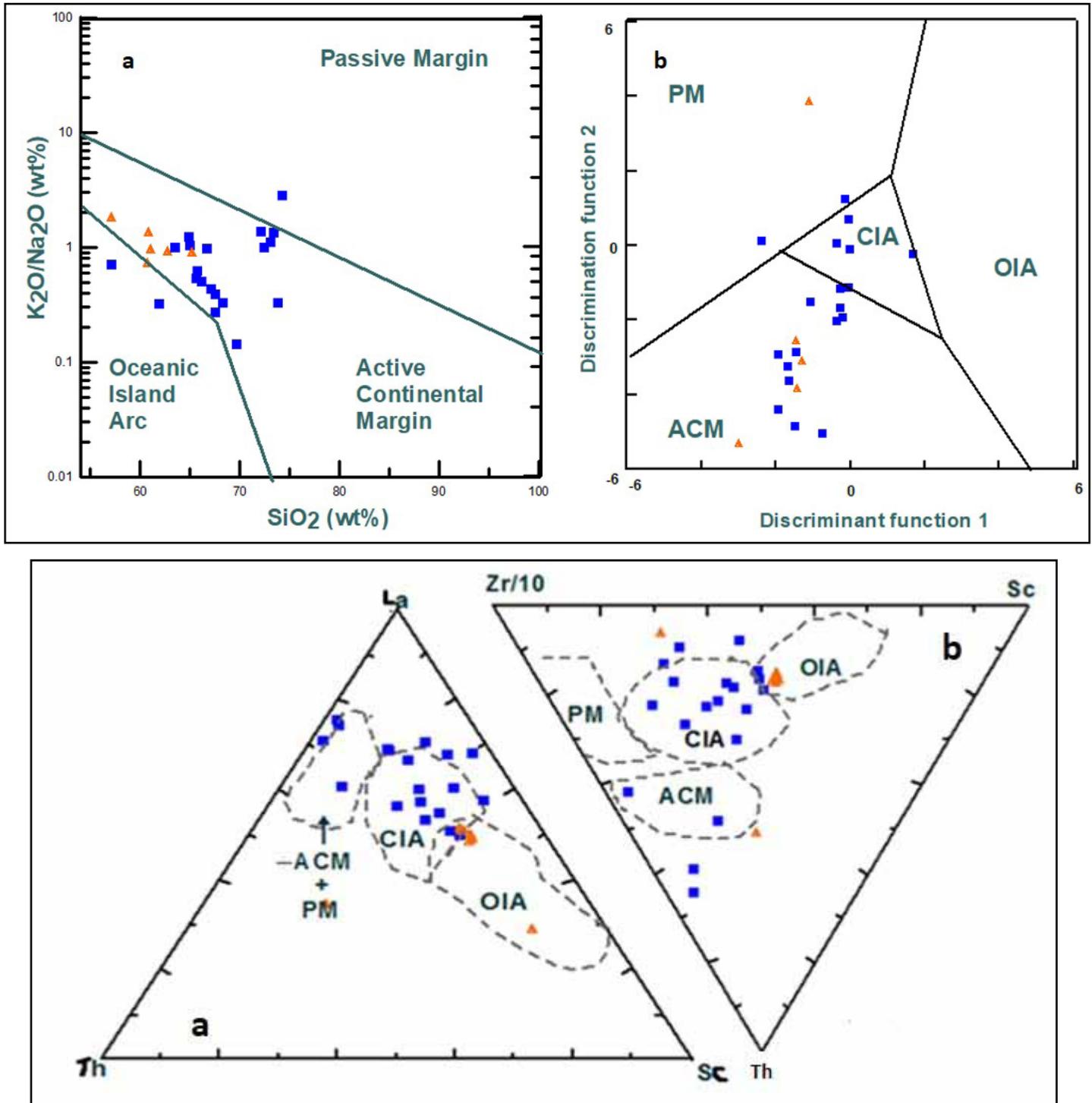


Figure 6. (a) Plot for the tectonic setting of the gneisses and schists in a: Discriminant function diagram (modified after Bathia 1988) for the gneisses and schists. ACM= Active Continental margin, CIA= Continental Island arc, OIA= Oceanic Island arc, and PM= Passive margin.

Composition of granitic rocks

The granitic rocks are generally hypersthene and corundum-normative. They have variable SiO_2 (60.86 to 77.18 wt%), Al_2O_3 (13.6 to 17.5 wt%), Fe^* (1.14 to 12.49 wt%) and alkalis (Na_2O+K_2O) (4.54 to 9.95 wt%) contents. Trace element data on the granitoids from the study area have been normalized to chondrites after Thompson (1982) and plotted as a spidergram (Fig. 7a). The rocks show an overall enrichment of the large ion lithophile elements (LILE: K, Th,

Petrological and geochemical study of the Precambrian... *continued from page 15*

Ba and Rb). HFS elements typically occur in accessory minerals such as rutile and zircon. The samples are relatively enriched in Zr, Hf and Nb indicating the presence of accessory minerals in the rocks.

The granitic rocks also show strong positive anomalies in Th, K, La, Ce, Nd, Sm, Tb and negative anomalies in Ba, Nb, Ta, Sr, Zr and Ti. They also show high concentrations of W and Co which resulted from the vibratory tungsten carbide (WC) disc mill used in preparing the samples but there was no Ca, Ta and Sc contamination, as expected. The granitic rocks exhibit similar REE patterns, relative to chondrite, exhibiting LREE enrichment relative to MREE and HREE, with distinct negative Eu-anomalies ($Eu/Eu^* = 0.23-0.71$), inclined MREE and flat HREE (Fig. 7b). The fractionated, La_N/Yb_N values in the granitic rocks range from 3.04-228.4.

Tectonic setting of the granitic rocks

In the FeO^*/MgO vs SiO_2 diagram of Chappell & White (1974), the granitic rocks plotted within the I and S type fields correlating positively with the shoshonites and syn-collisional granites in the plateau area of the Himalayan. S-type granites originate by partial melting or ultrametamorphism of metasedimentary protoliths (containing Al, Na and K oxides and are said to be peraluminous) observable in the deeply eroded cores of fold-thrust mountain belts formed as a result of continent-continent collisions and are thus syn-orogenic granites. The granitic rocks in the study area plot within the post-collisional (Post-COLG) field on the Rb vs $Y+Nb$ tectonic discrimination diagram after Pearce *et al.* (1984) (Fig. 8).

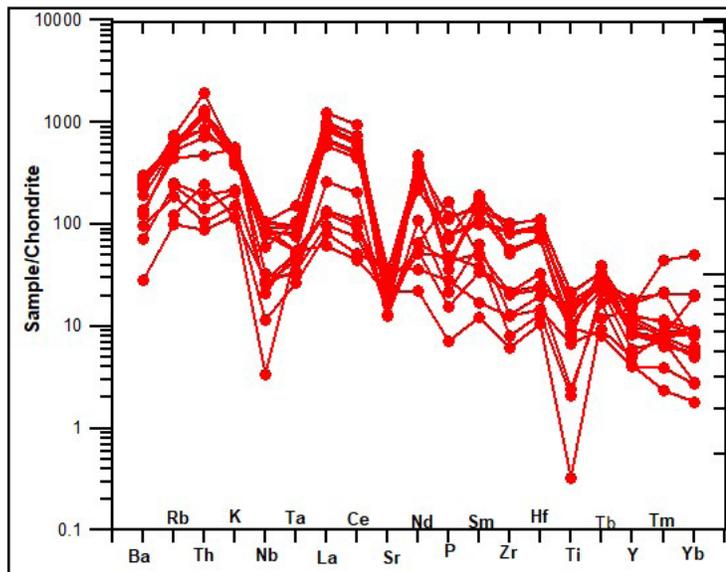


Figure 7a. Chondrite-normalized Spidergram for granitic rocks (values from Thompson 1982).

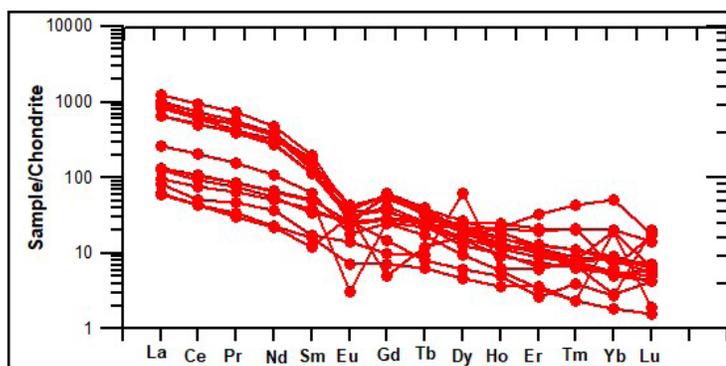


Figure 7b. Chondrite-normalized REE diagram for the granitic rocks (values from Sun & McDonough 1991).

Active continental margins include sedimentary basins of the Andean type, thick continental margins and the strike-slip types. These basins are developed on or adjacent to a thick continental crust composed of rocks of older fold belts and the sediments are dominantly derived from granite-gneisses and siliceous volcanics of the uplifted basement. Based on evidence from the eastern and northeastern margins of the West African craton, it has been observed by previous authors that the Pan-African trans-Saharan belt evolved by plate tectonic processes which involved the collision of the active margin of the Pharusian belt (Taureg shield) and the passive continental margin of the West-African craton, about 600 ± 10 Ma (Burke & Dewey 1972; Leblanc 1981; Black *et al.* 1979; Caby *et al.* 1987; Obiora 2006, 2012). Evidence of this collision includes the presence of basic to ultrabasic rocks believed to be remnants of paleo-oceanic crust that are characteristic rocks of an ophiolitic complex arc. In this context, the sources for the sediments may have derived from the obducted continental arc of the Tuareg shield. Crustal melting occurred towards the end of the collision between the active continental margin of the Tuareg shield and the subducted oceanic crust which is believed to have reactivated the internal region of the Pan African belt forming the Pan African granites.

The moderate to high fractionations with pronounced negative Eu anomalies shown in the REE pattern for the granitic rocks is a typical behavior of crustal-generated granites and suggest either the fractionation of plagioclase or its retention in the source in the case of partial melting (Frost *et al.* 2001). The similarity of the REE patterns of the granitic rocks suggests that they are co-genetic. The light REE enrichment relative to the heavy REE enrichment in the rocks in this

DISCUSSION

The metasedimentary (shale-greywacke-arkose) origin of the gneisses and schists is confirmed in the plots of $\log Fe_2O_3(t)/K_2O$ vs $\log SiO_2/Al_2O_3$. This diagram shows that the protoliths of the gneisses are predominantly Fe-shale, Fe-sand, greywacke and arkose while those of the schists are shales. Most of the inferences about the tectonic setting of the shales, greywackes, arkose and sandstones of the metamorphic complex point to a continental arc derivation with a tendency to active continental margins (Fig. 6).

Active continental margins include sedimentary basins of the Andean type, thick continental margins and the strike-slip types. These basins are developed on or adjacent to a thick continental crust composed of rocks of older fold belts and the sediments are dominantly derived from granite-gneisses and siliceous volcanics of the uplifted basement. Based on evidence from the eastern and northeastern margins of the West African craton, it has been observed by previous authors that the Pan-African trans-Saharan belt evolved by plate tectonic processes which involved the collision of the active margin of the Pharusian belt (Taureg shield) and the passive continental margin of the West-African craton, about 600 ± 10 Ma (Burke & Dewey 1972; Leblanc 1981; Black *et al.* 1979; Caby *et al.* 1987; Obiora 2006, 2012).

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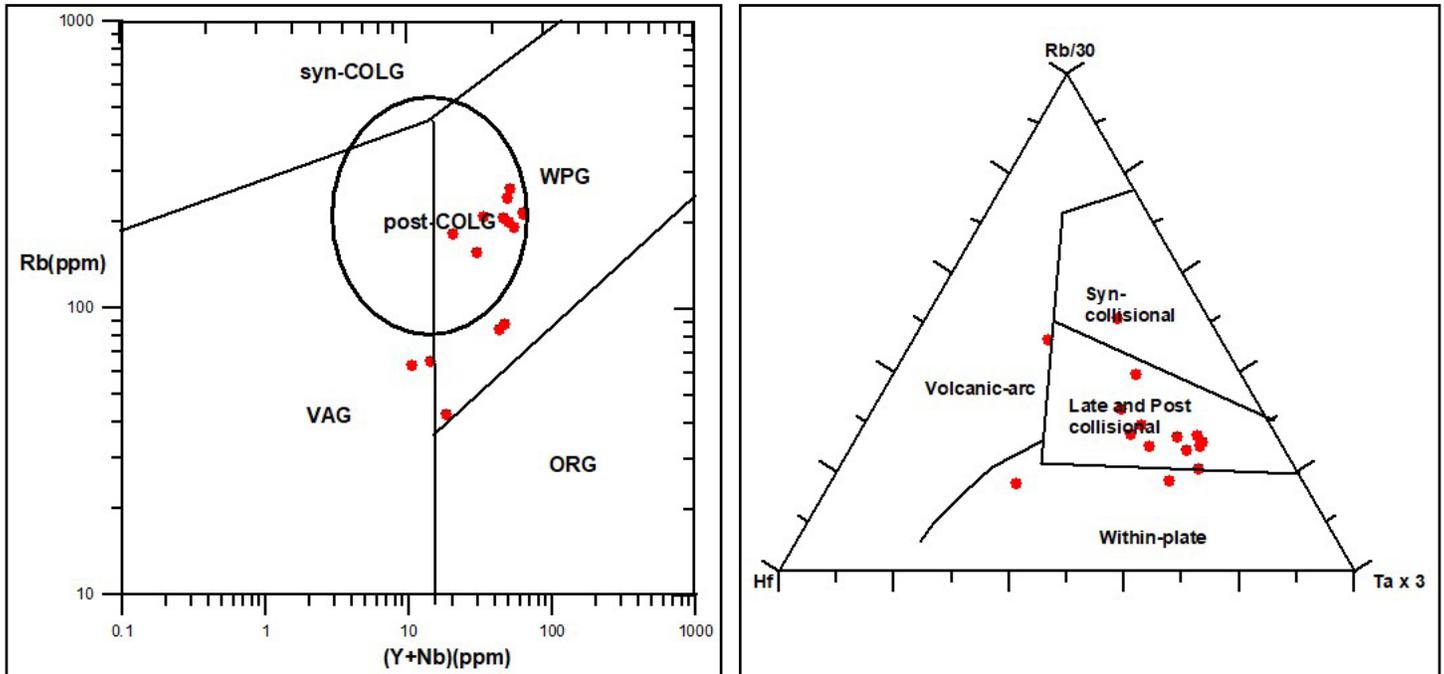


Figure 8. A) Post orogenic character of the granitoids shown on the Rb versus Y + Nb of Pearce et al. (1984). Syn- COLG= syn-Collision Granites; post-COLG= post-Collision Granites; WPG= Within Plate Granites; VAG= Volcanic Arc Granites; ORG= Ocean Ridge Granites; B) Plots of the rocks in the fields of Syn-collisional to Late/post-collisional granitoids on the Rb/30 Hf (Ta x 3) diagram of Harris et al. (1986).

study is considered as an indicator of varying degrees of partial melting. The granitic rocks in this study are quite similar to those of the Pan-African (older) granitic rocks which were emplaced towards the end of the Pan African orogeny (600 Ma), during the collision of the West African craton and the Tuareg shield.

CONCLUSIONS

Geochemical criteria applied to the metamorphic rocks show that Fe shales, greywackes, Fe sand and arkose are the protoliths of the gneisses whereas the schists are mainly composed of shales. These sedimentary rocks were originally derived from felsic to intermediate igneous provenance. Trace element data indicate a source with an average upper crustal composition for the metamorphic complex. Independent of the rock type the tectonic setting is related with continental arc or active continental margins. The overall geochemical feature of the granitoids indicate that they were most likely derived from partial melting of crustal materials in an orogenic (post-collisional) tectonic setting. They are therefore related to the Pan-African granites, otherwise known as the Older Granites which were emplaced during the Pan African orogenic event.

ACKNOWLEDGEMENTS

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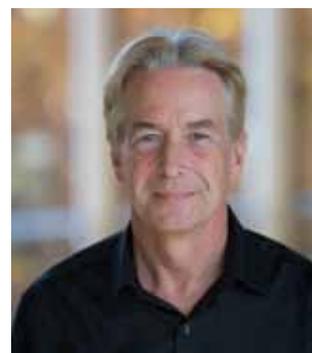
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Peter Winterburn (1962-2019)

Exploration geochemistry lost one of its most innovative and energetic champions with the tragic death of Dr. Peter Winterburn in an attempted street robbery in late June 2019 while in Valparaiso, Chile with his family. Peter and his wife Michelle had only recently returned to Chile to live, working out of Santiago with Vale. Over the course of a 30-year career in both the mineral exploration industry and in academia, Peter was a well-known and highly regarded geochemist with Anglo American, Vale and the Mineral Deposit Research Unit (MDRU) at The University of British Columbia (UBC), Vancouver, Canada, where for five years he carried out research and supervised students as a Professor of Exploration Geochemistry.



Peter was born in northern England in 1962 and graduated with his B.Sc. Hon from the University of Aston in Birmingham in 1983. He completed his Ph.D. at the University of Edinburgh, Scotland in 1988, studying peridotite xenoliths in southern African kimberlites. After a stint with the Council for Scientific and Industrial Research, he joined Anglo American Research Laboratories in Johannesburg, South Africa in 1990 as a geochemist, where he went to work managing the geochemical database. This was the beginning of a long 28-year (1990-2018) association with Anglo American, where he developed his geochemical skills in roles of increasing responsibility across Africa, including Senior Geochemist (1992-1993), Manager of the geochemical laboratory (1993-1995) and in 1995, Manager of Geochemistry for Africa. In 2002 Peter moved to Santiago, Chile to become Anglo's South American Regional Geochemist, a position that he was to hold for the next five years. He returned to South Africa in 2007 for a year as Chief Chemist at the Anglo American Research Laboratories, and then in early 2008 embarked on a new path, joining Vale as Chief Geochemist - Global Exploration. Based at first in Johannesburg and then, in 2009, in Toronto, Canada, Peter spent the next four years travelling the globe while directing Vale's worldwide geochemical exploration program.

In 2013 Peter joined (MDRU-UBC) in Vancouver, Canada. His appointment as NSERC/Acme Labs/Bureau Veritas Minerals Executive Industrial Research Chair in Exploration Geochemistry was a new position in which he would excel for the next five years. Here, Peter reinvigorated UBC's historic strength in exploration geochemistry with active research projects in British Columbia, the Northwest Territories, Colombia, Chile and Argentina. His research was not confined to traditional inorganic methods only but also included work in exciting new fields including soil hydrocarbons, microbial genomics and the geochemistry of hyper-arid terrains, among others. During this time he was also active with the Association of Applied Geochemists (AAG), serving on AAG Council (2015-2016) and chairing the Local Organizing Committee of the recent 28th International Applied Geochemistry Symposium (IAGS), which was held in June 2018 in Vancouver as part of the broader Resources for Future Generations (RFG) conference. It was a testament to Peter's character that he readily volunteered for the time-consuming role of chairing the AAG's flagship scientific event, all the while attending to his usual busy work schedule of supervising graduate students and conducting research. He guided the 28th IAGS to a successful conclusion and the outsized contribution of the AAG to the conference's overall success was largely due to Peter's energetic leadership. In early 2019, Peter left UBC and Vancouver and returned to Vale as Chief Geochemist, this time based in Santiago, Chile. He had been there for only a few months before his untimely death. Not surprisingly, he had already volunteered to join the Local Organizing Committee of the upcoming 29th IAGS, to be held in nearby Viña del Mar later in 2020.

Peter was an exceptional scientist and was among those few individuals who were able to successfully bridge the gap between the mineral industry, academic research, and teaching communities. He worked in over sixty countries during his career and in tropical to arctic to arid desert environments. With his broad practical industry experience - not just in all aspects of exploration geochemistry but also in mineral deposits, regolith development, metallurgy and laboratory analysis - his career embodied an almost old-school mix of field, analytical, interpretative and research geochemical skills. This background served him well as teacher and mentor to the new generation of enthusiastic young geochemists he supervised and inspired at UBC, where he initiated original research in non-traditional fields of geochemical exploration. His intellect was recognized early on by his colleagues in industry and he displayed the same sharp mind, quick wit and tireless work ethic that would later become apparent to a wider group at UBC. At MDRU, his friends and colleagues remember him for his scientific curiosity and enthusiasm, dedication to research, and dry sense of humour. On a personal level, Peter was a devoted husband and father. He was married to Michelle, whom he met in South Africa, for 29 years, and they raised two daughters, Cassandre and Keryn.

Peter's ashes were scattered over the mountains in Cajon Del Maipo, Chile. Celebration of his life events were held over the past few months in Santiago and at UBC in Vancouver. MDRU-UBC has established the *Peter Winterburn Memorial Fund* in his memory, with the objective of supporting and advancing the research of future students of exploration geochemistry and carrying on Peter's legacy and passion in this field. More information is available online at: <https://memorial.support.ubc.ca/peter-winterburn/>

Stephen Cook and Jeanne Liu

David John Gray (1961 - 2019)

The exploration geochemical community recently lost one of its most energetic members, Dr. David Gray. He died on November 21, 2019 in his home in Australia surrounded by his family following a battle with brain cancer.

David was a senior principal geochemist in CSIRO and one of the international leaders in exploration hydrogeochemistry. David would be more widely recognised had he not been such a selfless researcher. He always put the team, project, and organisation ahead of his own personal gain. David was a mentor for many, and he would engage with students and senior colleagues in the same manner; always constructive, supportive and considered. David formally supervised a number of students including three PhD students, not to mention the many more, like me, he unofficially mentored as undergraduates, post graduates, or colleagues.

David was a Fellow of the Association, a member and past President of the Australian Regolith Geoscientists Association, and served on the Editorial Board for Geochemistry: Exploration, Environment, Analysis.

David's early years were spent in Sydney, Australia, before moving to Perth with his job at CSIRO. He completed his B.Sc., (Honours) in inorganic chemistry at the University of Sydney in 1982, before completing his Ph.D. in Soil Science from the same institution in 1986, researching the geochemistry of uranium and thorium during weathering. David joined CSIRO in 1987 where he remained until his early retirement due to failing health in 2017. David led the establishment of hydrogeochemistry as an exploration tool that is now widely accepted and implemented by Australian State geological surveys and mineral explorers.

David remained an active Honorary Fellow of CSIRO. He was still passing on his ideas of simplifying exploration transition metal indices for groundwater by scaling with pH, until the last weeks before his death. He was always positive. His quality of life had been good until his last few days which I would attribute to David's personality. David's optimism is something that those that spent time in the field with him would know all too well. He was always convinced you could collect another few samples even as darkness was descending, and he would literally bounce in and out of vehicles all day, every day, to ensure he got as much possibly done in the field.

His dedication to his science in the office was also admirable – he spent years trawling through pdf versions of water reports and pulling out data, doing QAQC checks that has resulted in the Australian continental scale hydrogeochemistry data well summarised in this recent news article (<https://www.csiro.au/en/Research/MRF/Areas/Resourceful-magazine/Issue-19/The-groundwater-explorer>). The 320,000 quality groundwater data points are all thanks to David's tenacious nature for collecting and curating results and being certain that "true backgrounds" and major element data would show patterns for application in mineral exploration and other fields if we just had *enough* samples (there was always more David would look for).

David was 58 and is survived by his wife, Celia, and children Ahren, Alex, Bec, Adam and Nathan. As this article was being written, I was taking a break from working on groundwater data, the interpretation of which is all based on the learnings I received from David over the last 15 years and his ongoing mentoring. I will raise a glass of wine (preferably David's preferred sauvignon blanc) in his memory after I submit this memorial and continue to work on the data and further David's legacy. I am forever grateful for David's many years of mentorship and for hiring me. A terrific boss, teacher, scientist, colleague and friend. He will be missed.

For those who wish to make a donation in David's honour, see the AAG's Distinguished Geochemists Fund. <https://www.appliedgeochemists.org/association/distinguished-applied-geochemists->



Ryan Noble

Geochemistry

EXPLORATION, ENVIRONMENT,
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Comparison of methods for the geochemical determination of rare earth elements: Rock Canyon Creek REE-F-Ba deposit case study, SE British Columbia, Canada

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Geochemical mapping and estimation of background concentrations in soils of Carajás mineral province, eastern Amazonian Craton, Brazil
Gabriel Negreiros Salomão, Roberto Dall'Agnol, Rômulo S. Angélica, Marco Aurélio Figueiredo, Prafulla K. Sahoo, Carlos A. de Medeiros Filho and Marlene F. da Costa

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Petrography and geochemistry of tourmaline breccia in the Longtoushan Au deposit, South China: genesis and its exploration significance
Mingji Zhang, Dehui Zhang, Bo Zhao, Mingqian Wu, Bo Bao, Yingkang Liu and Chong Huang

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The determination of phosphate in rocks and iron ores using inductively coupled plasma with optical emission spectroscopy (ICP-OES)
M. M. R. Mostert

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Identification of the expression of earthquake-induced surface flooding by groundwater using detailed regolith mapping at the buried Atlántida Deposit, northern Chile

A. E. Brown, P. A. Winterburn and T. Bissig

Geochemistry: Exploration, Environment, Analysis, v. 19:474-486, first published on April 12, 2019, doi:10.1144/geochem2018-064 **OPEN ACCESS**
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Geochemical signature of earthquake-induced surface flooding by mineralized groundwater over the buried Atlántida deposit, northern Chile

A. E. Brown, P. A. Winterburn and T. Bissig

Geochemistry: Exploration, Environment, Analysis, v. 19:487-500, first published on April 12, 2019, doi:10.1144/geochem2018-065 **OPEN ACCESS**
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John Carranza



IAGS 2020: Experience Chile



29th International Applied Geochemistry Symposium, ***IAGS 2020 EXPERIENCE CHILE***

Facing the challenges of today using applied geochemistry

In Memory of Dr. Peter Winterburn

We are one year away from the start of the 29th International Applied Geochemistry Symposium, IAGS 2020, which will be held in Viña del Mar, Chile from November 8th to 13th, 2020.

This second circular provides the latest news regarding IAGS2020 and will guide you on how to write and submit your abstract. We hope to see you all in Viña del Mar!

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Abstracts must be submitted to one of the 9 Technical Sessions of the IAGS 2020 Scientific Program. Please keep in mind the following before submitting your abstract:

- English is the official language of the Symposium; Abstracts must be submitted in English
- Title: Maximum 190 characters
- Authors: Maximum 100 characters
- Affiliations: Maximum 800 characters
- Content of the Abstract: Minimum of 1500 characters to a maximum of 2500 characters (may include sub-sections and references directly in the text).
- Do not include figures in the abstract.
- Please note that the character counting system includes spaces.

IAGS 2020: Experience Chile... *continued from page 23*

Guidelines for abstract submission

The submission of abstracts will be performed exclusively through the website of the symposium (www.iags2020.cl).

The first step is registering for the Symposium through the following link <https://4id.cl/congress/registro?c=iags001&lang=en>. After registering, the attendee will have a web account for the symposium where his/her personal information, registration, payment, and abstract information can be accessed and edited.

Abstracts must be uploaded to the following link <https://4id.cl/congress/?c=iags001&lang=en>. Each participant is allowed to submit a maximum of two (2) abstracts as the first (primary) author. There are no restrictions regarding participation as a co-author.

It is not mandatory to pay for your registration fee in order to submit an abstract, but at least one author must be registered and paid for final acceptance to the Symposium.

Abstract online submission will be available November 1, 2019 to March 31, 2020

Technical Program

Session 1: Exploration geochemistry: present and future challenges

Chair: Carmina Jorquera, Teck Resources Ltd.

Description: This thematic session will be focused on, and open to studies related to the use of geochemistry for exploration. It will cover traditional techniques based on stream sediment, soil, rock chip sampling, litho-geochemistry, as well as more innovative techniques oriented to exploration in areas of transported overburden, partial extractions, biogeochemistry, mineral chemistry, hydrogeochemistry and any other novel uses of geochemistry applied to mineral exploration (at any scale). Geochemistry has been a long standing and traditional tool in mining exploration, in which advancing improvements of analytical techniques allow for new and novel opportunities to face the increasing challenges of exploration. Combination of geochemical exploration techniques with any other tools such as geophysics and mineral spectroscopy determinations is encouraged within an integrated geological framework.

Session 2: New field portable technologies: improving the analysis and turnaround times in exploration

Chair: Andrew Menzies, Bruker Nano GmbH

Description: The traditional use of geochemistry and mineralogy in mining exploration has evolved over time together with analytical capabilities, however the application of results has always been dependent on the turnaround time and sample processing capacity of internal or commercial laboratories. Consequently, this can have an impact on the timeous evaluation of exploration projects and can undermine the ability for quick decisions in the field. The advent and continual development of field portable technologies and their application to direct on-site analytical determinations has provided exploration geologists with a multiplicity of tools to assist quick decision making. This thematic session will focus on data quality and case studies of applications of field portable technologies in mining exploration, such as portable XRF, LIBS, XRD, spectroscopy, and any other on-site field geochemical analytical technologies.

Session 3: Big-data: squeezing multi-element geochemical data by means of data science and self-learning techniques

Chair: Álvaro Egaña, Universidad de Chile

Description: The use of multi element geochemistry in the mining industry, coupled with geological, mineral, geophysical and spectroscopy data, from exploration to resource and reserve estimates, and applications of multi element geochemistry to quantitative mineral characterization among many other uses, generates ever increasing amounts of information, in which data processing by Big-data science techniques offers novel and very powerful opportunities to perform data integration, multivariate analysis, data modeling and interpretation. This thematic session will focus on and welcomes studies related to the use of data science, machine learning, statistical learning or deep learning techniques in the mineral industry, with particular attention to those associated with maximizing the use of multi-element geochemical data integrated with other sources of information.

IAGS 2020: Experience Chile... *continued from page 24***Session 4: Geochemistry applied to mineral characterization for geological, geometallurgical and resource modeling**

Chair: Brian Townley, Universidad de Chile

Description: This thematic session is oriented to studies that evaluate the value of multi-element geochemistry as a tool for semi-quantitative to quantitative bulk mineral characterization in geological, resource and geo-metallurgical modeling of ore deposits, applied to the characterization of lithology, hydrothermal/supergene alteration types and intensities, as well as mineralization. This session will be focused on applications that permit numerical classification techniques for mineral characterization in ore deposits which are based on multi-element geochemistry and/or spectroscopy based technologies, allowing for semi-quantitative to quantitative high resolution modeling of key aspects of lithology, hydrothermal alteration and mineralization. It will also offer insights to applications that may be cross-referenced to metallurgical test samples and therefore to geo-metallurgical properties of rocks and predictive modeling.

Session 5: Environmental geochemistry: closing the gap for sustainable mining and development / Mine Tailing Revalorization (Unesco-IGCP682)

Chair: Manuel Caraballo, Universidad de Chile

Description: Increasing awareness and regulations on environmental impacts and mitigation in the mining industry, within the framework of sustainable mining, have placed important emphasis on the necessity of an integral understanding of chemical and physical stability of mine waste as well as the direct environmental impacts of mining operations. This thematic session will focus on the use of geochemistry applied to environmental studies that provide a deep understanding of the behavior and impacts of mining waste products, and hence the necessary knowledge to determine efficient mitigation and control protocols. This session will include a specific special sub-session sponsored by the Unesco-IGCP682 project of mine tailing revalorization, focused on reprocessing of old and present tailing deposits for the recovery of elements / minerals of economic interest, within a framework of circular economy and sustainability. Studies on the applicability of environmental geochemistry to other impacts of the mining industry as well as other studies that provide useful applications to the mining industry are also welcomed.

Session 6: Water and hydrogeochemistry: challenges in exploration, mining and sustainable development

Chair: Luciano Achurra, Amphos 21 Consulting Chile

Description: Hydrogeochemical studies provide us with relevant information about water sources and the processes that affect them surficially and underground. The activities associated with the exploitation of metallic and non-metallic mineral deposits can cause changes in the chemistry of rivers and aquifers. Currently, the infiltration of water from tailings storage facilities and mitigation or remediation of sulfate or metals in aquifers is common. Related to this matter, concepts such as monitoring plans on water quality and mining closure plans, which involve a hydrogeochemical component, can condition the environmental approval of large projects. On the other hand, hydrochemical studies on brines, in the salt flats, are becoming increasingly important due to the growing demand of the lithium-associated energy industry, as well as the use of chemical and isotopic techniques in the exploration of deep geothermal systems. These topics and a general water scarcity have led to the current challenges which are focused on efficient water management and the protection of its chemical quality, which is closely related to its management. In the session, discussions related to these issues are welcome through presentations of applied hydrogeochemical techniques in water studies as well as the use of modeling tools which allow for a better understanding of the processes involved in the water cycle and their implications in the environment.

Session 7: Isotopic geochemistry: new uses in applied geochemistry

Chair: Verónica Oliveros, Universidad de Concepción

Description: This session will deal with novel methodological approaches of isotopic geochemistry and geochronology in the fields of natural resources, environmental geology and earth dynamics. Examples of systematics studies and sampling protocols aiming at the discovery of new ore deposits, geochemical anthropic anomalies, paleoclimatic trends or processes and natural risk assessment are welcomed. Applications of new isotopic tools and geochronometers in the Earth Sciences will be also of interest in this session.

IAGS 2020: Experience Chile... *continued from page 25*

Session 8: Linking geology and geochemistry to viticulture and wine

Chair: Pamela Castillo, Universidad de Chile

Description: Climate, soil and agricultural management are the main factors that impact yield and grape quality. Geologic studies are important in viticulture since the physical and chemical properties of soils are strongly influenced by lithological, geochemical and structural characteristic of the soil parent materials. This thematic session welcomes contributions that link diverse areas of geosciences (geology, geochemistry, geomorphology, geophysics, mineralogy, soil sciences, hydrogeology, hydrology, climatology, biogeochemistry, etc.) that influence aspects such as viticultural potential and wine quality, the terroir concept, soil-plant interactions, root system development, water availability, the characterization of viticultural valleys, exploration of new areas apt for viticulture, environmental issues, challenges and impacts of climate change, standardization of methodologies, and technological solutions, among others.

Session 9: Analytical geochemistry technologies and quality assurance / quality control

Chair: Cliff Stanley, Acadia University

Description: Appropriate sampling, sample preparation, analysis, and data quality assessment and control procedures are essential for the proper exploration, evaluation, and exploitation of mineral deposits as well as for environmental assessments, remediation, monitoring, and related applied research designed to improve these activities. This session invites contributions addressing two themes: (i) presentations that improve our understanding of QAQC procedures, that expand/improve the application of QAQC procedures, or illustrate interesting successes or failures in quality control and (ii) presentations that illustrate new analytical technologies or applications that can be used to improve the practice of exploration or environmental geochemistry. Presentations accepted for this session will not involve the use of technologies that remain secret or proprietary; as such procedures cannot be fully evaluated in a scientific manner, preventing an objective assessment of their value and use in exploration and environmental geochemistry applications.

Workshops and Field Trips

Workshops will take place on November 6 and 7, 2020, before IAGS 2020. Field trips will take place after IAGS 2020. Costs related to workshops and field trips will be included in the Third Circular. The following workshops are preliminarily approved by the Local Organizing Committee:

| Responsible Person | Title |
|--------------------|--|
| David Cohen | Fundamentals of geochemical exploration. |
| Cliff Stanley | Quality control/Quality assurance. |
| Gwendy Hall | Field portable geochemistry: applications and limitations. |
| Brian Townley | Geology, mineralogy and geochemistry in viticulture. |
| Ryan Mathur | Stable and radiogenic isotopes in mining exploration. |
| Alvaro Egaña | Data science in geochemistry: from exploration to geometallurgy. |
| Reynaldo Charrier | Geology and metallogenesis of Chile. |
| Matthew Leybourne | Hydrogeology and hydrochemistry in the mining industry. |

Statements of interest for workshops will be received until March 30th, 2020 realization subject to a sufficient number of participants. Offered workshops will be confirmed on April 1st, 2020. Detailed outlines, scope and objectives of workshops will be soon posted in the IAGS 2020 web page.

IAGS 2020: Experience Chile... *continued from page 26*

The following Field Trips are proposed:

| Responsible Person/People | Title |
|-------------------------------|--|
| Reynaldo Charrier | <i>Tectono-magmatic evolution of Central Chile</i> A transect of Central Chile, from coast (Vina del Mar) to the pre cordillera in Argentina (Mendoza). |
| Constantino Mpodozis | <i>Mineral deposits of Northern Chile</i> Field visits to porphyry copper, precious metals epithermal and stratabound copper deposits of the Antofagasta region. |
| Sofía López and Ignacio Serra | <i>Geology and vineyards of Central Chile</i> Field visits and tour of vineyards of Central Chile, focused on geology, geomorphology, landscape evolution and relation of sites with their local geological and viticultural environments. |
| Joseline Tapia | <i>Polluted areas of Central Chile:</i> Field visits to polluted areas of central Chile with a focus on the sources and impacts of contamination in soil, sediment, water and air. Special attention will be given to the Puchuncaví-Quintero area. |

Statements of interest for field trips will be received until March 30th, 2020 and each field trip will be subject to a sufficient number of participants. Offered field trips will be confirmed on April 1st, 2020. Detailed outlines, scope and objectives of field trips will be posted soon on the IAGS2020 web page. Detailed itineraries will be defined before January 30th, 2020.



Welcome New AAG Members 2019

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.

Thomas Bissig
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Membership # 4351

Leah Treloar
Global MMI Product Manager
SGS
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Burlington, ON
CANADA L7L 7E1
Membership #4417

Chinedu Ibe
Lecturer
University of Nigeria
NSUKKA
NIGERIA 41001
Membership #4418

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.

Sarane Sterckx
Goldspot Discoveries
68 rue du Ménil
Braine-L'Alleud
BELGIUM 1420
Membership #4416

Dr. Andy Wilde
Chief Geologist
Deep Yellow Ltd
Suite 17 Spectrum Building
100 Railway Rd
Subiaco, WA
AUSTRALIA 6008
Membership #4419

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

As part of a master's research in the Department of Chemistry at Queen's University, Matthias Hermann developed a cost-effective, easy-to-use, and portable detector for cadmium in water that connects to a smartphone.

Read the article here:

<https://www.queensu.ca/gazette/alumnireview/stories/elements-education>



Association of Applied Geochemists
Student Membership
\$10 US

Encourage a student to join!



The AAG-SGS Student Presentation Prize

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

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

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

The Rules

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

The Prize

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

David Cohen

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



CALENDAR OF EVENTS

International, national, and regional meetings of interest to colleagues working in exploration, environmental and other areas of applied geochemistry. These events also appear on the AAG web page at: www.appliedgeochemists.org.

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

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Or Tom Meuzelaar, AAG Webmaster,

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2020

- 12-18 JANUARY Winter Conference on Plasma Spectrochemistry. Tucson AZ USA. Website: icpinformation.org
- 20-23 JANUARY Mineral Exploration Roundup. Vancouver BC Canada. Website: roundup.amebc.ca
- 7-9 FEBRUARY Atlantic Geoscience Society Annual Colloquium. Truro NS Canada.
Website: ags.earthsciences.dal.ca/Colloquium/Colloquium.php
- 16-21 FEBRUARY 2020 Ocean Sciences Meeting. San Diego CA USA. Website: www2.agu.org/ocean-sciences-meeting
- 23-27 FEBRUARY Minerals, Metals & Materials Society 2020 Annual Meeting & Exhibition. San Diego CA USA.
Website: www.tms.org/tms2020
- 1-4 MARCH Prospectors and Developers Association of Canada Annual Convention. Toronto ON Canada.
Website: www.pdac.ca/convention
- 2-8 MARCH 36th International Geological Congress. Delhi India. Website: 36igc.org
- 16-17 MARCH 5th International Conference on Earth and Planetary Sciences. Las Vegas NV USA.
Website: www.meetingsint.com/conferences/earthscience
- 18-22 APRIL 9th Geochemistry Symposium. Didim Turkey. Website: www.9thgeochemistry.com/en
- 3-6 MAY CIM Convention. Vancouver BC Canada. Website: convention.cim.org
- 3-8 MAY EGU General Assembly. Vienna Austria. Website: www.egu2020.eu
- 7-9 MAY 6th International Conference on Geographical Information Systems Theory, Applications and Management. Prague Czech Republic. Website: www.gistam.org
- 11-15 MAY GeoConvention 2020 (includes GAC-MAC). Calgary AB Canada. Website: www.geoconvention.com
- 11-15 MAY World Water Congress & Exhibition. Daegu South Korea. Website: www.worldwatercongress.com
- 20-24 MAY Geological Society of Nevada 2020 Symposium Vision for Discovery: Geology and Ore Deposits of the Basin and Range. Sparks NV USA. Website: www.gsnv.org/2020-symposium
- 23-29 MAY Geochemistry of Mineral Deposits (Gordon Research Conference). Castelldefels Spain.
Website: tinyurl.com/ybkjgl37
- 24-25 MAY Geochemistry of Mineral Deposits (Gordon Research Conference). Castelldefels Spain.
Website: tinyurl.com/ybkjgl37
- 30 MAY - 5 JUNE Ocean Biogeochemistry: Biogeochemical Processes Across Space and Time (Gordon Research Conference). Hong Kong China. Website: tinyurl.com/y249f47c
- 8-10 JUNE SIAM Conference on Mathematics of Planet Earth (MPE20). Garden Grove CA USA.
Website: www.siam.org/Conferences/CM/Conference/mpe20
- 14-17 JUNE 11th International Conference: Interfaces Against Pollution. Wuhan China. Website: tinyurl.com/y65l3cdp
- 15-18 JUNE 8th International Congress & Exhibition on Arsenic in The Environment. Wageningen Netherlands.
Website: tinyurl.com/y3zvgg6r
- 21-26 JUNE Goldschmidt 2020. Honolulu HI USA. Website: goldschmidt.info/2020
- 28 JUNE - 1 JULY 5th International Congress on 3D Materials Science. Washington DC USA.
Website: www.tms.org/3dms2020
- 13-16 JULY 7th Annual International Conference on Geology & Earth Science. Athens, Greece.
Website: www.atiner.gr/geology
- 14-16 JULY International Archean Symposium. Perth WA Australia. Website: 6ias.org
- 28-30 JULY 14th International Nickel-Copper-PGE Symposium. Marquette MI USA.
Website: www.nmu.edu/eegs/symposium-2020
- 1-7 AUGUST Organic Geochemistry: Mechanistic and Experimental Insights on Geochemical Archives (Gordon Research Conference). Holderness NH USA. Website: tinyurl.com/yzzz4fdg



CALENDAR OF EVENTS... *continued from page 30*

| | |
|---------------|---|
| 2-6 AUGUST | Microscopy & Microanalysis 2020. Milwaukee WI US. Website: www.microscopy.org/MandM/2020 |
| 9-14 AUGUST | Biom mineralization: Bridging Scientific Disciplines to Understand Biomineral Formation in Breadth and Depth (Gordon Research Conference). Castelldefels Spain. Website: www.grc.org/biom mineralization-conference/2020 |
| 17-21 AUGUST | 34th International Geographical Congress. Istanbul, Turkey. Website: www.igc2020.org/en |
| 19-21 AUGUST | 10th International Conference on Environmental Pollution and Remediation. Prague Czech Republic. Website: icepr.org |
| 24-28 AUGUST | Eurosoil 2020. Geneva, Switzerland. eurosoil2020.com |
| 6-9 SEPTEMBER | 11th International Conference on Environmental Catalysis. Manchester UK. Website: www.conferecare.manchester.ac.uk/events/icec2020 |
| 15 SEPTEMBER | SEG 2020: Celebrating a Century of Discovery. Whistler BC Canada. Website: www.seg2020.org |
| 18-23 OCTOBER | IWA World Water Congress & Exhibition 2020. Copenhagen Denmark. tinyurl.com/y8tpg3jt |
| 25-28 OCTOBER | GSA 2020. Montréal QC Canada. Website: tinyurl.com/yyz3jgq2 |
| 9-13 NOVEMBER | 29th International Applied Geochemistry Symposium (IAGS). Viña del Mar Chile. |

2021

| | |
|--------------|--|
| 16-20 AUGUST | 12th International Kimberlite Conference. Yellowknife NT Canada. Website: 12ikc.ca |
|--------------|--|



Call for papers: Big Data Advances in Exploration and Environment Geochemistry

Geochemistry: Exploration, Environment, Analysis (GEEA) is calling for papers to be submitted to the above thematic collection. With the advent of the era of big data, scientific research has moved into the fourth research paradigm: data intensive science. Big data and machine learning have brought earth sciences into an artificial-intelligence research stage. Machine learning algorithms and models have been applied to study large-scale, multi-resolution, multi-time, multi-type Earth observation data and socio-economic data. The goal of this thematic collection is to highlight recent progress in the research and applications of big data and machine learning in the fields of exploration and environment geochemistry, for instance:

- geochemical mineral resources prediction
- elemental migration and distribution
- anomaly identification
- global geochemical baselines
- geochemical analysis
- processing optimization
-

Please note that the thematic collection focuses exclusively on research based on real data, rather than theoretical discussions of mathematical techniques.

Papers should be submitted no later than **30 April 2020**.

Submission of a manuscript for possible inclusion in this thematic collection is no guarantee of eventual acceptance and publication. All published contributions must meet the normal, rigorous GEEA review standards with regard to both content and presentation. Authors who are non-native English speakers should consider having a native English speaker edit their manuscript prior to submission.

Any queries contact us: geea@geolsoc.org.uk

Author guidelines can be found at www.geolsoc.org.uk/geea-authorinfo

Submit your paper at www.editorialmanager.com/geochem/default.aspx



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